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Supervisor	Professor Markku Tuominen Department of Industrial Engineering and Management Lappeenranta University of Technology Finland
Reviewers	Professor Markku Sääksjärvi Department of Information Systems Science Helsinki School of Economics Finland
	Professor Harri Haapasalo Department of Industrial Engineering and Management University of Oulu Finland
Opponent	Professor Harri Haapasalo Department of Industrial Engineering and Management University of Oulu Finland

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ABSTRACT

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In the era of fast product development and customized product requirements, the concept of product platform has proven its power in practice. The product platform approach has enabled companies to increase the speed of product introductions while simultaneously benefit from efficiency and effectiveness in the development and production activities. The product platforms are technological bases, which can be used to develop several derivative products, and hence, the differentiation can be pushed closer to the product introduction.

The product platform development has some specific features, which differ somewhat from the product development of single products. The time horizon is longer, since the product platform's life cycle is longer than individual product's. The long time-horizon also proposes higher market risks and the use of new technologies increases the technological risks involved. The end-customer interface might be far away, but there is not a lack of needs aimed at the product platforms – in fact, the product platform development is very much balancing between the varying needs set to it by the derivative products.

This dissertation concentrated on product platform development from the internal product lines' perspective of a single case. Altogether six product platform development factors were identified: "Strategic and business fit of product platform", "Project communication and deliverables", "Cooperation with product platform development", "Innovativeness of product platform architecture and features", "Reliability and quality of product platform", and "Promised schedules and final product platform meeting the needs". From the six factors, three were found to influence quite strongly the overall satisfaction, namely "Strategic and business fit of product platform", "Reliability and quality of product platform", and "Promised schedules and final product platform meeting the needs". Hence, these three factors might be the ones a new product platform development unit should concentrate first in order to satisfy their closest customers, the product lines. The "Project communication and deliverables" and "Innovativeness of product platform architecture and features" were weaker contributors to the overall satisfaction. Overall, the factors explained quite well the satisfaction of the product lines with product platform development.

Along the research, several interesting aspects about the very basic nature of the product platform development were found. The long time horizon of the product platform development caused challenges in the area of strategic fit – a conflict between the short-term requirements and long term needs. The fact that a product platform was used as basis of several derivative products resulted into varying needs, and hence the match with the needs and the strategies. The opinions, that the releases of the larger product lines were given higher priorities, give an interesting contribution to the strategy theory of power and politics. The varying needs of the product lines, the strengths of them as well as large number of concurrent releases set requirements to prioritization. Hence, the research showed the complicated nature of the product platform development in the case unit – the very basic nature of the product platform development might be its strength (gaining efficiency and effectiveness in product development and product launches) but also the biggest challenge (developing products to meet several needs).

As a single case study, the results of this research are not directly generalizable to all the product platform development activities. Instead, the research serves best as a starting point for additional research as well as gives some insights about the factors and challenges of one product development unit.

Keywords: Product platform, product development, R&D, research and development, new product development, R&D organization

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To my Mom,

whose contribution to my dissertation was significant, but

who never saw it ready.

Thank you!

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Most patience, though, was required from my husband Hannu and son Aleksi. The time used for this research has partly been taken from the time with them – although it also enabled some more time spend at home. I thank them for their love and support, laughter and joy, as well as relaxing moments during the project.

Vantaa, December 2004

APPREVIATIONS

Generic terms

ANOVA	Analysis of Variance
ATM	Asynchronous Transfer Mode
CAFÈ	Concepts to Application in System Family Engineering
CMM	Software Capability Maturity Model
GSM	Global System for Mobile communications
HW	Hardware
ISDN	Integrated Services Digital Network
IT	Information Technology
ITEA	Information Technology for European Advancement Framework
KMO	Kaiser-Meyer-Olkin Measure of Sampling Adequacy
MSA	Measure of Sampling Adequacy
NMT	Nordic Mobile Telephone
R&D	Research and Development
Std.	Standard
SW	Software
VIF	Variance Inflation Factor

Case specific terms

PDSG	Platform Development Steering Group
PL	Product Line
PSG	DX 200 Platform R&D Steering Group
RDMT	SWP R&D Management Team
RIS	Release Integration Step
RISG	Release Integration Steering Group
RMSG	Release Maintenance Steering Group
SWP	Switching Platforms

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1. INTRODUCTION

1.1 Background of the Product Platform Concept

The successful product development is an issue of success or death to the companies. The history has shown, how the successful leading companies have failed to see a technological discontinuity, and have lost their position to the new entrants (Foster, 1986, Tushman and Anderson, 1986, Henderson and Clark, 1990, Utterback, 1996, Glasmeier, 1997, Tushman et al., 1997, Christensen, 2000). To survive in the competition, the companies must accelerate their new product development (e.g. Smith and Reinertsen, 1991, Rothwell, 1994, Cooper, 2000) and be innovative (Foster, 1986, Utterback, 1996, Christensen, 2000). Further, it is not enough to develop only one innovative product to the markets fast – there needs to be several products aimed at different market segments and even to several niches inside the segments (Robertson and Ulrich, 1998), hence there is a need to develop product families to survive in the competition (Burgelman and Maidique, 1988). The efficiency of a company depends on its ability to generate a continuous stream of new products (Meyer et al., 1997b) and to earn the large investment costs back fast (Meyer and Utterback, 1993).

The increasing speed of the product development can be seen especially in the area of high technology products (McGrath, 1995). Still, in the case of significant technological innovations involved in the first product of a start-up company, the development times are long (Schoonhoven et al., 1990). Hence, accelerating the product development is not as easy as it might sound. While the products should be developed faster, the products themselves are increasingly complicated (McGrath, 1995, Meyer and Zack, 1996), and while the products get more complicated, the prices of the products decrease at increasing speed (McGrath, 1995). The equation of faster product development, global competition, changing customer expectations, lower prices, and complicated products cannot be solved anymore with the previously worked mass-production paradigm (Abernathy and Wayne, 1974), whose goal of was to provide products that were affordable enough for the nearly everyone (Pine, 1993a). A relevantly new concept of mass-customization, instead, has been more successful in solving the previous equation

(Pine, 1993a, Gilmore and Pine, 2000). The goal of the mass customization is to provide variety in the product offering so that nearly everyone can find what he wants (Pine, 1993a). With mass customization, it has been possible to achieve more variation in the products as well as shorter product life cycles. The productivity can be improved by postponing the product differentiation to as late of a stage as possible (Feitzinger and Lee, 1997), e.g. using modular product and process design (Pine, 1993b), or re-using the components of a software product (Boehm and Papaccio, 1988).

During the 90's, the concept of product family based on product platforms has been introduced in the literature (even though it has been applied in the industry for a period of time) for solving the problem of faster product development, quickly gaining market share and filling the gaps in the markets (niches). The product platform based product development has been a significant success factor e.g. in the auto industry (Robertson and Ulrich, 1998), and the product platforms have been one of the secrets of continuous success for several companies in other industries as well (Meyer and Lehnerd, 1997a). The Black & Decker's power drills and Sony's Walkman product family are classical examples of successful product platform strategies. Brief summaries of these success stories are presented below.

Black & Decker (Meyer and Lehnerd, 1997a)

In the beginning of the 1970's, the Black & Decker's power drill product line was broad. The new products had been developed one-at-a-time, not as a family of products. As a result, there were e.g. 30 different motors in the power tool offering (each produced differently) and 104 different armatures. In 1971, along with a need to add double insulation around the power tool motors (to protect the user from electrical shock), the management of Black & Decker decided to renew its product offering: to gain a product family look, standardize the components, reduce manufacturing costs, improve performance and add possibilities to add new features with minimal costs, and design globally attractive products. A substantial ($17.1 million, 1971) long-term commitment

(7 year break-even point) was made to the program, whose goal was to create a product platform.

The project was finished 3 years later. By planning the entire product line, involving both the engineering and manufacturing in the product design phase and adopting a long-term planning horizon at the senior management level, the product platform approach with standardized parts yielded in significant improvements. The savings in the power tool motor manufacturing only were $1.28 million annually and the armature manufacturing process dropped to 1/5th of the previous level. The labor needed to the motor manufacturing decreased from 600 to 171 in 1976, saving the company $4.6 million. The product platform design reduced the total number of components leading to smaller stock and storage costs. The derivative product development costs sank radically and the design of the derivative products was fast - for several years new product was launched a week – because the designers could concentrate only on the business end of the power tools, i.e. a new type of drilling attachment. Black & Decker took the savings to the prices of the power tools and even 50% price reductions were witnessed. The break-even point of the project was about half the planned.

Sony Walkman (Sanderson and Uzumeri, 1997, Sanderson and Uzumeri, 1995)

Sony Walkman is another excellent example of a successful product platform strategy, which yielded in cost-minimization with the product platform and derivative product concept. The Walkman product platforms were developed by company's best design and manufacturing engineers (cross-divisional). The product platform development was done in an intense project of a year or more. The projects had clear targets and strong management support. When the product platforms were ready, the individual topological changes were cheap to design and produce: the break-even would come from selling only 30 000 units of the derivative product.

> Sony was effective in filling the existing market segments and creating new ones worldwide. During the 1980's, Sony launched nearly 250 models of personal portable stereos in the US markets. The whole product family was based on only four different new product platforms (1981 – 1989), while 99% of Sony's products were derivative products. From twenty to thirty models were based on the incremental innovations and others were based on the topological changes (rearrangements, cosmetic changes).

In addition to the power tools and Walkman's, the product platform approach has also been used in connection with the automobiles (Meyer and Lehnerd, 1997a, Robertson and Ulrich, 1998), HP's computers, Canon's copier machines, Chrysler's cars (Meyer and Utterback, 1993), DC-3 aero planes (Meyer and Lehnerd, 1997a), Kodak's cameras (Wheelwright and Clark, 1992), and Intel's processors (Cusumano and Gawer, 2002, Tabrizi and Walleigh 1997, Meyer and Lehnerd, 1997a). In the 1990's, the concept of product platform has been increasingly used in the information technology and pure software industry (Meyer and Zack, 1996, Sääksjärvi, 2002). There are some case examples of the software product platform successes, but fewer than of the product platforms in the mechanical engineering. E.g., Vision Corporate (a graphics-charting software producer) used a product platform strategy for creating a commercially successful product, for which it is easy to add add-in shapes. It launched its first product only 24 months from starting the product platform based design, and introduced new versions of its products almost annually to a number of market segments (Meyer and Lehnerd, 1997a). In addition, the Microsoft's software products (Meyer and Lehnerd, 1997a, Meyer and Seliger, 1998) are examples of product platform strategy applied to the software products.

A product family, based on a product platform, is aimed at the same market segment, while the individual products of the family are aimed at niches inside the segment (Meyer and Utterback, 1993). The strength of the product platform strategy comes from the ability to tailor products to the needs of market niches at reasonable price (i.e. mass customization). With the product platform, it is possible to postpone the product differentiation to a late stage of the product development, and to efficiently create a timely stream of derivative products to the markets (e.g. the Sony's case). When developing products with same technology and aiming them to close market segments, efficiency can be gained both in development, production, distribution and services (Meyer and Utterback, 1993, Meyer and Zack, 1996).

The product platforms can bring, at their best, significant cost-savings due to more effective and efficient product development when compared to the single product development activities. In the product platform development, the rare skills can be used more effectively, and the new application development based on the existing product platforms is fast (Meyer and Zack, 1996). There are several examples of how the development of derivative products on a well-designed product platform can bring significant timesavings in the derivative product development (e.g. the previously mentioned cases of Black & Decker and Sony Walkman). Product platform provides technological leverage to the derivative product development: incremental costs of derivative products are a small fraction of the product platform development costs. The cycle time to produce a derivative product is significantly shorter than to produce a product platform (Meyer and Lehnerd, 1997a). The risks are lower in the derivative product development, even though the risks of the product platform development are high (Robertson and Ulrich, 1998).

In addition to the product development, significant cost reductions can be gained in the production as well. The investment costs in the production can be lower due to the smaller amount of production lines. In the mechanical engineering, there have been savings in the procurement of materials as well as components (Meyer and Lehnerd, 1997a).

The product platform strategy can be though as a business model, while it ensures fast growth in the market shares and profits, and rapid product development for new market niches, competing with larger product family, rapid product launches, and possibility of becoming a standard in the industry (Meyer and Seliger, 1998). Market leverage is achieved through higher sales per engineering costs of product platforms. Market leverage can also be gained by quickly developing new products to new market areas.

Hence, the product platform strategy has proven its power in practice – it has solved the equation of faster product development, global competition, changing customer expectations, lower prices, and complicated products. The economic benefits as well as the competitive advantage gained in the two case examples, the Sony Walkman and the Black & Decker power tool cases, have been significant, making the area of product platform development an interesting target to the research activities.

1.2 Previous Product Platform Research

Caffrey et al. (2002) divide the field of product platform research into strategic, technical, economic and organizational research areas. Van der Linden (2002) uses rather similar division for the product family development field: he divides the field into business, architecture, process and organizational issues. The existing literature of the field will be shortly reviewed using combination of these categories, to identify the research areas that have not been addressed in the literature of the product platform development.

The basic definitions of the *product platforms* were provided by a few authors. Wheelwright and Clark (1992) defined the product platform development projects, and Meyer and Utterback (1993) and Meyer and Lehnerd (1997a) continued the work by providing the basic generic definitions to the product platforms as well as specific definitions for the product platforms in the information technology and software industries (Meyer and Zack, 1996, Meyer and Seliger, 1998).

McGrath (1995) introduced the product platform *strategy*. The product platform strategy has also been researched by Meyer and Lehnerd (1997a). Meyer and Lehnerd (1997a) and Sääksjärvi (2002) have studied the strategic product platform development in the field of information technology. Meyer and Seliger (1998) have also extracted the strategy concept to the software technology. *Economic and business* aspects of the product platform development include the efficiency and effectiveness metrics (Meyer et al., 1997b) as well as the economic success stories of product platform development (Sanderson and Uzumeri, 1995: Sony Walkman, Meyer and Lehnerd, 1997a: Black and Decker).

The literature of product platform *architecture* is quite new: a study done to several academic journal databases reveals that most of the articles concerning product platform architecture have been published after 1996 (Usrey and Garret, 2000). The architecture and technical field of study includes several researches. E.g., Gonzales-Zugasti and Otto (2000) have developed a method for choosing the subsystems for the product platform, e.g. in spacecraft design. Simpson (1998) has developed a method for designing product platforms, and methods for designing product families have been reported by Siddique (1999) and Nayak et al. (2002). Simpson and D'Souza (2002) reported an algorithm-based approach for resolving the tradeoff between commonality and distinctiveness in the product platform and product family design. Krishnan et al. (1999) proposed a model for planning the product family, which considers the R&D costs and optimizes the number of derivative products. Bin et al. (2002) have defined web-based system architecture for the development of product platform. Sivard (2000) has developed a model for integrating the information produced and used in the design phase of product family development with information used in the ordering process.

Muffatto and Roveda (2000) have conducted an exploratory research on the product platform development *process* of three case companies in the electro-mechanical industry. Tatikonda (1999) has studied the product platform projects and their success factors compared to the derivative product development, and Meyer and Selinger (1998) have given high-level guidelines for planning a new software product platform from the end-user needs to actual implementation plans and budgets. The *organizational impacts* of product platform development have been mentioned in research reports and articles (e.g. Tabrizi and Walleigh, 1997, Meyer and Selinger, 1998, Robertson and Ulrich, 1998). Van der Linden (2002) argues that the organizational issues are the least researched area in the product family development, and Caffrey et al. (2002) argue that the organizational issues are probably the most important issues especially when trying to implement new product platform initiatives. An ITEA (Information Technology for European Advancement Framework) project called CAFÉ (Concepts to Application in System-Family Engineering) will concentrate on the business aspects (how products make profit), architecture (technology needed to build the system), process (responsibilities during software development), and organization (for developing the software) of product family development (Van der Linden, 2002). Similar efforts for product platform development have not been reported in the literature.

Hence, there have been some activities in all the product platform research areas, but in most of the areas, the amount of research done is limited. The definitions and the architectural issues are the best-covered areas, but the other areas still require further research. The least researched area, though, is the organizational aspect of the product platform development. The organizational issues might include strategic aspects as well as product platform development process aspects, which have slightly been touched by the previous research. The aspects not researched previously include e.g. the competences needed in the product platform development, communication during the product platform development as well as the product platform projects and their management. Since the understanding of the organizational aspects of product platform development are of great importance in establishing a new product platform development unit or transforming from a single product to product family development environment, new research in the area is needed.

1.3 Scope of the Research

Many successful companies develop their product platforms in business units created for that purpose only (Tabrizi and Walleigh, 1997), but as discussed previously, the organizational aspects of product platform development have not been thoroughly studied yet. In fact, the research in the field is about to begin. Hence, the main aim of this research is to increase knowledge of the product platforms, not from the business or economic nor from the architectural or technical aspect, but rather from the aspect of the product platform development. As the understanding of the product platform development is seen as a prerequisite for implementing a change into the product platform development R&D, and as the research of the organizational aspects of the product platform development is limited, any information adding to the present knowledge is needed. As the area is not very thoroughly studied yet, the research is exploratory by its nature. Hence, the first research question is

> *1. According to the literature, of which factors does the product platform development consist?*

The research starts with literature review, and the more specific research questions will be derived from the results of the literature study in Chapter 3.1.

1.4 Structure of the Dissertation

The dissertation consists of seven parts, which each form an independent entity, and yet complement and support other entities. The structure of the dissertation is presented in Figure 1.

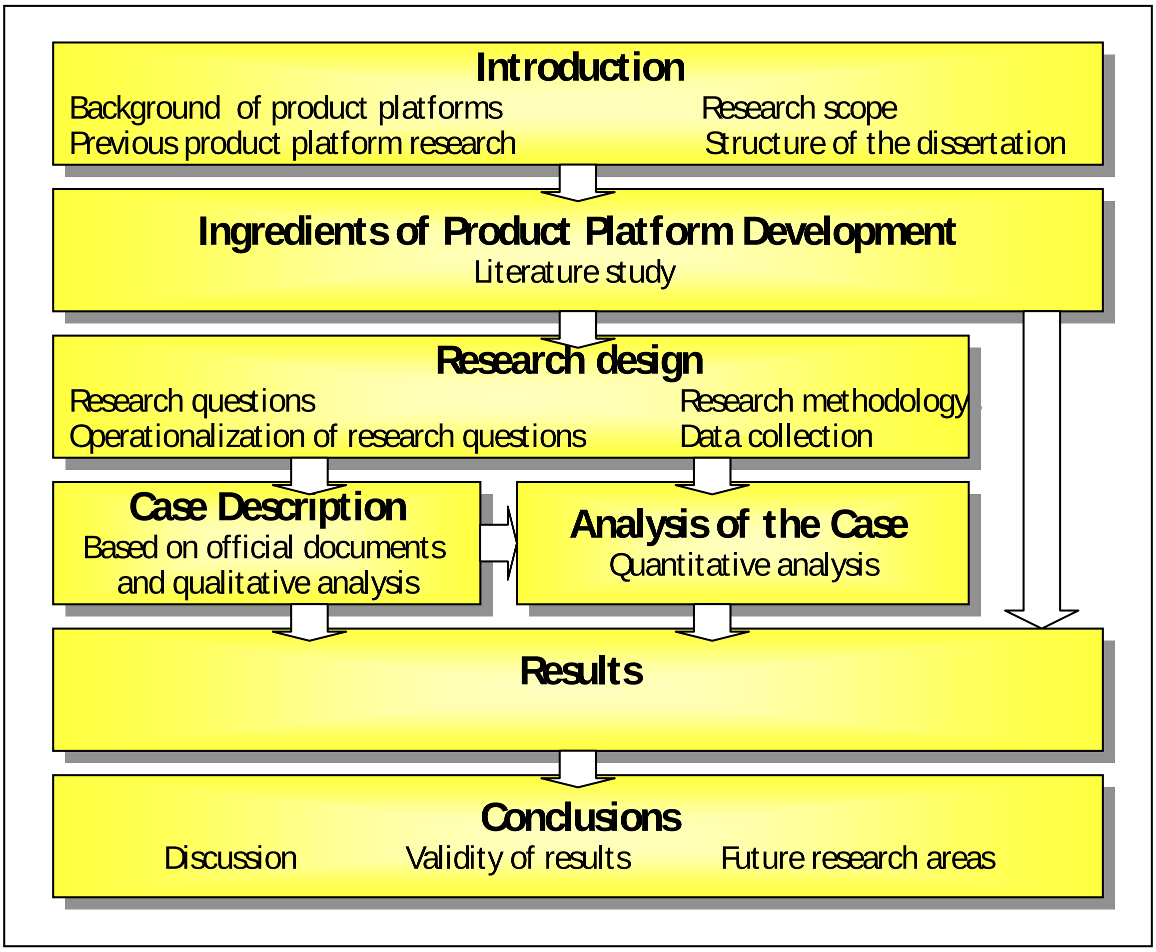

Figure 1. Structure of the dissertation.

The first chapter defines the environment of the research: the background of product platform research, importance of the research in the area, existing literature of product platform development theory, and gap in the research. In addition, the scope of the dissertation is presented in the first chapter, as well as the structure of the dissertation.

The second chapter is based on the theories of product platforms as well as generic product development. The aim of the chapter is to define the factors of the product platform development. The generic R&D theory, product development success factors, innovation management, and strategic technology management research areas will be shortly reviewed. The main emphasis is on the research available on the area of product platform development (e.g. the product platform definitions, product platform strategies, product platform development metrics, and benefits of product platform development).

The third chapter specifies the research questions based on the findings of the literature study. The chapter continues to present the chosen research methods. The research questions are operationalized to the use of empirical study, and the data collection methods are presented in the end of the chapter.

In the fourth chapter, the chosen product platform development unit, its product lines, products and functionalities are described. The case description includes both the official descriptions of the areas as well as findings from the qualitative data collected in the SWP R&D internal customer satisfaction surveys. The fifth chapter presents the case analysis in detail according to the selected research strategy.

The results of the analyses are further processed in chapter 6, and compared to the literature study of the product platform development. The chapter discusses the empirical and theoretical contribution of the research.

The last chapter concludes the dissertation by taking a glance through the main results of the research, and discussing the importance of them as well as their validity and reliability. Further research areas are defined.

2. PRODUCT PLATFORM RESEARCH AND DEVELOPMENT

2.1 Research and Development

The term Research and Development (R&D) is associated with both the organization (function) performing the research and development activities as well as with the activities themselves. The meaning of *research* is different for the academic and industrial world. For academicians the term research means discovering new knowledge about the universe with no restrictions, while in the industry, the business needs give the frame for the research (Roussel et al., 1991). Dussauge et al. (1994) divide further the research done in a company to basic research and applied research. Basic research keeps the company in touch with scientists and technology development, and it does not directly support any development project in a company. Applied research connects the research into product development. The target of applied research is to provide data for the development of a product or a process. *Development,* then, uses the new knowledge created by research to develop products (Roussel et al., 1991).

The research of the product platforms has not yet identified the entire set of factors of the product platform R&D. There is some information available, but a full picture is missing. The research arena of the product platform development has been divided into areas of strategic, technical, economic and organizational issues (Caffrey et al., 2002), and a similar divisions, i.e. business, architecture, process and organizational issues, was presented to the research of the product family development (Van der Linden, 2002). These areas can be used as a starting point in finding out which are the factors of the product platform development, but still, there is a need to use other literature in combination with the product platform research in the quest of identifying the potentially important factors of the product platform development.

Research in the R&D Management field has changed only moderately during the time. Allen and George (1989) conducted a study to the articles in the R&D Management journal between 1971 and 1987, and found that the areas of *Corporate and R&D Strategies* had remained quite stable during the time (although there had been a peak in

R&D strategy research in the 75-81), as well as the area of *Innovations*. The area of *Project selection and management* had been popular, but the amount has decreased from the 70's. The field of *Communication* had been stable, but the focus had shifted from the printed media to the communication between functions. In addition, the other organizational issues, as *relationships between organizations* had gained more attention.

The area of new product development includes the actual activities performed to develop a product (Cooper, 1995), and hence the activities performed in the research and development organization. Brown and Eisenhardt (1995) reviewed the field of the product development, and divided the field into three research streams. The first one stressed the importance of the *superior product*, *attractive market or rational organization*; the second one stressed the effect of external and internal *communication* in gaining success; and the third one stressed the *problem solving* actions, roles of *management* in giving the product vision, autonomous *project team* in solving the problems and fast *product development process*.

The problems and success factors of the research and development have also been reported in the literature. The problems in the *management of technology* have been researched by Scott (2001): They include the link between the *corporate and technology strategies*, *communication* between technologists, short-term focus on the product and technology plans, the *technical core competence* plan, and *customer participation* to product development. In addition, the failure to understand the customer needs has lead to failures in innovations (Freeman and Soete, 1997). The reported success factor of new product projects, on the other have, include e.g. a *superior product* with value to the customer, high quality *product process*, defined *new product strategy*, adequate *resources* (people and money), right *organizational structure, core competences* (Cooper and Kleinschmidt, 1996, Cooper, 2000).

Thus, the field of R&D management stresses the importance of strategies, innovations, communication, relationships between the organizations, and project selection and management in the product development. The new product development literature introduced the concepts of superior product, communication as well as the disciplined problem solving as important parts of product development. The reported product development problems and success factors, again, included the strategies, communication, competences, customer needs, product development process, organizational structure, and superior product.

Each of the item listed before is a broad area of research, but in this dissertation it is not purposeful study all the aspects of the areas. Instead, the chosen viewpoint, i.e. the product platform development, will be used to guide the discussion in the areas. The possible factors of product platform development will be described in the next chapters covering the areas described above. The aim is to identify the factors of product platform development, but the aim is not to define any relationships or theories between the factors. The following literature study starts with the product platform definitions, and continues with organization and management, strategy and process related aspects of the product platform development. The research about product platform development will guide the discussion. Since the literature of product platform development is quite thin on some areas, the strategic technology management, R&D management, and new product development literature will be briefly gone through whenever necessary. The amount of research in the area is significant, and hence, only a part can be gone through here. The significant aspects of each of the area from the chosen scope will be presented next. The main aim is to identify the factors of product platform development, but not to define any relationships or theories between the factors.

2.2 Product Platform R&D

2.2.1 Product Platform

In the literature, there are several meanings for the term platform. Wheelwright and Clark (1992) define the next generation platform projects, which introduce a significant change in either product or process. The platforms are defined to be the bases for the derivative products. Meyer and Utterback (1993) and Meyer and Lehnerd (1997a), on the other hand, have a broader view to the product platforms: they are not solely next generation products, but the existing product platforms can also be modified. In the software industry, the hardware or software (e.g. the operating system) has been referred as a platform. The definitions used in this dissertation are mainly derived from the work of Meyer and his colleagues. They define product and process platforms, and apply the definitions of product and process platforms from the mechanical engineering to the software industry and information product industry. The main aspects from this research's point of view will be next reviewed.

The concept of product platform was first introduced in connection with the mechanical engineering, but has been broadened to include pure information technology and software products, also. There are several definitions for the product platforms. According to McGrath the product platform is

> *a collection of common technical elements, especially the underlying core technology, implemented across a range of products* (McGrath, 1996, p.105).

Meyer and Lehnerd (1997a), on the other hand, specify the product platform further

> *A set of subsystems and interfaces that form a common structure from which a stream of derivative products can be efficiently developed and produced (Meyer and Lehnerd, 1997a, pp. xii, 39).*

Robertson and Ulrich (1998) have broadened the definition even further. According to them product platform is

collection of assets that are shared by a set of products,

where the assets are the components, processes, knowledge, and people and relationships (Robertson and Ulrich, 1998). In all the definitions, the product platform forms a common technological base for the applications (aka. complementaries, product families, or derivative products); hence, the goal of the product platform development is to create an architecture that is common to a group of products (Meyer and Lehnerd, 1997a). In this dissertation, though, the definition of Meyer and Lehnerd (1997a, p. 39) is used.

In addition to the product platform, the literature recognizes the importance of the process platforms, although the literature of the process platforms is far more limited than of the product platforms. The literature mainly stays on the definition level. Thus, the process platform is defined to be

composed of the technologies, facilities and processes for manufacturing a firms products (Meyer and Zack, 1996)

The process platform consists of producing or sourcing the components and materials, assembling the components to a product as well as the final testing of the product. In the process industry (e.g. petrochemical industry), the process technology is also a part of the process platform (Meyer and Lehnerd, 1997a). Changes in the process platforms cause volume and capacity increases. Well-designed process platforms may decrease the production ramp-up costs of new products, and thus increase the efficiency and effectiveness of the new product development. Concurrent engineering is an important part of designing product and process platform. In order to gain the advantages of product platform development, the link between the product development and production process planning is of utmost importance, especially in the mechanical and process engineering. According to Meyer and Lehnerd (1997a), the production personnel should be committed to the product platform development from the very beginning.

The products of the *information technology* (IT) are provided in electronic or printed form (e.g. data, information and knowledge products). The products may be sold to the customers or provided by the IT department of a company. In the information industry, the product itself and the process by which it is produced are tied even closer together than in mechanical engineering and thus requires the product and process platform to be defined for the purpose of information technology (Meyer and Zack, 1996, for the definitions, see e.g. Meyer and Lehnerd, 1997a, Sääksjärvi, 2002). The IT infrastructure for a company can also be developed as a product platform. IT infrastructure development resembles other software product platform development activities: it is a strategic competitive advantage which is hard to copy, it combines technological solution with core competences of a company, it requires large basic investments, and it is useful only when it eases the IT application development for different business needs (Sääksjärvi, 1998b). Benefits of applying the product and process platforms to the information technology products include e.g. flexibility, customization of services, cost-effective infra, and easier co-ordination of outsourced IT-products (Sääksjärvi, 1998a).

The concept of product platform in the *software industry* has changed along the years: in the 70's and 80's, the product platform referred to the type of computer (e.g. Intel's PC, Unix work station, etc.). From the late 80's, when the computer type was not important anymore, the product platform referred to the operating system (Windows, Unix, and so on) (Meyer and Lehnerd, 1997a). In addition to the operating system, the hardware and networking environments are part of software product platforms (Meyer and Seliger 1998). In the 90's, the product platform approach has been applied in the field of software products.

The product platform architecture consists of subsystems and the interfaces between them (Figure 2). The role the interfaces is important for any product, since the well-defined interfaces ensure shorter development times by making it possible to concurrently develop modules (Smith and Reinertsen, 1997). In the product platform development, the interfaces are critical: only clear, well-defined interfaces make it possible to easily create derivative products, and enhance product platforms. The internal and external interfaces of a product platform must be seamless and standardized in order to gain efficiency from the product platform thinking (Meyer et al., 1997b). The product platform developers can be active in the standardization work, and drive their interfaces to be the industry standards (Meyer and Lehnerd, 1997a).

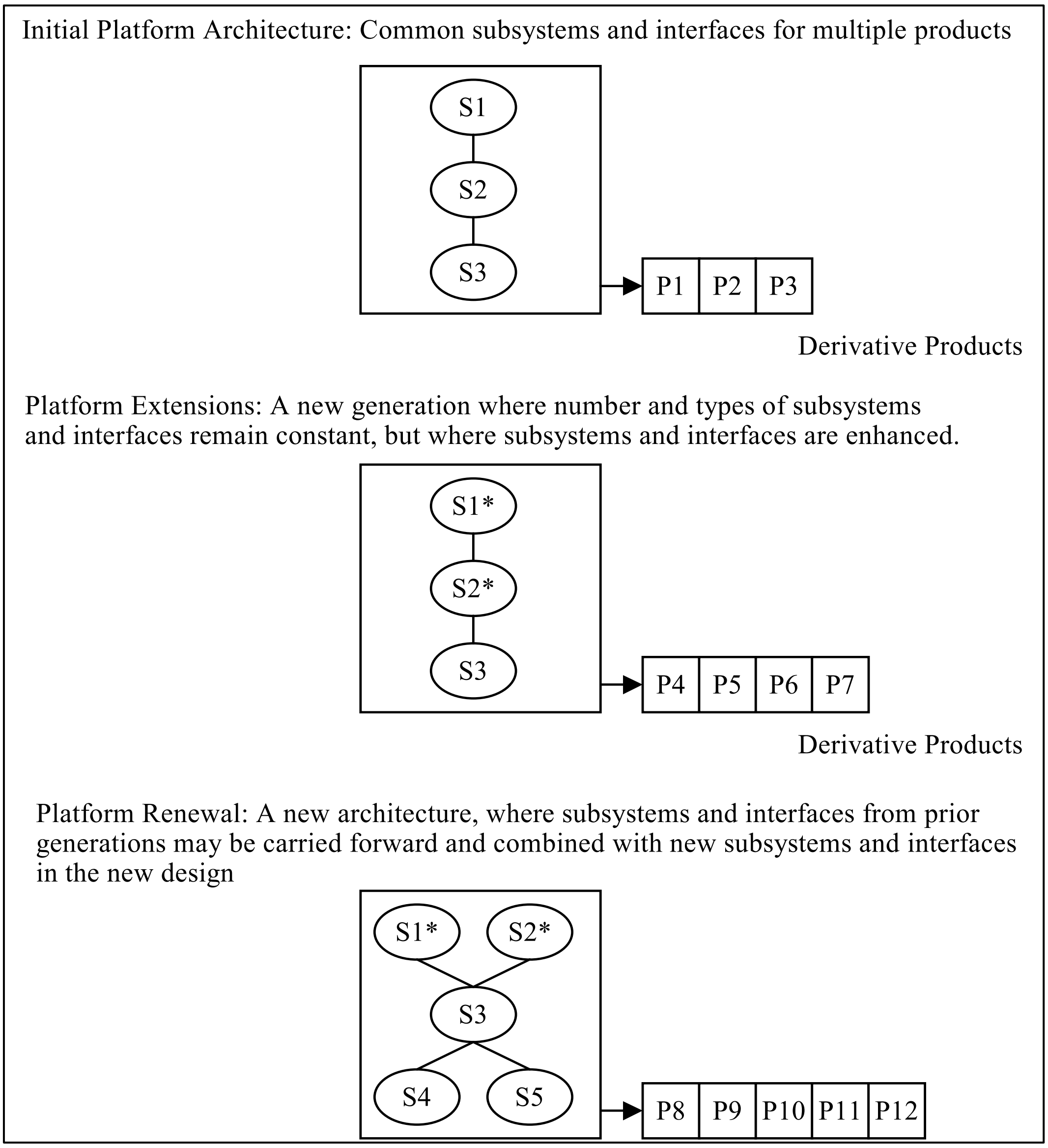

Figure 2. Product platform architectures (Meyer et al., 1997b).

The architecture of a software product can be fitted to the definitions of the product platforms. Software product typically consists of several layers: computer hardware, operating system, software development tools, and applications (Meyer and Lehnerd, 1997a). The software product platform architecture includes (in addition to the operating systems) the basic roles (design strategy) and tools for developing the product family, and gives thus the frame for the application development. The architecture of the software product platform consists of subsystems and interfaces, which enable time- and cost-effective development of derivative products (Meyer and Seliger, 1998). Usrey and Garret (2000) suggest that object-oriented design practice could be "benchmarked" in the architectural design and especially in the interface design of product platforms. The authors base their suggestion to the modular structure proposed to the product platforms, and modular structure of object-oriented products. Applications are pieces of software, which plug into the product platform, and can be developed either by own or external designers. Applications either can be common to all the market segments, or be aimed at a certain segment. The application development interface is an important control point: the interface is used by own and other companies to develop applications to the software product (Meyer and Seliger, 1998).

Sääksjärvi (2002) criticizes the above described software product platform architecture for combining the process and product architecture in a common frame. He further defines the process platform in the case of the software business by dividing it in two: the development methodology (software development process) and customer implementation process.

The existing product platforms can be further developed either by enhancing the subsystems and interfaces or by changing the entire architecture of a product platform. New generations of product platforms (product platform extensions) are developed, when the number and types of subsystems and interfaces of product platform are not changed but enhanced. Product platform renewals are developed when new subsystems and interfaces are introduced, and thus new architecture is designed (Meyer, et al., 1997b) (Figure 2).

Even though there are less technological uncertainties in the product platform extension development, from time-to-time, it is necessary to renew the product platform as a defense against technological and architectural discontinuities (Meyer and Utterback, 1993, Henderson and Clark, 1990). The product platform literature has not thoroughly studied the innovativeness aspect of the product platform development. The innovation management literature, on the other hand, is of wide scope. Product innovations have been shown to be tools for gaining competitive advantages, changing industries, redefining boundaries of industries and modifying the rules of the game. Innovations are essential in competition; they determine the success in the long run in the markets (Utterback, 1996). The innovations are evaluated from the commercial success point of view, thus whether an innovation is able to return the development costs and some profit (Burgelman et al., 1996). Innovations can e.g. be classified as sustaining (can be either incremental or radical technological innovations) or disruptive (Christensen, 2000), continuous (evolutionary, incremental) or discontinuous (revolutionary, radical) innovations (Robertson, 1967, Veryzer, 1998a). Another classification of the innovations is done according to the technological capability vs. product capability (Veryzer, 1998a). Sustained competitive advantage of a company depends on its ability to develop incremental, architectural and discontinuous innovations (Tushman, et al. 1997). Even though the incremental changes in technologies (compare product platform extensions) are more common, every now and then there are breakthroughs (compare product platform renewals) that either destroy the competitive advantage of the established firm, or enhance their positions (Tushman and Anderson, 1986). Usually, when new products based on new technology have competed for the markets for some time, a dominant design (in innovation) emerges. The dominant design is not necessarily the most advanced technologically, nor does it fulfill more user needs, but for some reason it wins in the market places. Competitors must use the dominant design also to get at least some market share (Utterback, 1996). Despite which definition of innovation is used, the role of product innovations in the context of product platform development can be seen as an important one. In the product platform development, the choices are made years before the derivative products are launched in the markets, and if new technological innovations are missed, it will be difficult to manage in the tough competition.

The product platform can be presented as building on the technologies, consumer insights, organizational capabilities and manufacturing processes. The product family, based on the common product platform, includes products aimed at different market segments or niches inside the segment as presented in Figure 3 (Meyer and Utterback, 1993). The derivative products can be created either in-house or by other companies (e.g. partners) (Meyer and Seliger 1998). The product platform decisions affect greatly on the application developers: the product platforms are tightly connected to the derivative products, and thus there must be close cooperation with the application developers (Cusumano and Yoffie, 1998).

