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Working Paper 01.06

Faculty of Technology Management

Eindhoven University of Technology, The Netherlands

September 2001

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Abstract
Firms in most industries increasingly are considering platform-based approaches to reduce complexity and better leverage investments in product design, manufacturing and marketing. Literature addresses a variety of concepts related to platform thinking: component standardization, product architecture, product platform, process platform, customer platform, brand platform, global platform and product family development.
In our paper we provide an overview of key topics related to platform and product family development as found in literature. We also use a multiple-case approach to investigate why and how three technology-driven companies adopted platform thinking in their development process. We discuss the rationale, but also the perceived risks and associated problems behind the process to create and manage product families and their underlying platforms. In the paper we will further show that although widely advocated, the knowledge and experience of how to apply platforms and product families in product development, platform driven development of product families is still only a young emerging field, both in theory and in practice.

Introduction
In a competitive environment that is global, intense, and dynamic, the development of new products and processes has become a focal point of attention for companies. Shrinking product lifecycles, increasing international competition, rapidly changing technologies and customers demanding high variety options are some of the forces that drive new development processes [16,23,25]. In their quest to manage the complexity of offering greater product variety, firms in many industries are considering platform-based product development [9]. 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 [19,24], Black & Decker power tools [12], Hewlett Packard [15], Microsoft's Windows NT [2] and Minolta's "Intelligent lens technology" [20] have shown both the benefits and the logic behind the platform concept. Gupta and Souder [5] 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-cycle-time companies. A clear gap in literature however 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 [6,9] have recently started e.g. to draw attention upon the significant costs associated with product platform development. This makes one wonder why and how different types of companies have actually taken up the advocated concepts. Based on the different industrial contexts, one might further 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 paper how three distinct technology driven companies adopted the concept of platform thinking in their product development process. Before doing this, we will first 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, including a subsection describing the background of the three industrial cases of our field research. After presenting our case study results, we close with discussing the implications of the main findings of our study and identify some important directions for future research.

Platforms and product family development: perspectives from literature

Previous studies [3,8,10,21] have suggested that if companies want to compete more effectively, they have to meet the customer's needs over time better than the competition by offering a high 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 the costs of 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 [9]. 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 at low costs [14,15,18,20,23]. Literature addresses a variety of concepts related to platform thinking: component standardization, product architecture, product platform, process platform, customer platform, brand platform, global platform and product family.

Component standardization is the use of the same component in multiple products. The use of standard components can lower the complexity, cost and lead-time of product development. Standardization can arise only when: (a) a component implements commonly useful functions; and (b) the interface to the component is identical across more than one different product [23]. Focusing on the process of developing and defining the required interfaces has shown to facilitate the often challenging shift from a single product development process to a product family approach [22].

Product architecture has been defined by Ulrich [23] as (1) the arrangement of functional elements; (2) the mapping from the functional elements to physical components; (3) the specification of the interfaces among interacting physical components. A key issue in the design of a product architecture is the ease in which the technical design of the architecture allows changes to be made to a product. Products with integral architectures require changes to several components in order to implement changes to the product's function. For products with a modular architecture on the other hand, desired changes to a functional element can be localized to one component. A modular product design therefore increases the likelihood to use standard components and also enables component interfaces to be identical across several products.

Product platform has been defined by McGrath [11] as a set of subsystems and interfaces that form a common structure from which a stream of related products can be efficiently developed and produced. Product platforms are therefore specifically designed to serve one specific group of related products, while a product architecture is not necessarily developed with this "restriction" in mind. 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 that the modules conform to).

Process platform refers to the specific set up of the production system to easily produce 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 [8]. Sanderson and Uzumeri [19] 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 multi-function 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 [20]. 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 [13].

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 sub-brands 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 sub-brands, a firm can leverage its brand equity across a diverse set of offerings [20].

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 customer preferences. Customization can involve physical changes in the product, and adaptation in pricing, service, positioning message or channel [20].

Product family has been defined by Meyer and Utterback [12] as a set of products that share a common platform but have specific features and functionality required by different sets of customers. The typical inclination is to only think of the product platform as the common platform for a product family. In line with recent discussions in literature [15,18,20] we argue that a product family should ideally be built however on sharing a multidimensional core of assets such as standardized components, manufacturing, supply and distribution processes, customer segmentation and brand positioning.

