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Platform-Driven Development of Product Families: Linking Theory with Practice

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Firms in many industries increasingly are considering platform-based approaches to reduce complexity and to better leverage investments in new product development, manufacturing, and marketing. However, a clear gap in literature still exists when it comes to discussing the problems and risks related to implementing and managing product families and their underlying platforms. Using a multiple-case approach, we compare three technology-driven companies in their definition of platform-based product families, investigate their reasons for changing to platform-driven development, and analyze how they implemented platform thinking in their development process and which risks they encountered in the process of creating and managing platform-based product families. The field study shows that the companies involved in the study use a homogeneous concept of platform-based product families and that they have similar reasons to turn to platform thinking and to encounter comparable risks. However, the companies analyzed use mainly product architecture as a basis for their platforms (and ignore many of the platform types advocated in literature), while on the other hand they show divergent applications of the platform concept regarding the combinations of product families and market applications. Through this exploratory study, some important white spots in literature became evident as well. In the discussion part of this article these white spots are discussed and directions for future platform research are proposed. The article concludes that given its importance, platform-driven development of product families clearly deserves further research to provide more insight into strategic planning for new products.

Introduction

In a global, intense, and dynamic competitive environment, the development of new products and processes has become a focal point of attention for many companies. Shrinking product life cycles, increasing international competition, rapidly changing technologies, and customers demanding high variety options are some of the forces that drive new development processes [19,24,26]. In their quest to manage the complexity of offering greater product variety, firms in many industries are considering platform-based product development [12]. Key in this approach is the sharing of components, modules, and other assets across a family of products.

Historical success stories such as the Sony Walkman [21,25], Black & Decker power tools [15], Hewlett Packard's Deskjet printers [18], Microsoft's Windows NT [3], and Minolta's "Intelligent lens technology" [22] have shown both the benefits and the logic behind the platform concept. Gupta and Souder [6] even claim that thinking in terms of platforms for families of products rather than individual products is one of the five key drivers behind the success of short

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cycle time companies. However, a clear gap in literature still exists when it comes to discussing possible limitations of the platform concept and the problems and risks related to implementing and managing product families and their successive platforms. Studies [e.g., 7,12] recently have started to draw attention upon the significant costs and trade-offs associated with product platform development. This makes one wonder why and how different types of companies actually have taken up the advocated concepts. Based on the different industrial contexts, one further might expect a variety of applications of platform thinking and product family development, probably far less straightforward as advocated in several of the historical success stories about product platform development.

As a first step to fill this gap in literature we will analyze and compare in this article how three distinct technology-driven companies adopted the concept of platform thinking in their product development process. Before doing this, we will discuss the rationale behind thinking in terms of platforms and product families by reviewing the relevant literature related to these concepts. This discussion is followed by an explanation of our in-depth case study approach. After presenting our case study results, we close with discussing the implications of the main findings of our study and with identifying some important managerial implications and directions for future research.

BIOGRAPHICAL SKETCHES

Dr. Johannes I.M. Halman is professor at the University of Twente in the Department of Technology and Management and also is associate professor of innovation management at Eindhoven University of Technology. He earned an M.Sc. in construction engineering from Delft University of Technology in The Netherlands; an M.B.A. (cum laude) from Rotterdam School of Management at Erasmus University in The Netherlands; and a Ph.D. in technology management from Eindhoven University of Technology in The Netherlands. His research interests are in the field of innovation management with primary focus on program and project management of innovation processes, new product platform development, and high-tech start-ups. He specializes in the area of risk management. He has advised international firms like Philips Electronics and Unilever on the implementation of risk management strategies within their innovation processes.

Dr. Adrian P. Hofer is a researcher and consultant specialized in product family management. He graduated from the Swiss Federal Institute of Technology in industrial management and manufacturing and earned a Ph.D. in business administration from the Institute of Technology Management at the University of St. Gallen, Switzerland, with a thesis on "Product Family Management: Competitive Advantage through Platform Concepts." His interests are new concepts for product family management and their application in industry. He currently is conducting a joint research project on a "Valuation Model for Product Platforms" in cooperation with Eindhoven University of Technology.

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Perspectives from Literature

Previous studies [4,9,13,23] have suggested that if companies want to compete more effectively, they have to meet customers' needs over time better than the competition by offering a large variety of products. More variety will make it more likely that each consumer finds exactly the option he or she desires and will allow each individual consumer to enjoy a diversity of options over time. In considering the implementation of product variety, companies are challenged to create this desired variety economically. In their quest to manage product variety, firms in most industries increasingly are considering product development approaches that reduce complexity and better leverage investments in product design, manufacturing, and marketing [12]. Platform thinking, the process of identifying and exploiting commonalities among a firm's offerings, target markets, and the processes for creating and delivering offerings, appears to be a successful strategy to create variety with an efficient use of resources (e.g., cost or time) [17,18,20,22,24].

Definitions

The terms *product families*, *platforms* and *individual products* are hierarchically different and cannot be used as synonyms. A *product family* is the collection of products that share the same assets (i.e., their platform) [15,22]. A *platform* therefore is neither the same as an individual product, nor is it the same as a product family; it is the common basis of all individual products within a product family [14,20]. As a consequence, a platform always is linked to a product family, while it can serve multiple product lines in the market. The leading principle behind the platform concept is to balance the commonality potential and differentiation needs within a product

family. A basic requirement therefore is the decoupling of elements to achieve the separation of common (platform) elements from differentiating (nonplatform) elements.