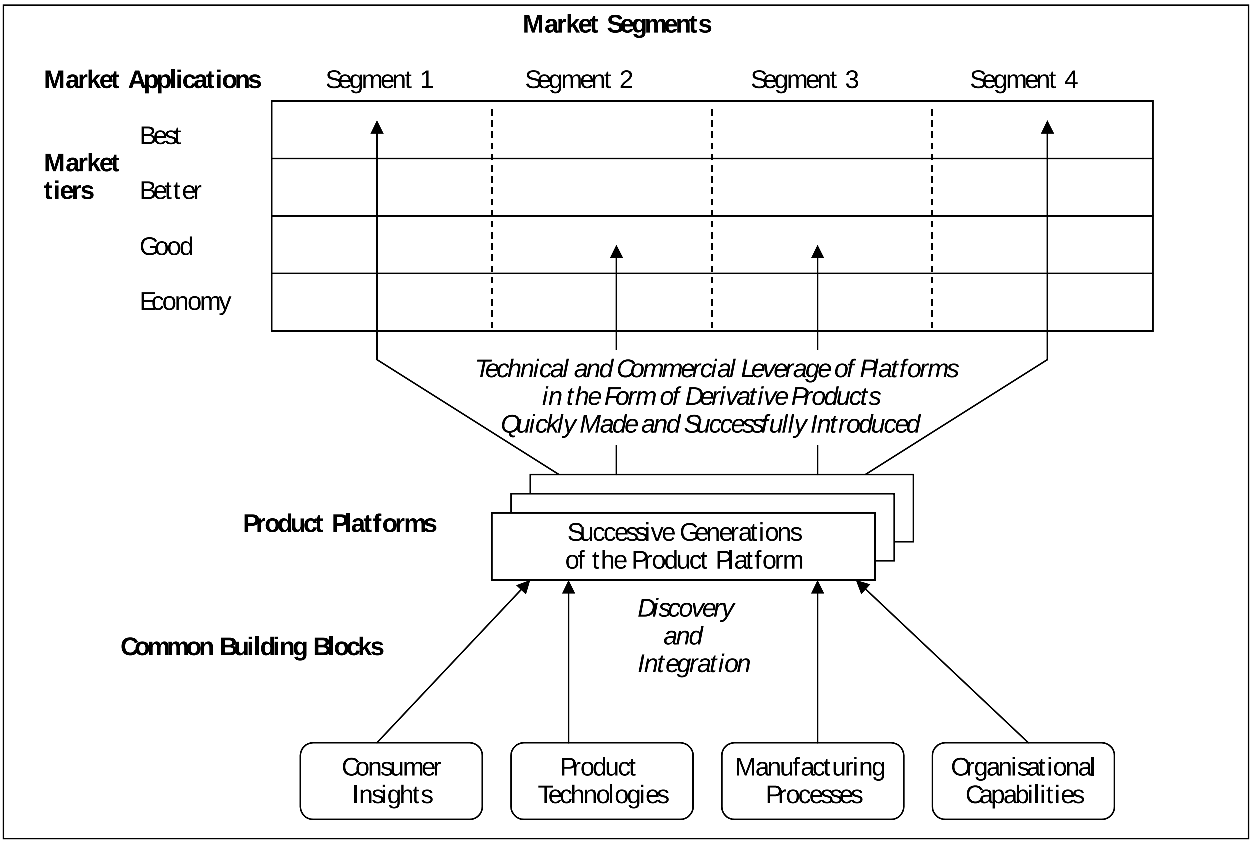

Figure 3. The power tower of product platforms (Meyer and Lehnerd, 1997a, p.38).

Hence, the product platform is a common technological base for several derivative products. Therefore, the output of the product platform development is used either by product lines in-house or by external customers. The product platform should enable easy, effective and efficient development of derivative products on the product platform. The easiness might include an innovative, good-quality, well-defined product platform, whose architecture and interfaces are clear and documented. The product platform needs to be renewed from time to time in order to sustain the innovativeness of the product platform and to defense against technological discontinuities. The role of the process platform is important both for the mechanical products as well as for the software products.

2.2.2 Product Platform R&D Organization and its Management

Organizational Structure and Relationships between the Organizations

Product platform development requires organizations to make major resource commitments (Tabrizi and Walleigh, 1997). A study by Tabrizi and Walleigh (1997) done to 28 product platform development companies revealed that the successful companies developed their product platforms in business units created for that purpose only. Meyer and Lehnerd (1997a) argue that the product platform development team should be small and cross-functional; e.g. in mechanical engineering, the manufacturing representative should be involved from the very beginning of the development. Collocation of the product platform development team is an important factor for it improves the communication and information sharing between the team members (Meyer and Lehnerd, 1997a). Cusumano and Yoffie (1998), on the other hand, emphasize the importance of close cooperation between the product platform and the application developers.

Hence, the organization of the product platform development has been mentioned in some studies, but the research has not, by any means, provided a thorough analysis of the possible organizational structures of the product platform development units. The possible organizational structures for the product development in general are many (e.g. Drucker, 1988, Mintzberg, 1994, Grant, 2001). Still, it can be questioned whether there is one right structure for the product platform development. E.g., Hankinson (1999) discovered in a research of the world's top 100-brand development organizations, that the structure itself was not as important as whether the particular structure fits to the particular company. Bartlett and Ghoshal (1990) argue that the focus should be shifted from trying to build a perfect organizational structure to enhancing the abilities and performance of individuals in the organizations (e.g. managers). Hence, the organizational structure per se might not be as important as the nature of communication inside the product platform development team as well as the interface and relationships between product platform development organization and the derivative product development.

Management and Decision Making

According to Mintzberg (1989)

> *there is more to organization than management (p.6). But no consideration of organizations is complete without careful attention to management process (p.7).*

Product platform decisions have a long-term effect on companies and to the products to be developed and sold several years from the decision. It can be argued that the product platform decisions are among the most important ones a company make. Thus, it can be argued that the role of management is utmost important in the product platform decisions (Robertson and Ulrich, 1998). The product platform development team should possess the ownership of the product platform as well as the authority to make decisions concerned the product platform and process (Meyer and Lehnerd, 1997a). The product platform development is responsible for coordinating the needs of different application developers (Meyer and Seliger, 1998). These needs might be conflicting proposing challenges to the new product platform definition. Thus, the planning of the product platforms should be a cross-functional activity (Robertson and Ulrich, 1998). In addition, the conflicting needs require strong control (cross-functional) functions, e.g. governing or steering groups consisting of business unit's managers (Meyer and Seliger, 1998, Nobeoka and Cusumano, 1995).

Hence, the decision-making and steering systematics are recognized to be important in the product platform development literature. The co-ordination between different product platform development needs (set by the derivative products) is a delegate issue, and the derivative product developers probably would like to influence and be a part of the decisions made.

Measurement

Management of an organization requires measurement (Kaplan and Norton, 1996). The single product development measures include the slip rate, which measures the gap between the estimated and realized project time and budget (Meyer and Lehnerd, 1997a), as well as defects, progress of work, costs, staffing, changes, and responsiveness to customer problems (Royce, 1998, Grady, 1992). E.g., the slip rate has been criticized of measuring more the estimation skills of project managers than the project's success. In addition, the slip rate is not very useful in the product platform projects, which can be based on new technologies and high market uncertainties making the project schedules difficult to estimate. The slip rate is more useful in measuring the derivative product projects, instead.

Meyer and Lehnerd (1997a) have defined product platform efficiency and effectiveness metrics. The product platform efficiency measures, how well a product platform allows derivative products to be generated economically (Meyer et al., 1997b). Product platform development efficiency (engineering costs) is calculated by dividing the derivative product development costs by the product platform development costs. An efficiency formulae for a single derivative product (Meyer and Lehnerd, 1997a, pp.152-159) is presented below.

$$Platform\ efficiency = \frac{Derivative\ product\ engineering\ costs}{Platform\ engineering\ costs} \quad [2.1]$$

The same measure can be used for several derivative products by dividing the average derivative product engineering costs by the product platform engineering costs. High efficiency is achieved if the value of 0.1 or lower is reached (Meyer and Lehnerd, 1997a).

The time-efficiency of product platform development can also be measured (Meyer and Lehnerd, 1997a). The metrics can be used as well for individual products as the entire product family or comparatively for different product families (Meyer et al., 1997b). The cycle-time efficiency metric is calculated by dividing the time used to develop derivative products with by the time used to develop product platform. The formulae is presented below (Meyer and Lehnerd, 1997a, p. 160)

$$Cycle\ time\ efficiency = \frac{Elapsed\ time\ to\ develop\ a\ derivative\ product}{Elapsed\ time\ to\ develop\ the\ product\ platform} \quad [2.2]$$

Again, the cycle time-efficiency across a larger number of products would be counted by dividing the average elapsed time to develop derivative products by the time to develop product platform.

The product platform effectiveness, i.e. the commercial leverage achieved by the derivative products over time (Meyer and Lehnerd, 1997a, pp.163-167) is calculated by dividing the sales of derivative products by the costs of a derivative product. As a formulae it can be presented as below.

$$Platform\ effectiveness = \frac{Net\ sales\ of\ a\ derivative\ product}{Development\ costs\ of\ a\ derivative\ product} \quad [2.3]$$

The costs of the derivative product development include the engineering, manufacturing, and market development costs. It can also be used to measure the whole product family by dividing the product family net sales by the product platform development costs. In successful electronics and system companies, the effectiveness has been around 30. Some products have achieved even 500.

The product platform efficiency and cycle-time efficiency measures can also be dangerous. If the product platform development is not efficient, the product platform engineering costs increase, leading to a low value of product platform efficiency. This should indicate about efficient product platforms, but in this case, the product platform development might be very inefficient. Hence, the product platform development measures need to be interpreted in conjunction with each other as well as with other metrics.

As to the measurement, the metrics are one of the communication tools between the product lines and the product platform development both on operational and strategic level. The operational measures specific to the product platform development have not been reported in the literature – and it can be questioned whether the metrics would differ from the ones connected with single product development. The strategic metrics (e.g. product platform development efficiency and effectiveness), on the other hand, might influence the choices of product platforms made by the derivative product developers (if there is a choice!).

Competences of Organizations

The competences are essential in the product development; they are needed from the product strategy definition to the execution of product strategy (Prahalad and Hamel, 1990, Hamel and Prahalad, 1994, McGrath, 1995, Mäkelin and Vepsäläinen, 1994). The competences have been mentioned by some research in connection with product platform development. Still, their impact in the product platform development has not been shown, so far.

The technological and market proficiencies are prerequisites for developing a successful, high-quality product (e.g. Cooper, 1995, Calantone et al., 1996, Song et al., 1997). The technological core competences are needed to develop better product platforms and derivative products than the competitors do. The marketing core competences (e.g. channels, distribution, customer relationship management) are needed to gain advantages in the market place. The marketing competences are needed during the product platform definition, and especially important they will become in the case the derivative product developers are external customers. The management core competences allow company to run its processes better than the competitors do (McGrath, 1995). The core capabilities (skills, competences) of a company are more permanent than a product platform, product family or a single product (Meyer and Utterback, 1993). The successful product platform developers excel in choosing the right amount of members and right mix of skills to their product platform definition (number, skills, experience) (Tabrizi and Walleigh, 1997).

Cooperation and Communication

There is no doubt in the literature of new product development and R&D management that effective internal and external communication is an important success factor of innovations and development projects (Roussel et al., 1991, Rothwell, 1992, Souder and

Moenaert, 1992, Moenaert and Souder, 1996, Li and Calantone, 1998, Lievens et al., 1999, Kivimäki et al., 2000). In addition, cross-functional integration and communication is a significant success factor for new products (Burgelman and Maidique, 1988, Song and Parry, 1997).

In the research of product platform development, the role of internal communication has been mentioned in connection with the rapid design transfer strategy. Nobeoka and Cusumano (1995) concluded that in addition to co-ordination of the concurrent product platform and derivative product projects, good communication is needed. Especially the communication between the project managers was stressed. In addition to Nobeoka's and Cusumano's results it seems obvious that communication in the product platform development is a necessity: the product platform decisions have a long term effect on the derivative product development and the visions of the future products based on the product platform must be communicated and sold to the internal as well as to the external customers. The co-ordination of requirements (by several derivative product developers) requires considerate amount of communication. The information of the project's progress, interfaces as well as changes in them, and testing must be communicated to the product lines.

Hence, communication has been mentioned in few studies about product platform development. It would seem that communication is essential for the product platform development. The communication with the marketing function grows stronger in the case the product platform is sold horizontally, when the derivative product development is actually an external customer. In both cases, i.e. the derivative product development consisting of either internal product lines or external customers, the role of the marketing function could be important in providing market knowledge to the product platform strategies.

2.2.3 Product Platform Strategies

The strategies have been studied for years and the literature of strategies is wide in scope (see e.g. Bowman, 1995, Spender, 1993, Mintzberg, 1978, Mintzberg, 1987a, Mintzberg, 1987b, Schendel, 1994, Prahalad and Hamel, 1994). The strategy research has been divided into several schools (Mintzberg, 1994, Mintzberg et al., 1998), e.g. to strategy process (Schendel, 1992a, 1992 b, Van de Ven, 1992, Pettigrew, 1992), decision-making (Eisenhardt and Zbaracki, 1992) and strategy content (Fahey and Christensen, 1986, Montgomery et al., 1989, Brahm, 1993, Ansoff, 1985, Ansoff, 1989, Porter, 1980, Porter, 1989). Hence, there are several definitions to the term strategy. A simple one is provided by Steele (1989, p.181), according to which, strategy is

> *"the array of options and priorities with which one elects to compete and to survive".*

The importance the technology and product development strategy has been noticed in the literature (Spencer and Triant, 1989, Urban and Hauser, 1980, Betz, 1993). Hierarchically presented, the technological and product strategies are (or at least should be) part of business or functional strategies, which should have (or should have) a strong link to the corporate strategy (Porter, 1985, Burgelman and Maidique, 1988, Steele, 1989, Danila, 1989, Coombs and Richards, 1991, Roberts, 1995a, Edler et al., 2002, Roberts, 2001).

McGrath (1995) has defined the product development strategy for the product platforms and derivative products. He argues that the product development strategy is of utmost importance especially in a high technology company, because its need to build new markets, manage short product life cycles, develop products with new technologies and adapt to rapid changes in the market places. Each of these challenges makes it difficult to develop a winning product strategy. McGrath (ibid.) has divided the product strategy in four distinct hierarchical levels: vision, product platform strategy, product line strategy, and individual product strategy (Figure 4). The purpose of product vision is to show a clear picture of where the company is aiming at, and to generate a common understanding inside the company of its future. The strategic vision gives frame for the product platform strategy, guides product development, and gives technological direction. Product platform strategy provides answers to the questions of what, when and how as to the product platform development. The product platform strategy defines the technological foundations of company's products as well as the core competences the company needs to develop the product platforms. Product platform strategy includes decisions of what product platforms, when and how to develop. Product platform strategy gives focus on the important decisions of products, gives frame and direction to the product line and business strategies, provides direction to the technology development, and links vision with the product line strategies. The product line strategy further specifies the products based on a common product platform. The main purpose of a product line strategy is to define products to fill the selected markets (McGrath, 1995).

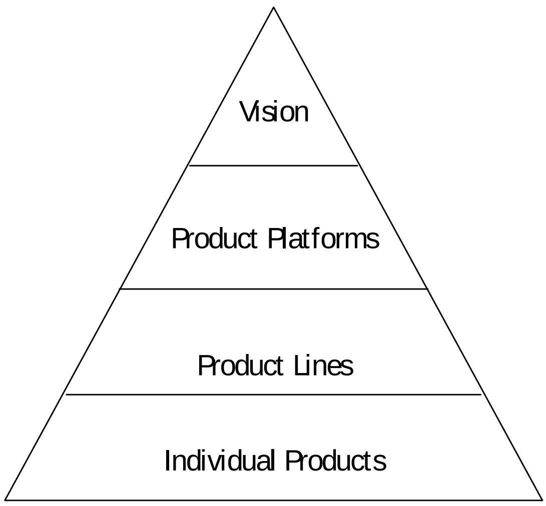

Figure 4. The levels of the product strategy (McGrath, 1995, p.14).

The number of product platforms and derivative products are strategic product decisions that need to be made by a company. The frequency of new product platform introductions is another one. Steinway, for example, introduced one piano product platform between 1970's and 1990's (Wheelwright and Clark, 1992). On the other hand, Sony had three Walkman product platforms, and introduced a next generation product every 18-24 months (Sanderson and Uzumeri, 1995). In some industries, the new generations of product platforms are designed in standardization forums, and thus the introductions of new generations are industry wide (Wheelwright and Clark, 1992). The number, timing and change rate of product platforms and derivative products is dependent on available resources (due to the long time-horizon of product platform development and resource intensive development efforts) as well as on technologies and competition (Wheelwright and Clark, 1992). The product platform strategies of successful companies have been reported to include maps of company's product streams in the near future. The maps included both the product platforms and derivative products, maps were changed along the time, and they were really used to manage the product development (Tabrizi and Walleigh, 1997).

Meyer and Lehnerd (1997a) define product platform strategies as to which product-market decisions are made, and thus they link the business aspects to the product strategies. The strategy work includes segmenting the markets, identifying the growth areas, defining current product platforms, analyzing the competing products and defining future product platforms. The product platform strategies are (Figure 5)

- Niche specific strategy: product platform is developed for a selected product-market square in the grid
- Horizontal leverage strategy: a product platform of selected performance level is aimed at several market segments
- Vertical scaling strategy: product platforms with different performance levels are aimed at selected market segment. The product platform can be stretched upward from the low-performance product or down from the high-end product
- Beachhead strategy: combining vertical and horizontal scaling (low cost low performance (but effective) product platforms scaled up and to different markets)

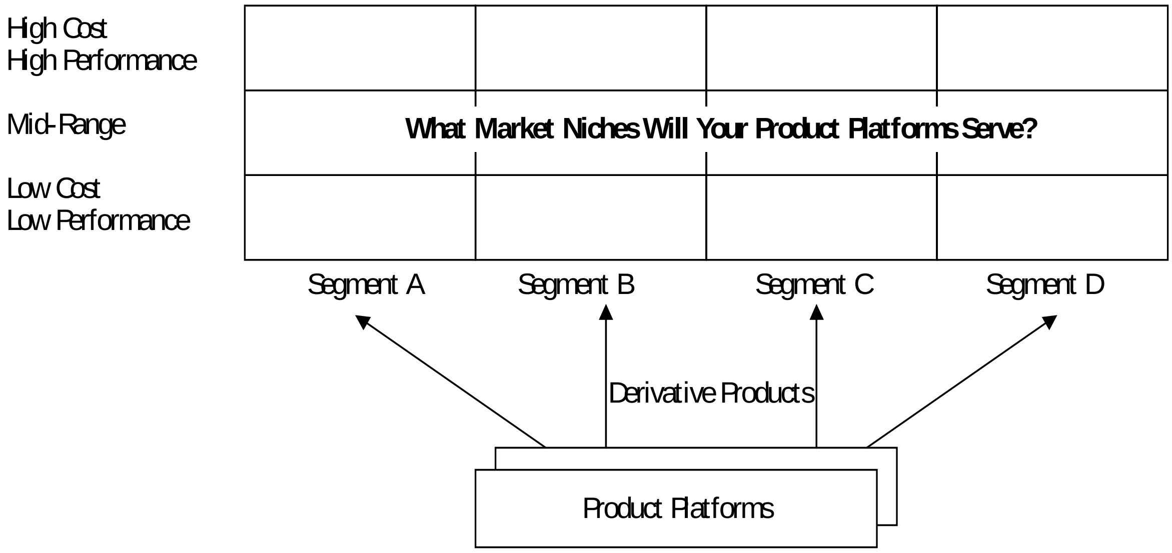

Figure 5. Market segmentation grid (Meyer and Lehnerd, 1997a, p.54).

Sääksjärvi (2002) has defined a strategic frame for software application product platforms. The main idea is to distinct the application structure strategies from the (software development and customer implementation) process-oriented technology strategies and customer oriented leverage strategies. The distinction is necessary because of the strong role of development and implementation processes in a case of software product. Despite of the distinction, these three strategies need to be integrated and aligned with one another. The integration is necessary between the customer needs and segments, processes and product architecture.

The strategic decisions concerning product platforms go even further: who produces the product platform and the derivative products, what is developed in-house (Cusumano and Yoffie, 1998). There are several alternative ways companies have chosen to compete; some develop both the product platforms and derivative products by themselves (e.g. Black & Decker, Sony), some develop the product platform and let other companies develop the applications (e.g. Intel-Microsoft relationship). A combination of the previous ones is the case where product platform is developed by a company and sold to horizontally to the competitors, while concurrently developing derivative product inside the company (e.g. Nokia Series 60). Horizontal sales channels can be used to gain efficiency in product platform development. Selling open product platforms horizontally to competing manufacturers and software developers is a way to increase profits and to gain a standard-like position in the markets (Meyer and Seliger 1998). The company may wish to utilize the network externalities (Shapiro and Varian, 1999) - the more there are users of either physical or virtual network, the more attractive that network becomes to the ones outside of it and the more attractive the network, the faster it will grow. The value of network thus depends greatly on the size of the network. In addition, when a network is large enough, the switching costs are higher: the larger the networks the more difficult it is to switch from one network to another. The difficulty, when selling product platforms horizontally, is to lead the development in a situation where the applications are developed by partners or even competitors (Cusumano and Yoffie, 1998). Here, the customer relationships are of special kind: even though the customer satisfaction is an antecedent to loyalty (Oliver, 1999), the satisfied external customers might not buy the product, if competitor's product performs better (Gale and Wood, 1994). In the case of internal product lines, there might be full loyalty to the product platform, and the satisfaction might be low – if there were no other choices available.

In the product platform development, the possible customer needs have to be seen years ahead, and the technological choices made for the product platform affect all the derivative products for years, which makes the product platform strategies important to the product lines. The fact that a product platform is not an end product by itself (Sääksjärvi, 1998b) requires companies patience – after the significant investment of time and resources to the product platform development, there still is nothing to sell until the derivative products are developed (unless the product platform is sold horizontally). Hence, the integration of product platform strategies with business strategies is important. The when, what, and how questions of the product platform development as well as the number and frequency of the product platform launches (i.e. the product platform strategy) are an area of cooperation between the product platform and derivative product development. The product platform roadmaps should be bases for product-market strategies of the derivative product development organizations. Finally, there is the strategic decision of who produces the product platform and the derivative products.

Hence, the research has considered the role of strategies in connection with the product platforms. The research on product platform strategies has concentrated on the strategy content, and the strategy hierarchy has been touched upon. However, the research has not considered the roles of strategy process and power and politics (decision making) in connection with the product platforms.

2.2.4 Product Platform Development Process and Projects

The work of research and development can be seen as a process, i.e. a workflow that transforms inputs (e.g. materials, people, energy, etc.) into outputs (products and services) to achieve a desired result (Evans and Lindsay, 2002). The process approach in new product development has been proved to improve the success of the resulting product (Cooper, 1987). Barclay (1992) stresses that product development processes are complex and iterative, and thus difficult to describe. Several models try to describe series of events, activities, decisions, or departmental stages. The processes differ mostly in what is included in the description. Generic product development models have been introduced for example by Urban and Hauser (1980), Jaakkola and Tunkelo (1987), Dwyer and Mellon (1991), Porter et al. (1991), Davenport (1993), Rothwell (1994), Heinonen (1994), and Ulrich and Eppinger (2000). As to the software development, there are specific process models starting from code and fix model, waterfall and spiral models to Software Capability Maturity Model (i.e. CMM) and unified software development process (Boehm, 1988, Royce, 1998, Humphrey, 1990, Jacobson et al., 1999, Royce, 1998, Kruchten, 2000). Barclay (1992) states, though, that there is no model available that can adequately describe the whole process of parallel events in product development.

The product platform development can be done concurrently for three different product platforms (Figure 6): derivative products developed from the initial product platform, improvements introduced to the existing product platform (product platform extensions), and the totally new product platform(s) (product platform renewals) developed (Meyer and Lehnerd, 1997a, Meyer et al., 1997b). Hence, the product platform development might require multi-project environment and management from the product development processes.

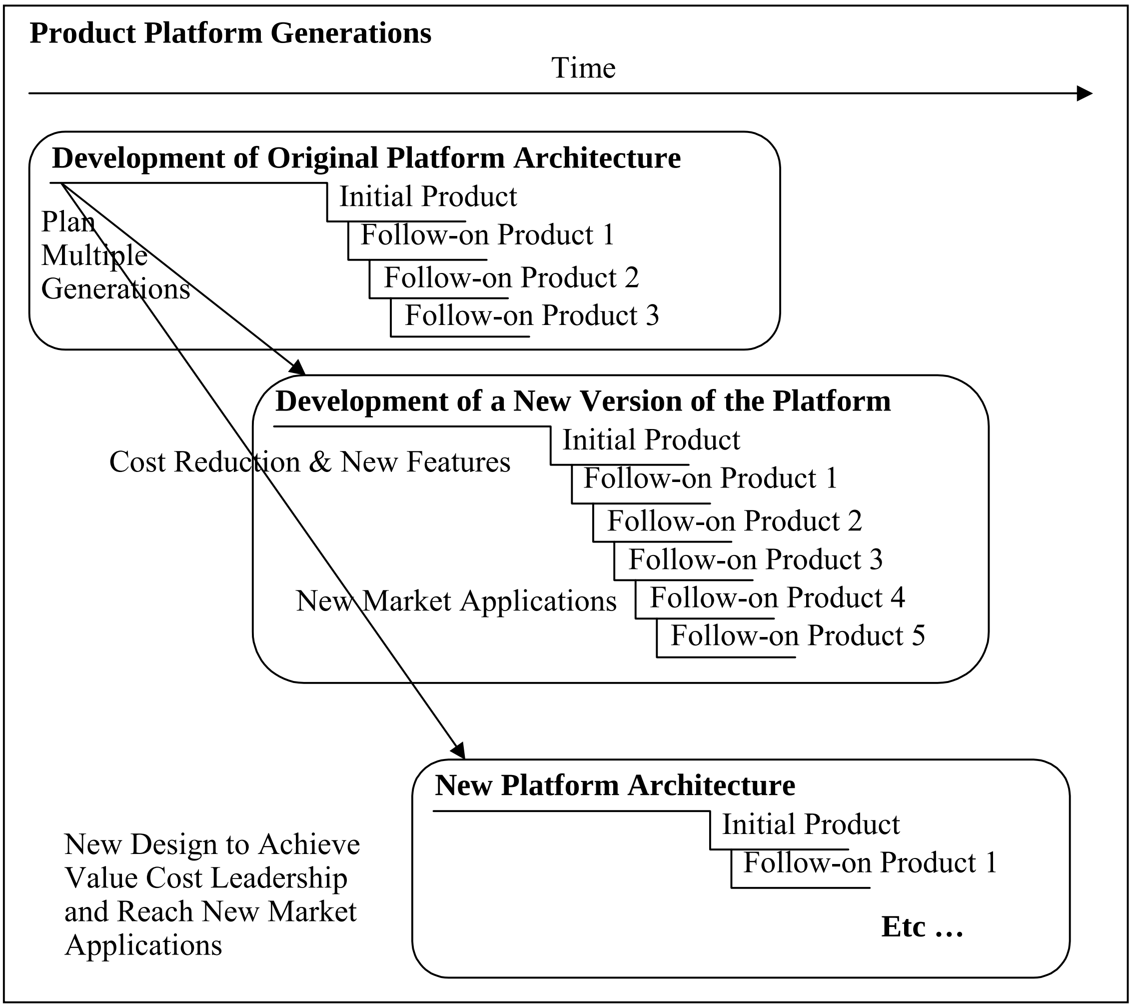

Figure 6. Product platform generations (Meyer et al., 1997b).

The actual implementation of a new product development (process) is often done in projects (Stenlund, 1986, Jaakkola and Tunkelo, 1987, Pelin 1999, Välimaa, 1994, Ulrich and Eppinger, 2000), with specific schedules, phases, resources, and objectives. There are several success factors identified to the product development projects, from the role of project management to planning and control, steering and risk management, transparency of projects, communication internally and to the interest groups (Jaakkola and Tunkelo, 1987, Pelin, 1999, Rothwell, 1992, Boehm and Ross 1989, Roussel et al., 1991, Boehm, 1991, Välimaa et al., 1994, Verner, 1999). Yet another significant success factor for product development projects are the customer needs, their proper assessment and transformation to the product specifications (e.g. Calantone and Cooper, 1981, Soin, 1993, Välimaa et al., 1994, Cooper, 1993 Cooper, 1995, Cooper, 2000, Evans and Lindsay, 2002, Kärkkäinen, 2002, Deutch, 1991, Sawhney, 2002, Rothwell, 1994, Verner, 1999). The customer needs assessment often fails (Kärkkäinen et al., 2001, Koivuniemi et al., 2002, Kärkkäinen and Elfvengren, 2002) and leads to changes during the project (Koivuniemi et al., 2002). On the other hand, a research conducted by Veryzer (1998b) showed that most of the notable product development ideas of *discontinuous* products came from inside the company – not form the customers.

Typical aspect of the product platform development is the long time-horizon; the product platform development requires time and patience. Significant time and resource investment decisions are made already in the product platform definition phase – in the beginning of product development (Krishnan et al., 1999). Meyer and Zack (1996) suggest that developing a product platform might take from 3 to 5 years, while the derivative products are developed from 3 months to 1 year's time. The new product platform development needs to be started concurrently with the development of derivative products on the previous product platform (Meyer and Utterback, 1993). The development of a new product platform requires more patience than the development of new versions of an existing product platform, because there are higher technological and market uncertainties involved (Meyer and Lehnerd, 1997a). The incremental innovations to the existing product platform might be less time-consuming and less risky, but time-to-time it is necessary to rethink the product platform. The long-time horizon stresses the importance of perceived and latent, simple and complex customer needs identification (Meyer and Lehnerd, 1997a, Meyer and Seliger, 1998). Since the product platforms are used as basis of several derivative products, product platform development needs to balance among varying business and technical needs. Hence, it is not surprising that the successful product platform development companies have excelled in collecting and utilizing good market information. This has been done by discussing with the customers (existing, potential new and former), sharing information about technologies and technical trends, and discussing with the sales channel participants (Tabrizi and Walleigh, 1997).

According to a study conducted by Tatikonda (1999), the product platform projects did not differ from the derivative product development projects in project planning and execution approaches, nor in the smoothness of project execution or project success. There were four factors identified, though, which increased the success of the product platform development; 1) reduced interdependence between the product's technological elements, 2) products new to the customers and markets, 3) contingency planning and project management involvement in setting the objectives, and 4) project-based evaluation of personnel and increased overlap between the design and manufacturing. The first two factors were specific to the product platform development, while the latter two factors increased the success of the derivative product development as well.

A study by Tabrizi and Walleigh (1997) done to 28 product platform development companies, on the other hand, revealed that there were severe problems in completing the product platform projects in schedule, and in developing the derivative products (product family). The problems originated mainly from the product definition phase. The successful companies, on the other hand, had learned to manage the technological and market uncertainties with their product strategies, project organizations and execution during definition phase. During the product definition phase, the successful companies tracked the progress of definition work, created early prototypes, and used development partners (Tabrizi and Walleigh, 1997). Without comparison to the derivative product development, it is impossible to say whether the schedule problems were specific to the product platform development or not.

A survey done in automobile industry on design transfer of vehicle product platforms between projects (Nobeoka and Cusumano, 1995) revealed that the rapid design transfer (product platform and derivative projects run concurrently) was the most efficient when measured by the engineering hours. The reason was that the new derivative project usually needed to modify the product platform, and in the concurrent mode, the modification needs could be planned in advance and the product platform could be designed to enable the modifications. It was possible to design together, share tasks and do adjustments to the product platform during the design phase. There also was a possibility to face-to-face contact, and communication between project managers. The rapid transfer management was complicated, though, for the interdependencies between the projects and hence, requires active multi-project coordination. Good communication was needed, as well as co-ordination in design and schedule.

Hence, the literature has included some aspects of the projects and process in connection with product platforms. The product platform development might require a multi-project environment to be implemented. Further, when developing a new product platform to be used years ahead, the real customer needs might not yet be seen. Ability to see the latent customer needs might determine who wins the race for the dominant design and thus the race for market share. Again, the product lines and the external customers should be very interested about the product platform fulfilling the external customer needs. Defining the customer needs and participating to the product definition (architecture and feature specification) at an early phases of the product development process improve the their ability to influence the contents of the final product platform. The customer need definition links closely to designing product new to the customers and markets. During the product definition phase, it is possible to reduce the amount of interdependencies between the technical elements in a product platform, also. During the product platform development, the concurrent derivative product development projects require constant communication, in order to gain efficiency in the product platform development.

2.3 Potential Product Platform Development Factors

The product platform development is characterized with high technological and market risks, and long time-horizon. The long time-horizon requires significant time and resource commitments to be made in already the product platform definition phase. The product platform is not an end product yet, and after the investments into the product platform, it must be used in several derivative products to earn the investment costs back. The product platform development thus is of great interest to either the product lines in-house product lines or external customers (i.e. in the case of horizontally sold product platforms). The product platform must support different sets of business applications and the development needs to balance with varying sets of requirements. Further, the product platform development might lack the direct external customer contacts, and thus the role of a product line as a source of e.g. customer needs information, is a significant one. The challenges of the product platform development include also the concurrent development of several products and finishing the product platform projects in schedule. Despite of the challenges, product platform development can, at its best, bring effectiveness and significantly shorter development times in the derivative product development, cost-efficiency, and finally competitive advantages in the markets through the market leverage gained from the product family concept. Proper management of the product platform development ensures that there is a possibility to enjoy of these benefits.

The research has concentrated on the definitions and architecture descriptions of the product platforms. To be successful, the product platform itself might have to fulfill several requirements. The product and process platforms must be closely linked with one another both in the mechanical engineering and in the software engineering. The architecture of the product platform and especially the interfaces of the product platform are of great importance. The product platform extensions are developed to enhance the product platforms, but every now and then a larger development effort is needed in a form of product platform renewals in order to retain the innovativeness of the product platform. The innovativeness was not studied in connection with the product platform development, though. Still, innovativeness of the product platform could definitely be seen as an advantage – although the innovative aspect of the final product might be added in the derivative product development (i.e. the business-end of the development), too. Innovativeness brings competitive advantage in the markets, and if the product platform was innovative, several derivative products would benefit from it. It is important to remember that inventing and using newest technology does not make a product platform innovative – the commercial success only is the check for the innovativeness. The easiness of building applications on the product platform enhances the derivative product development. Finally, the product platform should fulfill both the product lines' and external customer needs. Further, both the existing and latent customer needs should be understood – in order the derivative products to be competitive in the markets several years after the actual customer needs collection has been taken place.

The research has slightly touched the organizational structure of the product platform development. There might not be only one right organizational structure for the product platform development, and instead of organizational structure, the communication between the product platform development and the derivative product development has been discussed to some extent. In addition to the technological competences (i.e. the skills), the product platform development unit should also possess marketing and management competences. The decision-making and steering systematic are interesting factors of the product platform development – the derivative product developers might want to participate in the decision-making as it gives possibilities to influence the contents and schedules of the product platform generations and releases. The operational metrics of the product platform development help to steer the development, but also give the derivative product development a better view to the actual development, its progress and the quality of the product. The strategic measures (effectiveness, efficiency) help in the strategic decisions concerning the use of the product platform in the derivative product development. In addition to internal communication, the communication between the product platform development and the derivative product development should be a continuous activity in the areas from product platform strategies to changes in the releases and to the maintenance of the product platform.

The product platform strategies have been quite thoroughly studied from the content point of view. The strategies are of utmost importance not only to the product platform development but also to the derivative product developers. The product platform choices are made for years ahead, and thus the right choices have a long-term effect on the competitiveness of the derivative product development. Especially the in-house product lines might want to participate in one way or another to the strategy process and strategic decision-making of the product platform R&D, in order to bring the customer viewpoint to the process and to integrate business and market strategies with the product platform strategies. The product platform strategies, chosen technologies, and technological/product roadmaps (the when, what, and how questions of the product platform development) are success factors of product platform development, and further, they greatly affect the derivative product development. The literature on product platforms has not studied the process and decision making aspects of strategies, so far.

The product platform development process and projects include several potential factors. Management of the multi-project environment needs to be done carefully. Proper product line and customer needs collection done in an early phase of the product development, and turning the needs into product requirements and specifications requires cooperation. Especially in the case of rapid design transfer, when the product platform and derivative product development run concurrently, the real-time communication and information sharing is of great importance. In addition, the development of a new product platform generation based on new technology requires a lot of effort put on the communication and information sharing.

Hence, the according to the product platform literature, the potential factors of product platform development are

- clear architecture and interfaces (Meyer and Lehnerd, 1997a, Meyer et al., 1997b)
- steering and decision making (Robertson and Ulrich, 1998, Meyer and Lehnerd, 1997a, Meyer and Seliger, 1998, Nobeoka and Cusumano, 1995)
- strategic metrics (Meyer and Lehnerd, 1997a, Meyer et al., 1997b)
- technological and business/marketing competences (McGrath, 1995, Tabrizi and Walleigh, 1997)
- cooperation and communication of product platform and application development (Cusumano and Yoffie, 1998, Nobeoka and Cusumano, 1995)
- strategy content (Wheelwright and Clark, 1992, McGrath, 1995, Tabrizi and Walleigh, 1997, Meyer and Lehnerd, 1997a, Sääksjärvi, 2002, Cusumano and Yoffie, 1998)
- coordination of application development needs (Meyer and Seliger, 1998)
- customer needs identification (Meyer and Lehnerd, 1997a, Meyer and Seliger, 1998, Tabrizi and Walleigh, 1997)

It must be noted, however, that the list might not be comprehensive: there is a possibility that some important factors have been neglected from the research. Taken the basic nature of this research, the explorative research, more important than to exclusively find every factor, is to map the area and to give baseline for further research. In addition, if additional factors are found in the case study, they will be reported and discussed upon later on. The product platform literature will guide in specifying the research questions, next. Despite of the possible deficiencies, the earlier defined possible factors of product platform development will be used to guide the case description, later.

3. RESEARCH DESIGN

3.1 Research Questions

The literature study indicated that the product platform development differs from the single product development – e.g. the time-horizon of product platform development is longer, product platform development deals with greater technological and market uncertainties than the derivative product development, the product platform is not an end product itself but a part of derivative products, and the end-customer interface is further away than in the derivative product development units. Hence, the product development research concentrating on single products might not have identified the factors important specifically in the product platform development. The product platform literature has identified some product platform development specific factors, but it has not yet presented a full picture in a form of case description.

The product platform development organizations possess some special characteristics. While the product platform is not an end product by itself, the role of the derivative product developers is significant. The role of the derivative product developers differs according to the product development strategy; whether they are product lines inside the same company the product platform is developed or whether the product platform is sold to an external developer. The role of the product lines differs from the external customers in a sense, that they might have greater influence to the strategic planning and product definition, and more insights to the progress of product development activities than the external customers might have. Additionally they might have access to the databases, personal contacts to the development personnel, and so on. Hence, the product lines are in a good position to judge the issues concerning product platform development. They can be expected to be critical in their comments: after all, they must be able to develop their own product on the product platform, they will have to sell the product platform as a part of their product to the end-customers, and ensure that the final product works. The product platform development organization either helps them to succeed in their business or causes failure in meeting the business objectives.

The second research question aims at describing a product platform development unit and its operations from one specific viewpoint to achieve an empiric understanding about the product platform development activities: does an empiric product platform development case, presented from its product lines' aspect, add new potential factors or specify the theory findings?

2. When compared to the theory, does the empiric case of product lines' perspective to the product platform development add any potential factors?

The third research question specifies the factors seen by the product lines, and can be stated as below

3. What are the factors of the product platform development seen by the product lines?

Further, the knowledge of the future existing and latent (end) customer needs might not be inside the product platform development team. The feedback route from the end as well as external customers needs to go through a long route before reaching the product platform development personnel. The feedback to the derivative product development is a step shorter, and the derivative product development personnel (should) know the customer needs of their segment, and thus can help from their own point of view the product platform development to understand the external customer needs. The fact that the product platform is a common technological base for several derivative products leads to a situation where there are several varying (customer and product line) needs towards the product platform. The fourth research question aims at assessing the possible differences in the needs of the product lines:

4. Do the product lines see the product platform development differently from one another?

The product platform development is also characterized with multi-project environment: development of initial product platform, its extensions and renewals. The amount of technological and market uncertainties can be expected to differ according to the nature of the product platform development. An interesting question to be analyzed is whether the product platform development differs according to the nature of product platform development, i.e.

> *5. Are there differences in the product lines' opinions due to platform extension?*

In addition to clarifying the factors of the product platform development, it would be interesting to prioritize the factors; which factors affect to the product lines' satisfaction more than others do. Hence, the final research aims at figuring out whether there are some factors the product platform development should concentrate first when improving its operations. The question can be stated as

> *6. Which product platform development factors affect most to the product lines' satisfaction with the product platform development?*

The research questions 2-6 will guide the discussion about the selected research methods, operationalizing the research questions, as well as data analysis.

3.2 Research Methodology

There are several classification criteria to the research methodologies, e.g. quantitative vs. qualitative, positivist vs. its alternatives, and research based on large vs. small samples (Kasanen et al., 1993). Further, a research can be purely theoretical or be based on empiric data, and its approach can be descriptive, normative (Neilimo and Näsi, 1980) or explorative (Yin 1988). Possible research methodologies include the nomothetical, decision-oriented, action-oriented, and conceptual approach (Neilimo and Näsi, 1980), constructive research methodology (Kasanen et al., 1993, Lukka and Tuomela, 1998) as well as case study methodology (Yin, 1988).