Developing and implementing platforms and product families

Cost 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 product platforms. Implementing the platform concept can significantly increase the speed of a new product launch. The platform approach further contributes to cost reduction in all stages of new product development. By using standardized and tested components, the

accumulated learning and experience in general may also result in higher product performance. Unfortunately this is not a one-time effort. New platform development must be pursued on a continuous basis, embracing technological changes as they occur and making each new generation of a product line more exciting and value-rich than its predecessors. Meyer and Lehnerd [15] 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 consistent the platform concept is defined and implemented in terms of parts, components, processes, customer segmentation etc., the more effective a company can operate in terms of tailoring products to the needs of different market segments or customers. Robertson and Ulrich [18] 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 ten years or beyond, the types and levels of capital investment, and the R&D agenda for both the company and its suppliers, top management should play a strong role in this process.

Monitoring platform and product family development
Meyer *et al.* [14] have proposed platform *efficiency* and platform *effectiveness* as two methods to measure R&D performance, focused on platforms and their follow-on products within a product family. They define platform efficiency as the degree to which a platform allows economical generation of derivative products. At the follow-on product level this means:

$$\text{Platform efficiency} = \frac{\text{Derivative Product Engineering Costs}}{\text{Platform Engineering Costs}}$$

The question this measure seeks to answer is: How much did the follow-on product cost to develop, as a fraction of what was allocated to the base platform? In a similar way, platform effectiveness is defined as the degree to which the products based on product platform produce revenue for the firm relative to the cost of developing those products. At the follow-on product level this means:

$$\text{Platform effectiveness} = \frac{\text{Net Sales of a Derivative Product}}{\text{Development Costs of a Derivative Product}}$$

Other methods that can be useful for measuring performance for a product family perspective, proposed by Meyer and Lehnerd [15], are *cycle time efficiency* (i.e. elapsed time to develop a

derivative product compared with the elapsed time to develop the platform), *technological competitive responsiveness* (i.e. tracking the degree to which a firm has beaten its competitors to the market place with new features or capabilities in its products) and *profit potential* (i.e. targeting the profitability of derivative products by examining gross margins). These metrics do not explicitly tell management when to create a new platform, however, provide a rich context to determine when product platforms should be replaced and what to expect from new products based on these new platforms.

Risks related to product family development

Unlike the benefits of product family development, the risks related to product family development have not been widely and specifically addressed yet in literature. Indirectly some have been mentioned 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 may also result in the over-design of low-end variants in a firm's product family to enable subsystem sharing with high-end products [9]. Data collected by Hauser [6] at one firm over a five-year period further showed the platform-based development approach to be negatively correlated with profitability. Meyer and Lehnerd [15] address the risk related to the balance between commonality and distinctiveness. A weak common platform or weak common subsystems will undermine the competitiveness of the entire product line and therefore a broad array of products will feel the pain. Another risk relates to the renewal of product platforms. As pointed out by Meyer and Lehnerd [15], 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 [7] in the photolithography industry and may in fact be a concern in many other industries as well [23]. The metrics as suggested by Meyer *et al* [14] can help management to monitor, but they do not explicitly say when to create a new platform and companies can fail to embark in a platform renewal in a timely manner. Robertson and Ulrich [18] have pointed out organizational risks related to platform development. Platform development requires multifunctional 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.

Research method

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 research with a focus on "how" or "why" questions concerning a contemporary set of events [4]. 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 [26].

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, all three established in The Netherlands, 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) experienced 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.

Five companies were approached to participate in this study. 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. As is shown in the findings, no major deviations were found with regard to these initial assumptions during the process of data collection. Before describing our data collection and analysis we will first provide a profile of the companies involved.