One possibility to build a platform is to define it by means of the product architecture. This *product platform* has been defined by McGrath [14] as a set of subsystems and interfaces that form a common structure from which a stream of related products can be developed and produced efficiently. Baldwin and Clark [1] define three aspects of the underlying logic of a product platform: (1) its modular architecture; (2) the interfaces (the scheme by which the modules interact and communicate); and (3) the standards (the design rules to which the modules conform). The main requirements for building a product family based on a product platform are (a) a certain degree of modularity to allow for the decoupling of elements and (b) the standardizing of a part of the product architecture (i.e., subsystems and/or interfaces). A modular product architecture in this context is characterized by a high degree of independence between elements (modules) and their interfaces.

The typical inclination is to think only of the product architecture as the basis for a common platform of a product family. In line with recent discussions in literature [18,20,22] we argue that a product family ideally should be built not only on elements of the product architecture (components and interfaces) but also on a multidimensional core of assets that includes processes along the whole value chain (e.g., engineering and manufacturing), customer segmentation, brand positioning, and global supply and distribution.

Process platform refers to the specific set-up of the production system to produce easily the desired variety of products. A well-developed production system includes flexible equipment, for example programmable automation or robots, computerized scheduling, flexible supply chains, and carefully designed inventory systems [9]. Sanderson and Uzumeri [21] refer in this respect to Sony's flexible assembly system and an advanced parts orientation system, designed specifically with flexibility, small-lot production, and ease of model change in mind. Although the costs of this multifunction machine may be twice as much as a comparable single-function machine, the greater flexibility possible using manufacturing equipment designed with multiple products and rapid changeover in mind offsets its initial cost.

Customer platform is the customer segment that a firm chooses as its first point of entry into a new market. This segment is expected to have the most compelling need for the firm's offerings and can serve as a base for expansion into related segments and application markets [22]. Established customer relationships and knowledge of customer needs are used as a springboard to expand by providing step-up functions for higher price-performance tiers within the same segment or to add new features to appeal different segments [16].

Brand platform is the core of a specific brand system. It can either be the corporate brand (e.g.. Philips, Toyota, Campbell) or a product brand (e.g., Pampers, Organics, Nivea). From this brand platform subbrands can be created, reflecting the same image and perceived worth (e.g., Philishave, Hugo Boss perfumes, Organics shampoo). With a small set of brand platforms and a relatively large set of subbrands, a firm can leverage its brand equity across a diverse set of offerings [22].

Global platform is the core standardized offering of a globally rolled-out product. As an example, designing software for a global market can be a challenge. The goal is to have the application support different locales without modifying the source code. A global roll-out plan details the aspects of the product that can be standardized as well as those aspects that should be adapted to country-specific conditions and to customer preferences. Customization can involve physical changes in the product and adaptation in pricing, service, positioning message, or channel [22].

Management of Platform-Based Product Families

Cost and time efficiencies, technological leverage, and market power can be achieved when companies redirect their thinking and resources from single products to families of products built upon robust platforms. Implementing the platform concept significantly can increase the speed of a new product launch. The platform approach further contributes to the reduction of resources (cost and time) in all stages of new product development (NPD). By using standardized and pretested components, the accumulated learning and experience in general also may result in higher product performance. Unfortunately this is not a one-time effort. New platform development must be pursued on a regular basis, embracing technological changes as they occur and making each

new generation of a product family more exciting and value rich than its predecessors. Meyer and Lehnerd [18] propose a general framework for product family development. This framework represents a single-product family starting with the initial development of a product platform, followed by successive major enhancements to the core product and process technology of that platform, with derivative product development within each generation. New generations of the product family can be based on either an extension of the product platform or on an entirely new product platform. In case of an extension, the constellation of subsystems and interfaces remains constant, but one or more subsystems undergo major revision in order to achieve cost reduction or to allow new features. An entirely new platform emerges only when its basic architecture changes and aims at value cost leadership and new market applications. Systems and interfaces from prior generations may be carried forward into the new design but are joined by entirely new subsystems and interfaces.

The more consistently the platform concept is defined and is implemented in terms of parts, components, processes, customer segmentation, and so forth, the more effectively a company can operate in terms of tailoring products to the needs of different market segments or customers. Robertson and Ulrich [20] advocate a loosely structured process for platform planning, focusing on three information management tools: the *product plan*, the *differentiation plan,* and the *commonality plan*. The product plan reflects the company's product strategy, identifying the portfolio of products to be developed and the timing of their introduction to the market. The differentiation plan explicitly represents the ways in which multiple versions of a product will be different from the perspective of the customer and the market. The commonality plan describes the extent to which the products share physical elements. Since platform planning determines the products that a company introduces into the market during the next five to 10 years or beyond, the types and levels of capital investment, and the research and development (R&D) agenda for both the company and its suppliers, top management should play a strong role in this process.