Since the product platform development research is on its infancy, the research approach chosen in the dissertation is the exploratory and empiric. In a case of the exploratory “what” type research question (e.g. *What are the factors of the product platform development seen by the product lines?*), there are several possibilities for the actual research method, e.g. experiment, survey, or case study (Yin, 1988). Especially useful the case study approach is in a theory building process (Eckstein, 2000). Here, the case study method was chosen.

The case study research can be described with two dimensions: the number of cases and the depth of information studied. Usually the term case study is related to a research with relatively small number of cases to be thoroughly studied (Gomm et al., 2000). The case selection is a central choice for the generalizability of the results (Eisenhardt, 1989). The advantages of the case study include achieving an access to the places that would be beyond the reach of a large public otherwise, and seeing the case through the researchers eyes, and hence bringing new insights to the case (Donmoyer, 2000).

In this dissertation, a single case study strategy was chosen. The choice of a single case is justified with the lack of previous research in the area: a single-case study fits for new theory building and exploratory research. The case chosen for further investigation was a product platform development unit called Switching Platforms (SWP) of Nokia Telecommunications. The reasoning for the choice is twofold. First, the unit had developed the DX 200 Switching Platform, which was used by several product lines as a product platform for their derivative products, from the 1995 on. Hence, there was empirical experience on the product platform development in the unit, which is of great value in understanding the field. Further, the single-case strategy allows deeper analysis of the selected case. Second, the researcher worked in the product platform development and was involved in a product line satisfaction measurement project during the years 1996-1999. The project aimed at assessing the R&D work of the Switching Platforms and the goal was to improve the efficiency and effectiveness of the product platform development. Hence, the researcher had an access to data beyond the reach of larger public and the nature of the data was such, that it could bring new insights to the product platform research.

A single case study can be further divided into a holistic case-study design, with single unit of analysis, and an embedded case study design, with multiple units of analysis inside one case (Yin, 1988). In the case unit, there are multiple cases, i.e. the product lines of the product platform unit. Thus within the case it is possible to make cross case analysis.

In the theory-building case study, the role of the existing literature study should be on defining the potentially influential variables, but one should be careful not to think of relationship and theories between the variable in the beginning of the research (Eisenhardt, 1989). The theory part of the dissertation relied on the existing literature on strategic technology management and new product development, with an emphasis on the product platform development literature. The theories were used to collect the potential factors of the product platform R&D.

The case study research can use qualitative data, but the use of quantitative data is also possible (Stake, 2000). The research explores the product platform development in the case company, and since there was relevant quantitative data available in the company, the case study analysis relies mainly on it. The qualitative data, on the other hand, is used to describe the case company and its operations.

According to Yin (1988), the case studies make it possible to make analytical generalizations instead of statistical generalizations. Stake, on the other hand, states that case studies aim at particularization instead of generalization (Stake, 1995, Stake, 2000). He also introduces a term of natural generalization, which is based in a persons experience and intuitive generalization (Stake, 2000). Lincoln and Guba (2000) propose that the results of one case study might be transferred as working hypothesis to another similar case to help to understand the other case. Schofield (2000) discusses the techniques to increase the generalizability of a research. According to her, the generalizability issues should be taken into account already in the research design, e.g. choosing a typical case or site when studying something typical/ordinary. Gomm et al. (2000) argue that most of the case studies should make generalization to prove the relevance of the results and to cope with the generalizations within the case(s) studied. The single case study presented in this dissertation will not allow to generalize the results, but instead, this research aims at particularization.

To increase the construct validity of research, the case study should rely on multiple sources of evidence, e.g. on documentation, archival records, interviews, direct observations, participant-observations, and physical artifacts (Yin, 1988, Eisenhardt, 1989). Almost all the case studies involve a document review in addition to interviewing or making observations (Stake, 1995). The data analyzed in this dissertation include (Appendix 1)

1. Internal documents, reports, steering group meeting minutes, process description, description of SWP R&D operations, organizational charts, internal annual reports, strategy material, and project documents
2. Interviews of the management team members (vice president, and managers of the process development, product management, project management and testing departments) and two release project managers about organization and its relationships with the product lines
3. Unstructured interviews about strategy process in 1996
4. Product line satisfaction survey data from the years 1996-1999

Hence, the case description relies on the qualitative data available of the company: several documents, meeting minutes, etc. (data sources 1-3). The main analysis, on the other hand, is based on quantitative data of product line satisfaction survey data.

The analysis is the most challenging part of the case study research. Yin proposed two main strategies for the case study analysis: relying on the theoretical propositions and developing a descriptive framework for the case study, the first strategy being the preferable one. Possible modes of analysis include pattern-matching logic (comparing outcomes with the initially predicted values), explanation building (used mainly in explanatory studies), and time series analysis (tracing changes over time). Other possible modes of analysis (lesser than the previously mentioned) are the analysis of embedded units, repeated observations, and case surveys (when many case studies are available for the survey) (Yin, 1988). Even in a multiple-case study, the analysis should first be done within the case, to understand each case. Cross-case analysis continues the work started in within the case analysis, e.g. by defining dimensions based on the research problem or the previous research and comparing the cases in all the dimensions. Pair-wise comparisons of similarities and differences of cases bring further insights to the study. The cross-case analysis improves the reliability of the emerging theory. After the analysis, the emerging theory is iteratively tested against each case – in order to shape the hypothesis. In the theory building research, the hypotheses are based on judgment of the strength of evidence in within and cross-case analysis. The evidence must be fully documented with the results. The theoretical findings must be compared to the existing literature for similarities and differences. The incremental development of theory should be ended when the new cases added to the analysis do not give any new aspects to the analysis and the iteration between theory and cases does not significantly improve the new theory (Eisenhardt, 1989). The SWP case analysis relies on the potential factors of the product platform development defined in the theory part of the dissertation, and the results of the analysis will be compared with the theories. The modes of analysis used in the case study are a combination of analysis of embedded units as well as analysis of repeated observations. The cross-case analysis is done to the embedded units of the case, i.e. the aspects of the different product lines. The actual analysis is based on established, quantitative tests, which will be described, next.

3.3 Operationalizing the Research Questions

The second research question,

> *2. When compared to the theory, does the empiric case of product lines' perspective to the product platform development add any potential factors?*

requires qualitative description of the chosen case and its product platform development activities from the product lines' perspective. The case, Switching Platforms (SWP) R&D, will be described in the light of the potential factors defined in the theory. The qualitative data is collected from several data sources, including varying documents and interviews as described in Appendix 1. A database of the data used in the description will be developed in the course of the research.

The case description might give some indications as to the other research questions, also. Still, the other research questions will be analyzed mainly quantitatively, with the product line satisfaction survey data collected during the years 1996-1999.

The scale used in the SWP R&D internal product line surveys was the Likert-scale (Appendix 2, example of the questionnaire). There is an ongoing discussion about the nature of the Likert-scale data, whether it should be classified as ordinal data or interval-like data. The chosen classification is significant since it greatly affects the choice of statistical tests to be used in the analysis. The nonparametric tests can be used to a wider variety of data than the parametric tests. The nonparametric tests are suitable, e.g. when the sample size (N) differs between the questions, N is small, the level of measurement is lower than interval level, or the answers are not normally distributed and elimination of observations would reduce the amount of data (Kirkpatrick, 1981; Siegel 1956). Depending on the test, the nonparametric tests are somewhat weaker than their parametric counterparts, but the difference might be small – e.g. the power of the nonparametric test might be as high as 90% of it's parametric counterpart (Siegel and Castellan, 1988). The more powerful parametric tests should be preferred to the nonparametric tests whenever possible. Kirkpatrick (1981) speaks for using the nonparametric tests even though the parametric tests are more powerful - the sacrifice of using nonparametric instead of parametric measure is not very high in all the tests. Still, in practice, the parametric tests are often used to measure Likert-scale-based data in the customer satisfaction surveys (Gerson, 1993). Especially if the data is manipulated, e.g. with factor analysis or regression analysis, the scale can be treated as interval, if treated with caution (Urban and Hauser, 1980).

In this dissertation, it is assumed that the Likert-scale data can be analyzed with the parametric tests only if the specific requirements to the data are fulfilled (e.g. normality in the factor analysis). In addition, a factor analysis needs to be first conducted to the data, and only the results of the analysis will be analyzed with the other parametric tests.

The aspects to be studied from the data include

3. *What are factors of the product platform development seen by the product lines?*
4. *Do the product lines see the product platform development differently from one another?*
5. *Are there differences in the product lines' opinions due to platform extension?*
6. *Which product platform development factors affect most to the product lines' satisfaction with the product platform development?*

Next, the parametric statistical tests used to cover the questions listed above will be described.

3. What are factors of the product platform development seen by the product lines?

The product line satisfaction survey included questions about the relevant aspects of the case company's product platform development from the product lines' aspect. The amount of questions is large, and it should be compressed to see whether there are specific factors found from the data. Factor analysis is a useful tool to analyze structures of interrelationships among large number of statements, and hence is a proper tool for analyzing the factors of the product platform development. The entire description of the factor analysis presented in this chapter is based on Hair et al. (1998).

Factor analysis can be either exploratory or confirmatory. Explorative factor analysis (used in this research) is used to search structure in the data or to reduce data. There are several preconditions for the factor analysis. Factor analysis requires the variables to be normally distributed. The sample size of the factor analysis should be at least over 50, preferably over 100, and the absolute minimum of the sample size is 5 times the variables to be analyzed. There should be significant correlations ($r \geq 0.3$) among the variables included into the factor analysis. A correlation matrix can be used to analyze correlations between the statements, but the correlations of the entire model can be tested with Bartlett test of Sphericity. It tests the probability that the correlation matrix has significant correlations among at least some of the statements.

For the factor analysis model, there are certain conditions that need to be fulfilled. Measure of sampling adequacy (MSA) measures the appropriateness of factor analysis intercorrelations. MSA-values can be calculated to the single statements as well as to the entire model. For the individual statements, the MSA-values under 0.5 are unacceptable. For the entire model, the MSA values over 0.8 are classified meritorious and values over 0.7 middling, while the values under 0.6 are unacceptable. In a sample of 100, the factor loadings, i.e. the proportions by which each statement is loads the factor, should be over 0.55 to be statistically significant, but for practical significance it is enough that the loadings are over 0.5. Communalities, i.e. the estimates of the common variance among the variables, should be over 0.5. If the preconditions of the factor analysis as well as the conditions of the entire model are fulfilled, the factor analysis has succeeded. The results of the factor analysis should be validated; if the sample size permits, the sample could be, for example, split randomly into two, and factor analysis could be conducted to both groups. Comparison of the groups with the original analysis reveals the validity of the analysis.

The analysis can either end at the factor model, which reveals the hidden structure behind the data, or the results can be used for further testing. The further testing can be done in three different ways; 1) the highest factor loading can be chosen to represent the factor, 2) the original scores can be replaced with the factor scores or 3) the original scores can be replaced with summated scales based on the factor analysis. In summated scales the variables that load high on a factor are combined, and the reliability is checked with consistency measure e.g. Cronbach's Aplha, which should be over 0.7. For explorative research, Aplha values over 0.6 are good enough. The choice between using the highest loading, factor scores or summated scales depends on the problem. The highest loading is the simplest but it does not fully describe the factor it represents. The factor scores represent best every aspect of the factor, while the summated scales are a compromise in between the two previous classifications. The limitation of the factor scores is that the factor score means are (close to) zero, and hence the means of factor scores cannot be tested with one another e.g. with the t-tests.

In this research, the factor analysis will be conducted with the statements, which fulfill the requirements of normality and the conditions of the model derived.

4. Do the product lines see the product platform development differently from one another? and 5. Are there differences in the product lines' opinions due to platform extension?

The research questions about the differences in the product lines' opinions and development of product platform extensions will be analyzed with the product line satisfaction survey data. The factors derived from the factor analysis, as to whether there are differences due to another variable (here product platform extension, or product line), can be compared with the paired samples t-tests as well as with the one-way Analysis of Variance (ANOVA) test. The paired sample t-test gives the statistical significance of the difference between two means. ANOVA uses the F-test to analyze whether the set of means are from the same population or not. The test does not tell which means are different, but e.g. post hoc tests can be used to analyze exactly which means do differ (Hair et al., 1998). Both the t-tests as well as ANOVA will be conducted to the factors to find out the differences due to the product platform extension evaluated and to the product line evaluating.

6. Which product platform development factors affect most to the product lines' satisfaction with the product platform development?

The multiple regression analysis is used to determine the relationships between the single dependent and multiple independent variables. The description of the multiple regression analysis presented here is entirely based on Hair et al. (1998). The objective is to predict the value of the dependent variable with the help of the independent variables. The independent variables are weighted as to their contribution to the prediction of the dependent variable, and the weighted independent variables form the regression model. Multiple regression analysis can be used, in addition to predicting the dependent variable with the set of known independent variables, to assess the degree of relationships (e.g. relative importance of each independent variable) between the dependent and independent variables.

The sample size in the multiple regression influences directly to the statistical power of the test. E.g. a model of 5 independent variables, with significance level of 0.05, and sample size of 50, (detecting R^2 80% of the cases) will detect R^2 values of 0.23 and above. If the number of independent variables rises to 10, the detected R^2 values will be of 0.29 and above. In addition, the results to be generalizable, the ratio between the observations and the independent variables should be a minimum of 5 to 1, preferably 15-20 to 1. In the stepwise estimation the ratio should be even higher, 50 to 1. If the sample is not large enough for the chosen estimation method, the generalizability of the results should be otherwise validated.

The selection of the variables to be included into the model can be done either by confirmatory specification, in which the researcher subjectively chooses the variables to be included into the model, or by sequential search methods (stepwise estimation being the most popular one), in which the variables included into the model are selectively added or delete until certain criteria is met. None of the methods should fully guide the analysis, but the research context should be taken into account. The selection of the independent and dependent variables may cause two kinds of errors to the regression analysis. The selection of the dependent variable can cause a measurement error, i.e. how well does the dependent variable measure the concept being measured. In the independent variable selection, a problematic part is the specification error, i.e. whether irrelevant variables are chosen as independent variables or the relevant variables are omitted from the equation.

Both the individual variables (dependent and independents) entered to the regression model as well as the entire model needs to be assessed against some assumptions. The assumptions should be checked both before the actual regression analysis (for the independent and dependent variables) and after the regression analysis (for the entire model). The individual variables need to fulfill the requirements of normality, homoscedasticy, linearity and absence of correlated errors. The normality, i.e. the correspondence of a variable's distribution to the normal distribution, can be assessed either graphically or with statistical tests like Kurtosis or Skewness values. Homoscedasticy, i.e. the equality of dependent variables variances among the predictive variables, and linearity can be assessed graphically from the residual plots. The correlated error is mostly caused by the data collection process, e.g. from the combination of two separate groups into one. It can be found by identifying the possible causes and then comparing the separate groups with one another. If there were difference in the prediction errors, then there would be correlated errors. The correlated errors can be corrected by including the cause, e.g. the grouped variable, into the analysis.

The regression analysis produces the regression variate, which consists of constant term and the estimated regression co-efficients. The co-efficients found from standardized data are the beta coefficients, and they can be used to define the coefficients with powerful and weak impact on the predicted value of the dependent. The R^2, i.e. the coefficient of determination, expresses the level of prediction accuracy of a model. The adjusted R^2 should be used to prevent the R^2 from overfitting the data, especially in the case of small sample size. The statistical significance of the regression model is assessed with the F-test, and the t-test for the significance of each of the coefficients. The significance tests determine whether the regression result is generalizable to other samples from the same population.

The resulting regression variate needs to be examined with regard to linearity of the model, constant variance of error term, independence of the error terms and normality of the error distribution. The linearity in the multiple regression analysis can be done by analyzing residual plots, and especially in the multiple regression with partial regression plots, to see the relationship of a single independent variable with the dependent one. The constant variance of the error term, homoscedasticy, can be analyzed from the residual plots or with the Levene test, which measures equality of variances for a pair of variables at a time. The independence of the error term can, again, be analyzed from the residual plots: plotting the residual against a possible sequencing variable (e.g. time). The independent residuals show as a random pattern. If the error terms are not independent, the effect can be addressed by including the violating variables into the model. Normality of the error distribution can be analyzed from the histogram of residuals or normal probability plots.

The influential observations, i.e. outliers, leverage points, or influential observations, need to be analyzed, also, since they might have a great impact on the results of the analysis. Outliers have large residual values, leverage points have distinctive independent variable values, and influential observations are other observations that greatly influence the regression results. There are several measures for identifying the influentials, and no single measure represents all the aspects of possible influentials, hence, the process of identifying influentials includes the use of multiple measures.

After identifying the possible influentials, the possible causes need to be carefully analyzed. If the influentials are caused by an error or an extraordinary situation, the observation should be corrected or deleted. For the unexplainable cases, there are no reasons to keep the data nor there is a reason for deleting the data. If an observation is ordinary as individual characteristics but extraordinary as a combination of characteristics, the observation should be kept. Whenever justified, the influential observations should be deleted, and a new regression model should be estimated.

The regression variate needs to be analyzed with regard to multicollinearity. It can be analyzed from the correlation matrix of the independent variables (over 0.9 correlations are not acceptable). Other measures of multicollinearity are the tolerance value and the variance inflation factor (VIF), which tell the level an independent variable is measured by another independent variables. The tolerance values should not be under 0.1, and VIF values should not exceed 10. The multicollinearity can also be assessed by identifying condition index values higher than a critical value (usually 30), and then assessing from the regression coefficient variance-decomposition matrix for those variables, whose variance proportions are above 90 percent. There is a problem with collinearity when the condition index is high and it accounts for high proportion of variance of two or more coefficients.

The regression model should be validated, either by additional sample or by split sample. In any case, it is very probable that there will be differences in the models, and hence the best model across the samples needs to be searched. The very nature of the regression analysis is that no model is perfect.

In this research, the multiple regression analysis will be used to find out, which factors or background information best explain the scores given to the overall satisfaction.

Summary, operationalized research questions

The summary of the statistical methods used in the data analysis in this dissertation is presented in Table 1. Next, the SWP R&D product line satisfaction survey data will be analyzed with the methods described in this chapter.

Research Question	Analysis/Test
2. When compared to the theory, does the empiric case of product lines' perspective to the product platform development add any potential factors?	Qualitative case description
3. What are factors of the product platform development seen by the product lines?	Factor Analysis
4. Do the product lines see the product platform development differently from one another?	One-way ANOVA, t-test
5. Are there differences in the product lines' opinions due to platform extension?	One-way ANOVA, t-test
6. Which product platform development factors affect most to the product lines' satisfaction with the product platform development?	Multiple regression analysis

Table 1. The analysis and tests mapped to the research questions.

3.4 Data Collection

The data of the qualitative case description was collected mainly from the databases of the case unit, Switching Platforms R&D (SWP R&D), during the years 2002-2004 (Appendix 1). The case unit had archives available for the researcher, even though some years had passed from the actual research period. In addition to written and archived material, two sets of interviews were made: the first one about the strategies of the case company in 1996 and the second in 2003 about the product platform development activities and linking the product platform definitions with the empiric activities and products. In addition, the case analysis was reviewed by two of the case company representative, in order to ensure the right interpretation of the data.

The product line satisfaction survey data used in this research was collected during the years 1996-1999. The overall objective in SWP R&D was to design a simple (quick to conduct and analyze) method for assessing the R&D's operations and improving them according to the product lines' priorities.

There are plenty of literature available of satisfaction, its measurement and data collection (e.g. Soin, 1993, Kanji and Wallace, 2000, Kanji 2001, Barsky, 1995, Anderson et al. 1994, Gerson, 1993, Hill, 1996, Hill et al., 2002, Naumann and Giel, 1995, Vavra, 1997, Dickey, 1998, Chakrapani, 1998, Hayes, 1997, Webb, 2000, Djupvik and Eilertsen, 1995, Hall and Mesure, 1995, Fornell, 1992, Anderson and Fornell, 2000, Piercy and Morgan, 1995). Although the measures, models and steps of the customer satisfaction measurement system differ somewhat from author to author, the basic elements are quite common. Table 2 summarizes the steps of satisfaction data collection combined from the sources mentioned above as well as the activities done in SWP R&D each year.

Steps of satisfaction data collection	1996	1997	1998	1999
Define the objectives	To assess the product lines' priorities and improvement areas To measure performance			
Plan the project	Tasks, schedules, effort, reporting.			
Identify the customers and attributes of customer satisfaction	5 product lines Attributes based on external customer satisfaction survey and judgment	4 product lines Attributes based on previous year's comments	4 product lines Attributes based on previous year's comments	4 product lines Same attributes than the year before.
Decide the format of the survey and design the questionnaire	Personal structured interview 5-step Likert scale with "don't know/not relevant" -possibility: Performance (1996-1999) + Importance evaluation (1997-1999)			
Design the sampling method and sample size	Judgmental sampling 24 persons	Judgmental sampling 40 persons	Judgmental sampling 36 persons	Judgmental sampling 34 persons
Pretest the questionnaire	Tested with a product line representative	Tested in the interviews of previous year	Tested in the interviews of previous year	Tested in the interviews of previous year
Conduct the survey	Personal interviews of 1/2 – 1 1/2 hours. The questionnaire was filled in. The comments were collected.			
Record and use the data.	Database formed	Database filled	Database filled	Database filled

Table 2. The product line satisfaction data collection in SWP R&D.

The customer satisfaction survey is never a neutral measurement activity (McColl-Kennedy and Schneider, 2000). Thus, the fact that a survey is made will (and should) affect the results. For the accuracy of the results, the most important factors are: 1) asking the right questions 2) from the right people (Hill et al., 2002). The targets of the survey in SWP R&D were defined to be all the product lines using the DX 200 Platform. The amount of the product lines decreased from five to four after the first survey due to an organizational change.

To ensure the right questions are asked, the customer satisfaction attributes should be defined carefully (Chakrapani, 1998), and the questionnaire should be based on these attributes. In SWP R&D, the attributes important to the product lines were first benchmarked from the questionnaire aimed at the external customers, and second, judgment was used to leave the unnecessary questions from the questionnaire and to add some questions relevant to the product lines. The modification was necessary because of the nature of product platform development unit: 1) the product was not ready when transferred to the product lines, and thus there were less product dimensions to be asked, and 2) the product lines had more visibility to actual product development activities, and hence, they could be asked questions about them. The first year the risk was defined to be in the questionnaire; if it did not measure the right aspects, the results of the survey would be useless. The questionnaire was tested the first year by interviewing a product line representative. After the first year, the attributes were redefined according to the comments received from the product lines. By 1998, the questionnaire (Appendix 2) had been fine-tuned to such a state that there was no need to improve it for the next year. The questions asked included essential aspects of the product line relationship: from strategies to project management to product quality, etc (Appendix 2, an example of the questionnaire).

The format of the customer satisfaction survey can be for example mail, face-to-face, or telephone interview (Naumann and Giel, 1995). According to Dickey (1998), the personal interviews are effective tool for measuring customer satisfaction, if the customer base is small. In SWP R&D, the survey format was decided to be structured (specific questions in particular order) personal interview based on a questionnaire. The reasons for choosing the personal interview were several: to achieve a high response rate, to gain better validity by ensuring that the questions are understood similarly, to get qualitative comments from the product lines, and to be able to clarify the meaning of the comments immediately when necessary. Further, it ensured the collection of direct feedback to the survey itself. The interviews with the questionnaire lasted from half to one and half hours depending on the interviewee and the amount of feedback given during the interview. During the interview, the entire questionnaire discussed through. During the interview, the interviewer recorded the comments and possible questions of the interviewee, hence, collected the qualitative data.

The design of a questionnaire depends on the chosen interview method, type of respondents and the type of information that is wanted to achieve through the survey (Webb, 2000). The selection of questions can be done e.g. by asking two people to select the questions based on customer requirements and quality dimensions (Hayes, 1997). The questionnaire should not be too long; for example, Hill et al. (2002) define the maximum length of a questionnaire to be 50 questions. The same scale should be used as much as possible within the same survey (Gerson, 1993). The Likert –type scale (for example 1=very dissatisfied – 5=very satisfied) is useful and reliable scale in customer satisfaction surveys (Westbrook and Oliver, 1981, Hayes, 1997). Its advantage is that it gives more choices than e.g. a checklist format (or yes-no answers), and the reliability of the scale does not improve significantly if a larger scale is used (Hayes, 1997). Midpoint score and "don't know" option should be allowed, because the interview should not force anyone to give an opinion if he does not have one (Hill et al., 2002, Gerson, 1993). There are some problems in asking for importance rates with very important/not important-scale: only few attributes are rated as not important, and many questions will be given the same rate, which is not very discriminating (McNeil and Carpenter, 1995). On the other hand, Hill et al. (2002) argue that all the questions asked in a survey should be ranked important, otherwise, they should not have been asked at all – this relates to the careful definition of attributes of customer satisfaction. Satisfaction index can be either 1) asked (overall satisfaction) or 2) calculated (by weighting the questions with importance %) (Hill et al., 2002). Questionnaires need to be tested as the testing can improve the reliability (reaching the same result if interview is made again) of the questionnaire (Webb, 2000).

In addition to giving scores to SWP R&D performance, from 1997 to 1999, the survey also included questions about the importance of each statement. Both the score and the importance statements were graded with the Likert scale. It was decided to choose the scale 1 to 5 (instead of e.g. 4), because the middle score – everything was in order – was seen as an equally important answer with the satisfied or dissatisfied opinions. The scale ranged from 1 (very dissatisfied / not important) to 5 (very satisfied / very important). In addition, the possibility of giving no score at all (i.e. not relevant / I don't know) was given to the respondents (Appendix 2). Hence, the development of the questionnaire, the questions, and the choice of the measurement scale were acceptable from the theory point of view.

As to the sampling method, it is not recommended to use the judgmental sampling in a customer satisfaction survey since the statistical reliability suffers, but still, in practice, it is often used (Hill, 1996). Judgmental sampling is useful e.g. in case studies, where one or few cases are needed, but the drawback is that the results cannot be generalized to a population. However, it can be used as starting point to understand processes (Hayes, 1997). To be statistically reliable, the sample size should be over 200 customers according to Hill et al. (2002), but Gerson (1993) defines the range from 50 to 100 customers to be enough.

The sample consisted of all the customer product lines of the SWP R&D (Figure 7, Table 3). The interviewees from the product lines were selected using judgmental sampling. The choice of using the judgmental sample can be justified with the fact that next to all persons from the product lines' product platform interface were included into the sample: the first year about half the persons in the interface were interviewed, but later on, the percentage of interviewed persons from the total population (i.e. the persons involved with the product platform cooperation) was around 70-85%. Hence, random sample would have been an inappropriate method in such a small population. The first year the number of interviewees per product line resembled the sizes of the product lines. Later on the number of interviewees per product line approached constant, regardless of the sizes of the product lines. The number of interviews remained reasonable since the number of persons in the interface between the product lines and Switching Platforms was quite thin. The first year the total number of interviewees was 24, and originally it was thought that the amount of interviewees would be dramatically increased in the following survey. After the first survey, it was noticed that the amount of persons in constant cooperation with SWP/R&D was not large. During the next year, the amount of the interviewees was increased from 26 to 40 but not more. In 1998, the amount of interviewees decreased from 40 to 36 and the year after that to 34.

Year	**Product line**					**Total**
	1	**2**	**3**	**4**	**5**	
1996	8	7	5	2	2	24
%	33.3	29.2	20.8	8.3	8.3	100
1997	14	12	8	6	0	40
%	35.0	30.0	20.0	15.0	.0	100
1998	10	10	10	6	0	36
%	27.8	27.8	27.8	16.7	.0	100
1999	8	9	8	9	0	34
%	23.5	26.5	23.5	26.5	.0	100

Table 3. Number of interviewees yearly per product line.

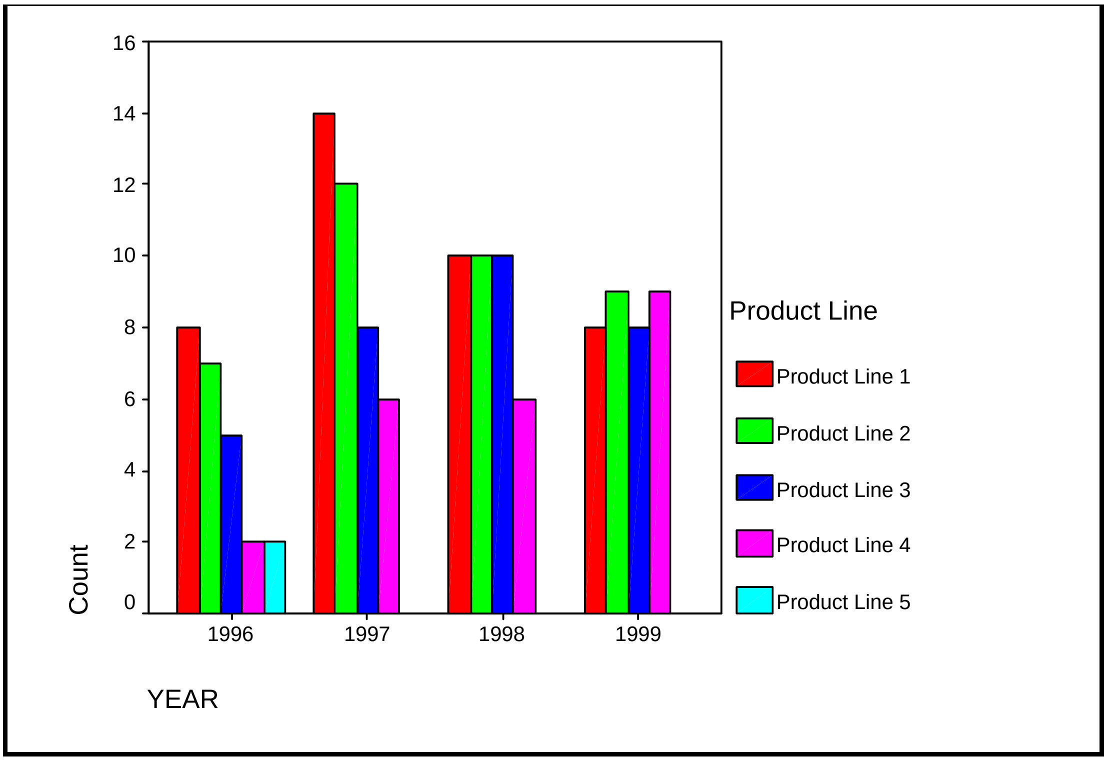

Figure 7. Number of interviewees yearly per product line.

The interviewees had cooperated with SWP R&D for from under a year to over 15 years (Figure 8, Table 4). The interviewees in 1996 had cooperated longer with SWP R&D than the interviewees of the latter years (Figure 9, Figure 10, Figure 11, Figure 12). The sample also included interviewees from different tasks of the product line organizations: line managers, project and program managers as well as specialists. The profile of the interviewee positions changed along the years (Figure 13, Table 5) – in 1996, next to all interviewees were line managers, but later on, the relative amount of line managers decreased while the amount of the project and program managers as well as specialists increased.

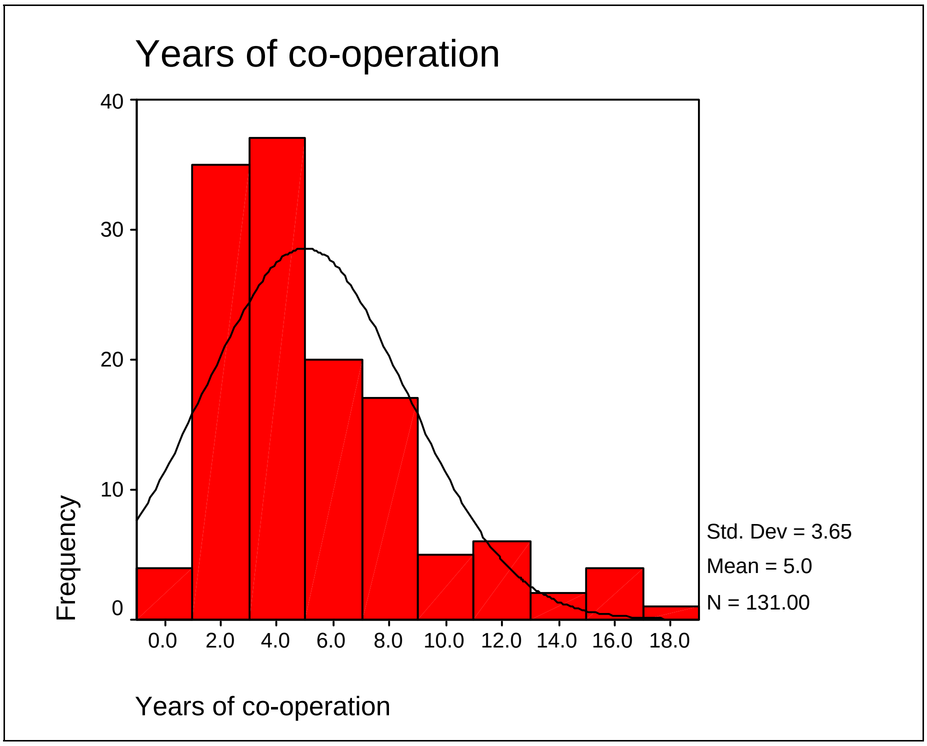

Figure 8. Interviewee's length of co-operation with SWP R&D.

1996	Valid	22
	Missing	2
1997	Valid	40
	Missing	0
1998	Valid	36
	Missing	0
1999	Valid	33
	Missing	1

Table 4. Statistics of the length of cooperation.

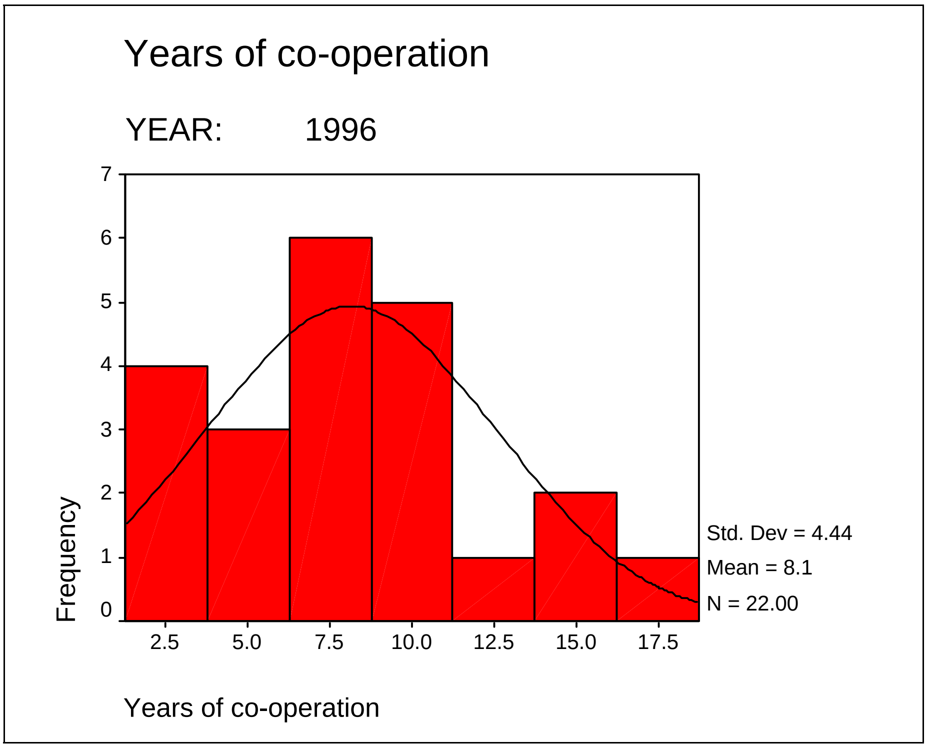

Figure 9. Interviewee's length of co-operation with SWP R&D, 1996.

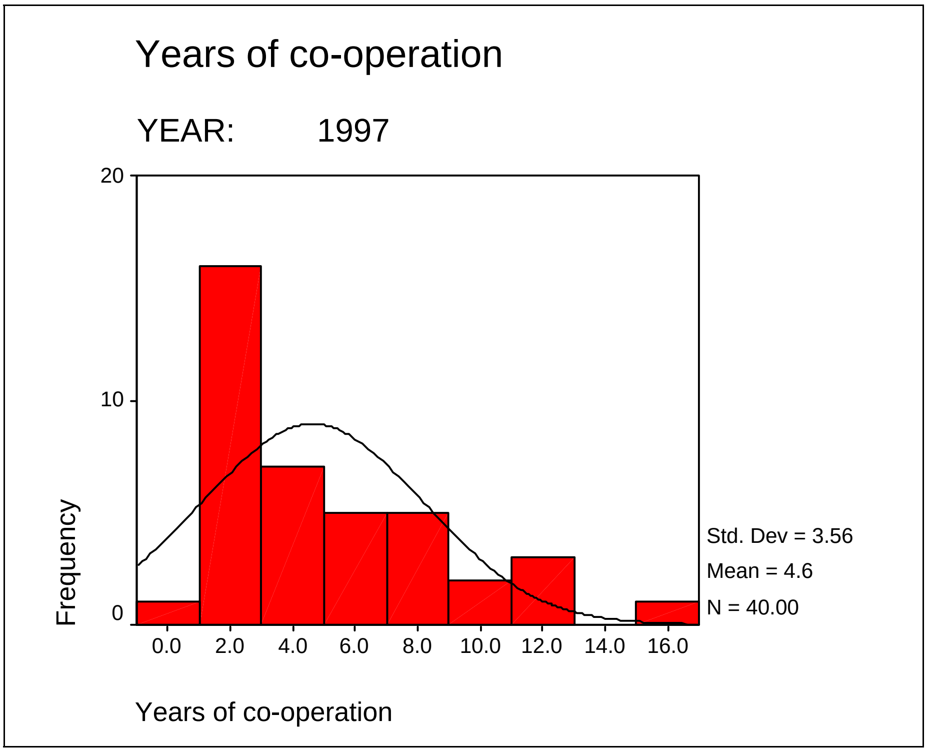

Figure 10. Interviewee's length of co-operation with SWP R&D, 1997.

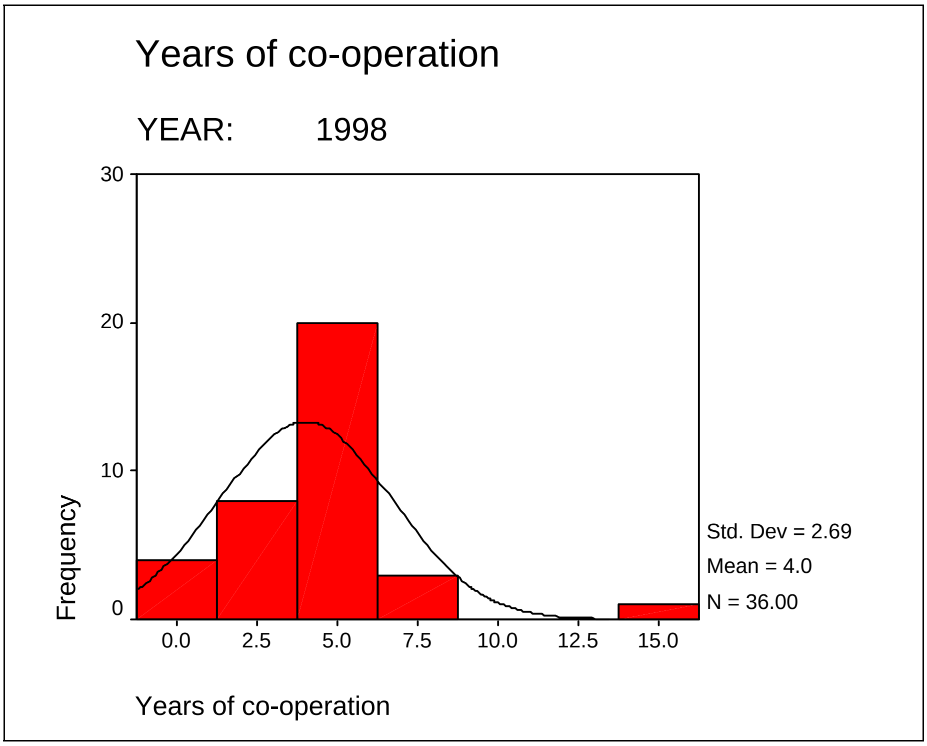

Figure 11. Interviewee's length of co-operation with SWP R&D, 1998.