Company profiles

The participant firms were: ASML, a market share leader in advanced micro lithography systems; Skil, a power tools division of Bosch; and Stork Digital Imaging (SDI), a worldwide operating company of digital print and pre-print applications for the graphic arts and textile printing markets. ASML, employing over 3000 people worldwide and with net sales of over 1000 million-dollar, is a typical business-to-business company. Its products are sold to IC manufacturers in the semiconductor market. Designing and assembling high-tech lithography systems generate the added value of this company. The system modules itself are bought from a selected group of main suppliers. Skil is a developer and producer of high-quality “do it yourself” tools, such as saws, sanders, routers, grinders, drills, screwdrivers and planers, employing over 400 people in Europe and with a yearly turnover of over 140 million dollar. Founded in the USA in 1924 as the Michel Electric Handsaw Company, it came to Europe in 1960 and was taken over by Bosch in 1996. The power tools are designed for the low-end of the consumer market. This means that cost reduction is of primary importance during product design. SDI is a business-to-business high-tech company that develops, manufactures and delivers systems for digital print and pre-print applications, employing over 200 people in the Netherlands. SDI is part of the Textile Printing group of Stork NV, with a yearly turnover of over 250 million-dollar. The products include proofing systems for both the graphic arts and textile printing markets, as well as end-printing systems for the textile printing market. Beside that, the company produces the consumables used in these applications such as ink, paper and textile substrates.

Company	Product	Market	Technological level	Number of employees	Sales
ASML	Advanced micro-lithography systems	Semiconductor industry	High	3000	1200 Million $
SKIL	High-quality power tools	Do-it-yourself consumer market	Medium	400	140 Million $
SDI	Systems for digital print and pre-print applications	Graphic arts and textile printing industry	High	220	250 Million $

Table 1: Characteristics of the three companies involved in the field study.

Although operating in different fields and producing different products, all participating companies are 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. Some of the main characteristics of these three companies are presented in table 1.

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. For this, documented background material of the companies involved was received from the companies itself and gathered from the Internet. Initial meetings within each of the firms provided additional background information and gave us also the opportunity to better clarify our research interests and goals.

The second phase consisted of a set of 15 in-depth interviews with employees involved in product family development. Participant firms hosted a minimum of two site visits and provided access to the appropriate individuals to be interviewed. Selection of persons to be interviewed took place on the basis of three criteria: (1) expertise and senior involvement in product family development; (2) including a maximum of disciplines involved in product (family) development; and (3) including a minimum of 3-4 interviewees per company. Within ASML, we interviewed five managers, responsible respectively for Program management; Marketing; Systems engineering; Pilot production; and Customer support. Within Skil, four managers covering the areas: Project management; Marketing; Engineering; and Manufacturing gave their input. Within Stork Digital Imaging (SDI) finally, we interviewed six managers. These managers were respectively accountable for Business management; Marketing; R&D (2 persons); and Production (2 persons). The interviews, each lasting approximately 1,5-2 hours, were semi-structured, confidential and were all recorded. Topics, based on the literature review, that were addressed during the interviews were:

- Involvement of interviewee in product family development;
- Definitions used related to product family development;
- Why and when the company changed to or started developing product families;
- The actual development process of the company;
- The link between the product family platform and the different stages of the development process of individual products belonging to the family;
- Benefits, problems and risks related to product family development;
- Organizational needs to enable product family development.

The interviews were analyzed during the third phase of the study. The aim of the analysis was to compare the experiences in practice with the state of the art as discussed in literature, and also to compare the three individual companies. The company specific results and conclusions were sent back to the companies for feedback before they were finally processed and included in a summary report.

In the fourth and last phase we organized a workshop with participants from ASML, Skil and SDI to discuss our research findings, to confront these with literature and to exchange ideas.

Field study results

Definitions of platform and product family concepts used in practice

In the first part of the interview interviewees were asked whether concepts like product family and product platform are used within their company and how they are defined. Knowing the terminology and definitions used within the company is of great importance for a proper

understanding during the interview. Besides that it gives insight into how well the concepts are defined and internalized within the company, and which disciplines are most knowledgeable about product family development. The majority of the interviewees stated that product family and product platform were known terms within their companies, although no clear definitions were found that were shared within any of the companies. Appendix 1 gives an overview of definitions of product families and product platforms provided during the interviews. Appendix 1 shows that the definitions related to product families differ among the respondents, however, in most cases refer to a group of related products based on a common, often technological, "part". Although not specifically defined this way, product families are often 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. Differences in definitions exist both within and between companies; however, overlap between the definitions exists 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. Appendix 1 does not reveal a clear distinction between disciplines that, over the three companies, appear to be more or less knowledgeable about the discussion on product family or product platform development in literature.