Unlike the benefits of product family development, the risks related to product family development have not been addressed widely and specifically yet in literature. Some have been mentioned indirectly already in the previous sections. Developing the initial platform in most cases requires more investments and development time than developing a single product, delaying the time to market of the first product and affecting the return on investment time. This implies that platform-based development may not be appropriate for all product and market conditions. On top of the fixed investments in developing platforms, platforms also may result in the overdesign of low-end variants in a firm's product family to enable subsystem sharing with high-end products [12]. Data collected by Hauser [7] at one firm over a five-year period further showed the platform-based development approach to be correlated negatively with profitability. Meyer and Lehnerd [18] address the risk related to the balance between commonality and distinctiveness. A weak common platform will undermine the competitiveness of the entire product family, and therefore a broad array of products will lose competitiveness. Another risk relates to the renewal of product platforms. As pointed out by Meyer and Lehnerd [18], long-term success and survival require continuing innovation and renewal. A potential negative implication of a modular product architecture approach is the risk of creating barriers to architectural innovation. This problem has been identified by Henderson and Clark [8] in the photolithography industry and may in fact be a concern in many other industries as well [24]. The metrics as suggested by Meyer et al. [17] can help management to monitor, but they do not say explicitly when to create a new platform and companies can fail to embark in a platform renewal in a timely manner. Robertson and Ulrich [20] have pointed out organizational risks related to platform development. Platform development requires multi-functional groups. Problems may arise over different time frames, jargon, goals, and assumptions. In a lot of cases organizational forces also seem to hinder the ability to balance between commonality and distinctiveness. Engineers, for example, may prepare data showing how expensive it would be to create distinctive products, while people from marketing may argue convincingly that only completely different products will appeal to different markets. One perspective can dominate the debate in the organization.

Our literature review shows that the concept of building product families based on platforms has been accepted widely in literature as an option to create variety economically. The reasons (or expected benefits) of the concept are mainly greater flexibility in product design, efficiency in product development

and realization, and effectiveness in communication and market positioning. The application of the platform principles leads to different platform types according to the kind of assets that can be used as a common basis. Literature also mentions the substantial risks and trade-offs that have to be made in developing and managing platform-based product families.

Research

The objective of our field study was to investigate how and why companies are adopting, developing, implementing, and monitoring platform and product family concepts in practice. In our field research we used a multiple case study approach. Case study research involves the examination of a phenomenon in its natural setting. The method is especially appropriate for explorative research with a focus on "how" or "why" questions concerning a contemporary set of events [5]. The research design involved multiple cases, generally regarded as a more robust design than a single case study, since the former provides for the observation and analysis of a phenomenon in different settings [27].

Sample

We studied three technology-driven companies that have customized platform and product family development to meet their specific product and market needs. These firms represent a variety of product and market contexts and provide examples of a range of platform and product family concepts and implementations. In addition to the technology-driven criterion, the following criteria were used for selecting the firms: (1) substantial experience in NPD; (2) developing relatively complex products; (3) experience in applying the platform and product family concepts; (4) operating in highly competitive markets; and (5) collectively representing a diversity of product and market needs.

We selected three companies that best met our criteria and the additional assumption that these companies would differ in their application of the platform and product family concepts. During the process of data collection, no major deviations were found with regard to these initial assumptions. Before describing our data collection and analysis we first will provide a profile of the companies involved.

Company profiles

The participant firms were ASML, a market leader in advanced microlithography systems; Skil, a power tools division of Bosch; and Stork Digital Imaging (SDI), a worldwide operating company of digital print and preprint applications for the graphic arts and textile printing markets.

All companies have many years of experience with platform-based product family development. Table 1 gives an overview of employee numbers and net sales figures for ASML, Skil, and SDI, respectively. ASML's customers, the semiconductor manufacturers, are building increasingly complex integrated circuits (ICs).

As a result, the critical dimensions of the product design (IC size) is reduced continually. ASML's microlithography is the enabling technology to realize faster and smaller ICs and consequently is under pressure to provide a product that can hold pace with the technological evolution. Skil is oriented to the consumer market for power tools. It is positioned in the low-end segment where a high pressure on market prices exists, which has to be answered by cost-efficient variation of the products offered. SDI produces systems for digital printing technology to its customers. To meet the very high standards in its markets it needs a deep knowledge of different printing processes and has to integrate the newest technology in its products.

Although operating in different fields and producing different products, all participating companies are original equipment manufacturers (OEMs) in a competitive environment that is global, intense and dynamic.

As a result, they all share the need to produce a high variety of products at competitive prices in order to meet customer demands and to face competition.

Table 1. Characteristics of the Three Companies Involved in the Field Study

	ASML	Skil	SDI
Employees (2001)	7,070	445	1,595
Net Sales (2001)	1,844 million US$	135 million US$	230 million US$

Data Collection and Analysis of Our Field Study

The data collection and analysis was carried out in four phases. The aim of the first phase was to get a general understanding of the companies involved, the products they make, and the markets they address.

The second phase consisted of a set of 15 in-depth interviews with employees of a different functional background involved in product family development. The expertise covered project management, program management, R&D, systems engineering, manufacturing, marketing, and customer support. The interview structure consisted of five main parts: (1) to define the concept of platform-based product families; (2) to identify the reasons for changing to platform-based product family development; (3) to get insight into how the product family concepts were implemented; (4) to identify the perceived risks in the development and management of platform-based product families; and (5) to derive the needs for supporting product family development. The average duration of the interviews was two hours.