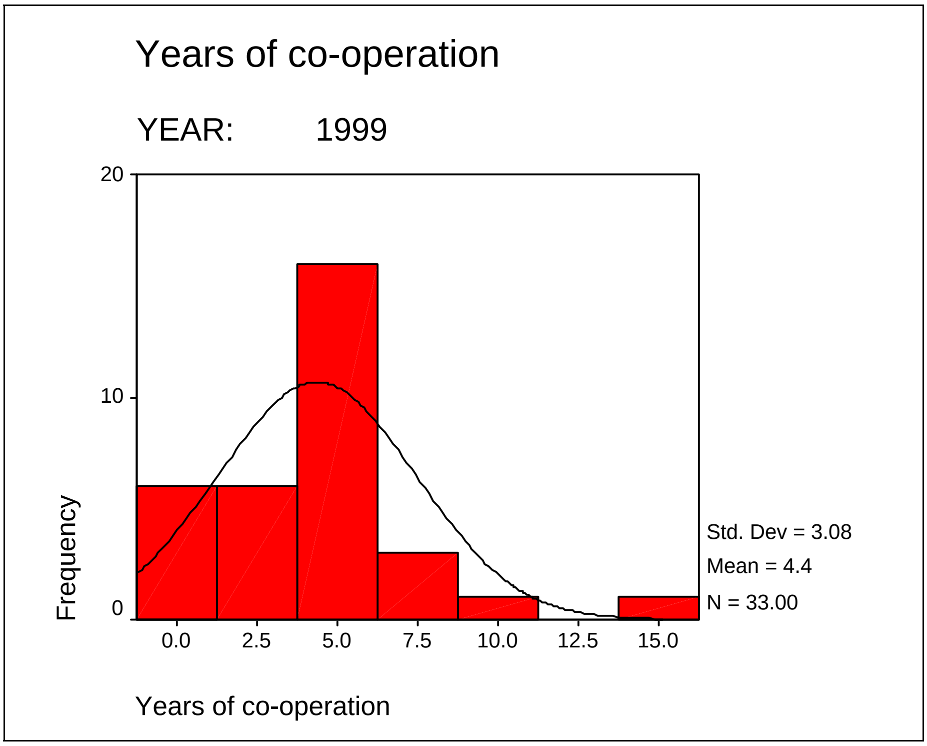

Figure 12. Interviewee's length of co-operation with SWP R&D, 1999.

Year (% of the year)	POSITION			Total
	Specialist	Release/project manager	Manager	
1996	2	2	20	24
%	8	8	83	100
1997	6	8	26	40
%	15	20	65	100
1998	9	7	20	36
%	25	19	56	100
1999	9	13	12	34
%	26	38	35	100

Table 5. Positions yearly.

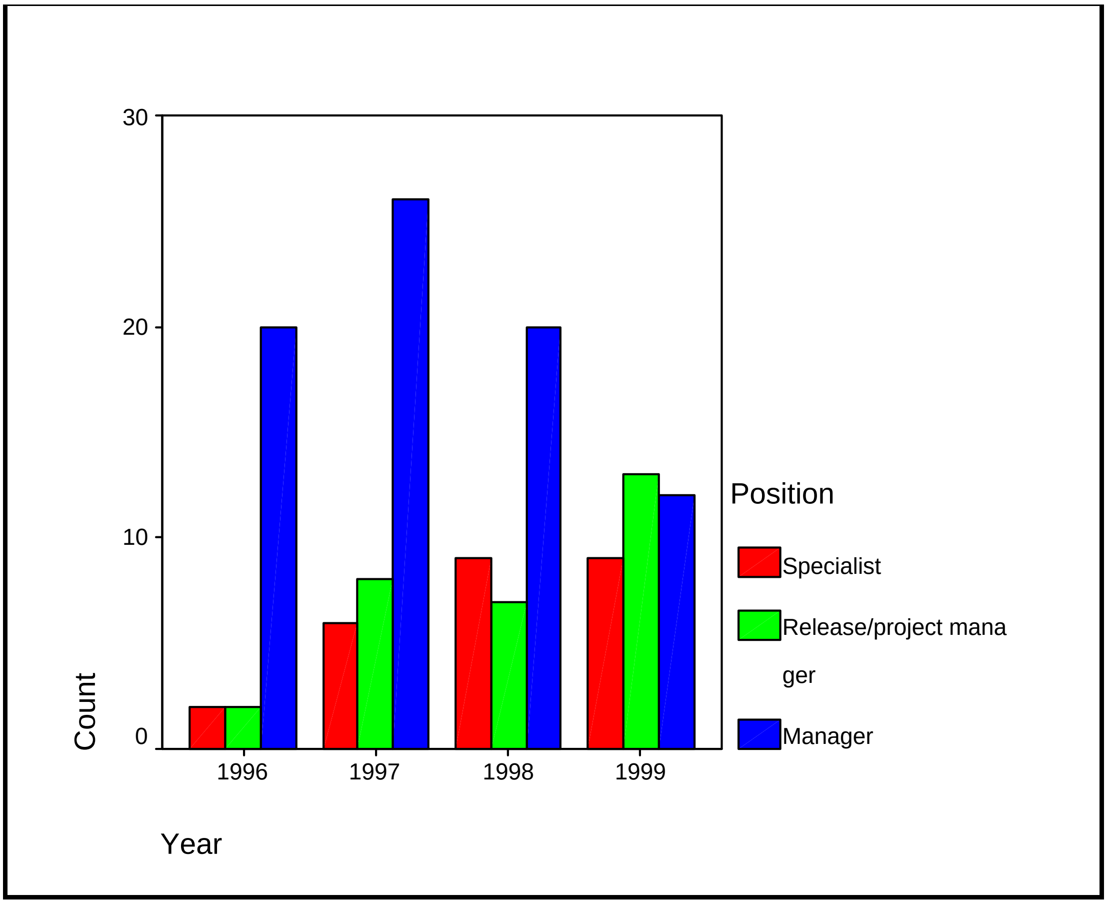

Figure 13. Positions yearly.

Thus, the process by which the product line satisfaction data was collected was done according to the recommendations of the customer satisfaction measurement literature. The changing questionnaire from the year 1996 to 1998 can cause some internal validity problems of the data – the results might not be fully comparable from year to year. If only the questions that remained the same are used in the analysis, the results will not include the product line satisfaction attributes added from the comments of the product lines, and some important information will be missed. If, on the other hand, the newer questions are included into the analysis, there will be a significant amount of missing data in the database in the earlier years. The use of personal structured interview, on the other hand, increased the internal validity of the data; it ensured that the questions were understood similarly from respondent to respondent and from year to year. In addition, the comments of the interviewees were written down in the personal interviews, and the comments can validate the results of the surveys. Further, the small sample size and judgmental sampling decrease the statistical validity of the data collected. The longitudinal research method of conducting the survey for 4 years, on the other hand, tries to solve the problem with statistical validity. The main limitation to the research is that the data is collected only from inside one company with small sample, and thus the external validity, generalizing the results to a larger population, is beyond the reach of the data. What the results can do, though, is to help to make analytical generalizations and to help other researchers to get a starting point for similar case studies.

4. PRODUCT PLATFORM DEVELOPMENT IN THE CASE UNIT

The qualitative case description has a twofold target. First, the description aims at answering to the second research question, “When compared to the theory, does the empiric case of product lines’ perspective to the product platform development add any potential factors?” Second, by describing the operations of the case, the chapter reasons for the questions analyzed in the quantitative case analysis.

The case to be researched is the Switching Platforms (SWP) R&D unit of Nokia Networks (previously Nokia Telecommunications). During the researched period from 1996 to 1999, the main product of the SWP R&D was the DX 200 Platform. The size of the Switching Platforms R&D unit was about 600 persons in 1996. There was significant growth in the unit; the number of personnel grew from about 600 to 1066 in 1999, the total growth being 78 percent. At the time of writing this dissertation, the Switching Platforms R&D unit has ceased to exist as such as described in this dissertation.

The mission of the Switching Platform R&D unit was to develop and maintain DX 200 technology based product platforms for switching, access, mobile, and service applications developed by the DX 200 product lines. The responsibilities of the unit included contributing to the strategy work, research, development, testing, and maintenance of the DX 200 Platform, its architecture and interfaces, and future product platforms. In addition, the unit was responsible for the methods and tools associated with the DX 200 product family development, and management, delivery, as well as the documentation of the product platform. Naturally, the patenting issues, process development, and quality measurement were responsibilities of the unit. Unit was also responsible for the project management and implementation, as well as the final quality of the product platform.

The customer chain of SWP R&D unit was quite long, which had an interesting contribution to the operations of the unit. In addition to the end-users of telecommunications services and applications, the operators and the product lines were also regarded as customers of the unit. The group of product lines was of a limited number and quite stable, the number of the product lines changed from five to four during the research. The product lines' businesses were on different phases of the business life cycle; the product line 4 was in the area of starting business, the product lines 1 and 3 were in the growth business, the product line 2 was in the mature business, and the product line 5 was a dying business (ceased to exist in 1997). As to the relative sizes of the product lines, the product line 1 was considerable larger than the other ones, while the product line 4 was the smallest one. During the period of the research, SWP R&D unit did not have competing products, and thus the product lines were dependent on the DX 200 Platform.

Organizations and their products change as the time passes by, and this has been the case with the Switching Platform R&D unit. Hence, the case describes the SWP R&D unit, its operations, as well as the changes in them as far as they relevant to this dissertation. The case description is based on several internal documents (Appendix 1) ranging from the internal annual reports to the manuals describing the operations of Switching Platforms R&D unit, the process descriptions, strategy material, etc. In addition, several semi-structured interviews of the key managers were conducted during 1996 about the strategies and strategy process of the unit. In 2003, some of the managers were interviewed to fit the DX 200 Platforms and its generations to the product platform development theories (Appendix 1).

Concurrently with the official description of the SWP R&D product development (based on the internal documents), the product lines' opinions about the SWP R&D operations will be presented, as far as they are relevant. The aspect is based on three sets of data: the qualitative data of the product line satisfaction surveys, the steering groups' minutes of meetings and functional requirements of one product line to the SWP R&D. The yearly conducted product line satisfaction survey was the product lines' main media for giving feedback to the SWP R&D unit. The interviews included, in addition to the questionnaire, personal interviews, and thorough documentation of the comments given by the interviewees. These comments will be used in the qualitative description. It must be noted, though, that the qualitative comments were not given in every interview, and hence the description might not be able to present the entire range of opinions.

The different steering groups formed the main interface between the Switching Platforms R&D unit and the product lines. Hence, the analysis of product line opinions about the Switching Platforms unit is not complete without a thorough analysis of the steering group meeting minutes; which issues were gone through in the meetings, which issues were discussed upon, and what kind of decisions were made? Finally, the product line 1 was active in giving feedback to the operations of SWP R&D unit. In addition to the previous channels, they prepared a document in 1998 listing the requirements to the operations of SWP R&D unit. This document will be used as an additional input to be analyzed in this chapter.

The data sources will not necessarily provide a comprehensive list of the product platform development factors, but the issues mostly discussed in the product line satisfaction interviews and the steering groups, as well as the issues written in to the requirements document, are possible candidates. The case description might give insights as to which operational modes functioned in practice and which did not. In addition to the product lines' opinions about the SWP R&D operations, possible differences in the opinions due to the product line or the product platform extension in question will be presented. There is a possibility, though, that some factors, which had been well taken care of in SWP R&D, will not be found in the qualitative description. Hence, the quantitative analysis will continue the work started in this chapter.

Next, a deeper look into the Switching Platforms R&D unit's product development is taken. The factors, which were defined to be potential in the theory part, will guide the case study research – but will not restrict it. All of the identified factors will be described in the context of the case unit. The case description starts with the description of the DX 200 Platform and compares it to the product platform concept introduced in the literature, to see how well the product platform concepts fit to the case company. The analysis continues with the presentation of aspects connected with the organization and management, strategies, and ends with the processes and projects. Finally, a summary of the qualitative description will be provided.

4.1 Case Product Platform

According to the factors identified in the literature study, the success of a product is defined by its ability to meet the customer needs. In addition, some aspects special to the product platforms were identified. First, the architecture as to the interfaces of the product platform must be well designed and clear, as the derivative product developers use the interface in their own product development. Closely connected to the interfaces is the easiness of building applications on the product platform, although the easiness may include other elements in addition to the interfaces, like interface documents, as well as tools and methods. Next, the case product, the DX 200 Platform, will be described: the product platform architecture and interfaces (on a very abstract level), easiness of building applications on the product platform as well as meeting the needs of several product lines.

Product Platform Architecture and Interfaces

The development of the DX 200 switching exchange was started in the 1970's. The first generation was a pilot switch based on distributed architecture of Intel's 8-bit processors, which proved to be a good choice later on as the power of Intel's processors continued to grow at increasing speed. The second generation was a digital switch with the main development emphasis on the mobility (NMT, i.e. Nordic Mobile Telephony) and ISDN (Integrated Services Digital Network), and it was based on 16-bit processors. The third generation took further advantage of the increased processor speed (32-bit), with an emphasis on the 2^{nd} generation mobile networks, namely the GSM (Global System for Mobile Communications). Along the time, the DX 200 technology was used in an increasing number of applications, and in 1995, the development of the DX 200 Platform was detached from the development of the business applications into an organization of its own, called Switching Platforms R&D.

The architecture of the DX 200 Platform consisted of two layers, namely a computing platform and a switching platform, which each consisted of subsystems and interfaces between them (Figure 14). In addition, there was the hardware platform included into some architectural descriptions. In addition to the hardware and software, the DX 200 Platform included documentation as a part of the product. The DX 200 Platform, with its hardware, computing, and switching platforms, closely resembles the architecture of the product platform presented earlier in Figure 2.

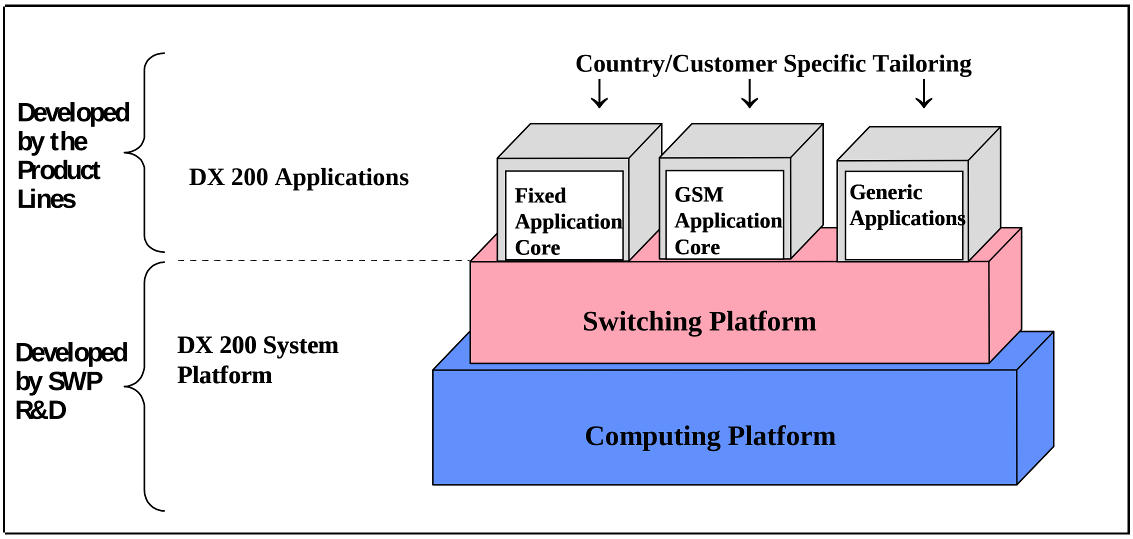

Figure 14. DX 200 Platform architecture.

The development of several extensions, new versions and two renewals of the product platform were started during the research period. The product platform development was already rehearsed with release B2, but the first actual product platform was developed in release B3. Release B3 included systematic tasks of platform productization in co-operation with the product lines, with emphasis on the platform interface clarification, definition, and description. The releases B4, B5, and B6 continued the work started in the B3, but they did not include any substantial changes in either the subsystems or interfaces of the platform, and hence were extensions to the initial product platform. Each B-release was further develop to correspond to the needs of each product line, hence the initial platform as well as its extensions were versioned.

Two releases, A1 and A2, aimed at renewing the platform: some subsystems were adopted from the B-releases (initial product platform and its extensions), but significant renewals were made in part of the subsystems as well as in the interfaces. The development of the B5 and B6 releases and renewed product platforms (A1 and A2) were started during the research period, but not finished. Hence, the dissertation concentrates on the pre-product platform (developed in release B2), initial product platform (developed in release B3) and platform extension (developed in release B4). Table 6 presents the concurrent product platform development of the existing (initial) product platform, its extensions, versions as well as renewals. Hence, the Meyer's concurrent development of the existing product platform, extensions and renewals (presented in Figure 6) was implemented in SWP R&D.

The DX 200 Platform was the common technological base for the DX 200 product family, i.e. the derivative products, which were produced by the product lines (Figure 14). The DX 200 product family included network elements for both the fixed and mobile networks. The size of the product family was about 15 products in 1996, and the amount of product versions was significantly higher.

The shared hardware (pug-in-units) of the product family ranged approximately from 58 percent to 75 percent. The shared software (code lines), on the other hand, ranged from 52 to 86 percent, depending on the actual network element and its version.

Pre-Product platform release B2	
->	B2 version for Product Line 3
->	B2 version for Product Line 1
->	B2 version for Product Line 2
->	B2 version for Product Line 2
->	B2 version for Product Line 2
Initial product platform - release B3	
->	B3 version for Product Line 3
->	B3 version for Product Line 3
->	B3 version for Product Line 1
->	B3 version for Product Line 1
->	B3 version for Product Line 4
Product platform extension - release B4	
->	B4 version for Product Line 3
->	B4 version for Product Line 1
->	B4 version for Product Line 2
Product platform extension - release B5	
->	B5 version for Product Line 3
->	B5 version for Product Line 3
->	B5 version for Product Line 2
->	B5 version for Product Line 4
->	B5 version for Product Line 1
Product platform extension - release B6	
->	B6 version for Product Line 1
->	B6 version for Product Line 2
->	B6 version for Product Line 3
->	B6 version for Product Line 3
->	B6 version for Product Line 3
Product platform renewal – release A1	
Product platform renewal – release A2	
->	Version for Product Line 3
->	Version for Product Line 1

Table 6. Initial DX 200 Platform, its renewals and extensions.

Hence, the DX 200 Platform resembles the software product platform, with its interface to several derivative products.

Easiness of building Applications on the Product platform

Due to the detachment of the product platform from the DX 200 switch, the first real product platform release (B3) included tasks of defining the product platform interface with the applications and productization of the product platform. The discussion of the interface (i.e. the clarity of the product platform interface, the lack of interface documents as well as the easiness of building applications on the top of the product platform) and of what belonged to the product platform or to the application continued far beyond the first product platform release. The easiness of building applications on the product platform was seen as an important feature, and in the end of the research period, one product line regarded it as an important criterion when deciding the next product platform to be used.

The interviewees saw challenges in the new technologies brought along with the product platform renewals. One product line considered that the interface issues as well as the easiness of the application creation had been well and systematically taken care of in the product platform renewals.

Meeting Several Needs

The product line requirements (written in 1996 by the product lines 1 and 3) were aimed at the architecture, hardware, software, ease of use, upgradability, and power of the product platform. It was seen both a strength and a weakness of the product platform that it was used as a base for several derivative products. More visibility was requested to the other product lines' features, which become a part of the product platform. Documents describing the features (used by other application) visible to a product line’s customers (but not relevant to them) were also requested. The generic (to all the product lines) software features of the product platform were not seen as generic; they were not always fully compatible to all the derivative products. The generic features were also claimed responding to no-one’s needs. The large size of the product platform made it difficult especially for the newest product line to know the entire product in the beginning of the cooperation, and the thorough knowledge would have been needed in order to know which parts of the product platform could have been useful in their derivative product.

The importance of the product platform quality and reliability were recognized by the interviewees. It was discussed that the main input to the product platform development should be the technical research instead of the product lines, and that the product platform development should concentrate on the architectural issues, while another opinion was that the internal and external customer needs were buried under the technological innovativeness. The product platform was regarded not being flexible because of the varying needs of the product lines.

Innovativeness

As to the innovativeness of the DX 200 Platform, an auxiliary measure was discovered in the case company. Even though an invention (new knowledge) is not yet an innovation, the number of inventions (patents) might give some signs as to whether there is a possibility for an innovation. The patenting activities of the Switching Platforms R&D unit compared to 1995 figures (level 100) are presented in Figure 15. The figure shows increasing activity in both writing the invention reports, and making the patenting decisions, hence, giving an indication of a possible innovation activity. The next generation product platform development might have influenced the figure.

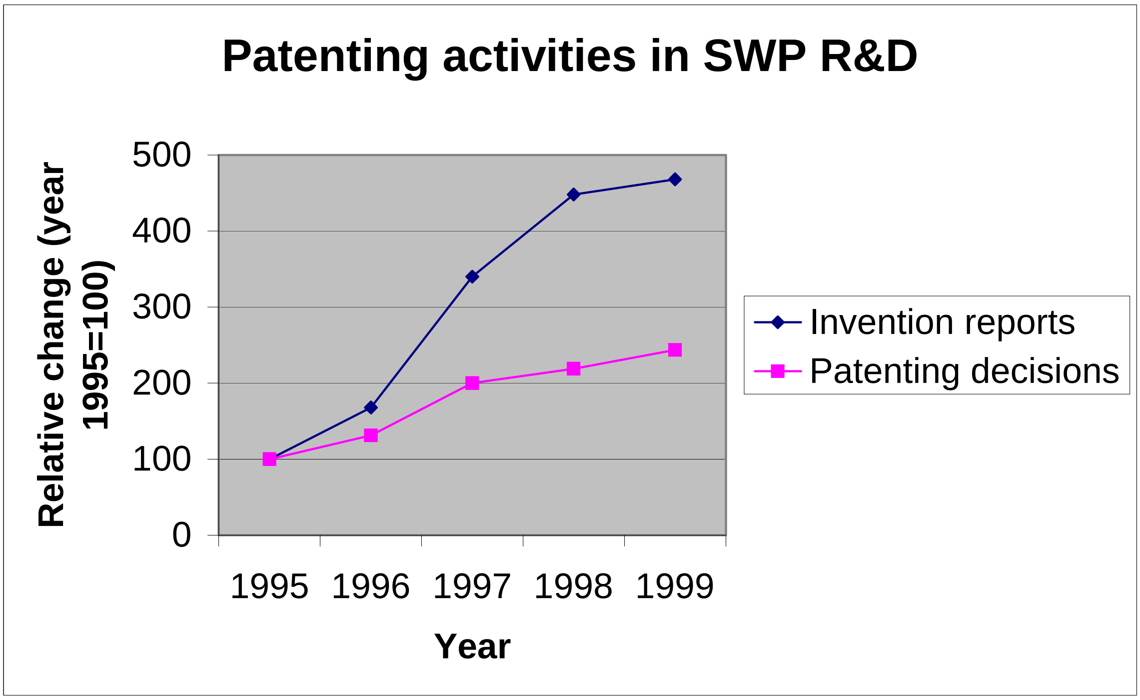

Figure 15. Patenting activities in SWP/R&D.

The product lines considered that the DX 200 Platform architecture had been innovative, and it had enabled building innovative solutions on it. Some interviewees questioned the need for product platform to be innovative, and said that the product platform is innovative enough, when the orders were fulfilled. The architecture, stability, well-functioning product meeting the needs, as well as the schedules were considered more important than the innovativeness.

Summary

The DX 200 Platform, hence, fits to the definitions of product platform presented in the theory. The product platform consisted of subsystems and interfaces, and it was a common technological base to several derivative products. The product platform development consisted of simultaneous development of existing product platforms, product platform extensions and renewals. The product lines regarded clear product platform interfaces being important, as well as the easiness of developing applications on the product platform. In fact, the easiness was mentioned as one of the criteria when choosing a new product platform. The product platform quality was regarded as important to the product lines. Innovativeness was an interesting issue, since qualitatively, it was not raised among the most important factors. Hence, in the case product platform development unit, the qualitatively found important issues were

- product platform quality
- clear interfaces
- easiness of building on the product platform
- meeting the needs

Some comments of the interviewees raised a question, whether the product platform was too generic – forced fit to all the needs. A question remains open, whether there should have been separate platform extensions for at least some of the product lines.

Since the DX 200 Platform fits to the frame of the software product platform, the DX 200 Platform development organization can be used as a case example in the study of software product platform development. Hence, our focus shifts next from the product platform to other factors of the DX 200 Platform development: organization and management, strategies, and processes and projects.

4.2 Organization and Management

The Interface with the Product Lines

The organization of Switching Platforms R&D was a matrix; on one hand, there were the competence-based departments, which actually implemented the product platform, and on the other hand, there were the product and project-based steering and specification functions (Figure 16). In addition to the permanent matrix organization of SWP R&D, there were temporary project organizations decomposed according to the needs at given time. The project organization consisted of release projects, which were further divided into projects and subprojects.

The product lines developing the derivative products based on the product platform were considered being internal customers of the product platform development unit. The interface to the product lines was mainly managed though the product and process based steering functions. The architecture function cooperated with the product lines in the area of the architecture and interface definitions. The product management function took care of the product line requirements and needs analysis, the definition of release contents and orders, while the project management function was the primary interface during the actual release implementation (the progress of the releases, risks, change management, etc.). In the product management function, there were contact persons for each of the product lines, and in the projects function the release, project and subproject managers were assigned to each subcontracting project to co-operate with the product line in question. In addition, the product line specific system testing teams had an interface to each of the product lines.

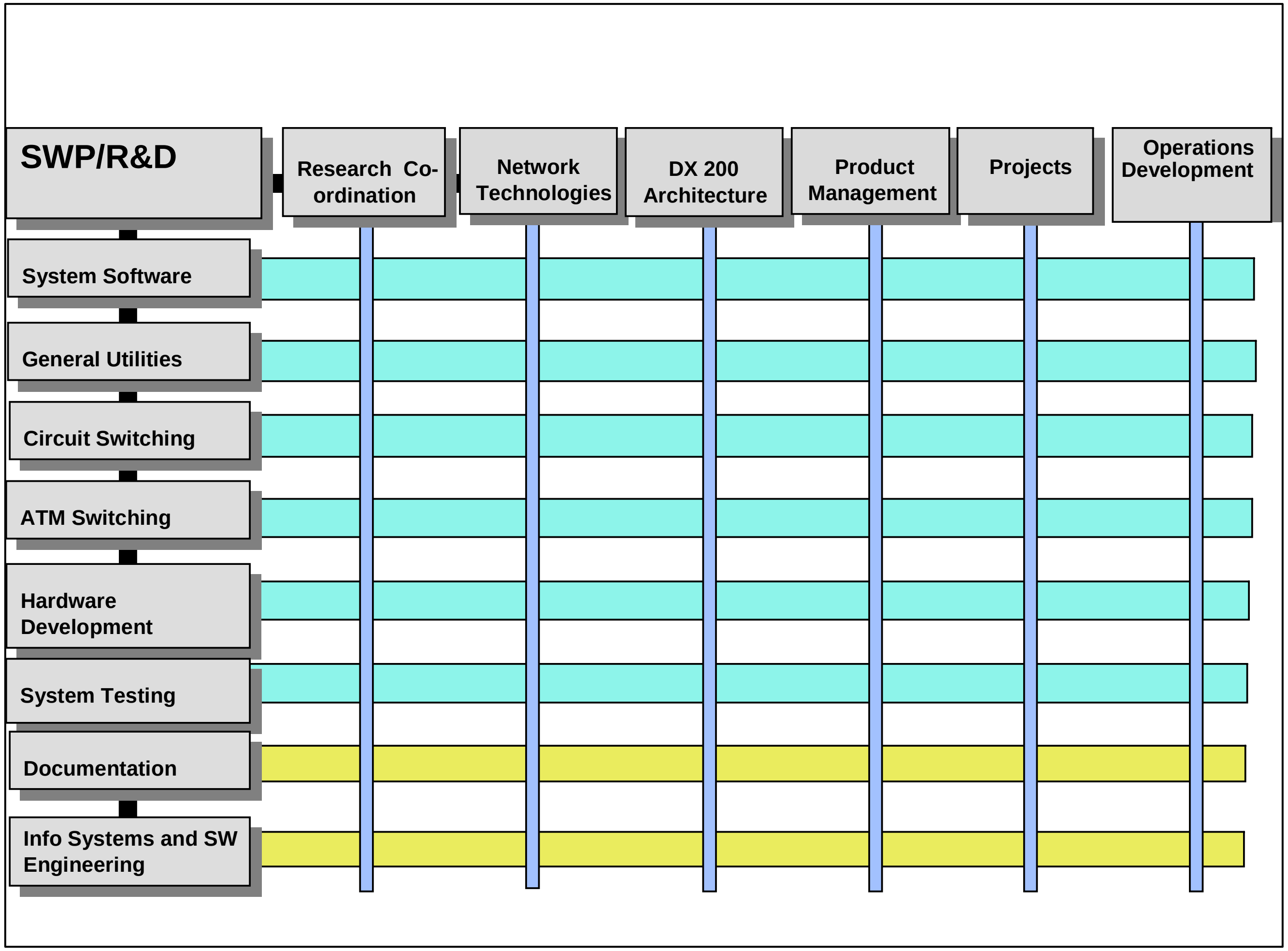

Figure 16. SWP R&D organization.

The information about the organizational changes was presented to the product lines in the SWP R&D steering group meetings. The steering groups also handled the resource deficiencies, as well as principles of flexible use of resources inside SWP R&D (1999). Few times the changes in the contact persons between the SPW R&D and the product lines were presented in the steering group meetings, also.

The product lines commented the SWP R&D as being large, stable, complicated, and bureaucratic organization, which was seen as difficult to change – even though the ability to change was mentioned to have improved during the research period. Some interviewees wanted to know more about the organization, have an access to the organizational charts, and know more about the organizational changes, but some considered it was good if the changes were not visible to the product line. In general, the knowledge of the interface and the contact persons was considered being in order. Regardless of the product line, though, some interviewees commented that finding new contacts from SWP R&D was difficult, especially at the designer level. The existing contacts and old relationships were used to find new contacts, and it was difficult for a new person to find the right contacts.

Steering and Decision Making Practices

The product development of SWP R&D was managed with several steering groups, which were the main communication channels of the contents and progress of the releases. Here a brief discussion of the boards with representatives from the product lines is given. The steering groups were many (Figure 17), and their job descriptions were partly overlapping. Summary of the issues recorded to the minutes of the steering group meetings is presented in Table 7.

The steering group of the highest level, namely the *DX 200 R&D Steering Group (PSG)*, consisted of the SWP's and product lines' top management as well as the program management. The focus of the group was on the product platform visions and strategies, but quite significant amount of time was also used to release follow-up.

The next level steering group, i.e. the *Product Platform Development Steering Group (PDSG)* was a gigantic meeting with focus on coordinating the different needs of the product lines and managing the releases. The priorities were gone through in next to every meeting and the prioritization activity was art by itself; there were from over ten to thirty items in the priority list depending on the exact date. The function and purpose of the list was an often-discussed issue – it was stressed by the SWP R&D that the list was used in resource conflicts situations, or when negotiating about new releases or resource commitments. The release situation was gone through in every meeting, and new orders and change requests had a significant role in the meeting. All the milestone decisions were presented in the meeting – if the decision had been done in another meeting, it was presented for information in the PDSG meeting. Often, the milestones were actually postponed if the criteria had not been met.

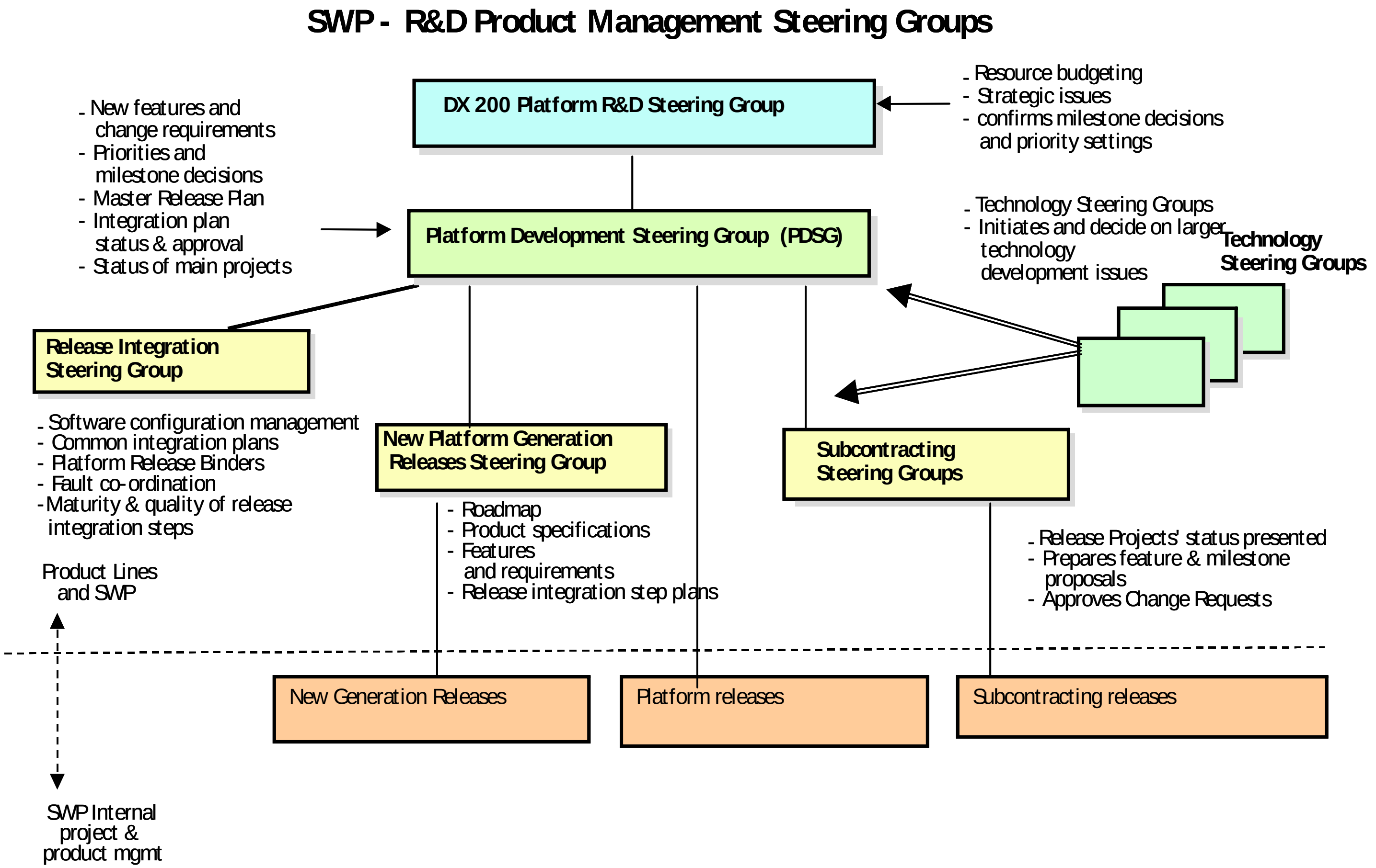

Figure 17. Product development steering groups.

In addition to the PDSG meeting, all the product platform extension releases were reported in two *Subcontracting Steering Groups* comprising of the SWP R&D and product line representatives, and chaired by a product line representative. The steering groups approved the content of the main projects and the proposals of the milestone dates, monitored and managed the progress of the main projects, approved the decision material of each milestone, ensured that the contents of the main project met the customers' needs, and reported deviations and corrective actions to the higher level steering group. Hence, the tasks of the groups were entirely overlapping with the tasks of the PDSG meeting. Along the time, one of the subcontracting steering groups finished its work. Another one continued its work, since the product line 2 insisted it – the product line claimed its requirements and needs were run over in the PDSG meeting by the larger product lines, and hence, wanted to have a steering group of their own.

The *Release Maintenance Steering Group* (RMSG) and later on, Release *Integration Steering Group* (RISG), was responsible for the software configuration management related decisions, communication and cooperation with the product lines. The participation of the product line representatives decreased towards the end of the period, and sometimes there were no other than SWP representatives in the meetings in 1999.

Three steering groups concentrated on the technological aspects of product platform (architecture, features and documentation): one on the computing platform, one on the Switching Platform, and one on the hardware platform. Because these steering groups concentrated mainly on the technical aspect of the DX 200 Platform, their meeting minutes did not bring any new insights to the research.

Hence, there were quite a few steering groups and the steering group activities covered a wide area of cooperation between the SWP R&D and the product lines. Different steering groups managed the product architecture, strategies, priorities and release decisions as well as the follow-up of the projects.

	Product	Organization and management	Strategies	Processes and projects
DX 200 R&D Steering Group (PSG), (~15 participants)	Responsibilities of some program blocks Product platform principles	New organizations Steering group structures Metrics (systematic from 1998 on) Portfolio Requirements from product line 1	Strategies Road maps New derivative products Priorities Budgets Product line strategies	Master release plan follow-up Release situation: progress, risks, schedule and content changes, resource shortages, specification, hardware and software problems and delays, testing environments, work amount increases New releases: contents and schedules Improvement requested to project visibility, fault management, change management, documentation and cooperation in testing
Product Platform Development Steering Group (PDSG) (10-over 30 participants)	Changes in the product platform Responsibilities of product platform subsystems and documentation Language of the design documents Implications of the change requests to the documents	Steering group practices: job description and participants, changes in roles Budgets of all the SWP R&D projects SWP R&D and release level metrics.	Future product platforms and their roles Priorities	Master release plan and release integration plan follow-up Practices: ordering, system testing, documentation, interface definitions, release integration, fault reporting Release situation: contents, successes, risks, and progress, new orders, change requests, schedule and milestone delays, resource problems, architectural, hardware or software problems, testing environments, fault targets, open faults Milestone decisions: estimated milestone schedules, preliminary contents, fulfillment of the milestone criteria
Subcontracting steering groups (10-25 participants)		Subcontracting budgets Metrics Steering group meeting Changes in the SWP R&D – product line interface	Priority list	New releases: plans, contents, schedules commitments, work estimations Release situations: orders, work loads, risks, change requests, release contents, schedules, changes, software and hardware problems, builds, defects and their corrections, testing situation Milestone decisions Product lines' projects: contents, schedules, progress, and problems.
Release Integration and Maintenance Steering Groups		Steering group practices New steering groups		Software build plan and integration plan Testing situation: problems, faults, corrections, testing support to the product lines. Maintenance policy, fault targets Situation of product lines' releases
Technology Steering Groups	Software and hardware related architecture and features		Priorities, road maps	

Table 7. Issues found from the steering group meeting minutes.

The product lines generally criticized the number of the groups as well as clarity of the roles and responsibilities: the classification of steering groups to informative and decision- making was suggested, as well as reduction of the number of the groups. On the other hand, it was regarded positive that all the product lines had representation in the groups. The PDSG meeting was criticized for being too complicated and lengthy a meeting, where the larger product lines run over the smaller ones, even though large amount of good information was shared in the meeting. It was also pondered that the same issues were gone through in several meetings. Hence, there were overlapping meetings either because of power and politics between the smaller and larger product lines or because the platform was too generic to fit to everyone's needs.