Reasons to adopt platform thinking and product family creation
Different companies are likely to have different reasons for changing to a family concept. These reasons can be related to dealing with threats in the markets or from competitors, or "simply" relate to additional opportunities provided by a family approach. The three companies involved have a current history with product family development. Table 2 gives an overview of both the "when" and the "why" behind the change to a family development approach for the companies involved.

	ASML	**Skil**	**SDI**
When	From the early start in 1984 of the company, with the first product	No agreement (Engineering: always, Marketing: since take-over by Bosch in 1996)	Since the introduction of so called General Purpose Modules (GPMs)
Why	Volume and costs	Costs and time; styling	Two markets and one budget
Benefits	Efficiency, time to market, assembly, service, maintenance, training, learning curve	Improve learning, efficient use of resources, shelf of products	Less work, time and costs, maximize profits in 2 businesses, easier to explain

Table 2: Reasons to shift to a product family development approach.

ASML has been working with product families from its early start in 1984. Two main reasons were given for following a family approach. First, once you have a stable platform it is 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 there was no consensus among respondents about when the company started to think in terms of product families and platforms. Engineering claimed to have always focused on reducing costs and development times by making use of what was already available.

Efficient use of resources and reducing time to market were seen as the major advantages. People from Marketing on the other hand claimed 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 to make comparisons and choose tools that fit their needs best. Marketing claimed that this way of thinking became much stronger since Bosch took over the company in 1996.
For SDI the starting point for platform-driven development coincides with the development of so called “General Purpose Modules” (GPMs) in 1993. Based on these GPMs a variety of machines can be easily derived from the same building blocks. The GPM-based platforms leveraged a horizontal expansion for SDI. The GPMs 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, also a more efficient training program could be developed. According to a SDI Marketing manager: “Once you understand one product, you understand them all”.