In the third step we performed a content analysis using the procedure recommended by Kassarjian [10]. The aim was to standardize the outcome of the different interviews within and across companies. Three researchers independently performed this analysis and afterwards compared their outcomes and discussed any differences until they reached a consensus. After the analysis and comparison of the interviews, the results were generalized and served as a basis for identifying gaps in literature and practice.

In the fourth phase a workshop was organized with participants from all three companies. The aim of the workshop was to confront the company experts with the platform ideas from literature and to present our research findings (i.e., the gaps in practice as well as in theory) concerning the building of product families based on platforms. The results of this phase were the verification of our conclusions, the sharing of platform experience among the company experts, and the identification of further implications for the management of product families and for research.

Field Study Results

Definitions of Platform and Product Family Concepts Used in Practice

In the first part of the interview, interviewees were asked to give definitions for the concept of platform-based product families used within their company. The terminology and definitions used within each company helped for the proper understanding during the interview. Additionally, it gave insight into how well these concepts are defined and are internalized within the company and which disciplines are most knowledgeable about product family development. The Appendix gives an overview of the definitions provided during the interviews.

The majority of the interviewees stated that platform-based product families was a known concept within their company. The analysis shows that although the definitions related to product families differ among the respondents, most refer to a set of related products with different applications based on a common, often physical or technological, ''part.'' Although not specifically defined this way, product families often are seen from a marketing perspective, providing different products to the same or related market segments, using a product platform.

The definitions of product platforms show a similar picture. Although differences in definitions exist both within and between companies, there is an overlap between the definitions with respect to the importance of ''basic modules,'' ''a similar concept,'' or ''a core technology.'' This highlights the technical perspective from which platforms are considered within these three technology-driven companies. Although again semantic differences exist, the same underlying principle applies to most of the definitions used. The Appendix does not reveal a clear distinction between disciplines that, among the three companies, appear to be more or less knowledgeable about the discussion on product family or product platform development in literature.

Although many different definitions were encountered in the three companies, the results show that the recursive character of product families and platforms is recognized and is accepted in practice. The principles behind building platform-based product families generally are understood and applied. The platform concept is associated with the reuse of elements (modules, components, designs) across multiple products. All the definitions clearly point to a ''core'' called platform from which specific products are derived. These products constitute a product family. There are differences in the focus and level of detail but not in the general meaning. The interpretation of the platform concept in practice results in fewer platform ideas than could be expected from literature. Product architecture is

Table 2. Specific Situations and Expectations for Product Family Development

	ASML	Skil	SDI
Products	Microlithography systems for the semiconductor industry (high end)	Power tools for the consumer market (low end)	Systems for digital print and preprint applications (high end)
Market	one market segment with different applications (stepper, scanner, twin scan)	Different applications (saws, drills, etc.) each in two market segments (opening price point, lower price point)	two market segments with different applications (graphic arts, textile printing) and a potential new market (photo printing)
Platform Potential	High commonality among products within an application (reuse of basic modules)	Very high commonality within applications (across segments), high commonality across all products (components)	Two available technologies for solutions in both market segments (GPMs)
Expected Benefits	Efficiency (volume and costs, maintenance) Flexibility (time to market, assembly) Effectiveness (training, learning curve)	Efficiency (costs and time, high variety) Flexibility (time to market, styling) Effectiveness (brand identity, understanding the structures)	Efficiency (time and costs for product variation) Flexibility (serving two market segments) Effectiveness (products are easier to explain)

the predominant basis for identifying platform potential, while other areas (e.g., processes) remain largely untapped. The answers received lead to the conclusion that often the platform idea is applied only within a part of the company (e.g., engineering) and rarely in a cross-functional context.

Reasons to Adopt Platform Thinking in Product Family Development

All three companies involved have experience with product family development. Table 2 gives an overview of their products, market structures, and reasons for changing to a family development approach. ASML develops platform-based product families for its whole product range. It gave two main reasons for following a family approach. First, a stable platform makes it easier to come up with newer modules and to ramp up volume. Second, from an engineering point of view, it is unaffordable to design a new machine from scratch every time a change in a local part of the machine is needed. Besides efficiency in the development process, shorter time-to-market and ramp-up times, advantages for servicing and maintaining the machines and improved learning curves during training were mentioned.

Within Skil, efficient use of resources and reducing time to market were seen as the main goal from an engineering and manufacturing perspective. Marketing goals, on the other hand, were that a product family should be based on commonality in terms of styling, perceived worth, and resulting in a strong brand identity. Clearly distinctive product families will help customers make comparisons and choose tools that fit their needs best.

For SDI the starting point for platform-driven product families was the development of so-called ''general-purpose modules'' (GPMs). Based on these GPMs, a variety of machines easily can be derived from the same building blocks. The GPM-based platforms leveraged a horizontal expansion for SDI and were designed in such a way that it became possible to build machines suitable for both the textile and graphic arts markets. The GPM-based platform approach enabled SDI to maximize its profits while keeping the development budget the same. Besides cost efficiencies in the product development process and time-to-market reduction, a more efficient training program could be developed as well. According to an SDI marketing manager, ''Once you understand one product, you understand them all.''