Metrics

The SWP R&D work was measured at different project levels, as well as on the R&D unit level. There were slight modifications in the metrics set during the time, but the main measures remained the same during the period. There were specific metrics for resources, portfolio, projects, changes, product quality, responsiveness to customer and customer satisfaction. The measures were followed on several different steering groups, and along the time the product lines presented some requirements towards the measures. The exact descriptions (excluding the internal customer satisfaction survey) of the measures are presented in Table 8.

Area	Metrics	Period	Description
Resources	Total Resource Demand	1996-1999	The entire project portfolio including all the work done and estimated during a certain period.
	Resource Estimation Accuracy	1996-1999	The accumulative amount of release's (project's, subproject's) realized work and the estimated amount of work remaining, as compared to the baseline (estimated workload in frozen plan).
	Relative overload index	1997-1999	The percentage the next month's overflow in the projected work compared to the actual output of that month.
Progress of Releases	Planned versus Realized Work	1996-1999	The amount of work performed and the remaining work, as compared to the baseline (estimated workload in frozen plan) on monthly bases.
	Average Subproject Schedule Slip	1996-1999	The average realized slip related to the original target date of subprojects completed during a certain month. The trend calculated over the last 12 months also shown.
Changes to releases	Release Integration Step Completeness	1997-1999	The amount of RIS changes during a year. If a feature, which is planned to be implemented into a certain RIS, misses that RIS, the amount of RIS changes is increased by one.
	Software Release Completeness	1998-1999	The share (%) of the implemented features compared to the E1 baseline.
Fault finding in releases	Cumulative created and closed failure reports	1996-1999	The cumulative amounts of created and closed failure reports of a release.
Product quality measures	Customer Fault Reports	1996-1999	The number of all fault reports by customers over the previous twelve months, calculated for each month.
	Hardware quality index (short term)	1996-1999	The faulty plug-in units found within time period (0 to 2 months, 2 to 4 months and 4 to 6 months) from the installation.
	Hardware reliability (long term)	1996-1999	The component failure rate during the last 12 months in plug-in units taken in use during (approximately) the last four years. The purpose of this index is to follow up the long-term reliability of delivered hardware (design's point of view).
Responsiveness to customer	Fault repair time	1997-1999	The weekly-created customer problem reports closed within 50 days.
	First response to problem report	1997-1999	The weekly-created customer problem reports, state, and responses given (other than new within 3 weeks).

Table 8. Descriptions of the metrics used in SWP R&D.

However, all the measures in SWP R&D were operational, and the strategic measures, i.e. the product platform effectiveness and efficiency, were not calculated nor measured. The operational measures used in SWP R&D were not platform development specific – in fact, similar measures could have been followed in a single product development environment, also.

Since the financial data of the product platform effectiveness and efficiency was missing, an auxiliary measure to analyze the effectiveness was developed. Sample data of B4 releases' code lines by product platforms' subsystems used by three product lines was available for the researcher. Product line 4 did not use the release B4, and hence their releases cannot be compared with other data. From the 32 subsystems, seven were used by only one of the product lines (three by product line 1, three by product line 3 and one by product line 2). Altogether 13 subsystems were used by two product lines, from which 12 by the product lines 1 and 3. Finally, 15 subsystems were used by all the three product lines (Table 9). Hence, on a subsystem level, the total reuse rate of the product platform would be around 46%.

32 Subsystems, from which

- 15 were used by product lines 1,2, and 3
- 12 were used by product lines 1 and 3 only
- 1 was used by product lines 1 and 2 only
- 3 were used by product line 1
- 3 were used by product line 3
- 1 was used by product line 2

Table 9. Product platform efficiency by subsystems.

However, the shared subsystems mainly included more code than the ones used by only one or two product lines. Of the product line 1's product platform code, 68% belonged to subsystems used by all the other product lines as well. Correspondingly, 90% of product line 2's and 71% of product line 3's product platform code belonged to the subsystems used by all the other product lines as well.

Shared code	Product Line 1	Product Line 2	Product Line 3
% of code belonging to subsystems used by all the product lines (1,2,3)	68%	89.5%	71%
% of code belonging to subsystems used by two of the product lines (1&2, or 1&3)	30%	10%	27%
% of code of belonging to subsystems used by the specific product line only	2%	0.5%	2%

Table 10. Product platform efficiency by code-lines.

The figures presented above can only give direction as to the amount of B4 product platform code shared between the product lines 1, 2 and 3. The data available for the researcher was on subsystem level, and the actual lines of code shared inside each subsystem might cause additional differences among the product lines. The data does not reveal anything about how well the product platform code fitted to the needs of the product line 4, though.

Technological and Business/Marketing Competences

According to the theory, the product platform development should possess resources and competences on both technological and business/marketing areas. Interviews of the strategy process made in 1996 resulted in analyses of the competences of the SWP R&D unit as follows

> *" … (a) problem with the competence strategies is the lack of the business knowledge in the technological field"*

Direct measures of the distribution of competences were not found from the case company, but an indirect one was produced in February 1998 (Figure 18). As described in the context of the organizational structure, the business and market understanding lied primarily in the product management function. In addition, the managers as well as project managers might have had some competence on the market or business area, depending on the experience of a specific person. The figure indicates a strong technological competence base (architecture (3%), software design and implementation (39%), hardware design and development (8%), testing (9%), as well as tools and methods development (11%)). Hence, 70% of the tasks were strongly product development oriented. If the managers and assistants of the development functions as well as the project managers are added, the figure increases even more. In comparison, the product management tasks comprised 3 % of all the tasks, which might be a signal of a small amount of business and market focus in the unit.

Even though the figure above might give some signs of the competence base of the SWP R&D unit, it does not tell the levels of competence, i.e. the experience years and areas of the personnel nor the competences person might have in addition to the current tasks, and hence it cannot be completely trusted.

The product lines regarded important the existence of expertise in the product platform development. There was also consensus among the product lines, that there could (and even should) be more market and business knowledge on the product lines' businesses. It was wondered by several interviewees, whether the SWP R&D was too far away from the end-customers. Still, some interviewees were satisfied with the level of business understanding in SWP R&D, and it was pondered that especially the top management understood the product lines' businesses. The business knowledge in the area of product platform renewals was also pondered; since the business did not yet exist, even the product lines did not know the customer needs nor the business yet.

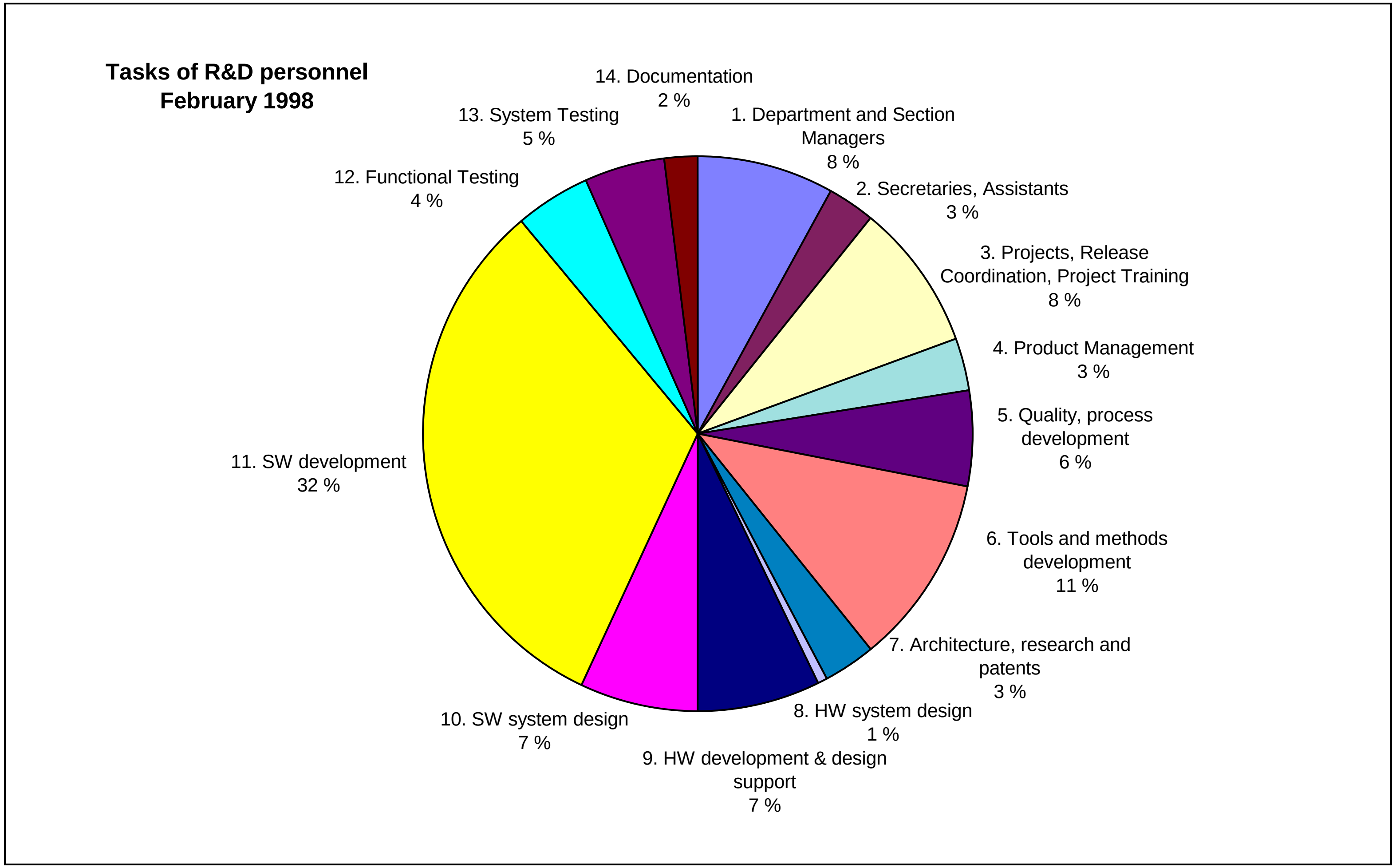

Figure 18. The distribution of task types in SWP R&D.

Cooperation and Communication

The cooperation between the product lines and the SWP R&D unit was quite tight. The cooperation was coordinated by the steering groups, consisting of representatives from the product lines and SWP R&D, as described before. The cooperation done in the steering groups included decision-making (e.g. about the contents, milestones and priorities of product platform and subcontracting releases), discussion and information sharing (e.g. about progress of the programs, metrics), and feedback (about SWP's operations). It was necessary that the product lines took part in the decision-making and prioritization, because the product platform had to fit to the different needs of the derivative products.

In addition to the steering groups, the concurrent development of the product platform and the derivative products brought some additional communication methods with the product line. The orders, change requests, specifications, and release delivery material as well as the project/program and testing reports were additional communication methods between the product line and the SWP R&D unit (described in Chapter 4.4). Communication was necessary in the areas of strategies as well as technological choices and implementation. Training to the product lines had been organized about the new product platform releases on a needs bases.

The minutes of the steering group meetings mentioned several projects aimed at improving the cooperation between the product lines and SWP R&D. Regardless of the product line and year, though, the personal relationships were regarded being well functioning. Several product lines figured that the geographical distances as well as busy schedules were reasons complicating the cooperation.

Summary

The product lines mainly considered the SWP R&D organization being large, bureaucratic, and difficult to change. Still the product lines were mainly concerned about the interface between them and the product platform development. There was a defined interface between the SWP R&D and the product lines in the areas of architecture and interfaces, product requirements, release contents, release implementation, and testing. The product lines mainly considered the contact persons from the SWP R&D known. The main communication channels as well as steering, management and decision-making tools were the steering groups, which were many. The steering groups concentrated on strategic issues, priorities, and the progress of the releases. The amount of steering groups and the roles of them were criticized by the product lines. Especially one meeting, namely the PDSG, was considered being too large a meeting where the large product lines run over the smaller ones. Product line 2 had its own subcontracting steering group with whose activities it was very satisfied. Hence, the efforts to steer between the varying needs of the product lines resulted in a complicated and overlapping steering group mechanisms. Especially the overlapping meetings open a question, whether the platform was too generic for the product lines or whether there was power conflict between the product lines.

Several metrics were followed in different steering groups, and there were few requirements about the operational metrics during the research period. The operational metrics followed in SWP R&D were not specific to product platform development. There were no requirements towards the strategic metrics, i.e. the product platform efficiency or effectiveness, which were not measured in SWP R&D. According to the auxiliary measure, calculated for this research, the reuse rate of product platform code between the product lines 1, 2, and 3 was high. The result might close the open question about whether there should have been more than one platform extension for the product lines 1, 2, and 3. Since the data was not available for the product line 4, the question remains open.

Expertise in the product platform development was considered crucial by the product lines. The resources of SWP R&D mainly consisted of technically oriented employees, but still more expertise on some special areas as well as on the product lines' products was requested. More business knowledge and understanding was also requested for, even though there was some available in SWP R&D. It was also considered that SWP R&D was too far away from the customers. Overall the product lines were satisfied with the personal relationships and cooperation, even though it was wished that the SWP R&D personnel could participate more to the product lines' meetings.

From the organization and management related issues, the focus will be changed to the strategies of the case company. Hence, the SWP R&D will be described from the strategic aspect, next.

4.3 Strategies

The characteristics of SWP R&D business required that a lot of attention was paid to the strategies. The product platform was developed during quite a long time-horizon, and the strategic choices had an influence on the success of the company in a long run. It was necessary that the product platform was developed in a way that allowed the product lines to add features later on, even such features that were not yet known during the product platform development. Therefore, the needs of each link in the customer chain needed to be anticipated with proper strategies. Next, the strategic issues of the SWP R&D will be discussed from the strategy process and content aspects.

Strategy Process

The SWP R&D strategy process was a yearly cycle and the product lines participated into the strategy creation by defining architectural requirements to the product platform and by attending the upper level steering groups (i.e. PSG). The role of the steering groups, and especially the high level steering groups (PSG and PDSG), was a significant one in the area of strategy development and communication. The strategies, road maps, contents and schedules of the product platform renewals, extensions and new versions were gone through in the meetings. The strategies were also communicated in the PSG meeting to the product lines’ management. From 1998, the communication of the strategies included road-map presentation days, where the competence areas of SWP R&D presented their road maps to other competence areas of SWP R&D and to the product lines. The strategies were communicated in separate communications event to the product lines, and the product lines arranged specific strategy sharing sessions to communicate their strategies and roadmaps to the SWP R&D. Through the years, the importance of cooperation in the area of strategies and roadmaps as well as the product line’s ability to influence the road maps was recognized by the product lines.

Strategy Content

The SWP R&D strategies consisted of competence, technology and product, tools and methods, and process strategies. The technology strategy included the strategic technological and architectural choices, while the product strategies included the product platform roadmaps. From 1998 on, the line organization of SWP R&D unit systematically prepared roadmaps for each technical competence area to ensure that all the competence areas were included into the strategic considerations. The technological and product strategies were consolidated into SWP R&D strategy, which was then consolidated at a higher level.

In 1996, a strategic will of improving the product platform and application interfaces in the following release as well as clarifying the organizational interface according to the product structure was expressed in the official strategy material. It was stated, that the renewed product platform would include formally defined interfaces between product platform and applications. The renewed product platform would also support three level product development model: common product platform, generic applications and fast customization to the needs of the customers. In 1997, the product platform productization was included into the strategies of the following releases. In 1998, the product platform productization was still a strategic will and the product platform was defined as follows

> *DX 200 System Product platform Product is...*
> *clearly defined and solid entity,*
> *detailed documented,*
> *measurable, and*
> *portable to different network elements.*

Goals of the product platform were described as *"Time-to-Market, faster development cycles, One Generic SW for all HW Product platforms, Better Quality and Reliability, Easy to Understand and Develop as a Product*". In 1998, the customer documentation improvements were included into the strategies; documentation was defined to be "*flexible, changeable and proactive*". In 1999, the well-defined interfaces were still a strategic intent. The product platform was also presented as a product, including the core product as well as its package: functionality, quality (e.g. 100% of the requirements tested), documentation (user and internal ones), customer care, tools and methods for application development, as well as training. Hence, the product platform productization moved forward on the strategic level during the years.

The importance of the product platform strategies was recognized by some of the interviewees and generally. The product line 2 was consistent in its comments throughout the research period. The message was that the strategies and road maps should take the product line's business needs as well as the end-customer needs better into account. The distance of the SWP R&D from the customers was regarded being part of the problem, and other product lines' needs were seen to be better included in to the roadmaps. In general, the varying needs and different time perspectives of the product lines were seen to cause troubles in the strategies and road maps; both in the contents as well as on the schedules.

Interviews of the SWP and SWP R&D managers about the strategy process (1996) resulted in analyses of the SWP R&D strategies as follows

> *"Giving the nature of business of SWP, namely the long customer chain, it is not surprising to notice that market strategies are a serious problem. The short-term market strategies are formatted in the business units, and the information of strategies is not easily accessible. It often happens that the information about short-term strategies does not reach SWP until quite late, even though SWP R&D should be able to react in the early phases to the strategies of the business units. Also, it is not quite clear what information on market strategies is needed in SWP. While SWP should see the markets beyond the timeline of business units, the SWP market strategies should be focusing on the future market structures - who the*

customers are, what needs they have, what the competitive environment is like, etc…"

The analysis thus recognized the interface to the business and market strategies, which was found to be problematic. The business and market aspects were not included into the strategies at the SWP R&D unit level. Still, the market information was acquired through the product lines. In 1996, the SWP R&D strategy material included a will to increase the market knowledge especially in the area of the next generation product platforms.

The lack of market strategies in the SWP R&D was recognized by all the product lines. It was commented that the strategies of SWP R&D were too much technology-driven, the market strategies were missing, and the end customers were not visible to the SWP R&D. The business knowledge and understanding needed improvement, even though some regarded the business understanding in SWP R&D already being improved. Commonly, it was stated that it should be in the interest of everyone to cooperate: the product lines needed to input the market and customer information to the SWP R&D strategies as well as SWP R&D needed to take the offered information into account.

The analysis of the SWP R&D strategies (1996) continued as follows

"A problematic part of R&D work of the Switching Platforms is achieving a right balance between short and long-term requirements and development. The internal customers, i.e. the product lines usually require such subcontracting work and features that are needed in the markets almost immediately. Quite often the long-term development of a product platform suffers from the ad-hoc feature development."

The different needs and the short-term requirements of the product lines were taken into account in the strategies by allocating a separate versioning budget to each of the product lines. The budgeting was tied to the strategy formatting process, and hence, was a yearly cycle. Already in 1996, there were requests for a shorter budgeting cycle – a half a year cycle was suggested in the PSG meeting, but at that point, the cycle was not changed. The budgets were followed in the steering groups (PSG, PDSG).

From 1997 on, the product lines requested for more emphasis on the product platform development (product platform extensions and renewals) by decreasing the budgets of the product platform version development. In 1998, a strategic will for decreasing the amount of product platform versioning work in order to ensure the product platform extensions and renewals was written in to the minutes of the PSG meeting. Later on the same year, the will was implemented when defining the next year's budgets. Hence, the focus of the product lines changed from short-term fixes to long-term product platform development.

One of the strategic decisions made in the steering groups was the one of giving priorities to the SWP R&D releases. A priority list was updated in the meetings, and the content of the list was one of the most discussed issues in the meetings. Several times, when an agreement was not reached in discussion, the prioritization decisions had to be escalated in the organization and sometimes the escalation was taken to very high a level to find the one person for whom all the arguing parties were accountable. Sometimes the priorities were simply decided by the SWP R&D personnel. Quite a few times, the meaning of the priority list was also gone through; it was supposed to be used only in a conflict situation, when the same resources were loaded by several releases.

The product lines commented the prioritization as being a complicated issue; the product lines requested for clear rules and accurate information about the changes of priorities. For some it seemed that the larger product lines got higher priorities easier. In 1999, the opinions about the priorities were varying, but the positive opinions seemed to be winning. Even though it was regarded that the prioritization practices were bureaucratic, and that the decisions were not always what the product line had wished for, the process itself was seen as well functioning, well structured and clear. The large amount of concurrent releases as well as the varying needs of the product lines were seen reasons for the difficulties in the prioritization practices.

Summary of the strategic issues

The product lines were able to participate to the product platform strategy work especially through the steering groups. *Cooperation during the strategy process* was found to be important by the product lines, as well as the ability to influence the strategies.

Naturally, the *strategy and road map content* was found to be of great importance by the product lines. The interviewees were mainly satisfied with the communication of the strategies and roadmap as well as the contents of the strategies and road maps. There were challenges in considering all the product lines' needs in the strategies. Again, the product line 2 clearly stated that its needs were not taken into account as well as the bigger product lines' needs. The lack of market aspect in the SWP R&D strategies was noticed by the interviewees, and some cooperation in the area was requested. Productization i.e. clarifying the product platform and its interfaces continued for a long time on the strategic level also.

The *prioritization* was also found to be important but complicated issue; clear procedures and rules were requested for, and especially the small product lines were worried about the large ones getting higher priorities. The satisfaction with the priorities improved towards the end of the research period. The large number of concurrent releases was seen as causing difficulties in prioritization. In addition, the large subcontracting budgets (for product platform versions) as compared to the product platform development (product platform extension and renewal) budgets caused some concern among the interviewees and lead to actions during the research period. Hence, the focus of the product platform development moved from shorter to longer-term development.

After the strategies, the focus of the case analysis will be turned to the actual implementation of the product platforms. Hence, the processes and projects of SWP R&D will be gone through, next.

4.4 Product Platform Development Process and Projects

Product platform development environment

The product development of SWP R&D was done in multi-project environment, simultaneous development of the initial product platform, product platform extensions, and versions, and in addition, product platform renewals. In 1996, the average lifetime of a Switching Platform was estimated to be ten years, and the development of a new generation was estimated to take from two to three years. In 1999, one of lessons learned was that the product platform renewal differs fundamentally from extending the existing product platform.

In the concurrent development mode, the releases loaded the same resources. The concurrent releases in SWP R&D unit during the research period are presented in Figure 19. During the period under research, there were from approximately 10 to 16 concurrent release projects depending on the exact month.

In 1996, the actual work amounts of the product platform development (the initial product platform development, its extensions and renewals) and the product platform versioning were approximately the same. During the research period, the amount of product platform development work (extensions and renewals) increased significantly, while the product platform versioning work decreased. In 1999, the amount of product platform extension and renewal development comprised over double the work done for the product platform versions, which was in line with the strategic decision made together with the product lines and SWP R&D.

The releases active at a specific point of time were managed with the master release plan (Figure 20). The plan shows all the active releases and their specific phase in the product process. The plan shows the management complexity of a multi-project environment.

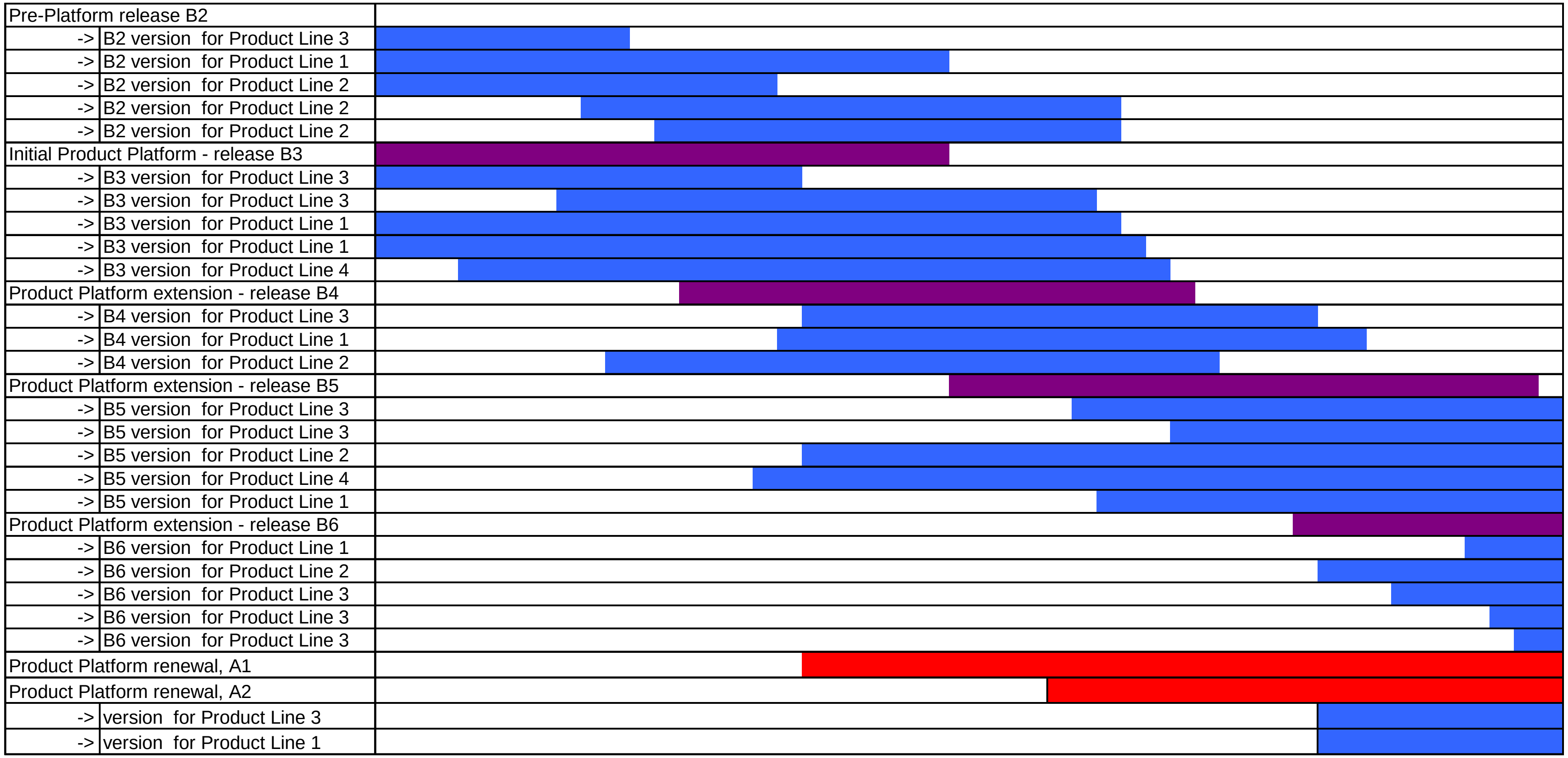

Figure 19. Concurrent release projects in SWP R&D during the research period.

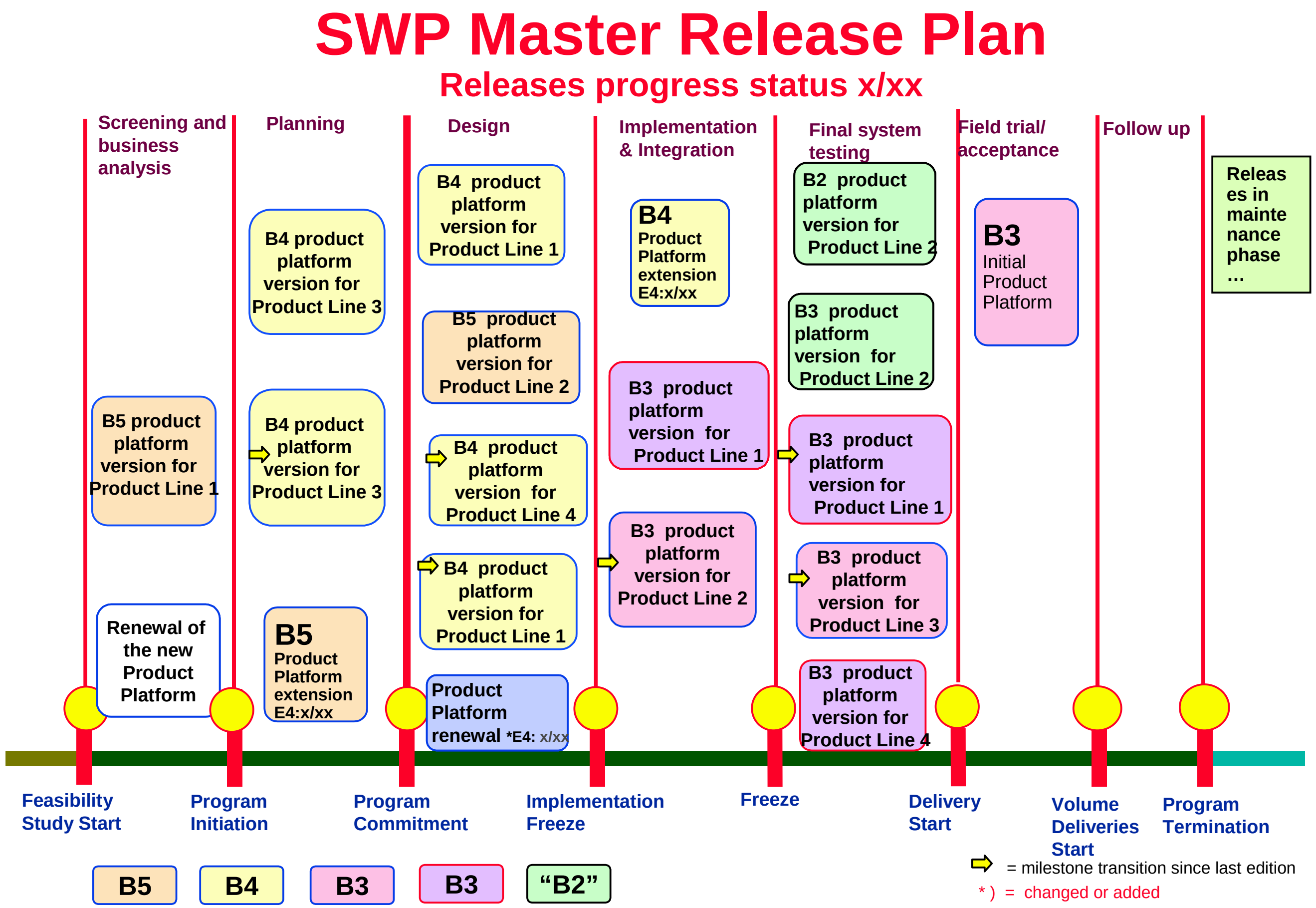

Figure 20. Example of a master release plan.

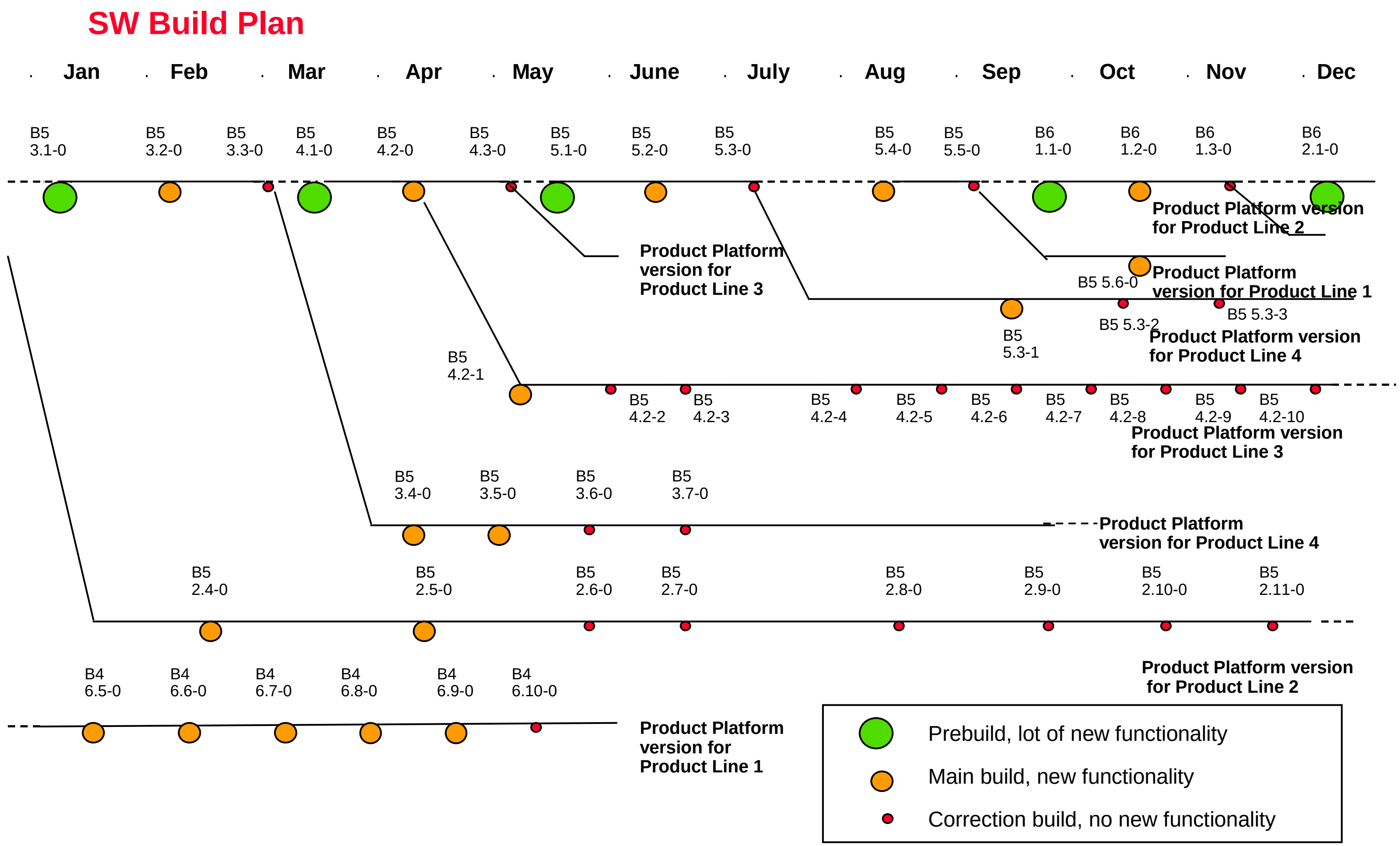

Figure 21. An example of a software build plan.

The multi-project environment proposed challenges to the management of the product platform releases. The releases were integrated in steps (RISes), and the product lines were able to take any product platform build to be used e.g. when testing their own application (i.e. as software prototypes). Figure 21 presents the software build plan of a year (excluding the correction builds and the product platform renewal builds), which was used to manage the complicated environment of the release integration steps of the product platform extensions and versions.

In addition to concurrent development inside SWP R&D, the product lines developed their derivative products on the product platform concurrently with the product platform projects. Even thought the SWP R&D project environment was complex by its nature, only few product line representatives saw a possible problem with the large amount of concurrent projects. Only in 1997, some product lines expressed concern about concurrent schedules of one product platform release and two subcontracting releases. In addition, the large amount of concurrent projects was seen as a factor influencing to the difficulties in prioritization.

Product development process

The product platform extension and versioning releases were developed according to a defined product process (Figure 22). The product process was divided into phases and milestones between the phases. The tasks were performed during the phases, and at each milestone the status of the tasks, schedules and resource situation were checked and it was decided whether to continue to the next phase. The product process description of SWP R&D was different from the product lines’ ones and the definition work of the process description had been done inside SWP R&D unit. Hence, the milestone criteria as well as the contents of the processes were different from the product lines’ processes.

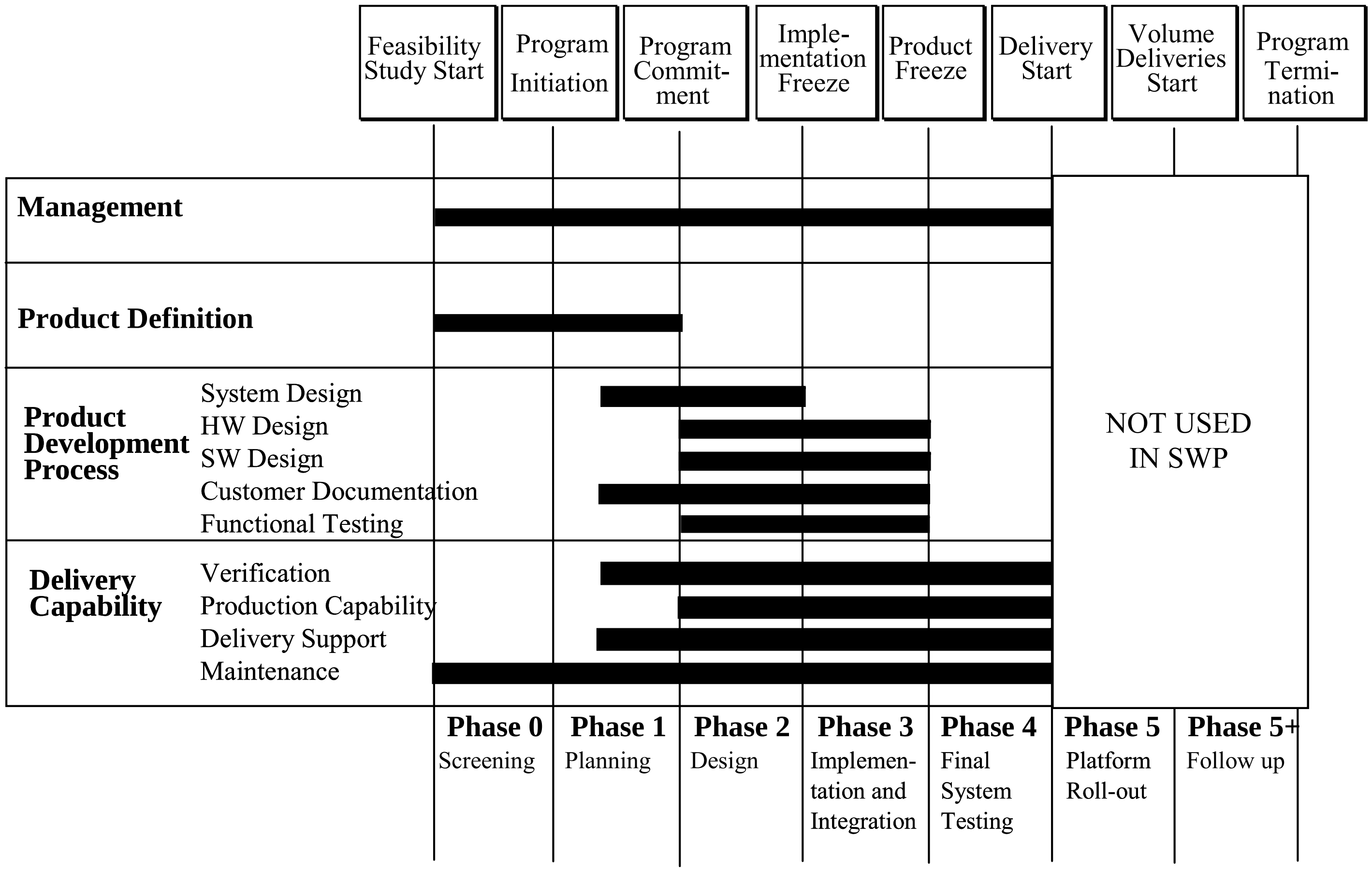

Figure 22. Subprocesses and milestones.

The product lines had interfaces to all the main level processes: management process (steering group activities, decision making, and project tracking), product definition process (needs acquisition, orders, change requests, and specifications), product development process (reviews, customer documentation, and testing), and delivery capability process (test plans and reports, fault correction and co-ordination, product platform release training, and release information). In the steering groups, the process issues were discussed from two points of view: sometimes the practices were gone through for information purposes and sometimes improvement were requested. The process issues gone through in the meetings included the milestone criteria, ordering process and ordering tool, system testing practices, documentation process renewal, initiations for improving the interface definitions and changes in them, (internal) release documentation practices, release integration practices, and fault reporting practices.

Regardless of the product line in question, the processes of the product lines and SWP R&D were considered functioning well together, even though there were differences in e.g. milestones and phases in between. Some interviewees saw a need to harmonize the processes, e.g. milestones and their contents, testing processes, and deliverables. There was also a need for common higher-level process development. Improvement was requested e.g. in the area of the interface issues and informing about them. One interviewee, though, noted that the problems were neither in the milestones nor their criteria, but in the information flow between the SWP R&D and the product lines.

Product platform releases

The product platform release (initial product platform and its extensions) final reports were available from 1996 on, and the following examples are gathered from them. The average time of product platform extension development was one and half years, and the work amounts varied from a bit under and well over 100 000 hour. The work amount typically grew along the release project, but growth was smaller in the latter product platform projects. The slips ranged from none to a couple of months – the slips got smaller towards the end of the period in question – hence, in the initial product platform release, the slip was larger than in the extension development. The amount of changes in the product platform releases varied from about 60 to over a 100 change requests. The features typically slipped in the beginning of the release, but in the end, next to all features were included into the releases. The amount of faults found internally ranged from 500 to over 1000. The last finished product platform extension release had targets for the open faults at the end of the release and met the targets (two percent open, and all the critical faults corrected), while in the earlier releases, the amount of open faults was higher.

The release schedule accuracy as well as the work amounts of some of the releases are presented in Figure 23. The figure shows that some of the schedules were accurate, while there were small slips in some schedules. This might have to do with the fact that the product platform releases shown in the figure were extensions and new versions; hence, the technological risks were lower than in the product platform renewal projects. The importance of keeping the promised schedules was discussed several times in the interviews – the impact of slips to the product lines' own releases was considered being tremendous. Still, in the example, the product platform extension releases with higher technological risks reached more accurate schedules than some of the versioning releases. The high work amounts of the product platform versioning releases can be explained with the strong emphasis on testing – the product platform extensions were not system tested, but instead, the versions were tested in the network environments.

The schedules of the product lines' releases were taken into account when deciding the milestone dates of the SWP R&D releases, since the product lines were dependent on the SWP R&D's schedules. The contents of the releases were planned in cooperation with the product lines: the technical ideas (based on research and architectural studies) and market needs were captured in a release content plan. The product lines provided feature proposals, needs, feedback, and change requests in addition to other inputs (results of architectural studies, strategies, standards, competitor analysis, and inventions). New orders and change requests as well as the release contents were approved in the steering groups.

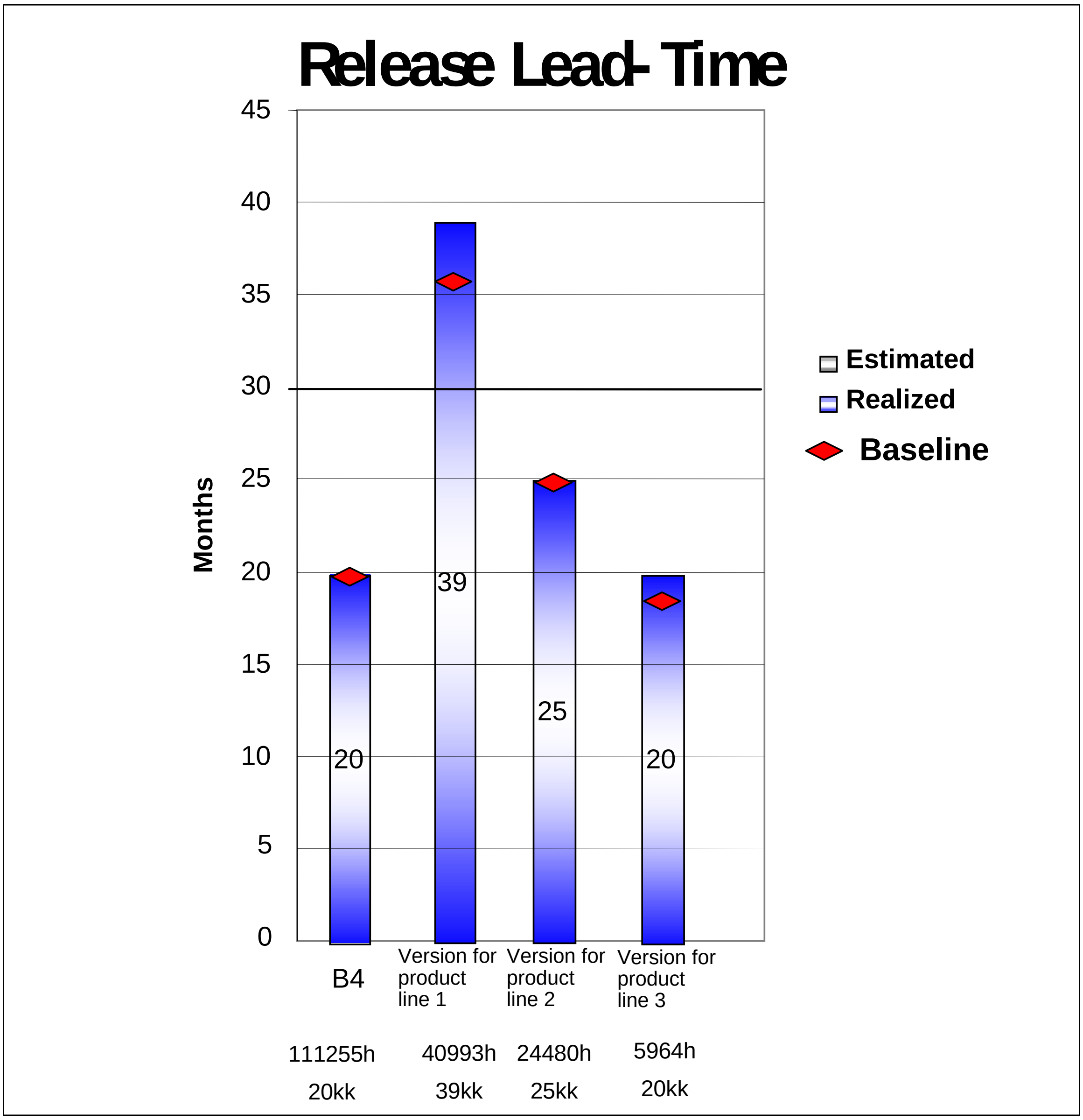

Figure 23. B4 platform extension and it's versioning release lead times.

In 1996, the interviews about the SWP R&D strategy process resulted in an analysis of the internal and external customer needs acquisition:

"SWP R&D follows-up the technical aspects of competitor intelligence, keeps up with standardization, participates in conferences, and keeps up with technological development. There is plenty of information available - that is not the problem; the real problems are connected with the interpretation, communication, and distribution of the information. Due to the complicated customer chain, keeping up with the customer needs is a problem in SWP."

Still, according to the data from the product line interviews, it was generally understood that the SWP R&D considered the product line's needs even though not all the needs could be taken into account. The smaller product lines, though, saw that the larger product lines' needs tended to run over the smaller one's needs. The ordering was considered to require too much effort and the process to be lengthy in the beginning of the research period. In addition, the requirements for the product lines to specify the exact work amounts in the orders, to direct the orders straight to certain section in SWP R&D, and to produce the requirements specifications, were considered difficult.

During the implementation, monthly reports of the projects (successes, risks, progress) were delivered to the product lines through the steering groups. The steering groups (PSG, PDSG, and the subcontracting steering groups) made milestone decisions (postponed the milestones, also) and tracked the progress of the releases.

The visibility to projects' real situations (e.g. possible slips, milestone criteria) was considered important by the product lines, and the satisfaction with the visibility improved during the years. Yet another product development aspect found important by the product lines was the change management (timely information about the schedule and content changes as well as changes between RISes and releases), and especially the interface change management. The product lines agreed that the timely information about the missing components (i.e. well functioning change management) was extremely important. It was expressed that the timely schedules were more important than complete releases. In addition, the availability of information about other product lines' features (included into the product platform renewals or extensions) was considered being problematic.

During the projects, the product lines participated to the specification work, to the reviews of the specifications, and sometimes even prepared the requirements specifications. There were some cooperation activities in the areas of documentation and testing, e.g. common reviews of plans and reports. The busy schedules as well as geographical distances were mentioned as reasons for not attending the reviews, even if an invitation had been received. A problematic part of the development was the development of features partly in SPW R&D's responsibility and partly in the product line's. Hence, the product platform interface was not entirely clear. Yet, another area needing improvement was the testing interface between the product lines and SWP R&D (responsibilities, information flows). The concurrent testing done in the SWP R&D and the product line was seen as one of the problems – the release was not completely tested in SWP R&D before the tests started in the product line, and hence some faults were found after the product line had started its tests, sometimes by SWP R&D sometimes by the product line.

The software fault corrections were a controversial issue, since testing was also done in a concurrent mode. The fault corrections were discussed several times in the steering groups as well: the fault correction times and targets, reporting practices, procedure for testing the corrections, and fault classification. The requests included fault targets as well as faster responses to the customer fault reports.

Training was an area of dividing opinions inside the product lines; some considered that there was enough training available, while some requested for more training. Some interviewees wanted to get training right after the product decisions. Here the concurrency of the releases might have caused some of the problems – the product lines needed the information of the release's contents before the release was actually finished.

Summary of the Processes and Projects Area

There was a multi-project environment in SWP R&D: concurrent development of product platform renewals and extensions as well as new product platforms. However, the complex environment was not a concern to the product lines and neither was the fact that the product process of SWP R&D was different from the product lines' ones. The project success data found from the product platform extension projects did not give any signs of failures caused by the high technological risks. Still, comments and issues raised in the product line satisfaction surveys revealed that the concurrent development of the product platform products and derivative products did complicate the development. The concurrent product development of the product platform renewals and or extensions with the derivative products caused communication and coordination needs in the areas of fault management, testing, and training.

Most of the interviewees thought that their product line's needs had been taken into account in the product platform development, especially in the case of the next generation product platform releases. There were concerns, though, that the needs of the larger product lines were better taken into account than the smaller ones'.

In the area of projects, two issues were emphasized as being important to the product lines; accuracy of the schedules and information about the interface changes. It was stated that the product lines were dependent on the product platform schedules, and fast and accurate information about changes was needed.

The area of processes and projects concludes the qualitative case description of SWP R&D. Next, a discussion of the qualitative findings will be provided and some additional conclusions will be made about the qualitative findings across the specific areas described before.

4.5 Implications of the Case Description

The case description had a twofold target: 1) to answer to the second research question "2. When compared to the theory, does the empiric case of product lines' perspective to the product platform development add any potential factors?" and 2) to reason for the questions analyzed in the following quantitative case analysis. Both of the aspects are covered in the analysis provided in this chapter by the areas defined in the literature study: product platform, organization and management, strategies and processes and projects.

Product platform

The product of the Switching Platforms R&D unit (i.e. the DX 200 Platform) and the derivative products of the product lines fit to the product platform and product family definitions. Hence, the SWP R&D case is a proper example of a product platform development unit.

The DX 200 three-level product platform was regarded to meet the basic needs of the product lines. Simultaneously with the development of the derivative products based on the existing product platform, product platform renewals, extensions, and versions were developed. During the research period, only part of the product platform extension and versioning releases were finished, and hence, the analysis considers only those releases. The issues found important in the area of product platform were the product platform quality, the product platform interfaces, the easiness of building the derivative product on the product platform as well as the product platform's ability to meet several needs. Hence, as compared to the list of factors derived from the theory, the product platform quality, easiness of building the derivative products on the product platform and product platforms ability to meet several needs were additions to the list provided by the case.

Surprisingly, the innovativeness of the product platform was not raised among the most important issues.

As to the quantitative questions asked from the product lines, the interfaces and productization related questions were asked from the product lines during the first two years, but the questions were left from the survey since the product lines requested it. The issues covering the other aspects of product platform itself are presented below

- Innovativeness in product platform design and development (architecture)
- Innovativeness of new features from SWP
- The easiness of building own applications on the top of the product platform
- DX200 product platform meeting the needs
- Reliability and quality of software
- Reliability and quality of hardware
- Quality of documentation

Organization and management

The organization of the SWP R&D was a matrix comprising of the development and steering functions. The product lines often referred the SWP R&D organization as being large and bureaucratic, and not very easily changed. The interface to the product lines was managed with specified contact persons from the product management and project management functions and with several steering groups. The product lines mainly considered the contact persons known, but there were problems in finding new contacts, and especially designer contacts. The personal relationships were in a good condition; the old relationships were used to find new contacts, and it was felt that the old relationships resulted in faster responses from the SWP R&D. The main communication channel and cooperation forums between the product lines and the SWP R&D unit were the steering groups, which were many. Through the steering groups, the strategies and priorities as well as projects and their progress were discussed and agreed or decided upon. The number and responsibilities of the steering groups were criticized by the product lines: especially the PDSG steering group's meetings were criticized for being too lengthy. It was also a concern that the small product lines were being overrun by the larger ones. Hence, one of the smaller product lines insisted on having a steering group for their own issues, while the other product lines wanted to decrease the amount of the steering groups. The metrics followed in the SWP R&D included several operational metrics, while the strategic metrics about the product platform effectiveness and efficiency were missing. The operational metrics were not specific to product platform development only. The auxiliary measure of product platform efficiency seemed to be on a high level. The product lines presented some requests towards the operational metrics, but not towards the strategic metrics. Still, one could assume that the role of the strategic metrics would be very important for the derivative product development when choosing a new product platform. The SWP R&D personnel seemed to be more technically than commercially oriented as to their tasks in the organization. The existence of the business knowledge was criticized, although some interviewees held the opinion that there was some expertise in the area. The importance of expertise was stressed in the interviews, though.

Hence, as to the organization and management, the case did provide some new insights when compared to the theory. The contact persons, the decision making and steering practices, competences and co-operation included no surprises. The role of clear priorities and prioritization practices was stressed by the product lines. However, the lack of strategic metrics might be an indicate a difference between the roles of product lines (as internal customers) and external customers of product platform development. The product lines might not have other choices for the product platforms and hence, the product platform development might not have to prove the effectiveness and efficiency to the product lines. Hence, there were no questions presented to the product lines about the strategic metrics. The other organization related questions are presented below.

- Experience / expertise of SWP/R&D people
- Telecommunications know-how
- SWP/R&D people understanding the business operations
- SWP informing Product Lines of SWP/R&D contact persons
- Getting responses/help from SWP/R&D
- Functioning of prioritization/decision making

Strategies

The product lines were able to participate to the strategy process of SWP R&D, and thus, were able to contribute to the contents of the product platform strategies. The cooperation with the strategy process continued to the communication of strategies – during the research period, separate sessions were arranged for communicating the SWP R&D strategies to the product line representatives and vice versa, and the strategies were communicated in the upper level steering groups, also. In the beginning of the research period, there were several requests for closer cooperation in the area of strategies. The nature of the cooperation in the area seemed to improve during the time, though. The area of strategy communication was felt being on a good condition. The importance of the strategies themselves was emphasized by the interviewees. The product lines were mainly satisfied with the strategies and roadmaps, even though some smaller product lines complained that the needs of the larger ones were better included into the roadmaps. The SWP R&D strategies did not include the market strategies, but the market and derivative product aspects were included into the consolidated strategies at the higher hierarchy levels. Still, it was noticed by the product lines that there was need for more cooperation in the area of including the market aspects to the DX 200 Platform strategies. The prioritization was found to be a difficult task. An often-discussed issue in the steering groups was the different priorities as well as the meaning of the priority list. For several years, the product lines requested for clear rules to prioritization. In the area of priorities, it was felt that it was easier for the large product lines to get high priorities, and the large amount of releases did not make the prioritization any easier.

The cooperation during the strategy process as well as the prioritization were additions found in the qualitative case description when compared to the theory. As to the questions asked from the product lines, the strategies and roadmaps as well as prioritization we included into the survey. However, there were no questions about the cooperation during the strategy process. The questions asked about the strategies are summarized below:

- SWP/R&D ability to develop clear long-term direction (strategies and road maps)
- SWP/R&D strategies /road maps meeting the strategic / business needs
- Functioning of prioritization/decision making

Processes and projects

The product development in SWP R&D was done in releases. There were multiple simultaneous releases developed in SWP R&D during the whole research period. The multi-project environment was complicated to manage, but it was not a concern to the product lines. Still, comments and issues raised in the product line satisfaction surveys revealed that the concurrent development of the product platform products and derivative products did complicate the development, requiring communication and coordination in the areas of release's progress, feature development, fault management, testing, and training.

The product process (implemented in releases) was different from the product line's ones – the process and the contents of the milestones were developed from the aspect of the SWP R&D only. There were parts in the product development process, which considered the product lines, though. The steering group and project reporting practices, customer needs collection and ordering tasks, test planning and reporting, fault corrections and release training tasks were included into the product development process. The product line representatives mainly thought that their processes functioned well together with the SWP R&D processes.

In the area of processes and projects, two issues were emphasized as being important to the product lines: the accuracy of schedules and information about the interface changes. It was stated that the product lines were dependent on the product platform schedules, and fast and accurate information about changes was needed. As to their realized schedules, the product platform extension releases seemed to succeed better than the product platform versioning releases. Most of the interviewees thought that their product line's needs had been taken into account in the product development done in SWP R&D, and especially well in the case of the next generation product platform releases. Some thought, though, that the needs of the larger product lines were better taken into account than the smaller ones'. The areas needing improvement through the years included change management (schedule, contents and interfaces), and concurrent testing in the product line and SWP R&D.

When compared to the theory, the complications caused by the multi-project environment were specified in the case unit. The questions aimed at the product lines related to the challenges of the multi-project environment and concurrent development mode: common reviews, training, receiving information, and software corrections. Also the level SWP R&D considered the product lines needs as well as schedules and deliveries were asked from the product lines. Questions related to the change management and testing were not asked every year, though. The projects and processes related questions asked from the product lines each year are summarized, next.

- SWP/R&D people participating in the Product Line's meetings / reviews when asked
- Informing / training on the use of SWP products
- Promised schedules of product platform products (Lead time)
- Receiving needed information of projects in SWP (visibility to projects)
- Quality of SWP project documents / meeting minutes
- Delivery completeness
- Shared reviews of deliverables
- Software corrections
- The level SWP takes customers/product lines' needs into account in product development

Observations on the product platform development

In the case analysis, several interesting findings were made, which can be linked back to the very basic nature of the product platform development. The very basic requirement of the product platform development, i.e. the clear architecture and interfaces, seemed to require special attention. In the case, the productization of the product platform was a long process. One of the reasons might be the fact, that the product platform was not designed from the beginning, but instead separated from an existing product. Further, the product platform was a common technological base for the derivative products and still, the interviewees complained that the generic features did not meet anyone's needs and not all the generic features really were generic. Further, there were features in the product platform, which were used by only some of the product lines, and the others saw that those features only consumed space and capacity in the final product. Hence, the nature of the product platform (common technological base), even though it was a strength in optimizing the use of resources and concentrating the development, was also its weakness for developing features, which were not optimized for anyone – or if optimized not used by everyone. The varying needs of the product lines were considered as having a negative impact on the flexibility of the product platform.

Further, several derivative products based on the product platform meant several parties needed to be heard in the course of development. This led into a situation that the steering mechanisms were difficult and even bureaucratic: large steering group meetings with everyone’s representation, difficulties in prioritization and decision making, and large ones overrunning the smaller ones. Large number of concurrent existing and new product platform development projects combined with varying needs and different time perspectives of the product lines led to difficulties in prioritization activities. Similarly the different needs and time perspectives of the product lines and the product platform development as well as the different sizes of the product lines and different business situations lead to varying opinions in the area of strategies, road maps and release contents. In addition, the nature of the product platform development, i.e. the distance of the end-customers (lack of business competences and touch with customers) was seen as a potential problem in the areas of strategies and customer need collection

Hence, there were complaints about the platform not fitting to all the needs, the large product lines overrunning the smaller ones’ needs and focus of strategies being on the large product lines’ products. Still, the reuse rate of product platform software, as shown with the auxiliary measure, was high among the product lines 1, 2, and 3. The fitness of the product platform to the product line 4’s needs is still left open, but otherwise, power and politics may have played a role in the comments.

The strategic measurement and the proof of the effectiveness and efficiency of the product platform were not seen as a necessity in SWP R&D. One of the reasons might be the fact that SWP R&D did not have to do business with its product platforms. The only customers it had were the internal product lines, which might not have had any other feasible choice as their product platform. The case could have been different if the customers of the product platform development would have been external ones: the new potential customers might be very interested about the efficiency and effectiveness measures of the product platform development.

An interesting curiosity was the consideration of the product lines as internal customers of the product platform development. The literature study did not reveal that the term internal customers had been used in connection with the product platform development literature, before. The conceptualization of the product lines as the internal customers is an interesting one. Especially useful the concept would be in a case where the derivative product developers would be both in-house product lines and external companies, i.e. internal and external customers.

Hence, in addition to complementing the theory and specifying the questions used in the quantitative analysis, the case revealed several interesting aspects about the product platform development: the very basic nature of the product platforms may lead into problems in the development.

5. QUANTITATIVE ANALYSIS OF THE CASE UNIT

In the context of the case described in the previous chapter, the analysis continues with the research questions

3. What are factors of the product platform development seen by the product lines?
4. Do the product lines see the product platform development differently from one another?
5. Are there differences in the product lines' opinions due to platform extension?
6. Which product platform development factors affect most to the product lines' satisfaction with the product platform development?

The analysis starts with the descriptive data of the statements. Then the research questions are analyzed with the operationalized tests as described in Chapter 3.3 and the results of the statistical tests will be presented.

5.1 Descriptive Statistics

The questionnaire of the product line satisfaction survey was based on the nature of cooperation between the SWP R&D and its product lines. As described in Chapter 3.4, the statements were first derived from the questionnaire aimed at the external customers, tested with an product line representative, and later on improved yearly based on the comments given in the interviews. Therefore, the questionnaire changed from 1996 to 1998, and only during the years 1998 and 1999, the questionnaire remained the same. The 1996 survey was first of its kind, and as such, the questionnaire included some questions that were found hard to answer or unnecessary. Respectively, some aspects of the product platform development were not included into the first year's questionnaire at all. Hence, a decisions needs to be made which data will be used in the analysis and which will be ignored. Since the 1998 questionnaire included all the questions, which had been asked from the 1996 on, and which were asked 1999, also, it was decided to use the 1998 questionnaire as the base for planning the analysis (Appendix 2). The Table 11 presents the questions that remained the same the entire period. The choice of the questions could have been based on a different timeframe, which would have increased the number of statements to be analyzed, but it would also have decreased the amount of data in other questions. This choice was made to get the longest possible period into the analysis.

In the actual customer satisfaction surveys, there were questions about product platform, organization and management, strategies, and processes and projects. The actual question groups, though, might not necessarily have been balanced from the theoretical viewpoint. As to the product platform, for example, the statement about the interfaces was discarded from the questionnaire in 1998 (hence, will not be included into the analysis here). In the area of organizations and management, the steering group practices were included into the survey from the year 1997, and there were no question about the strategic metrics. In addition, the overall satisfaction with the product platform development was asked in the survey. The product lines' ability to influence the SWP R&D strategies was not covered by the questions.

The data descriptives are presented in Table 11. The number of missing answers ranged from 0 to 26 percent of the answers. There was only one statement whose response rate was less than 80 percent, i.e. the statement about shared reviews. The means of the score statements ranged from 2.8 to 3.9. There was only one statement (experience/ expertise of the SWP R&D people) whose Kurtosis absolute value exceeded 1. The use of the more conservative criteria (two times the standard error being lower than the Skewness or Kurtosis value) detected some more statement, whose distributions were not normal enough. The outlier analysis (standardized value over 3) detected three outliers for one question, namely the experience/ expertise of the SWP R&D people, but the removal of the outliers did not improve enough the Kurtosis value of the statement. The data transformations (inverse, square root and logarithmic) did not improve the distribution, either.

Question (bolded: missing answers >20%, skewness >1 or <-1, and kurtosis >1 or <-1, std deviations which doubled are less than the absolute value of the corresponding skewness or kurtosis)	N				Descriptives					Normality measures			
	Total	Valid	Missing	%	Mean	Std. dev.	Median	Min.	Max.	Skewness	Std error	Kurtosis	Std error
1.1 Experience / expertise of SWP/R&D people	134	131	3	2	3.9	0.6	4	2	5	-0.80	**0.21**	**2.66**	**0.42**
1.2 Telecommunications know-how	134	128	6	4	3.8	0.7	4	2	5	-0.25	0.21	0.12	0.42
1.3 SWP/R&D people understanding your business operations	134	128	6	4	2.8	0.8	3	1	4	0.06	0.21	-0.81	0.42
2.1 SWP/R&D ability to develop clear long-term direction of where SWP is going (i.e. road maps)	134	123	11	8	3.3	0.9	4	1	5	-0.59	**0.22**	-0.26	0.43
2.3 SWP/R&D strategies /road maps meeting your strategic / business needs	134	124	10	7	3	0.8	3	1	5	-0.13	0.22	-0.28	0.43
3.1 Innovativeness in Product platform design and development (architecture)	134	123	11	8	3.3	0.8	3	1	5	-0.70	**0.22**	0.14	0.43
3.2 Innovativeness of new features from SWP	134	118	16	12	3.2	0.8	3	1	5	-0.21	0.22	-0.12	0.44
4.1 SWP informing Product Lines of SWP/R&D contact persons	134	131	3	2	3.4	1.1	4	1	5	-0.52	**0.21**	-0.51	0.42
4.2 Getting responses/help from SWP/R&D	134	131	3	2	3.7	0.8	4	2	5	-0.33	0.21	-0.39	0.42
4.3 SWP/R&D people participating in your Product Line's meetings / reviews when asked	134	126	8	6	3.6	1	4	1	5	-0.40	0.22	-0.15	0.43
4.6 Informing / training on the use of SWP products	134	121	13	10	2.9	0.8	3	1	5	0.38	0.22	-0.15	0.44
5.1 Functioning of prioritization/decision making	134	115	19	14	2.8	0.9	3	1	5	-0.13	0.23	-0.32	0.45
5.3 Promised schedules of product platform products (Lead time)	134	115	19	14	2.9	0.9	3	1	5	0.23	0.23	-0.35	0.45
6.1 Receiving needed information of projects in SWP (visibility to projects)	134	128	6	4	3.1	0.9	3	1	5	-0.11	0.21	-0.69	0.42
6.2 Quality of SWP project documents / meeting minutes	134	119	15	11	3.4	0.6	3	2	5	0.20	0.22	-0.12	0.44
6.4 Delivery completeness	134	117	17	13	3.1	0.8	3	1	5	-0.11	0.22	-0.52	0.44
7.1 Shared reviews of deliverables	134	99	35	**26**	2.9	0.8	3	1	5	-0.06	0.24	-0.45	0.48
8.2 Software corrections	134	116	18	13	3.1	0.8	3	1	5	-0.24	0.22	-0.08	0.45
9.1 The level SWP takes customers'/your Product Line's needs into account in product development	134	129	5	4	3	0.9	3	1	5	-0.29	0.21	-0.44	0.42
9.2 The easiness of building own applications on the top of the product platform	134	117	17	13	3.1	0.9	3	1	5	-0.28	0.22	-0.15	0.44
9.3 DX200 product platform meets your needs/end customers' needs	134	129	5	4	3.4	0.8	3	1	5	-0.45	**0.21**	-0.12	0.42
10.1 Reliability and quality of software	134	122	12	9	3.2	0.8	3	2	5	-0.18	0.22	-0.77	0.43
10.2 Reliability and quality of hardware	134	112	22	16	3.3	0.9	3	1	5	-0.44	0.23	-0.44	0.45
10.3 Quality of documentation	134	115	19	14	2.8	0.8	3	1	5	-0.11	0.23	-0.34	0.45
11.1 Overall satisfaction with SWP/R&D	134	134	0	0	3.3	0.8	3	2	5	-0.21	0.21	-0.70	0.42

Table 11. Descriptives of the statements.

The background data used in the analysis includes the information about the product line as well as the product platform extension in use at the time of the interviews. Even though the product platform extension used by a product line at the time of the interview was not asked in the questionnaire, the data was later on coded to include the information. A product line was assumed to assess the latest finished product platform extension at the time of the interviews. In practice, all the extensions had been finished at least a couple of months before the corresponding interviews.

5.2 The Factors of the Product Platform Development

In order to find out the structure behind the statements, i.e. the factors of product platform development, factor analysis was conducted. From the factor analysis, the statements with large amount of missing data (>20%) and high skewness or kurtosis values (<-1 or <1) were excluded. The extraction method used in the factor analysis was the Principal Component Analysis, and the rotation method was the Varimax with Kaiser Normalization. The factor analysis was first conducted simultaneously to all the statements chosen to the further investigation. The results showed enough correlations between the statements (each statement had correlation over 0.3 at least with one another statement). The Measure of Sampling Adequacy (MSA) values were at acceptable level (well over 0.5), but the communalities of the statements as well as the loadings in the factor analysis were too low for some statements. Hence, the factor analysis was conducted several times excluding the statements, which did not fulfill the criteria, from the analysis one by one until all the loadings and communalities in addition to the MSAs (Table 12) and correlations (Appendix 3) were on acceptable level. The analysis resulted in six factors comprised of 19 statements (hence 6 statements were excluded from the analysis) (Table 13). The factors were normally enough distributed, i.e. the skewness and kurtosis values were on acceptable level (Table 14). From the possible 134 cases, 68 were included into the analysis: other cases included one or more missing value(s). The resulting model fit was over middling, the Kaiser-Meyer-Olkin Measure of Sampling Adequacy was 0.75 and the Bartlett's Test of Sphericity $X^2(171)$ was 572.35 ($p<0.001$).

Factor analysis Communalities and MSA-values of the statements included into the Factor analysis	**Communality**	**Measure of Sampling Adequacy**
s_2.3 SWP/R&D strategies /road maps meeting your strategic / business needs	0.589	0.851
s_9.1 The level SWP takes customers'/your Product Line's needs into account in product development	0.612	0.842
s_5.1 Functioning of prioritization/decision making	0.585	0.838
s_1.3 SWP/R&D people understanding your business operations	0.583	0.688
s_2.1 SWP/R&D ability to develop clear long-term direction of where SWP is going (i.e. road maps)	0.708	0.796
s_6.1 Receiving needed information of projects in SWP (visibility to projects)	0.708	0.737
s_6.2 Quality of SWP project documents / meeting minutes	0.716	0.697
s_10.3 Quality of documentation	0.513	0.856
s_6.4 Delivery completeness	0.623	0.736
s_4.1 SWP informing Product Lines of SWP/R&D contact persons	0.666	0.641
s_4.3 SWP/R&D people participating in your Product Line's meetings / reviews when asked	0.614	0.751
s_4.2 Getting responses/help from SWP/R&D	0.603	0.784
s_3.2 Innovativeness of new features from SWP	0.748	0.557
s_3.1 Innovativeness in Product platform design and development (architecture)	0.801	0.638
s_10.1 Reliability and quality of software	0.679	0.778
s_8.2 Software corrections	0.7	0.81
s_10.2 Reliability and quality of hardware	0.647	0.588
s_5.3 Promised schedules of product platform products (Lead time)	0.747	0.803
s_9.3 DX200 product platform meets your needs/end customers' needs	0.6	0.807

Table 12. Statements included into the factor analysis.

Factor analysis	**Factor 1**	**Factor 2**	**Factor 3**	**Factor 4**	**Factor 5**	**Factor 6**
Extraction Method: Principal Component Analysis. Rotation Method: Varimax with Kaiser Normalization. Kaiser-Meyer-Olkin Measure of Sampling Adequacy 0.75 Bartlett's Test of Sphericity, X^2 (171)= 572.35, p= 0.000	Strategic and business fit of product platform	Project communication and deliverables	Cooperation with product platform development	Innovativeness of product platform architecture and features	Reliability and quality of product platform	Promised schedules and final product platform meeting the needs
Eigenvalue – initial % of Variance (cumulative %)	4.797 25.25 (25.25)	2.064 10.86 (36.11)	1.781 9.38 (45.48)	1.600 8.42 (53.90)	1.251 6.58 (60.49)	0.974 4.99 (65.48)
Rotated sums of squared loadings % of Variance (cumulative %)	2.891 15.22 (15.229	2.457 12.93 (28.15)	2.036 10.716 (38.86)	2.007 10.57 (49.43)	1.789 9.42 (58.84)	1.260 6.63 (65.48)
s_2.3 SWP/R&D strategies /road maps meeting your strategic / business needs	**0.737**	0.010	-0.078	0.171	0.087	0.053
s_9.1 The level SWP takes customers'/your Product Line's needs into account in product development	**0.727**	0.094	0.182	-0.001	0.138	0.146
s_5.1 Functioning of prioritization/decision making	**0.678**	0.197	0.235	0.125	-0.087	0.091
s_1.3 SWP/R&D people understanding your business operations	**0.660**	-0.103	0.175	-0.183	0.121	0.242
s_2.1 SWP/R&D ability to develop clear long-term direction of where SWP is going (i.e. road maps)	**0.616**	0.430	-0.128	0.345	0.055	-0.075
s_6.1 Receiving needed information of projects in SWP (visibility to projects)	0.190	**0.811**	0.044	0.068	-0.051	0.069
s_6.2 Quality of SWP project documents / meeting minutes	-0.080	**0.759**	0.356	0.033	0.081	-0.006
s_10.3 Quality of documentation	0.113	**0.556**	0.146	-0.054	0.367	0.177
s_6.4 Delivery completeness	0.022	**0.511**	-0.105	0.146	0.441	0.367
s_4.1 SWP informing Product Lines of SWP/R&D contact persons	-0.042	0.061	**0.765**	0.175	-0.077	0.196
s_4.3 SWP/R&D people participating in your Product Line's meetings / reviews when asked	0.141	0.248	**0.728**	-0.026	0.003	0.044
s_4.2 Getting responses/help from SWP/R&D	0.206	0.004	**0.704**	0.063	0.197	-0.149
s_3.2 Innovativeness of new features from SWP	0.051	0.024	0.068	**0.854**	0.066	0.081
s_3.1 Innovativeness in Product platform design and development (architecture)	0.188	0.112	0.131	**0.852**	0.091	0.017
s_10.1 Reliability and quality of software	0.110	0.099	-0.029	0.086	**0.787**	0.172
s_8.2 Software corrections	0.296	0.339	0.236	0.021	**0.621**	-0.238
s_10.2 Reliability and quality of hardware	-0.091	-0.388	0.078	0.442	**0.534**	-0.020
s_5.3 Promised schedules of product platform products (Lead time)	0.303	0.233	0.168	-0.008	0.023	**0.756**
s_9.3 DX200 product platform meets your needs/end customers' needs	0.432	-0.031	-0.101	0.292	0.228	**0.514**

Table 13. Factors.

The factors were straightforward to name. Factor 1 consisted of strategic issues, the business fit of the product platform strategies and taking the product lines' needs into account, and hence it was named to "Strategic and business fit of product platform". The second factor included the project information in different forms, as well as the resulted delivery completeness, and the factor was named to be "Project communication and deliverables". There was one peculiar statement included into the factor 2: the quality of documentation. The documentation can be thought as being a part of the project's result, i.e. the release, and hence it can be seen as an integral part of the factor 2 "Project communication and deliverables". The factor 3 included the contact person information as well as receiving help and participating into the meetings, and therefore the factor name was chosen to be "Cooperation with product platform development". The factor 4 included both the questions about the product platform innovativeness, thus the name "Innovativeness of product platform architecture and features" was given to the factor. Factor 5, named to be "Reliability and quality of product platform ", consisted of the reliability and quality of software and hardware, as well as the software corrections. Factor 6 comprised of two statements, namely the statements about the promised schedules and the product platform meeting the needs. The factor name, "Promised schedules and final product platform meeting the needs", included the both aspects of the factor. It is strange though, that the product platform meeting the needs should be combined with the schedules needed to produce the product platform – but in the eyes of the product line, getting the product in right schedule might be a part of fulfilling their needs.

The sample of 134 cases was not large enough to validate the factor analysis by splitting the database into two (if the absolute minimum for factor analysis is 5 cases for each variable in the analysis, meaning 95 cases). Hence, a weaker validation method was chosen. From the database about 80% of the cases were randomly selected – depending on the variable, the number of cases included into the analysis ranged from 81 to 102 – hence the sample size was about large enough to fulfill the minimum required. The single statement MSAs were on acceptable level, and there were enough correlations between the statements. For the entire model, the KMO was 0.74 compared to the original one's 0.75, and Bartlett's Test of Sphericity $X^2(171)$ was 520 ($p<0.001$). The communalities were well over 0.5, and the total cumulative variance explained was 68.8 (compared 65.5). Only one variable loaded different factor than in the original analysis, namely the factor "8.2 Software corrections" loaded the factor 2 "Project communication and deliverables" by 0.534, but it loaded also significantly the factor 5 "Reliability and quality of product platform " (0.468), which was loaded more in the original analysis. The variable can be justified to be in either of the factors. Hence, with only small changes, the validation strengthens the results of the original analysis, even though it is not a fully robust validation. Because the factor analysis did not include all the statements, the results of the factor analysis were not expected to be perfect, either.

The bolded factor loadings from the Table 13 were used to create summated scales to be able to compare the factors with one another. The descriptives of the factors and the summated scales are presented in Table 14. The Cronbach's Alpha values calculated for the summated scales were not all on the acceptable level (i.e. over 0.6), and hence it was decided to use mainly the factors in the further analysis. The low Cronbach's Aplha value of factor 6, "Promised schedules and final product platform meeting the needs", indicates of low reliability of the factor. The summated scales will be used only to analyze the differences between the factors with the t-test. The normality measures of the factors as well as the summated scales were on acceptable level. In addition, the Pearson correlation coefficients between the summated scales and factor scores were high: they ranged from 0.78 to 0.95 ($p<0.001$). Hence, the summated scales can be used to compare the scores with one another.

Factor / Summated Scale	N	Mean	Std. Deviation	Skewness	Std. Error	Kurtosis	Std. Error	Cronbach's Alpha
Factor 1: Strategic and business fit of product platform	68	-0.02	0.99	-0.77	0.29	0.73	0.57	
Factor 2: Project communication and deliverables	68	-0.13	1.00	0.00	0.29	-0.36	0.57	
Factor 3: Cooperation with product platform development	68	0.15	0.97	0.25	0.29	-0.33	0.57	
Factor 4: Innovativeness of product platform architecture and features	68	0.08	0.84	-0.19	0.29	-0.90	0.57	
Factor 5: Reliability and quality of product platform	68	-0.09	1.06	-0.31	0.29	-0.22	0.57	
Factor 6: Promised schedules and final product platform meeting the needs	68	0.02	0.92	-0.10	0.29	-0.27	0.57	
sum 1: Strategic and business fit of product platform	68	2.94	0.58	-0.74	0.29	0.41	0.57	0.77
sum 2: Project communication and deliverables	68	3.07	0.62	0.12	0.29	-0.43	0.57	0.73
sum 3: Cooperation with product platform development	68	3.65	0.70	-0.16	0.29	-0.47	0.57	0.65
sum 4: Innovativeness of product platform architecture and features	68	3.28	0.61	-0.44	0.29	-0.65	0.57	0.82
sum 5: Reliability and quality of product platform	68	3.17	0.63	-0.26	0.29	-0.67	0.57	0.53
sum 6: Promised schedules and final product platform meeting the needs	68	3.09	0.71	0.03	0.29	-0.72	0.57	0.50

Table 14. Descriptives of the factors and summated scales.

5.3 Differences due to Product Platform Extension or Product Line

The possible differences in opinions were studied by the product platform extension and product line with the t-tests and ANOVA (for the exact results of the ANOVA, see Appendix 4). The descriptive statistics are presented in Table 15.