It can be concluded that, compared to the broad differences regarding the product applications and market structures found in the cases, the reasons and expected benefits from building platform-based product families fall basically into three different categories: (1) enhancing the flexibility in product design; (2) increasing efficiency in product development and realization; and (3) improving effectiveness in communication and market positioning. In a managerial sense, family thinking was found a way of simplification (complexity reduction) for supporting decision-making. This argumentation in practice for the development of platform-based product

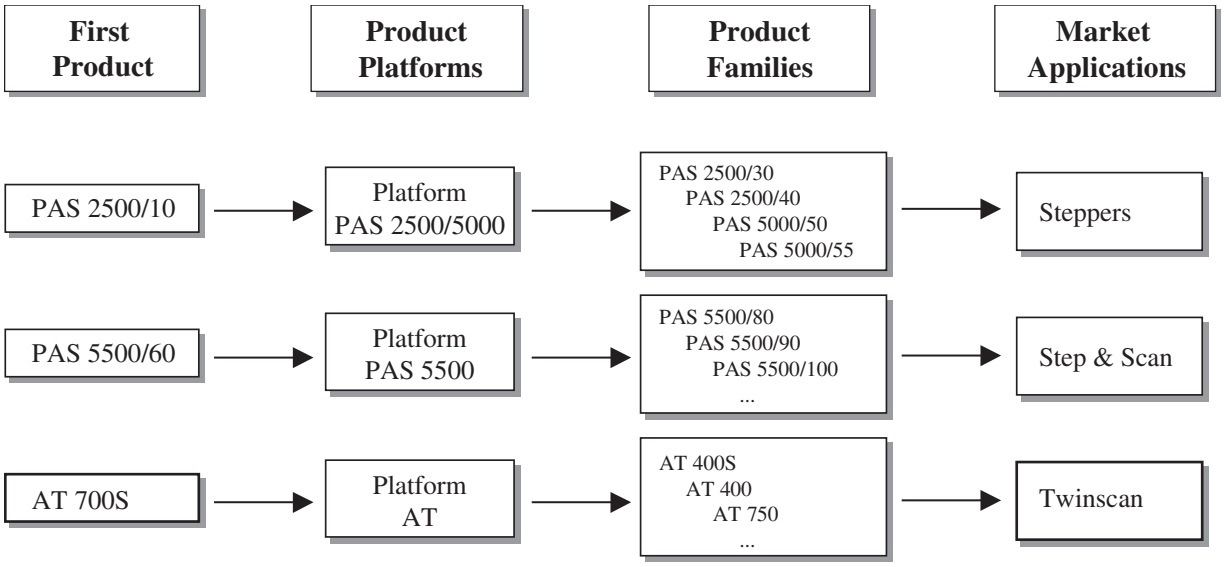

Figure 1. Platform-Based Development of Product Families within ASML

families is very similar to the reasons found in literature.

Implementing Platform-Based Product Families in Practice

Figure 1 shows the evolution of product families within ASML. A product family is defined on the basis of the available technology and expected market needs. The first developed product type of each family will serve as the platform for subsequent products belonging to the same product family. Follow-on products are enhancements of the initial platform, meaning that one or several modules, mostly related to the optics of the machine, are replaced by an enhanced version without changing the product architecture. Changes to the product architecture are made only when it is absolutely technically necessary. Since only internal modules are replaced, products belonging to a family look exactly the same from the outside. Approximately 80 percent of the modules remain similar over the lifetime of a family. This strategy of evolving the product line yields two key benefits. First, customers know that the ASML systems they install today are backward compatible with the manufacturing processes and the installed base of equipment they are using already. Secondly, it enables customers to reduce their manufacturing risks by using the same operator interface, spare parts, and machine-to-machine "mix-and-match" connectivity while adding new imaging capabilities needed to develop more advanced semiconductor devices. In past years, ASML has developed three different platforms (2500/5000 Steppers, 5500 Scanners, and Twinscan), each serving as the basis for subsequent specific product versions. The three product families basically address the same market needs; however, the platforms differ in their performance limits. Products from all three product families still are being sold. However, no new models are developed based on the first platform. New products still are being developed from the second platform, while the production of the first products based on the third platform has only just started being produced.

Skil develops a range of different power tools for the low end of the do-it-yourself consumer market. The first step in the development process is taken by marketing. Marketing selects new product ideas and defines the product requirements. At this point the focus is on developing a single product that fits in an existing brand and can be introduced in the market as soon as possible. It is then up to the engineering department to meet these requirements and to meet cost targets. It is at this (cost reduction) stage that technological commonalities between products (component standardization) are considered. By reusing existing components instead of by developing everything new for every new product and by developing or by redeveloping components for multiple use, engineering intends to achieve cost reduction. As a result, commonality exists (approximately 80 percent) within the same types of tools (e.g., drills) as well as among different types of tools