Factor	Descriptive statistics	B2	B3	B4	Product Line 1	Product Line 2	Product Line 3	Product Line 4
Factor 1: Strategic and business fit of product platform	**Mean**	2.79	3.23	3.00	2.99	2.59	3.21	2.87
	N	39	18	11	24	16	19	9
	Std. Deviation	0.62	0.44	0.52	0.50	0.74	0.48	0.43
Factor 2: Project communication and deliverables	**Mean**	2.79	3.44	3.48	2.68	3.29	3.20	3.47
	N	39	18	11	24	16	19	9
	Std. Deviation	0.54	0.51	0.51	0.53	0.63	0.45	0.66
Factor 3: Co-operation	**Mean**	3.51	3.96	3.67	3.83	3.52	3.55	3.63
	N	39	18	11	24	16	19	9
	Std. Deviation	0.69	0.81	0.37	0.56	0.66	0.65	1.15
Factor 4: Innovativeness of product platform architecture and features	**Mean**	3.31	3.33	3.09	3.23	3.41	3.24	3.28
	N	39	18	11	24	16	19	9
	Std. Deviation	0.66	0.54	0.58	0.72	0.58	0.56	0.51
Factor 5: Reliability and quality of product platform	**Mean**	3.11	3.29	3.15	2.92	3.21	3.43	3.19
	N	39	18	11	24	16	19	9
	Std. Deviation	0.62	0.72	0.54	0.73	0.41	0.55	0.65
Factor 6: Promised schedules and final product platform meeting the needs	**Mean**	2.95	3.45	3.04	3.11	2.67	3.36	3.25
	N	39	18	11	24	16	19	9
	Std. Deviation	0.70	0.68	0.64	0.64	0.61	0.80	0.55

Table 15. Descriptives of summated scales by extensions and product lines.

The scores given to the factors improved from the pre-product platform release (B2) to the first real product platform release (B3) on several areas, if only the means are compared (Table 16): “Strategic and business fit of product platform”, “Project communication and deliverables”, “Cooperation with product platform development” as well as “Promised schedules and product platform meeting the needs”. In the ANOVA comparison, significant difference was found only in the area of projects form B2 to B3 (Table 16). On the other hand, there was no significant change in the “Reliability and quality of product platform” nor in the “Innovativeness of product platform architecture and features” between the pre-product platform (B2), the initial product platform (B3) and product platform extension (B4). Hence, the mode of operations improved on some level, but the product itself did not according to the opinions of the product lines.

	Paired sample t-test		**ANOVA**	
Summated scale	**Significant result (p<0.05)**	**Result of the t-test**	**F(2,65) p<0.05**	**Post-hox Bonferroni / other**
sumFactor 1: Strategic and business fit of product platform	B2<B3	t(55)= -2.71		
sumFactor 2: Project communication and deliverables	B2<B3 B2<B4	t(55)= -4.32 t(48)= -3.80	17.513	B2<B3
sumFactor 3: Co-operation	B2<B3	t(55)= -2.16		
sumFactor 4: Innovativeness of product platform architecture and features				
sumFactor 5: Reliability and quality of product platform				
sumFactor 6: Promised schedules and final product platform meeting the needs	B2<B3	t(55)= -2.53		

Table 16. Significant changes and differences in by product platform extensions.

As to the product line comparison, there were some differences. If only the means are compared (Table 16), there were quite a few differences between the product lines. The product line 1, the largest one, was less satisfied with the “Project communication and deliverables” as well as the “Reliability and quality of product platform”. The medium size product line which was in the mature business, the number 2, was less satisfied with the “Strategic and business fit of product platform to the product lines” as well as with the “Promised schedules and final product platform meeting the needs”.

Next, the significant differences between the opinions about the product lines were analyzed with the ANOVA (Table 16). The scores given by the product lines differed for the factor 1 “Strategic and business fit of product platform” ($F(3,64)=5.198$, $p<0.01$), factor 2 “Project communication and deliverables” ($F(3,64)=6.311$, $p<0.01$), and factor 5 “Reliability and quality of product platform” ($F(3,64)=3.938$, $p<0.05$). The test of homogeneity of variance reveals that the variance of factor 1 was not homogenous between the different product lines, and hence, the result of the ANOVA test is not valid for that factor. The post-hox Bonferroni test showed that the product line 1 was less satisfied with the “Project communication and deliverables” (factor 2) than the product lines 2 and 4 ($p<0.05$). As to the “Reliability and quality of product platform”, the product line 1 was less satisfied than the product line 3 (Bonferroni, $p<0.05$).

Summated scale	**Paired sample t-test**		**ANOVA**	
	Significant result (p<0.05)	**Result of the t-test**	**F(3,64) p<0.05**	**Post-hox Bonferroni**
sumFactor 1: Strategic and business fit of product platform	Product Line 2 < Product Line 3	t(25)=-2.87 *) equal variances not assumed	5.198	* variances not homogenous
sumFactor 2: Project communication and deliverables	Product Line 1 < Product Line 2 Product Line 1 < Product Line 3 Product Line 1 < Product Line 4	t(24)=-1.86 t(41)=-3.39 t(31)=-3.57	6.311	Product line 1< product lines 2, 4
sumFactor 3: Co-operation				
sumFactor 4: Innovativeness of product platform architecture and features				
sumFactor 5: Reliability and quality of product platform	Product Line 1 < Product Line 3	t(41)=-2.52	3.938	Product line 1 < product line 3
sumFactor 6: Promised schedules and final product platform meeting the needs	Product Line 2 < Product Line 1 Product Line 2 < Product Line 3 Product Line 2 < Product Line 4	t(38)=2.19 t(33)=-2.85 t(23)=-2.36		

Table 17. Significant changes and differences in the factors by the product lines.

Neither test found significant differences between the product lines' opinions with regards to co-operation and innovativeness of the product platform architecture and features.

5.4 Relationships between the Factors and Overall Satisfaction

To assess the relationships between the overall satisfaction with SWP R&D and the factors, i.e. to find the factors affecting the most the overall satisfaction, a multiple regression analysis was conducted. It was decided to choose the stepwise method for the regression analysis, even thought there was not enough data available (50 times the amount of independents), and hence, special attention must be paid on the validation of the model. The choice was done because the research is exploratory, and in the confirmatory analysis, the independents should have been entirely chosen by the researcher, which was not the desired case.

The initial analysis of the independent variables included all the six factors. The normality of the possible independents and dependent were analyzed with the Kurtosis and Skewness measures (Table 18). The chosen dependent, statement "11.1 Overall satisfaction with SWP R&D", was normal enough to be chosen to the regression model. The selection of the dependent variable may cause a measurement error, if the selected variable does not measure the concept studied well enough. Because the concept studied is the relationship between the overall satisfaction and independents, the chosen statements "Overall satisfaction with SWP R&D" contains no measurement error. The selection of the independent variables may cause a specification error of the regression model, i.e. either irrelevant independents are taken to the model or relevant are omitted. There is a risk of the specification error in the conducted regression model for two reason. First, the factor analysis did not contain all the statements due to the large Kurtosis values, and hence the factors might not represent all the necessary aspects of the overall satisfaction. Second, some of the possible influencers to the satisfaction, i.e. the product line and product platform extension were excluded from the analysis. The possibility of the selection error must be kept in mind through the regression analysis and especially when analyzing the results. The selected stepwise method, on the other hand, tries to minimize the effect of the selection error with the independents initially qualifying for the model.

Statements (both the dependent and the independents)	N	Minimum	Maximum	Mean	Std. Deviation	Skewness	Std. Error	Kurtosis	Std. Error
Factor 1: Strategic and business fit of product platform	68	-3.25	1.546	-0.02	0.987	-0.77	0.291	0.729	0.574
Factor 2: Project communication and deliverables	68	-2.34	1.953	-0.13	1.003	0.002	0.291	-0.36	0.574
Factor 3: Cooperation with product platform development	68	-1.9	2.59	0.147	0.968	0.249	0.291	-0.33	0.574
Factor 4: Innovativeness of product platform architecture and features	68	-1.77	1.596	0.079	0.838	-0.19	0.291	-0.9	0.574
Factor 5: Reliability and quality of product platform	68	-2.79	2.376	-0.09	1.06	-0.31	0.291	-0.22	0.574
Factor 6: Promised schedules and final product platform meeting the needs	68	-2.27	2.009	0.023	0.92	-0.1	0.291	-0.27	0.574
11.1 Overall satisfaction with SWP/R&D	134	2	5	3.3	0.8	-0.21	0.21	-0.70	0.42

Table 18. Descriptives of the dependent and possible independents.

A stepwise regression analysis was conducted to all the chosen variables. After the first regression analysis, the results were checked for the influential cases. Three influential cases were found to be influential to the model. The reasons for them being influential were analyzed; there were no explanations found. Hence, it was decided to delete the cases and see the impact to the regression model. The model fit improved significantly, R^2 from 0.548 (adjusted R^2=0.511, std. error=0.544) to 0.699 (adjusted R^2=0.674, std error=0.442), and it was decided that the cases remain deleted from the analysis.

After the deletion, the sample size of the factor analysis was 65, the number of independents entered stepwise to the model was six, and hence the ratio of independents to the sample size was about 1 to 11 (generally on acceptable level, although for the stepwise analysis not good enough). The regression analysis was conducted with the choices described above, and from the new model, no additional influentials were detected. The descriptives of the variables entered stepwise in the improved regression model are summarized in Table 19, and the correlations of the variables are presented in Table 20. There were moderately significant correlations between the dependent and factors 1, 5 and 6, but no other significant correlations were found.

Dependent and independent variables	Mean	Std. Deviation	N
11.1 Overall satisfaction with SWP/R&D	3.310	0.774	131
Factor 1: Strategic and business fit of product platform	0.014	0.972	65
Factor 2: Project communication and deliverables	-0.126	1.022	65
Factor 3: Cooperation with product platform development	0.113	0.935	65
Factor 4: Innovativeness of product platform architecture and features	0.073	0.836	65
Factor 5: Reliability and quality of product platform	-0.115	1.063	65
Factor 6: Promised schedules and final product platform meeting the needs	0.065	0.918	65

Table 19. Descriptives of the variables in the regression analysis.

The resulted regression model's fit (R^2=0.699, adjusted R^2=0.674, standard error=0.442; significance $F(5, 59)$= 27.463, $p<0.001$) was not excellent nor was it unsatisfactory, either. The coefficient statistics are presented in Table 21. The single most significant predictor of the overall satisfaction score was the factor 1 "Strategic and business fit of product platform" (standardized beta 0.666). The variable not included into the model (factor 3 "Cooperation with product platform development") was excluded because it was not significant enough of co-efficient for the model (i.e. no collinearity problems, for example).

Pearson correlation **Significance (1-tailed)** Correlation coefficients (r) – above Significance (p) - below	**11.1 Overall satisfaction with**	**Factor 1: Strategic and business fit of**	**Factor 2: Project communication and**	**Factor 3: Cooperation with**	**Factor 4: Innovativeness of**	**Factor 5: Reliability and quality of**
Factor 6: Promised schedules and final product platform meeting the needs	**0.323** **0.004**	0.061 0.313	0.026 0.419	0.106 0.2	-0.05 0.359	-0.03 0.408
Factor 5: Reliability and quality of product platform	**0.403** **0.000**	0.127 0.157	0.13 0.15	-0.06 0.313	0.004 0.487	
Factor 4: Innovativeness of product platform architecture and features	0.018 0.445	-0.24 0.026	-0.04 0.391	-0.09 0.244		
Factor 3: Cooperation with product platform development	0.103 0.208	0.038 0.382	-0.05 0.335			
Factor 2: Project communication and deliverables	0.199 0.056	-0.07 0.296				
Factor 1: Strategic and business fit of product platform	**0.66** **0.000**					

Table 20. Correlations between the variables in the regression analysis.

Constant and independent variables	**Unstandardized Coefficients**		**Std. Coefficients**	**T**	**Sig.**	**Collinearity Statistics**	
	B	Std. Error	Beta			Tolerance	VIF
(Constant)	3.313	0.056		59.341	0.000		
Factor 1: Strategic and business fit of product platform	0.530	0.059	0.666	8.915	0.000	0.913	1.095
Factor 5: Reliability and quality of product platform	0.218	0.053	0.299	4.112	0.000	0.961	1.041
Factor 6: Promised schedules and final product platform meeting the needs	0.248	0.060	0.295	4.116	0.000	0.993	1.007
Factor 2: Project communication and deliverables	0.155	0.055	0.204	2.819	0.007	0.971	1.030
Factor 4: Innovativeness of product platform architecture and features	0.183	0.068	0.197	2.677	0.010	0.937	1.068
R^2=0.699, adjusted R^2=0.674, standard error=0.442; significance F(5, 59)=27.463, p<0.001							

Table 21. Coefficients of the regression model.

The partial regression plots of each of the variables included into the model were analyzed for nonlinearity and heteroscedasticy (Figure 24, Figure 25, Figure 26, Figure 27, Figure 28). There were no signs of the previously mentioned phenomena found. The partial regression plot of the factor 3 “Cooperation with product platform development” was also analyzed, and no signs of nonlinearity or heteroscedasticy were found. The assumption of normality was checked in the process of choosing the independents, by analyzing the Skewness and Kurtosis figures of each of the variables. Therefore, the individual variables fulfilled the requirements of the regression analysis.

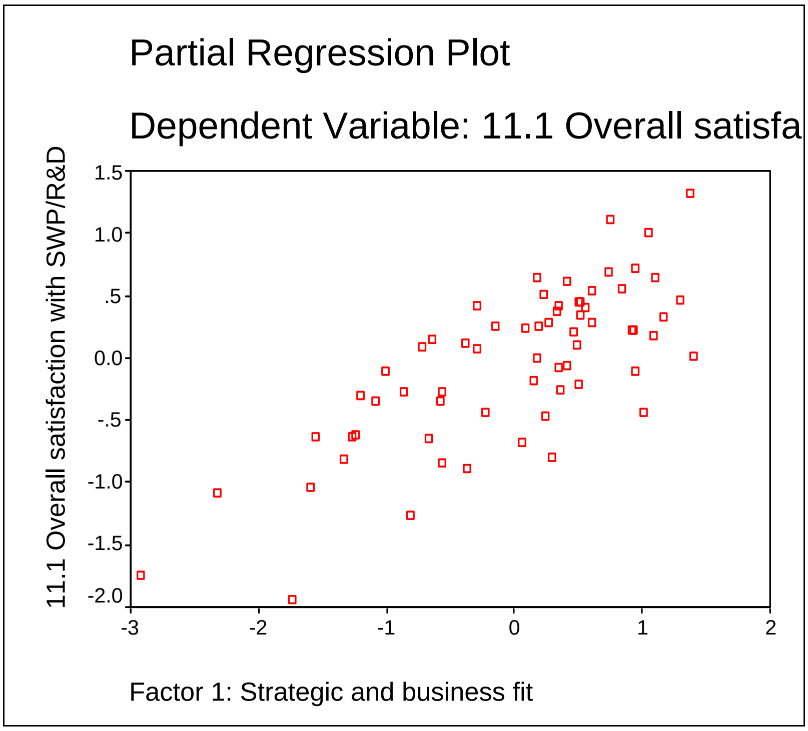

Figure 24. Partial regression plot of factor 1.

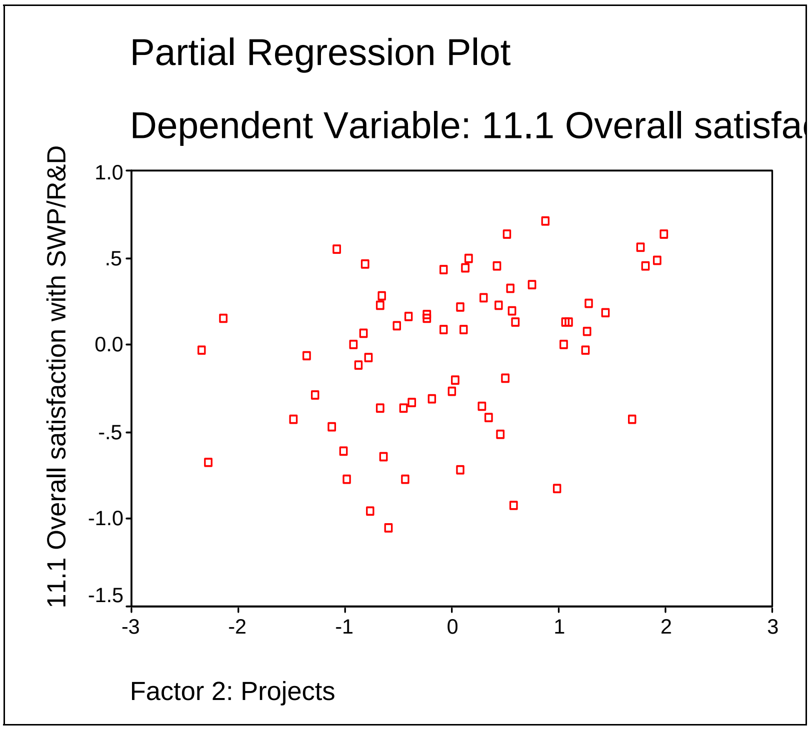

Figure 25. Partial regression plot of factor 2.

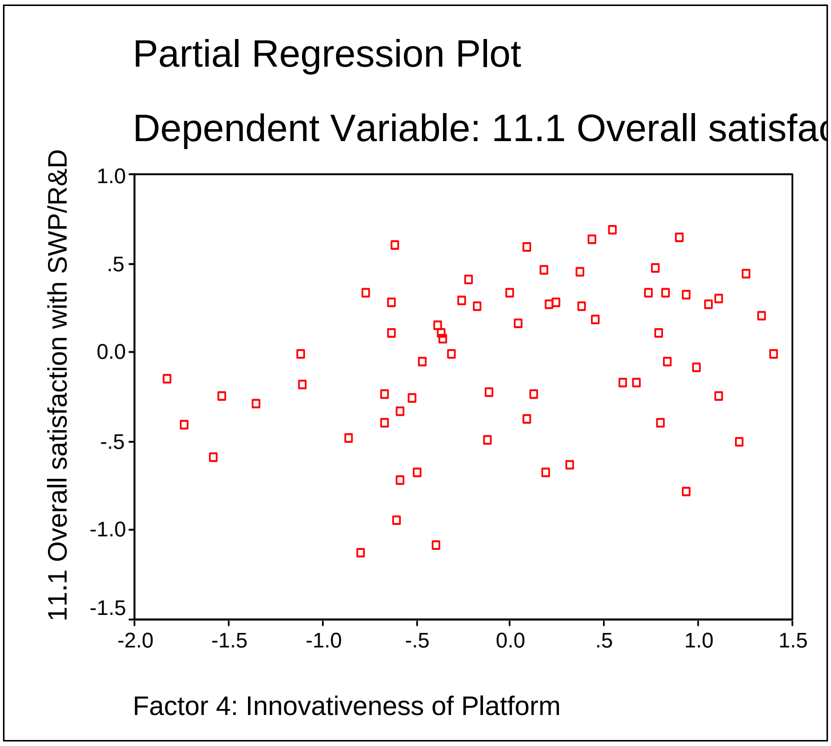

Figure 26. Partial regression plot of factor 4.

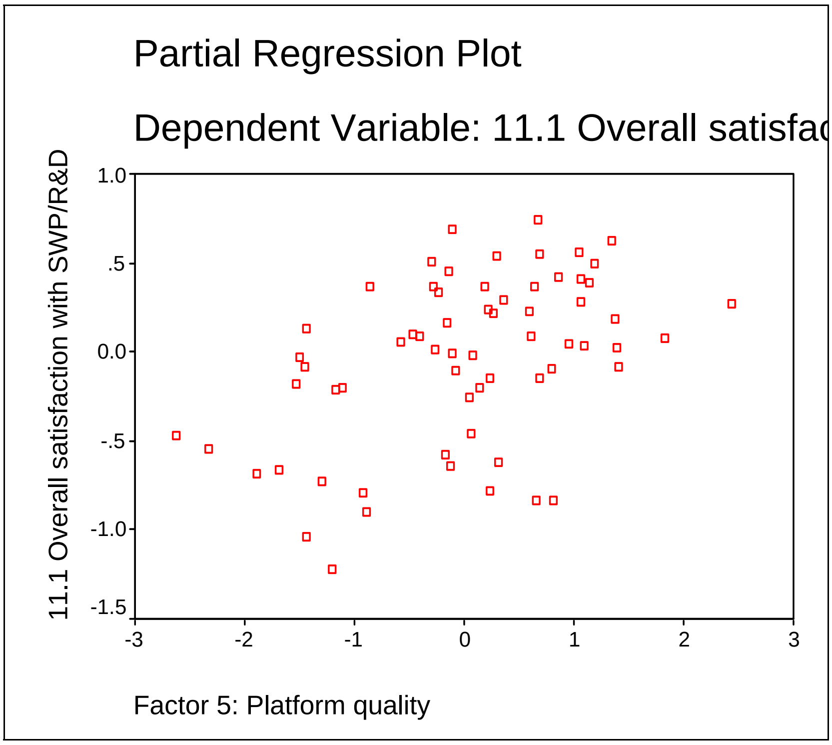

Figure 27. *Partial regression plot of factor 5.*

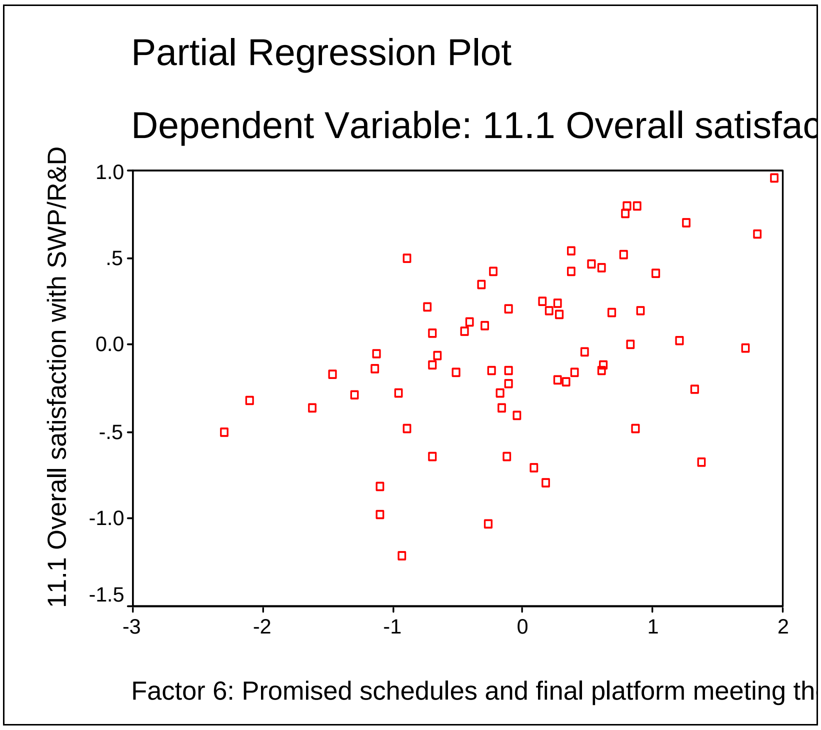

Figure 28. *Partial regression plot of factor 6.*

Next, the assumption of linearity, constant variance of error term, independence of the error term and normality of the error distribution were checked for the entire regression model. The linearity of the model was analyzed from the residual plot of the model (Figure 29, Figure 30) as well as from the partial regression plots (Figure 24, Figure 25, Figure 26, Figure 27, Figure 28). The partial regression plots showed linearity of some level. In the residual plot, there were no signs of linearity or nonlinearity. Hence, it can be assumed that the linearity requirement was fulfilled. There were no signs of heteroscedasticy in the residual plot (i.e. nonconstant variance of error term). Independence of the error term was analyzed by plotting the residuals against interview number, year, product line, product platform extension, and cooperation years in addition to all the independents in the regression analysis. No regular patterns were found, and hence the error terms were found to be independent. Also the autocorrelation measure, Durbin Watson was on acceptable level (1.925). The normal probability plot analyzed for the normality aspect of the entire regression model, and the results were normal enough for accepting the model. Hence, the assumptions for the entire model were fulfilled.

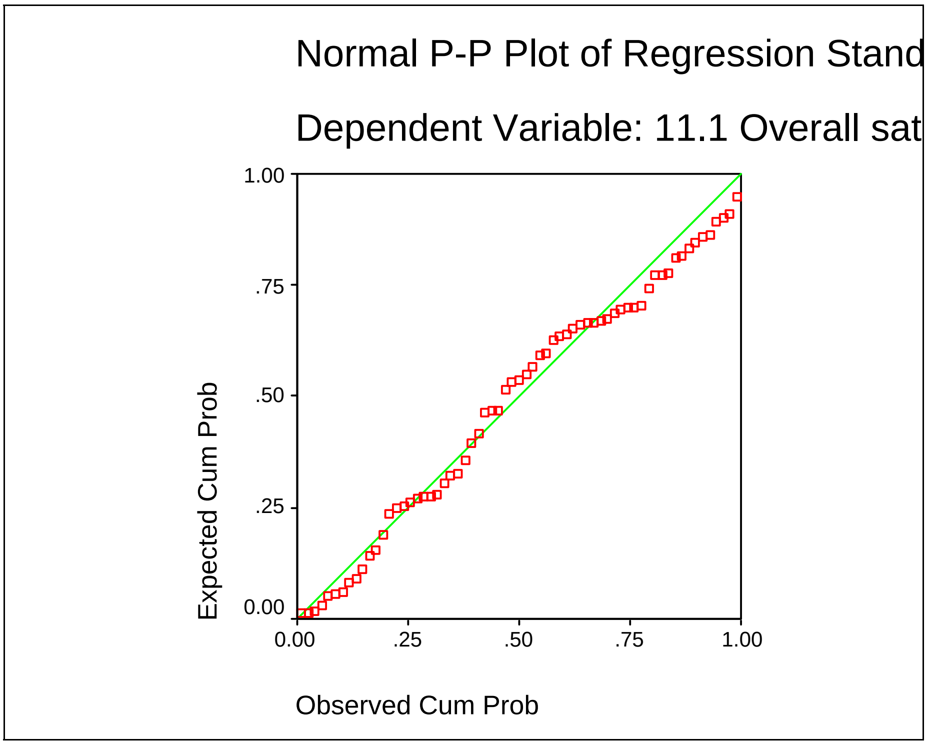

Figure 29. Normal p-p plot of the regression model.

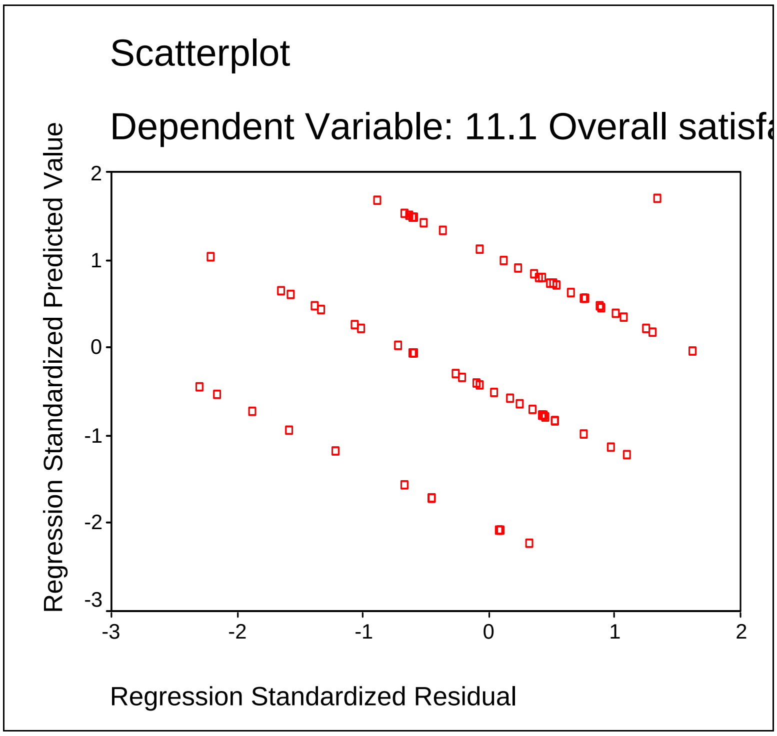

Figure 30. Model's residual plot

The tolerance and VIF (variance inflation factor, i.e. the extent to which the standard error of the specific regression coefficient is enlarged due to collinearity) values of the coefficients (Table 21) were on acceptable level (tolerance well over 0.1 and VIF well under 10), and hence the multicollinearity was not a problem in the regression model. The multicollinearity was also analyzed with the condition indexes, which ranged from 1 to 1.4 (well under the critical value, 30).

The resulted regression model was validated by conducting new multiple regression analysis to three random samples created from the original database. The requirement of the regression analysis, i.e. the 5 cases against each individual variable, set limits to the size of the random split sample – and hence, split of the database into two for validation was not possible. Results of the stepwise estimation are presented in Table 22.

The model fit varied from sample to sample; the adjusted R^2 ranged from 0.597 to 0.674. All the models included three coefficients: "Strategic and business fit of product platform", "Reliability and quality of product platform" as well as "Promised schedules and final product platform meeting the needs". They seem to be the strong contributors in the regression model. As the size of the sample decreases, the ability of the regression analysis to detect regression co-efficients also decreases, and hence the weaker contributors, "Project communication and deliverables" and "Innovativeness of product platform architecture and features" might not have been found in the random sample analysis. It is remarkable, that the factor 3 "Cooperation with product platform development", whose scores were significantly higher than the scores of other factors, was not included into the regression model at al.

Regression co-efficients **Statistics**	**Original model (N=65)**	**Random sample 1 (N=51)**	**Random sample 2 (N=52)**	**Random sample 3 (N=44)**
Constant				
Regression co-efficient	3.313	3.250	3.337	3.353
t- value	59.341	49.924	51.509	45.433
Significance	0.000	0.000	0.000	0.000
Factor 1: Strategic and business fit of product platform				
Regression co-efficient	0.530	0.542	0.496	0.483
Beta co-efficient	0.666	0.698	0.669	0.663
t- value	8.915	8.061	7.414	6.914
Significance	0.000	0.000	0.000	0.000
Factor 5: Reliability and quality of product				
platform	0.218	0.231	0.192	0.235
Regression co-efficient	0.299	0.335	0.285	0.324
Beta co-efficient	4.112	3.950	3.141	3.390
t- value	0.000	0.000	0.003	0.02
Significance				
Factor 6: Promised schedules and final product platform meeting the needs				
Regression co-efficient	0.218	0.187	0.208	0.213
Beta co-efficient	0.295	0.222	0.258	0.249
t- value	4.116	2.670	2.889	2.595
Significance	0.000	0.011	0.006	0.013
Factor 2: Project communication and deliverables				
Regression co-efficient	0.155	0.155	0.133	-
Beta co-efficient	0.204	0.199	0.193	
t- value	2.819	2.360	2.126	
Significance	0.007	0.023	0.039	
Factor 4: Innovativeness of product platform			-	-
architecture and features	0.183	0.155		
Regression co-efficient	0.197	0.199		
Beta co-efficient	2.677	2.361		
t- value	0.010	0.023		
Significance				
Model Fit				
R^2	0.699	0.691	0.629	0.635
Adjusted R^2	0.674	0.657	0.597	0.608
Standard error of the estimate	0.442	0.451	0.455	0.484
F	27.463	20.158	19.918	23.227

Table 22. Validation results of the regression model.

To test each factor's ability to explain the overall satisfaction, series of additional test were conducted (Table 23). Since the additional tests were confirmatory from their nature, the regression analysis was conducted with enter instead of stepwise method.

MODEL	I	II	III	IV	V	VI	VII
Constant	3.298** (0.073)	3.324** (0.096)	3.296** (0.097)	3.304** (0.097)	3.339** (0.089)	3.288** (0.092)	3.313**
Factor 1: Strategic and business fit of product platform	0.526** (0.075)						0.530
Factor 2: Project communication and deliverables		0.150[1)] (0.093)					0.155
Factor 3: Cooperation with product platform development			0.085 [1)] (0.104)				
Factor 4: Innovativeness of product platform architecture and features				0.016[1)] (0.116)			0.183
Factor 5: Reliability and quality of product platform					0.293* (0.084)		0.218
Factor 6: Promised schedules and final product platform meeting the needs						0.272* (0.100)	0.218
Adjusted R^2	0.427	0.024	-0.05	-0.16	0.149	0.090	0.674
F-ratio	48.720	2.591	0.670	0.19	12.180	7.352	27.463
Df	64	64	64	64	64	64	64
** p<0.001, * p<0.01, [1)] ns, standard errors in brackets.							

Table 23. Single factor regression models.

Model I tested the association between the overall satisfaction and factor 1, “Strategic and business fit of product platform”. The variable in the model is significant, indicating that the better the “Strategic and business fit of the product platform is to the product lines”, the greater the satisfaction with the platform development activities is. Factor 1 explains over 42% of the variance in outcomes. Models II, III, and IV test the association between the overall satisfaction and factor 2 “Project communication and deliverables”, factor 3 “Cooperation with product platform development”, and factor 4 “Innovativeness of product platform architecture and features”, respectively. In none of the models is the variable significant. Model V test the association between factor 5 “Reliability and quality of product platform” and overall satisfaction. The variable is significant in the model, and explains about 15% of the variance in the outcome. Finally, model VI tests the association between the Factor 6: “Promised schedules and final product platform meeting the needs” and overall satisfaction. The variable in the model is significant, and hence the better the promised schedules and final product platform meets the needs, the greater the satisfaction with the platform development activities is.

Model VII presents the regression model developed in the beginning of the chapter, as comparison. The models predicting the overall satisfaction with single factors are stricter as to which factors significantly affect the overall satisfaction. In fact, the factors significantly explaining the variance in the overall satisfaction (found in Models I-VI) are the same, which were found by all the validation models (Table 22). Hence, the results of the single factor models strengthen the results of the original and validation models, and indicate that the factor 1 “Strategic and business fit of product platform”, factor 5 “Reliability and quality of product platform”, and factor 6 “Promised schedules and final product platform meeting the needs” best explain the variances in the overall satisfaction of the product lines.

Since the product lines each used own product platform extension, it was decided to run the regression analysis by product lines, also. The sample in each model is small, and hence, the results must be interpreted with caution. The results are presented in Table 24. Model III resembles most the results received from the overall model and the single factor models, before. Hence the overall satisfaction of product line 3 is best explained (74 % of the variance) by factors 1 “Strategic and business fit of product platform”, 5 “Reliability and quality of product platform”, and 6 “Promised schedules and final product platform meeting the needs”. Models II and I indicate that the overall satisfaction of product lines 1 and 2 is explained by factor 1, "Strategic and business fit of product platform". The product line 4 differs interestingly from the others. Model IV indicates that the overall satisfaction in the case of product line 4 is best explained with the factor 3 "Cooperation with product platform development". The small sample size hinders conclusions from the observation, but the result opens questions. Why would product line's view to the product platform development be different? Was the platform right for the specific product line? Since the co-operation started with product line 4 during the early years of the research, were the product line representative able to assess all the aspects of product platform development as well as the others?

Regression models of the product lines	Model I Product line 1, N=23	Model II Product line 2 N=15	Model III Product line 3 N=19	Model IV Product line 4 N=8
Constant	2.959*** (0.145)	3.476*** (0.168)	3.421*** (0.079)	3.361*** (0.158)
Factor 1: Strategic and business fit of product platform	0.435* (0.190)	0.462** (0.127)	0.374** (0.098)	
Factor 2: Project communication and deliverables				
Factor 3: Cooperation with product platform development				0.456** (0.112)
Factor 4: Innovativeness of product platform architecture and features				
Factor 5: Reliability and quality of product platform			0.274* (0.099)	
Factor 6: Promised schedules and final product platform meeting the needs			0.152* (0.066)	
Adjusted R^2	0.161	0.423	0.743	0.688
F-ratio	5.228	11.276	18.304	16.446
Df	22	14	18	7
*** p<0.001, ** p<0.01, *p<0.05 [1)] ns, standard errors in brackets.				

Table 24. Regression models by product lines.

Summary

The aspects analyzed in this chapter included the predefined issues: the structure behind the statements, analysis of changes or difference due to product platform extension or product line, and relationships between the statements and overall satisfaction. The statistical methods used in the analysis included the factor analysis, t-test, One-way ANOVA, and regression analysis.

The parametric tests found clear structure behind the statements: altogether six factors were derived from the data. The factors found were “Strategic and business fit of product platform”, “Project communication and deliverables”, “Cooperation with product platform development”, “Innovativeness” “Reliability and quality of product platform ”, and “Promised schedules and final product platform meeting the needs”. These are the factors of the product platform development in the case company.

Some changes and differences were found due product platform extension or product line. The factor 2 “Project communication and deliverables” improved from the pre-product platform release to the first real product platform release. However, no significant differences were found between the initial product platform and its extension. The product line 1 gave lower scores to the factors 2 “Project communication and deliverables” and 5 “Reliability and quality of product platform ” than some other product lines.

The relationship between the factors and overall satisfaction was investigated with the regression analysis. In the model and its validation models as well as in the single factor models, the “Strategic and business fit of product platform”, “Reliability and quality of product platform” as well as “Promised schedules and final product platform meeting the needs” were the strong contributors. The factor “Cooperation with product platform development” was included into the regression model explaining the overall satisfaction only in the product line 4 specific analysis.

All in all, the quantitative analysis succeeded in its quests: finding the structure in the data, finding changes and differences in the single questions due to product platform extension or product line, and finding the areas affecting the overall satisfaction the most.

In the next chapter, the results of both the quantitative analysis and qualitative description will be compared and combined to form a full picture of the product platform development from the product lines aspect. The results of the comparison and combination will, in turn, be compared to the product platform literature reviewed in Chapter 2.

6. RESULTS

Results of the analysis

The theory study, described in Chapter 2, included the areas of product platform, strategies, organization and management as well as processes and projects. The basic nature of each area in connection with the product platform development were described in Chapter 2. The organization and management is characterized by the distance from the end customers, the interface with the derivative product development and the need to steer several varying needs. The strategies are affected by the long time-horizon and high technological and market risks, as well as coping with several varying needs. The area of processes and projects copes also with the varying needs as well as with the concurrent development of several product platforms. The product platform theories further specified the potential factors of the product platform development:

- clear architecture and interfaces
- steering and decision making
- strategic metrics
- technological and business/marketing competences
- cooperation and communication of product platform and application development
- strategy content
- coordination of application development needs
- customer needs identification

The description of the selected case was based on both the official internal documents and descriptions of the operations of SWP R&D as well as on the product line opinions about the different aspects of the product platform development. The product line opinions were collected from the product line satisfaction surveys' qualitative data from the years 1996-1999, as well as from the steering group minutes and from the product line 1's requirements to SWP R&D. The description revealed some areas of product development found important by the product lines (e.g. platform quality), and hence added some case specific aspects to the theory and specified the questions to be analyzed in the quantitative analysis. The description did not systematically reveal the important areas to the product lines, rather the areas raising most of the discussion. On the other hand, if an area found important was functioning properly in SWP R&D, it probably would not have been discussed upon, and hence, it might not have been noticed in the case description.

The quantitative analysis was based on the questions specified in the case description. The data was collected in the product line satisfaction surveys 1996-1999, in which the performance of SWP R&D with respect to each question was assessed. The analysis included studying structure behind the statements, factors affecting the overall satisfaction, and the possible changes and difference in the factors due to product platform extension or product line in question. Hence, the quantitative analysis specified the results of the case description.

The product line aspect, presented in the case, specified the product platform development factors in the case company as follows:

- Factor 1: Strategic and business fit of product platform
- Factor 2: Project communication and deliverables
- Factor 3: Cooperation with product platform development
- Factor 4: Innovativeness of product platform architecture and features
- Factor 5: Reliability and quality of product platform
- Factor 6: Promised schedules and final product platform meeting the needs

Hence, the factors found in the case include factors from the list of potential factors defined in the literature study. Still the new structure of factors compresses the information (e.g. combines the decision making and strategy content into the factor 1

“Strategic and business fit of product platform”), highlights some parts of the information as well as presents new factors. “Project communication and deliverables” was highlighted in the analysis as a factor independent from co-operation. Reliability and quality, and innovativeness of product platform were not covered at all by the literature study and the promised schedules were an addition to the product platform meeting the needs.

Unfortunately, the quantitative analysis could not assess two aspect highlighted in the review of product platform literature: the efficiency and effectiveness of platform (strategic metrics), and competences. The questionnaire included one statement slightly connected with product platform development efficiency, i.e. the easiness of building applications on the product platform. The question was excluded from the factor analysis, since it did not meet the requirements set to it by the model. The questions related to the competences, on the other hand, were discarded from the questionnaire because either they did not fulfill the requirements of normality or they did not meet the requirements set to it by the model. Hence, the research did not bring any evidence on how the product lines would see the product platform efficiency and effectiveness or the competences.