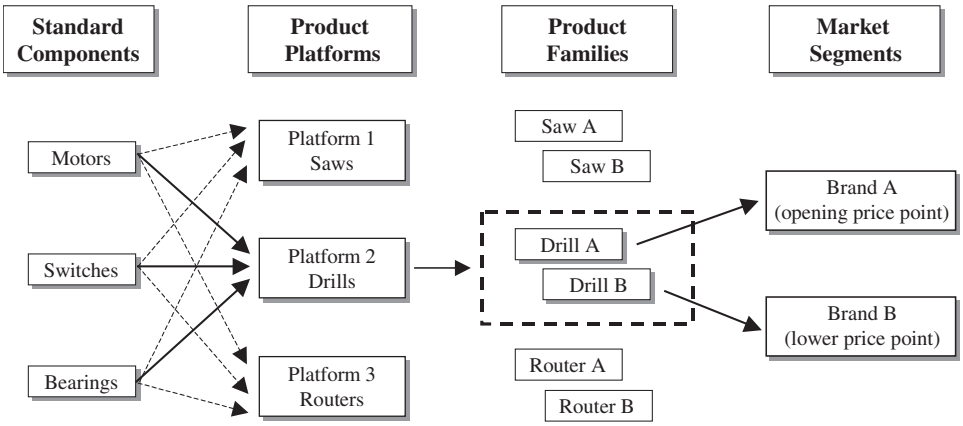

Figure 2. Platform-Based Development of Product Families within Skil

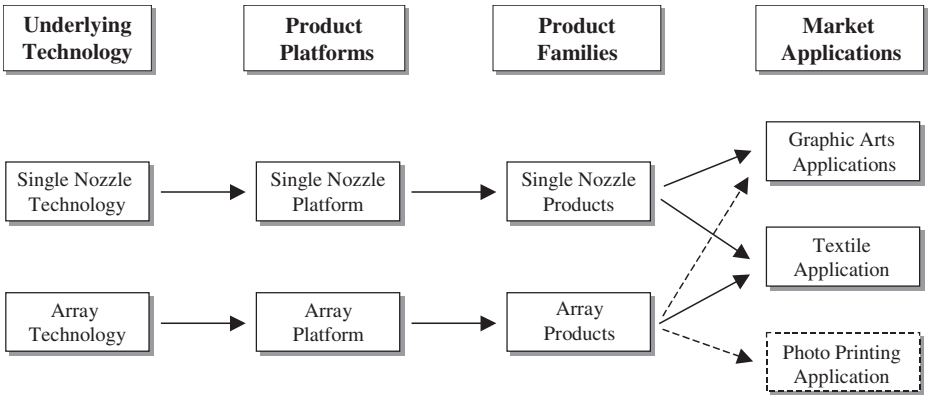

Figure 3. Platform-Based Development of Product Families within SDI

(approximately 50 percent) and is found on a component level (e.g., switches, motor, bearings, electronics). Platform thinking in this company therefore relates to the reuse of components, as opposed to the architecture of the complete product in ASML. Family development in this situation is more market driven than technology driven. Multiple product families (e.g., a set consisting of a saw, drill, router, and grinder) are developed to address different brand segments—each product family with its own core styling and perceived worth—but all product families utilizing the same technical components as much as possible. Figure 2 shows the relationship between components commonality within the same and among different types of power tools, and brand segmentation.

Figure 3 shows how SDI provides different printing applications for two target groups (i.e., the textile market and the graphic arts market). The company distinguishes between two different platforms underlying their products. Platform thinking in this company therefore is related to the reuse of two different printing technologies: the somewhat older single-nozzle technology and the new array technology. For each of these two technologies GPMs have been developed, which are used in different products. A modular design is chosen to speed up development and to reduce costs. The single-nozzle technology is applied to both the textile and graphic arts market. The array technology so far has been used only for products for the textile market; however, applications for the graphic arts are on their way. Applications for a totally new market, photo printing, are being investigated based on the new possibilities offered by the array technology. The platform concept emerges during the concept generation phase, where a range of products is defined based on a similar underlying technology. New product ideas are screened on their technological feasibility and on their link to customer needs. During design and development the focus is on keeping as many modules the same among the different applications. The

Table 3. Platform Characteristics

	ASML	Skil	SDI
Platform Type	• Three Product Platforms (basic modules and system architecture) for three applications	• Product Platforms per tool type (common components)	• Two Product Platforms (technology-related basic modules and system architecture)
Effects (Reuse)	• 80 percent commonality within products of the same family • low commonality across product families	• 80 percent commonality within products of the same family (application) • 50 percent commonality across tool types (components)	• 70–80 percent commonality within products of the same family

products belonging to the same product family, either to the textile or graphic arts market, are up to 70–80 percent similar, with just small differences in size, color, inking components, or frame.

Although comparable in terms of their understanding of the platform and product family concepts and of the potential benefits resulting from their use, the three companies are quite different in the way they have adopted and have implemented these concepts so far in practice. Table 3 shows the platform types the companies developed and to what level of reusability they achieved *within* product families and *across* them.

Companies also have specific ways in using their platforms and product families in the market. For example, one market segment can be served by multiple product families (as SDI's textile market); a single platform can serve as a basis for multiple market segments (e.g., drills at Skil); or each platform can address a single application (ASML). This shows the importance of a company-specific definition of platform-based product families.

The high variance in the use of product families and platforms with regard to the market structure, however, contrasts sharply to the few platform *types* used in practice. In all three cases, the predominant framework for finding commonality was the product architecture (i.e., modules and interfaces). This corresponds with the findings from the concept definitions by the companies, and it shows a clear gap compared to the variety of platform types presented in literature.

In two of the three cases, a platform was not planned or defined at the beginning of product development. It emerged later in the product life cycle, when a higher stability in the market requirements made the development of a common platform less risky. This also contrasts with the ideal picture in literature, where product family definition takes place before developing individual products.