There were few significant changes and differences in the results due to the product platform extension or the product line in question. The scores given to the factor “Project communication and deliverables” improved from the pre-product platform release to the initial product platform release. However, no significant changes were found between the initial product platform and its extension. The lack of significant differences in other factors might have to do with the fact, that the releases under study were only product platform extensions and versions. On the other hand, one product line gave lower scores for the factors “Project communication and deliverables” and “Reliability and quality of product platform ” than other product lines. It is curious that the less satisfied was the largest one, product line 1. Yet, in the case description the smaller product lines complained that the largest product lines were given more attention than the smaller ones.

The issues mostly affecting the overall satisfaction with the product platform development were (in the order presented below)

1. Strategic and business fit of product platform
2. Reliability and quality of product platform
3. Promised schedules and product platform meeting the needs

The "Strategic and business fit of product platform" was found to affect most strongly to the overall satisfaction. It can be questioned whether the role of "Strategic and business fit of product platform" is different in product platform development than in the single product development. The amount of varying needs might highlight the importance of the fit in the case of product platform development, though. The participation to the strategy process was brought up in the qualitative comments of the product line satisfaction interviews, but since there was no such question in the qualitative data, the importance of the issue can only be qualitatively assessed. It might be argued that the results of the participation are more important than the participation per se. Still, without participation, it can be doubted whether there will be "Strategic and business fit of product platform" with the derivative products. The next two strong contributors to the overall satisfaction were the "Reliability and quality of product platform", which was not included to the theory study at all, and the "Promised schedules and product platform meeting the needs".

Hence, the factors affecting less to the overall satisfaction were "Project communication and deliverables", "Cooperation with product platform development" and "Innovativeness of the product platform architecture and features". It is curious, that the product lines' comments in the satisfaction surveys were largely connected with the factor "Project communication and deliverables" even though it did not affect their overall satisfaction as strongly as some other factors. Surprisingly, the innovativeness of product platform architecture and features was not among the most important aspects in the case unit. An explanation might be that in the scope of the survey; most of the interviewees assessed the existing product platform and its extensions. There were some comments about the innovativeness of the product platform architecture and features in connection with the product platform renewal in the interviews. Yet another explanation might be found form the innovation theories; there are not that many radical technological innovations than there are commercial innovations, and hence, it might be argued that the product platform needs not be as innovative as the applications, i.e. the business ends, should be. Hence, the derivative product developers might be the ones bringing the innovativeness to the end product. The question relates to the theories of radical versus incremental innovation as well as to the classification of technological, product, and commercial innovation.

Other observations

The qualitative case description revealed that in the case unit, the product lines were considered internal customers. The conceptualization might be useful in the case company: due to the long development times of the product platform, the feedback from the end-customers came late to the product platform development. The end-user feedback also came along longer routes (multiple of them) than in the single product development units, through the product lines. Hence, by considering the product lines as customers, the customer feedback was a step closer. In addition, the product lines could have been even more critical than the end customers could – after all, they had to use the product platform to develop their own products, and they possessed more inside information about product platforms than any end-customer.

In the case analysis, many of the areas found to be problematic, had to do with the very basic nature of the product platform development. In the area of product platform, problems with productization and interfaces lead back to the basic definitions of the product platform; a clear architecture consisting of subsystems and interfaces between them as well as the interfaces to the derivative product development.

The product platform was a common technological base for the derivative products and still, the interviewees complained that the generic features did not meet anyone's needs and not all the generic features really were generic. Further, there were features in the product platform, which were used by only some of the product lines and others saw that those features only took space and capacity in the product. Hence, the nature of the product platform (common technological base), even though it was strength in optimizing the use of resources and concentrating the development, was also its weakness for developing features, which were not optimized for anyone – or if optimized not used by everyone. The varying needs of the product lines were considered as having a negative impact on the flexibility of the product platform. Despite of several comments about the platform not fulfilling everyone's needs, according to the auxiliary measure of product platform efficiency (% of shared product platform code), the product platform development in the case company seemed to be efficient. The measure left the question open, though, in the case of one product line, since there was not comparable data available from them. Also the fact, that the factors affecting the product line 4's overall satisfaction with product platform development differed from other product lines' factors, leaves the question open, whether there should have been a different product platform for the product line 4. On the other hand, the product line 4 just started to use the product platform in the beginning of the research period, and hence, it could have affected its opinions.

The definition of the product platform, as to what was included in it (productization) and which were its interface, was discussed continuously in the case company. Hence, a clear definition or the product platform and its interfaces become crucial issues as several derivative product developers' work is affected by the poor definitions.

Further, several derivative products based on the product platform meant that several parties needed to be heard in the course of development. This led into a situation that the steering mechanisms were difficult and bureaucratic: large steering group meetings with everyone's representation, difficulties in decision making, and large ones overrunning the smaller ones. Due to the amount of derivative products, it might have been difficult to accumulate technical expertise about all the derivative products. In addition, the nature of the product platform development with the derivative product development between the customer and product platform development might have been a reason leading to the lack of business and market knowledge. The long time horizon, on the other hand, complicated SWP's possibilities to react to fast changes experienced by the derivative product developers.

Large number of concurrent existing and new product platform development projects combined with varying needs and different time perspectives of the product lines led to difficulties in prioritization activities. The opinions of larger product lines' getting higher priorities and overrunning the smaller ones can be led back to the power and politics in the strategy theory: the powerful people (and here, organizations) often get what they want! The different needs and time perspectives of the product lines and the product platform development as well as the different sizes of the product lines and different business situations led to varying opinions in the area of strategies and road maps and in the area of release contents. In addition, the nature of the product platform development, i.e. the distance of the end-customers was seen as a potential challenge in the areas of market strategies and customer need collection.

The varying needs of the product lines caused problems in the release contents as well. On the other hand, the large number of concurrent releases with the existing product platforms and its variations and the product platform renewals resulted in prioritization problems. The concurrent releases of the derivative product lines and product platform development unit caused problems in testing – the product platform was not fully tested before the product lines used it as a base in their own development activities. Finally, the importance of the interfaces is emphasized by the fact, that the problems in the interface changes were a great concern to the product lines – which roots back to the easiness of building applications to the product platform.

The strategic measurement and the proof of the effectiveness and efficiency of the product platform were not seen as a necessity in SWP R&D. One of the reasons might lie in the fact that SWP R&D did not have to do business with its product platforms. The only customers it had were the internal product lines, which might not have had any other feasible choice as their product platform. The case could be different if the customers of the product platform development would be external ones: the new potential customers might be very interested about the efficiency and effectiveness measures of the product platform development.

7. CONCLUSIONS

7.1 Discussion of the Results

The role of an internal customer (other divisions of the company) in addition to the external customers has been recognized especially in the total quality management literature (e.g. Juran and Gryna, 1993). While the product platform is not an end product by itself, the role of the derivative product developers, i.e. the internal customers (except in a case of horizontally sold platform), is even more significant. The internal customers differ from the external customers in a sense, that they might have greater influence to the strategic planning and product definition, and they have more insights to the progress of product development activities than the external ones. Additionally they might have access to the databases, personal contacts to the development personnel, and so on. The internal customer loyalty is also different from the external customer's one. Even though the customer satisfaction is an antecedent to loyalty (Oliver, 1999), the satisfied external customers might not buy the product, if competitor's product performs better (Gale and Wood, 1994). In the case of the internal customers, there might be full loyalty, and the satisfaction might be low – if there were no choices available.

The internal customers are in a good position to judge the issues concerning product platform development, and they can be expected to be critical in their comments: after all, they must be able to develop their own product on the platform, they will have to sell the platform as a part of their product to the end-customers, and ensure that the final product works. The platform development organization either helps the internal customers to succeed in their business or causes failure in meeting the business objectives. Hence, the chosen viewpoint to the research was the one of the product lines'.

From the product lines' (i.e. the internal customers') aspect, the research identified six product platform development factors: "Strategic and business fit of product platform", “Project communication and deliverables”, “Cooperation with product platform development”, “Innovativeness of product platform architecture and features”, “Reliability and quality of product platform” and “Promised schedules and final product platform meeting the needs”. The found structure compresses the information found from the product platform literature and links together the pieces scattered around in the product platform literature. These results are interesting in a sense, that even though there exists literature on e.g. strategies (e.g. Allen and George, 1989, Scott, 2001, Wheelwright and Clark, 1992, McGrath, 1995, Tabrizi and Walleigh, 1997, Meyer and Lehnerd, 1997a, Sääksjärvi, 2002, Cusumano and Yoffie, 1998) as well as on communication (Nobeoka and Cusumano, 1995, Allen and George, 1989, Brown and Eisenhardt, 1995) both in the single product development and product platform development literature, the amount of empiric evidence on the contribution to product development and satisfaction is small.

The factor “Strategic and business fit of product platform” combines the decision-making and strategy aspects. Both the aspects have been covered to some extent by the previous product platform development literature (decision making: Robertson and Ulrich, 1998, Meyer and Lehnerd, 1997a, Meyer and Seliger, 1998, Nobeoka and Cusumano, 1995, strategies: Wheelwright and Clark, 1992, McGrath, 1995, Tabrizi and Walleigh, 1997, Meyer and Lehnerd, 1997a, Sääksjärvi, 2002, Cusumano and Yoffie, 1998) It can be questioned whether the role of strategic and business fit in product platform development is different from its role in the single product development. The amount of varying needs might highlight the importance of the fit in the case of product platform development, though. The varying preferences often lead to conflicts and to the game of power and politics, which highlights the importance of strategic decision making (Eisenhardt, 1999, Eisenhardt and Zbaracki, 1992) – the more there are varying needs the more delicacy and thought must be addressed to the strategic and business fit of the platform. The “Strategic and business fit of product platform” was found to be the strongest contributor to the product lines’ satisfaction with product platform development in this dissertation.

The factor "Project communication and deliverables" was highlighted in the analysis as a factor independent from co-operation. The communication during the development has been reported to cause problems or influence the success of projects both in the single product and product platform development literature (Scott, 2001, Nobeoka and Cusumano, 1995). Hence, the results of this dissertation support the existing literature on the communication's role in the product platform development. Still, "Project communication and deliverables" was found to be a weak contributor to the product line's satisfaction with the product platform development.

The importance of cooperation with customers in the new product development process is stressed in the latest literature (Sawhney, 2002, Rothwell, 1994), and this applies to cooperation with the internal customers, too. The product line involvement to the product development has been reported as being a ways to gain the internal customer satisfaction (and finally the external customer satisfaction) (e.g. Addey, 1999). Still, in this dissertation, the factor "Cooperation with product platform development" was not a significant contributor to the product lines' satisfaction, except for one product line.

Innovativeness of product platform was not covered by the study of product platform literature, even though it has been reported to be a contributor to the success and failure of companies (e.g. Foster, 1986, Tushman and Anderson, 1986, Henderson and Clark, 1990, Utterback, 1996, Glasmeier, 1997, Tushman et al., 1997, Christensen, 2000). In this research, "Innovativeness of product platform architecture and features" was found to be one of the factors of product platform development from the product lines' aspect; hence, it brings new aspects to the research of product platform development. Still the product platform literature had noticed the role of clear architecture and interfaces in connection with product platforms (Meyer and Lehnerd, 1997a, Meyer et al., 1997b). The factor was a weak contributor to the product lines' satisfaction. An explanation might be found from the life cycle of the product platform. The innovativeness of product platform architecture and features might not be that evident in the case of developing new extensions and versions of the existing product platforms; the innovativeness at that stage of the product life cycle might be done with the business end, i.e. the application part of the end-product. Hence, the innovations might be purely commercial ones at that state. On the other hand, innovativeness in the product platform renewal might be of more importance.

Reliability and quality of product platform was not covered at all by the study of product platform literature. Despite of the fact, that the product quality has not been studied in connection with the product platform literature, its importance has been recognized in both the quality management and product development literature (e.g. Garvin 1984a, Garvin, 1984b, or Evans and Lindsay, 2002, Crosby, 1979, Juran, 1989, MacCormack et al., 2001). In this dissertation, one of the factors in product platform development was found to be “Reliability and quality of product platform”. The factor was found to be quite strong contributor to the product lines’ satisfaction, also.

The results of the analysis combined the promised schedules with the platform meeting the needs set to it (factor “Promised schedules and final product platform meeting the needs”). The combination is peculiar, but the product development literature has already earlier noticed, that project schedules have a great affect on the internal customers (in addition to the end customers) (Roberts, 1995b). There existing literature on both the single product and product platform development has also emphasized the importance of understanding and meeting the (internal) customer needs (Meyer and Lehnerd, 1997a, Meyer and Seliger, 1998, Tabrizi and Walleigh, 1997, Soin, 1993, Välimaa et al., 1994, Cooper, 2000, Evans and Lindsay, 2002, Kärkkäinen, 2002, Davis, 1994). The factor was a strong contributor to the product lines’ satisfaction in this dissertation, and hence strengthened the results of previous research.

Unfortunately, the quantitative analysis could not assess two aspect found in the review of product platform literature: the efficiency and effectiveness of platform (strategic metrics) (McGrath, 1995, Tabrizi and Walleigh, 1997), and competences (McGrath, 1995, Tabrizi and Walleigh, 1997). The questionnaire included one statement slightly connected with the efficiency of product platform development, i.e. the easiness of building applications on the product platform. The question was excluded from the factor analysis, since it did not meet the requirements set to it by the model. The questions related to the competences, on the other hand, were discarded from the questionnaire because either they did not fulfill the requirements of normality or they did not meet the requirements set to it by the model. Hence, the research did not bring any evidence on how the product lines would see the product platform efficiency and effectiveness or the competences.

Even though there are several important factors of product platform development, in a case of building a new product platform development organization, the stress should be on the utmost important issues first. The analysis also revealed the factors, which had the greatest affect on the overall satisfaction level of the product lines: hence, “Strategic and business fit of product platform”, “Reliability and quality of product platform” and “Promised schedules and final product platform meeting the needs”.

The findings made about the case specifically (reported in chapter 6) were interesting, and along with the case description, could be of help in understanding the dynamics of the product platform development. Still, they cannot be generalized to other product platform units, and hence, they must be treated with cautiousness.

To conclude, the research produced new and interesting results about the product platform development, which could be used in the following research as well as in practice. Since the results cannot be generalized to concern all the organizations developing product platforms, this research calls for continuation and is not complete without other research following and complementing it.

7.2 Validity and Applicability of the Results

The case study method, and especially the single case study method, requires the case selection to be done carefully. In this research, the case unit's product platform was compared with the product platform definitions presented by the literature, to justify its use as a case example. The product platform corresponded to the definitions, and hence, the specific case could be used in the research.

The quality of case study research can be analyzed with regard to (Yin, 1988)

- the construct validity, i.e. whether the operational measures for the concepts being studied are correct or not. The tactics, which can be used to ensure the internal validity, include the use of multiple evidence, building a chain of evidence, as well as asking the key informants to review the case description.
- the internal validity, i.e. the whether presented causal relationships are correct. The internal validity of the case study is relevant especially in the explanatory research. As the research was more exploratory than explanatory, the request of the internal validity of the case study (i.e. validity of the causal relationship) was not relevant to this research.
- the external validity, i.e. whether the results can be generalized to a larger population. The tactic to be used is e.g. the replication logic in the multiple case studies
- the reliability, i.e. whether someone else have conducted the same research and reached the same conclusions with the help of the research description. The tactics to be used to ensure reliability of the case study are the use of the case study protocol and the development of a case study database.

To ensure the construct validity, multiple sources of evidence were used in the research, both in the literature study as well as in the actual case study. The evidence included official descriptions about the functionalities of the case unit in question, but also large amounts of internal data as well as data about the requirements and opinions of the product lines. The product line opinions were collected to assess and improve the SWP R&D operations at the time, and hence, the comments can be expected to realistically describe the state of operations at the time being. In addition to using multiple sources of evidence, the case was reviewed twice by a couple of the SWP R&D representatives in 2003 and 2004 to ensure the construct validity.

The external validity proposes the first and the largest threat to the validity of the results. In the case of the single case study strategy, the results of the research cannot be generalized to a larger population. The research strategy, on the other hand, was to strive towards particularization instead of generalization, and hence, give a thorough example about the aspects important to the product lines in the selected case of product platform development. Although these aspects might not be important for every product platform developer, they still provide a baseline for further research.

The reliability of the study was ensured by following the case study protocol presented in Chapter 3.2, and collecting the data during the four years with the same protocol. The protocol itself was compared to the theoretical models of customer satisfaction measurement in Chapter 3.4 and found to be compatible with them. Still, the fact that the interviewees were consciously selected (not random samples) proposes a risk to the validity of the results. On the other hand, there was not that many persons involved in the interface, and the choices could not have been much different. The databases of both the qualitative and quantitative data from the product line satisfaction surveys had been developed during the actual process of collecting the data. The correctness of the quantitative data was double-checked from the original filled questionnaires, and few mistakes were found which were corrected to the database.

The validity problem with the changing questionnaire was managed analyzing the statements remaining the same the entire research period. The use of personal structured interview increased the internal validity of the data, for it ensured that the questions were understood similarly from respondent to respondent and from year to year. In addition, the comments of the interviewees were written down in the personal interviews, and a database of the qualitative evidence found in the course of the research was developed. The qualitative data validated the quantitative results of the surveys. The small sample size and judgmental sampling decreased the statistical validity of the data collected, though. The longitudinal research method of conducting the survey for four years, on the other hand, solved at least partly the problem with statistical validity. The main limitation to the research is that the data was collected only from inside one company with small sample, and thus the external validity, generalizing the results to a larger population, is beyond the reach of the data. What the results can do, though, is to help to make analytical generalizations and to help other researchers to get a starting point for similar case studies.

The qualitative description brought background information about the opinions, and showed the varieties in the answers and opinions of the interviewees. Hence, the information gained through the case description was of great importance in understanding the product platform development of the case unit, SWP R&D. Still, the case description could only give some signs as to which areas of the product platform development were more important than other areas. In the interviewees, the importance of an issue was highlighted only occasionally. It could be argued that the issues discussed the most would be among the important ones, but they could as well be the areas where SWP R&D is not performing well enough, be the areas more or less important to the product lines. Further, the questionnaire used in the SWP product line satisfaction survey may have been a threat to the validity of the qualitative data. Even though the qualitative comments were collected, the questionnaire steered and guided the conversations, and not necessarily all the important aspects were asked in the questionnaire.

Yet, another threat for the validity of the results presented in this dissertation is brought by the fact that the data was entirely based on opinions, and hence the nature of the information gathered from the product lines might be speculative. Since the product lines knew that the data was used to set priorities and improve operations, they might have over or underemphasized some issues. A product line might have agreed beforehand, how to answer to the questionnaire. Hence, the results might not represent the true opinions of the individuals, but instead, the collective opinions of product lines. In this case, the results of the research might be somewhat biased. Further, it might be possible that the interviewees would not have been the right experts of every area in the questionnaire. The threat was lowered by allowing the interviewees not to answer.

The results of the research should be used only as a baseline in the further research of the product platform development. Since the single case study was part of the research strategy, the results are not directly applicable to any other unit developing product platforms. However, as a start, the results can be utilized best in the research of other product platform developers and their relationships with their product lines. In a case of external and or horizontal customers, the settings of the interface with the customers change – the visibility to the product platform development might be different as well as the abilities to cooperate in the area of strategies, and so on. However, the results of this research can be used as a baseline in a research of other types of customer relationships, also. It could be argued that the interfaces of the product platform as well as the quality of them, for example, are important whether the derivative product developer is internal or external. Of course, it will be the task of the future research to find out whether the argument is true or not.

7.3 Future Research Areas

In the case unit, there still are several areas to be studied. The product platform renewals might give a significantly different view on the important factors of the product platform development. The economic and business aspects, i.e. the commercial success of the DX 200 Platform was not in the scope of this research, but would be very interesting subject to research. Similarly the effectiveness and efficiency measures as well as the competences of the case unit would be interesting research areas. In the case company, there also are several other units developing product platforms, and it could be worth of studying whether the results of this dissertation would be of use in the other units as well.

The most evident area, though, for the future research would be the operations of the other product platform developers from their product lines' aspects. In such a research, the results of this dissertation would be of best use. The operations of the target unit should be thoroughly studied in order to find out whether there were areas, which were not part of SWP R&D's operations. The results would then either strengthen the results or conflict with them. Either way, the study would bring more insights to the study of the product platform development.

An extended research strategy from the product lines' aspect would be the one of an external or horizontal customer. Here the interface of the product platform development and the customers would be somewhat different from the case of product lines. The external and horizontal customers might have more choices as to the product platform for their derivative products, and hence there might be competitors to the product platform development. They might have less visibility to the actual product platform development operations, but the final product platform with its interfaces and documents as well as its quality and ability to fulfill the customer needs, would be as visible as to the product lines.

Another interesting aspect to the product platform development could be brought by analyzing different types of product platform development units; the ones with a small number of customers (be them product lines, external or horizontal) and the ones with large number of customers. This type of research could bring more insights to the area of considering the customer needs in the product platform development, and prioritizing between the different product platform releases. Hence, the research would dig into the very nature of the product platform development: balancing between several customers and their needs.

One step further in the research of the product platform development would be another viewpoint to the development than that of a customer. The product platform development could be studied in the frame given by the software capability maturity or quality excellence models, for example. In addition, a comparison whether the product platform development really differs significantly from any product development, could be interesting to see.

Hence, the possibilities for further research in the area of product platform development. Since this research is only the first step: it might be argued that this research is of no use, if the results are not utilized in further research of the area. To soften the argument, it could also be argued that in any case, this research, from its own part, helps to understand the product platform development.

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APPENDICES

Appendix 1. Internal data sources

Operating Procedures

YAR 0946/6 en R&D Manual (1996)

YAR 1371/1 en Project Management in SWP/R&D (1996)

YAN 1283/2 en DX 200 Product Process Description (1996)

YAR 0946/7 en R&D Manual (1997)

YAN 1283/3 en DX 200 Platform Product Process Description (1997)

YAR 0946/7 en R&D Manual (1999)

Annual Reports

SWP R&D Annual Report 1997

SWP R&D Annual Report 1998

SWP R&D Annual Report 1999

Strategies

SWP R&D DX 200 Strategy Material (1996)

SWP R&D DX 200 Strategy Material (1997)

SWP R&D DX 200 Platform Strategy (1998)

SWP R&D DX 200 Platform Strategy (1999)

Interviews about strategy process, 1995 and 1996 (Eero Hyvärinen, Raimo Kantola, Maaret Karttunen, Aate Kirjanen, Jukka Koskimäki, Kai Kurru, Pekka Niiranen, Keijo Olkkola, Jaakko Riihinen, Heikki Salovuori, Martti Syväniemi, Jorma Veijalainen, and Timo Vesterinen)

Quality Reports

DX 200 Software Quality Report 1/97

DX 200 Software Quality Report 1/98

DX 200 Software Quality Report 2/98

Descriptions of the SWP R&D

SWP R&D Toiminnan kuvaus, 1998 (Description of SWP R&D Operations 1998)

SWP T&K:n toiminnan kuvaus, 1999 (Description of SWP R&D Operations 1999)

Interviews about SWP R&D, 2003 (Eero Hyvärinen, Maaret Karttunen, Jukka Koskimäki, Kai Kurru, Seppo Taanila, Hannele Tainio, Jaakko Timperi)

Steering Groups

SWP R&D Boards, 1999

DX 200 Platform R&D Steering Group meeting minutes 1/96 – 5/99 (24 documents)

Product platform Development Steering Group meeting minutes 1/97 – 11/99 (26 documents)

Mobile Subcontracting Steering Group meeting minutes 1/96 – 6/98 (25 documents)

Fixed Subcontracting Steering Group meeting minutes 2/98 – 3/99, 6/99, 8/99-12/99 (19 documents)

Release Maintenance Steering Group meeting minutes 1/96 – 8/97 (13 documents)

Release Integration Steering Group meeting minutes 2/97-9/98 (15 documents)

Release and project related material

Release project final reports (12 documents)

Release Integration Plans

Master Release Plans 1996-1999 (37 documents)

Other documents

Internal announcement of the organizational change 1997

Functional requirements of Product Line 1 to SWP R&D, 1998

Appendix 2. Example of the questionnaire to the product lines

PRODUCT LINE SATISFACTION SURVEY

Date and Place: ________________________
Interviewer: ________________________

Your Product Line:

1. Product Line 1
2. Product Line 2
3. Product Line 3
4. Product Line 4
5. Product Line 5

Your Position: __________________________________
How long have you co-operated with Product platform development unit?______________

Please rate your satisfaction with the following statements using the rating scale of 1-5.

Grade:
1 = very dissatisfied (--)
2 = dissatisfied
3 = OK
4 = satisfied
5 = very satisfied (++)
? = I don't know / not relevant

Importance of a subject:
1 = not important
2 = little importance
3 = somewhat important
4 = quite important
5 = very important
? = I don't know / not relevant

Organization competence												
1. Expertise	**Grade** -- OK ++ ?						**Importance** -- OK ++ ?					
1.1 Experience / expertise of SWP/R&D people	1	2	3	4	5	?	1	2	3	4	5	?
1.2 Telecommunications know-how	1	2	3	4	5	?	1	2	3	4	5	?
1.3 SWP/R&D people understanding your business operations	1	2	3	4	5	?	1	2	3	4	5	?
2. Strategies	**Grade** -- OK ++ ?						**Importance** -- OK ++ ?					
2.1 SWP/R&D ability to develop clear long-term direction of where SWP is going (i.e. road maps)	1	2	3	4	5	?	1	2	3	4	5	?
2.2 SWP/R&D ability to implement road maps	1	2	3	4	5	?	1	2	3	4	5	?
2.3 SWP/R&D strategies /road maps meeting your strategic / business needs	1	2	3	4	5	?	1	2	3	4	5	?
3. Innovativeness and ability to change	**Grade** -- OK ++ ?						**Importance** -- OK ++ ?					
3.1 Innovativeness in Product platform design and development (architecture)	1	2	3	4	5	?	1	2	3	4	5	?
3.2 Innovativeness of new features from SWP	1	2	3	4	5	?	1	2	3	4	5	?
3.3 Ability to change	1	2	3	4	5	?	1	2	3	4	5	?
4. Cooperation and information sharing	**Grade** -- OK ++ ?						**Importance** -- OK ++ ?					
4.1 SWP informing Product Lines of SWP/R&D contact persons	1	2	3	4	5	?	1	2	3	4	5	?
4.2 Getting responses/help from SWP/R&D	1	2	3	4	5	?	1	2	3	4	5	?
4.3 SWP/R&D people participating in your Product Line's meetings / reviews when asked	1	2	3	4	5	?	1	2	3	4	5	?
4.4 Functioning of SWP/R&D Steering Groups	1	2	3	4	5	?	1	2	3	4	5	?
4.5 Ease of co-operating with SWP/R&D	1	2	3	4	5	?	1	2	3	4	5	?
4.6 Informing / training on the use of SWP products	1	2	3	4	5	?	1	2	3	4	5	?
4.7 Inviting Product Line's representatives to SWP/R&D's reviews	1	2	3	4	5	?	1	2	3	4	5	?

Processes		
5. Product Management	**Grade** -- OK ++ ?	**Importance** -- OK ++ ?
5.1 Functioning of prioritization/decision making	1 2 3 4 5 ?	1 2 3 4 5 ?
5.2 Functioning of ordering process	1 2 3 4 5 ?	1 2 3 4 5 ?
5.3 Promised schedules of product platform products (Lead time)	1 2 3 4 5 ?	1 2 3 4 5 ?
5.4 SWP/R&D informing your Product Line other Product Lines' Product platform features	1 2 3 4 5 ?	1 2 3 4 5 ?
5.5 SWP/R&D informing your Product Line required interface changes	1 2 3 4 5 ?	1 2 3 4 5 ?
6. Project Management	**Grade** -- OK ++ ?	**Importance** -- OK ++ ?
6.1 Receiving needed information of projects in SWP (visibility to projects)	1 2 3 4 5 ?	1 2 3 4 5 ?
6.2 Quality of SWP project documents / meeting minutes	1 2 3 4 5 ?	1 2 3 4 5 ?
6.3 Reliability of project schedules	1 2 3 4 5 ?	1 2 3 4 5 ?
6.4 Delivery completeness	1 2 3 4 5 ?	1 2 3 4 5 ?
7. Quality Assurance	**Grade** -- OK ++ ?	**Importance** -- OK ++ ?
7.1 Shared reviews of deliverables	1 2 3 4 5 ?	1 2 3 4 5 ?
7.2 Quality of testing	1 2 3 4 5 ?	1 2 3 4 5 ?
7.3 Test reports	1 2 3 4 5 ?	1 2 3 4 5 ?
8. Maintenance / support	**Grade** -- OK ++ ?	**Importance** -- OK ++ ?
8.1 Quality of hardware corrections/repairs	1 2 3 4 5 ?	1 2 3 4 5 ?
8.2 Quality of software corrections	1 2 3 4 5 ?	1 2 3 4 5 ?
8.3 Quality of documentation corrections	1 2 3 4 5 ?	1 2 3 4 5 ?

Product		
9. Product meeting the needs	**Grade** -- OK ++ ?	**Importance** -- OK ++ ?
9.1 The level SWP takes customers'/your Product Line's needs into account in product development	1 2 3 4 5 ?	1 2 3 4 5 ?
9.2 The easiness of building own applications on the top of the product platform	1 2 3 4 5 ?	1 2 3 4 5 ?
9.3 DX 200 Platform meets your needs/end customers' needs	1 2 3 4 5 ?	1 2 3 4 5 ?
10. Quality of the product	**Grade** -- OK ++ ?	**Importance** -- OK ++ ?
10.1 Reliability and quality of software	1 2 3 4 5 ?	1 2 3 4 5 ?
10.2 Reliability and quality of hardware	1 2 3 4 5 ?	1 2 3 4 5 ?
10.3 Quality of documentation	1 2 3 4 5 ?	1 2 3 4 5 ?
10.4 Product platform products fulfilling the environmental requirements	1 2 3 4 5 ?	1 2 3 4 5 ?

11. Overall grade	**Grade** -- OK ++ ?	**Importance** -- OK ++ ?
11.1 Overall satisfaction with SWP/R&D	1 2 3 4 5 ?	1 2 3 4 5 ?

12. Interview	**Grade** -- OK ++ ?
12.1 Your willingness of answering to similar questionnaires in the future	1 2 3 4 5 ?
12.2 Question that should have been in the questionnaire:	____________

13. This year's extra question	**Grade** -- OK ++ ?	**Importance** -- OK ++ ?
13.1 Features that require parallel SW and HW development in SWP/R&D	1 2 3 4 5 ?	1 2 3 4 5 ?

Thank You!

Appendix 3. Correlation matrices of factor analysis

Correlation matrix		10.3	10.2	10.1	9.3	9.1	8.2	6.4	6.2	6.1	5.3	5.1	4.3	4.2	4.1	3.2	3.1	2.3	2.1	1.3
1.3 SWP/R&D people understanding your business operations	Correlation	0.175	-0.08	0.195	0.298	0.416	0.232	0.016	-0.04	0.135	0.333	0.408	0.142	0.202	0.086	0.067	0.043	0.351	0.201	1
	Sig. (1-tailed)	0.034	0.204	0.018	4E-04	8E-07	0.007	0.434	0.334	0.068	2E-04	4E-06	0.059	0.012	0.171	0.24	0.322	4E-05	0.015	
2.1 SWP/R&D ability to develop clear long-term direction of where SWP is going (i.e. road maps)	Correlation	0.288	0.001	0.207	0.369	0.427	0.335	0.229	0.204	0.409	0.261	0.451	0.149	0.056	0.016	0.262	0.373	0.432	1	
	Sig. (1-tailed)	0.001	0.495	0.015	2E-05	6E-07	2E-04	0.008	0.016	2E-06	0.003	5E-07	0.055	0.271	0.432	0.003	2E-05	6E-07		
2.3 SWP/R&D strategies /road maps meeting your strategic / business needs	Correlation	0.139	0.086	0.176	0.38	0.473	0.202	0.122	-0.03	0.173	0.259	0.38	0.141	0.069	-0.01	0.154	0.257	1		
	Sig. (1-tailed)	0.076	0.191	0.032	9E-06	2E-08	0.019	0.101	0.373	0.029	0.003	2E-05	0.064	0.225	0.475	0.054	0.003			
3.1 Innovativeness in Product platform design and development (architecture)	Correlation	0.138	0.253	0.17	0.312	0.225	0.236	0.243	0.09	0.163	0.115	0.215	0.096	0.218	0.237	0.688	1			
	Sig. (1-tailed)	0.077	0.005	0.036	2E-04	0.007	0.007	0.006	0.174	0.039	0.118	0.013	0.152	0.008	0.004	1E-17				
3.2 Innovativeness of new features from SWP	Correlation	0.085	0.31	0.181	0.219	0.023	0.106	0.131	0.079	0.066	0.136	0.162	0.06	0.127	0.093	1				
	Sig. (1-tailed)	0.195	8E-04	0.03	0.009	0.406	0.141	0.091	0.209	0.24	0.085	0.049	0.265	0.087	0.159					
4.1 SWP informing Product Lines of SWP/R&D contact persons	Correlation	0.123	0.092	0.013	0.06	0.148	0.14	5E-04	0.276	0.161	0.178	0.19	0.448	0.332	1					
	Sig. (1-tailed)	0.097	0.17	0.444	0.25	0.049	0.068	0.498	0.001	0.036	0.03	0.022	9E-08	6E-05						
4.2 Getting responses/help from SWP/R&D	Correlation	0.143	0.089	0.102	0.024	0.259	0.306	0.091	0.217	0.087	0.129	0.294	0.384	1						
	Sig. (1-tailed)	0.065	0.177	0.133	0.394	0.002	4E-04	0.165	0.009	0.165	0.086	8E-04	5E-06							
4.3 SWP/R&D people participating in your Product Line's meetings / reviews when asked	Correlation	0.26	-0.05	0.058	0.057	0.234	0.263	0.039	0.416	0.206	0.239	0.217	1							
	Sig. (1-tailed)	0.003	0.298	0.27	0.267	0.005	0.003	0.342	2E-06	0.012	0.006	0.011								
5.1 Functioning of prioritization/decision making	Correlation	0.161	-0.03	0.078	0.279	0.481	0.223	0.191	0.207	0.278	0.345	1								
	Sig. (1-tailed)	0.053	0.37	0.213	0.002	4E-08	0.013	0.026	0.017	0.001	1E-04									
5.3 Promised schedules of product platform products (Lead time)	Correlation	0.322	-0.1	0.172	0.334	0.345	0.148	0.335	0.163	0.262	1									
	Sig. (1-tailed)	6E-04	0.164	0.038	2E-04	9E-05	0.066	2E-04	0.047	0.003										
6.1 Receiving needed information of projects in SWP (visibility to projects)	Correlation	0.357	-0.23	0.136	0.118	0.199	0.253	0.379	0.572	1										
	Sig. (1-tailed)	6E-05	0.008	0.072	0.098	0.013	0.004	2E-05	8E-12											
6.2 Quality of SWP project documents / meeting minutes	Correlation	0.389	-0.13	0.157	0.029	0.116	0.305	0.316	1											
	Sig. (1-tailed)	2E-05	0.104	0.051	0.378	0.109	8E-04	4E-04												
6.4 Delivery completeness	Correlation	0.375	0.085	0.326	0.275	0.231	0.341	1												
	Sig. (1-tailed)	5E-05	0.199	3E-04	0.002	0.007	2E-04													
8.2 Software corrections	Correlation	0.361	0.111	0.399	0.145	0.272	1													
	Sig. (1-tailed)	8E-05	0.136	6E-06	0.062	0.002														
9.1 The level SWP takes customers'/your Product Line's needs into account in product development	Correlation	0.247	0.033	0.163	0.367	1														
	Sig. (1-tailed)	0.004	0.368	0.039	1E-05															
9.3 DX200 product platform meets your needs/end customers' needs	Correlation	0.088	0.166	0.325	1															
	Sig. (1-tailed)	0.179	0.043	2E-04																
10.1 Reliability and quality of software	Correlation	0.281	0.287	1																
	Sig. (1-tailed)	0.001	0.001																	
10.2 Reliability and quality of hardware	Correlation	-0.04	1																	
	Sig. (1-tailed)	0.355																		
10.3 Quality of documentation	Correlation	1																		
	Sig. (1-tailed)																			

Appendix 4. ANOVA results: differences due to product platform extension and product line

ANOVA – product platform extension	Descriptives				Homogeneity of variances		Anova F(2,65)	
	Product platform	N	Mean	Std. dev	Levene Statistic	Sig.	F	Sig.
Factor 1: Strategic and business fit of product platform	B2	39	-0.17	1.07	1.200	0.308	1.565	0.217
	B3	18	0.32	0.72				
	B4	11	-0.07	0.98				
Factor 2: Project communication and deliverables	B2	39	-0.63 [a)]	0.85	0.231	0.794	17.51	0.000
	B3	18	0.51 [a)]	0.70				
	B4	11	0.63 [a)]	0.88				
Factor 3: Cooperation with product platform development	B2	39	0.08	1.02	3.398	0.039	0.792	0.457
	B3	18	0.39	1.07				
	B4	11	0.00	0.53				
Factor 4: Innovativeness of product platform architecture and features	B2	39	0.17	0.88	0.522	0.596	0.742	0.480
	B3	18	0.05	0.84				
	B4	11	-0.18	0.67				
Factor 5: Reliability and quality of product platform	B2	39	-0.16	1.07	0.591	0.557	0.212	0.809
	B3	18	0.03	1.15				
	B4	11	-0.03	0.95				
Factor 6: Promised schedules and final product platform meeting the needs	B2	39	-0.05	0.95	0.077	0.926	0.377	0.687
	B3	18	0.18	0.86				
	B4	11	0.01	0.96				

a) Group means are different at 0.05 level (Bonferroni test)

ANOVA – product lines	Descriptives				Homogeneity of variances		Anova F(3, 64)	
	Product Line	N	Mean	Std. Dev.	Levene	Sig.	F	Sig.
Factor 1: Strategic and business fit of product platform	Product Line 1	24	0.137 [a)]	0.749	3.668	0.017	5.198	0.003
	Product Line 2	16	-0.68 [a)]	1.258				
	Product Line 3	19	0.464 [a)]	0.817				
	Product Line 4	9	-0.3	0.692				
Factor 2: Project communication and deliverables	Product Line 1	24	-0.72 [b)]	0.929	1.142	0.339	6.311	0.001
	Product Line 2	16	0.282 [b)]	1.069				
	Product Line 3	19	-0.04	0.723				
	Product Line 4	9	0.554 [b)]	0.837				
Factor 3: Cooperation with product platform development	Product Line 1	24	0.452	0.837	3.049	0.035	1.334	0.271
	Product Line 2	16	0.056	0.99				
	Product Line 3	19	-0.1	0.823				
	Product Line 4	9	0.025	1.42				
Factor 4: Innovativeness of product platform architecture and features	Product Line 1	24	0.076	0.993	1.762	0.163	0.605	0.614
	Product Line 2	16	0.267	0.784				
	Product Line 3	19	-0.11	0.718				
	Product Line 4	9	0.151	0.761				
Factor 5: Reliability and quality of product platform	Product Line 1	24	-0.61 [b)]	1.228	1.257	0.297	3.938	0.012
	Product Line 2	16	0.06	0.783				
	Product Line 3	19	0.409 [b)]	0.811				
	Product Line 4	9	-0.02	0.988				
Factor 6: Promised schedules and final product platform meeting the needs	Product Line 1	24	0.118	0.825	0.648	0.587	1.308	0.280
	Product Line 2	16	-0.37	0.909				
	Product Line 3	19	0.134	1.059				
	Product Line 4	9	0.228	0.805				

a) Group means are different at 0.05 level (Bonferroni test), but the group variances are not homogenous

b) Group means are different at 0.05 level (Bonferroni test).

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