Perceived Risks Related to Platform-Based Product Family Development in Practice

Developing product families not only provides opportunities for companies, but there also are risks involved. As stated earlier, product family development is more strategic and long term in nature, focusing less on singular opportunities than on single product development. Product families require a strong platform on which follow-on products can be built effectively and efficiently, and these platforms need to be renewed in time to be able to meet changing customers' demands.

Just like single products, product families have a limited lifetime that needs to be managed. Therefore, decisions have to be made about when to start a new family, which products to launch and in which order, when to move on to an extended or new platform and consequently to a new product family, and where best to allocate scarce resources. Clear metrics or designated methods to take these decisions, as discussed in literature, could not be identified in any of the cases.

For ASML, making revolutionary steps in platform design increases the risk of not getting the platform to work according to specifications or in time (i.e., being too ambitious). It was further brought up that platform development might lead to restrictions on the use of new technologies in a later stage of the product family life cycle (i.e., does not match with the platform), to rigidity in design when a lot of choices have to be made in a very early stage, and to failure correctly to forecast future user needs. Much of the risk encountered is explained by the need for decisions early in the product life cycle, the analysis of future market requirements, and the high initial investments for platform development.

Interviewees from Skil stressed that product platform development should not be a goal in itself. Developing a product platform only should be considered when there are clear views on reuses in future products. The main risks considered are the forecasting of future consumer needs, the integration of existing elements, and the high impact of mistakes early in the development phase.

For SDI, the challenge of developing product families (in order to make it suitable for a wide range of products) lies in the correct choice of the platform. The major risks encountered are the restrictions for different market segments, and the high initial cost and time for platform development.

Table 4 gives a summary of the risks and problems facing platform and product family development, as perceived by the interviewees. As can be seen in Table 4, most companies mention increased development times, costs and complexity of the initial platform as a risk of product family development, reflecting the importance of developing the right platform.

There is a general agreement that having the "right" platform-based product families results in substantial competitive advantage. The different trade-offs in the definition, development, and management of platforms, however, must be considered. These platform related trade-offs can be identified within the same categories as proposed in our presentation of reasons to adopt platform thinking: (1) Flexibility in product (family) design versus restriction through a platform; (2) efficiency in the development and realization of single products versus high initial efforts (time and cost) for platform development; and (3) low differentiation through the platform versus distinct positioning through individualized elements.

Through the balancing of commonality potential and differentiation needs, these trade-offs can be influenced, and consequently the optimum platform can be determined. As these decisions have to be made early in the product life cycle, they contain a high risk.

It is interesting to see, that although the companies analyzed came from clearly different initial situations, they all encountered more or less the same trade-offs during the definition, development, and management of their product families. These results also fit well into what is found in literature. Table 5 summarizes the lessons learned regarding the platform-driven development and management of product families for the three companies. The effects of developing platform-based product families are dependent on the specific platform definition. All companies agree that making wrong decisions is very expensive. The development of platform-based product families re-

Table 4. Perceived Risks Related to Platform-Based Product Family Development

	ASML	Skil	SDI
Risks	• Development time and costs of platform • Rigidity in design • Restrictions on the integration of new technologies • Incorrect forecast of future user needs • Change form one platform to another	• High cost and time for integration of existing elements • Platform development becomes easily a goal in itself • Mistakes made in the beginning have a high impact • Failure to forecast customer needs correctly	• Development time and costs to meet specifications of all target markets • Development process becomes more complex • Restrictions for all market segments • Selecting the right platform

Table 5. Lessons Learned from Platform-Based Development of Product Families

	ASML	Skil	SDI
Lessons Learned	• definition of a platform requires choosing from alternatives • development of a platform is a strategic decision • understanding of market requirements is necessary	• development of a product family needs a clear concept • a product family makes communication easier • customer needs have to be identified early	• having one platform for two market is difficult for the stability of the platform • market requirements have to be tested before platform development

quires a clear concept and a cross-functional understanding of the trade-offs involved between marketing, sales, engineering, sourcing, manufacturing, etc.

What generally is needed is a better understanding of mechanics and risks involved in platform development and consequently tools for decision-making. Our research indicates that it should be possible to develop a general framework for decision-making, as the underlying principles (mechanic) in building platforms stay the same and similar trade-offs and risks were found in all cases.

Discussion

The objective of this study was to explore the current state of literature concerning the concept for platform-based product family development and management and to compare this with actual application in practice. When comparing the theoretical and practical perspectives, several observations can be made.

Compared to the literature, the concept of platform-driven product family development was not defined identically either within or across the companies investigated. The underlying ideas and principles, however, generally are agreed upon and lead to the development of platform-based product families in practice. The definition of what constitutes a platform has a much wider meaning in literature than encountered in our case studies. According to literature [9,14,16,18,20,21,22], a platform can be related to product architecture, technology, sourcing, manufacturing and supply processes, customer segmentation, brand positioning, and even people and relationships. In our case studies, respondents predominantly associated this concept with product architecture and technology and in a limited way with customer needs and branding. The interviews did not reveal any structural or planned use of sourcing or manufacturing and supply processes as a base for platform development, which highlights opportunities to benefit further from the principle of platform thinking.

The reasons why companies choose to follow the platform concept when developing product families show a high degree of similarity. Although the companies analyzed differ substantially in the products they offer and in the markets they address, all of them have the same goals in mind when opting for platforms. The resulting commonalities (degrees of reuse) show comparable results in consequence. The platforms they developed, on the other hand, although mainly focused on the means of product architecture (i.e., modules and interfaces), reflect various combinations of product families and market structure. As a result, in one case a single platform can be used in multiple market segments; in another case multiple platforms are applied in a single market segment; and in a third case we found one platform per market application each.

The companies involved in the study do acknowledge similar risks as well as opportunities when developing product families. These trade-offs relate mainly to the increased development efforts for the initial platform and to the uncertainty of whether the right platform is chosen in order to develop enough follow-on products to gain back these extra expenses. No clear concepts or metrics are in use for managing these risks effectively. It still remains difficult for companies to anticipate the consequences of risky platform decisions in advance.

Taken all together, the three cases discussed in this study show that a gap still exists between what is written in literature and what is done in practice. Part of this problem originates from the fact that the knowledge transfer from literature to practice has not taken place sufficiently in the companies discussed. None of the respondents expressed any in-depth knowledge about the discussion that takes place in literature.

When seen from applying the concepts in practice, several white spots in literature also became evident. First, we have seen in our field study a rich and divergent application of platform thinking and product family development, which is far less straightforward as advocated in several of the historical success stories about platform and product development that have been reported in literature. By understanding and focusing on the different organizational contexts in which platforms and product families are applied, future research may develop categories of options for platform and product family development that are useful in practice given a specific context.

Platform decisions predispose a company's flexibility to react to technological or market changes. Our study showed that, although strongly interested in and convinced about the benefits of product family development, the companies claimed to lack practical guidelines and decision rules to help them in their platform decision-making process. Most platform decisions are not concerned primarily about whether to invest in a platform or not but instead about the

valuation and strategic selection among platform alternatives. A second important gap in platform literature however is the lack of a sound valuation model, as traditional methods (e.g., net present value (NPV)) fail to provide the necessary support for valuation and decision making [2,11].

The companies involved also expressed a great concern about the risks involved in platform and product family development and the lack of knowledge and tools to deal with these risks effectively. Available literature so far has focused mostly on the underlying concepts and benefits of product family development (i.e., effective and efficient product development through reuse) and less on investigating what might be successful strategies to manage the risks and problems related to platform and product family development and implementation. It is suggested therefore to initiate a third stream of research that could provide insight into our understanding of potential successful strategies of how to identify and manage successfully the risks related to platform-driven development of product families.

A fourth direction of future research concerns the variety in the use of platform types in practice. The fact that, compared to literature, only a narrow range of platform types was found in our exploratory study leads us to the conclusion that continued, expanded research involving companies in different industries should be directed to investigate, whether a substantial platform potential remains undetected and unused in practice.

Filling the aforementioned gaps in literature would be an important contribution, both from an academic as well as from a managerial point of view. We are positive that our research has started on the road to answering these pending issues by narrowing the focus for further research and thus by laying a useful foundation for expanding the investigation to other industries to broadening our knowledge about platform-based product families. This is an essential prerequisite to answering the industry needs for continued support in the strategic planning, design and management of platform-based product families.

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Appendix. Definitions of Product Families and Platforms as Found in Our Case Studies

Company	Discipline	Product Family and Product Platform Definitions
ASML	Marketing	*Family:* a group of products that have the same outside. *Platform*: the physical shape on the inside (determines the mechanical and electrical lay-out of the inside)
ASML	Customer support	*Family:* related to the body of the product. *Platform:* no definition - technology related term.
ASML	Pilot production	*Family*: no definition. *Platform*: new baseline from which new families can be derived.
ASML	System engineering	*Family*: a family of products with a lot of common modules where you change some of the modules to make a new product. *Platform*: is a family of machines, existing of a lot of different types, with different options and modules.
ASML	Program management	*Family*: a number of modules are basic on which you build a number of products. *Platform*: no definition
Skil	Marketing	*Family*: a group of products based on a similar technical concept with a differentiated look of the product to the end users. *Platform*: no definition
Skil	Project management	*Family*: several children / products going from lower to higher specs (including price) related by appearance (e.g. green housing, similar look) and are not all the same. *Platform*: having as much as possible common parts.
Skil	Manufacturing services	*Family*: different products / models on the highest level (e.g. hammer drills, circular saws). *Platform*: no definition
Skil	Product development	*Family*: no definition. *Platform*: no definition.
SDI	Product development	*Family*: term not used *Platform*: term not used
SDI	Business management	*Family*: kind of basis / technology on which you build different products. *Platform*: software related.
SDI	Business management	*Family*: a group of products that are all based on the same components (building blocks). Look the same, but have small differences to make them suitable for different markets. They have all the same technology inside. *Platform*: more related to underlying technology (less appearance).
SDI	Operations	*Family*: a group of products that is produced for a certain market. *Platform*: term not used.
SDI	Production and process engineering	*Family*: a group of products for the same application field with small changes to the products itself (same underlying principle). *Platform*: underlying core technology.
SDI	Research and development	*Family*: several products based on the same platform. *Platform*: the way separate modules of a system are organized and how the interfaces are arranged.