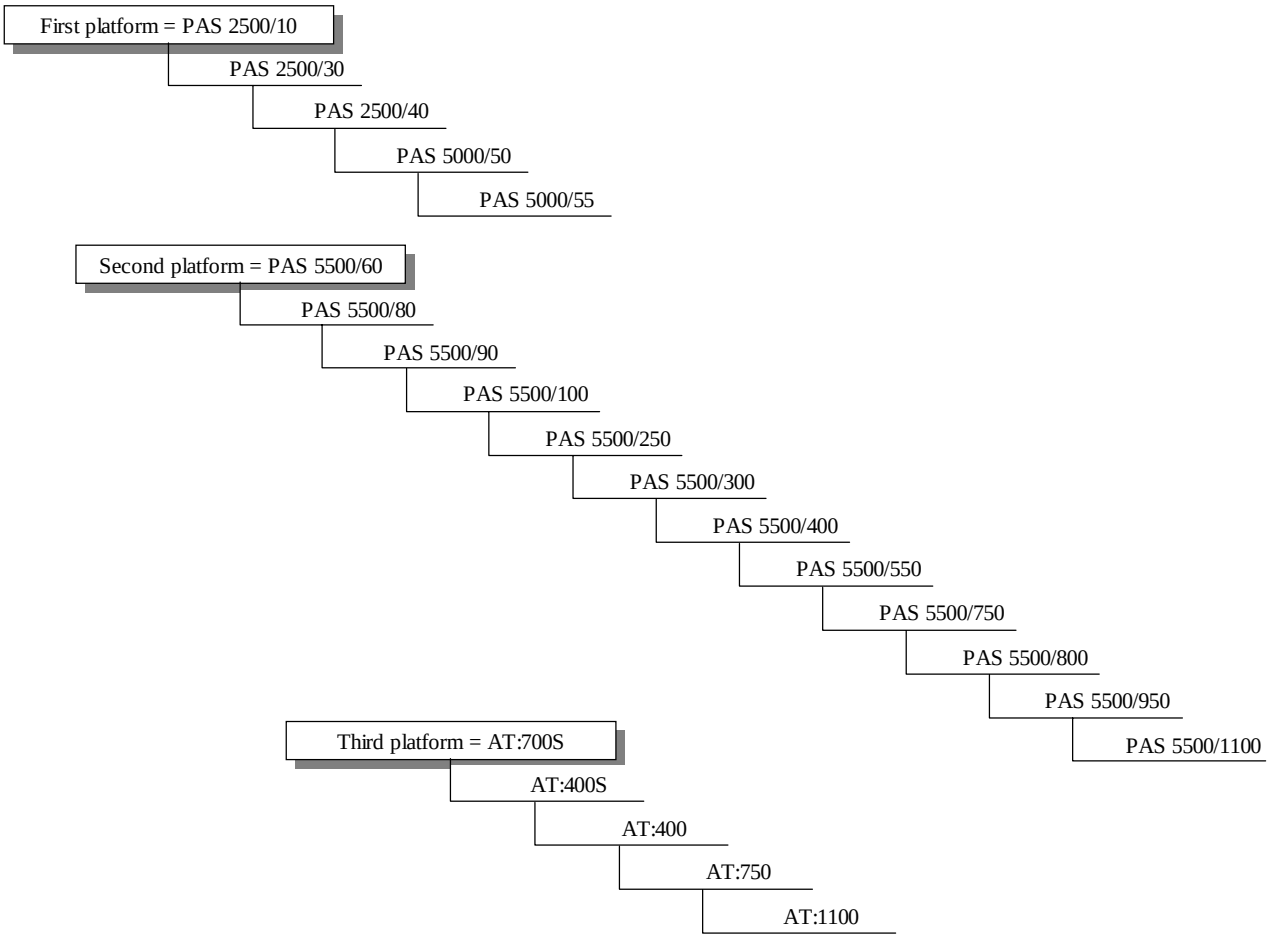

Figure 1: Platform-based development of a product family within ASML.

Implementing platforms and product families in practice
Although comparable in terms of their understanding of the platform and product family concepts and the potential benefits resulting from their use, the three companies are quite different in the way they adopted and implemented these concepts so far in practice. Figure 1

shows the evolution of product lines within ASML. A whole product line for the years to come is defined on the basis of the available technology and (expected) market needs. As shown in figure 1, the first developed product type will serve as the platform for subsequent product types belonging to the same product family. Follow-on product types are enhancements of the initial platform, meaning that only 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 only made 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% of the modules inside 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 already using. 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. Since the early start of ASML, three different platforms (2500/5000 steppers; 5500 steppers and Step & Scan; and TWINSCAN) have been developed each serving as the basis for subsequent specific product versions. The three product lines basically address the same market needs; however; the platforms differ in their performance limit. Products from all three product lines are still being sold. Products of the first platform are still enhanced; however, no new models are developed anymore based on this platform. New products are still being developed from the second platform, while the first products based on the third platform have only just been produced.

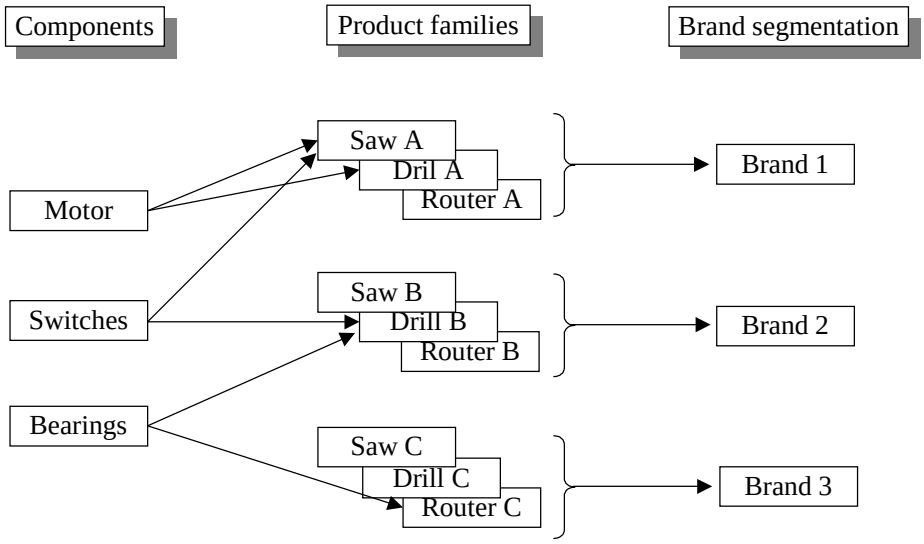

Figure 2: Developing product families within Skil.

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 re-using existing

components instead of developing everything new for every new product, and by (re-) developing components for multiple use, Engineering intends to achieve cost reduction. As a result, commonality exists (approximately 80%) within the same types of tools (e.g. drills) as well as between different types of tools (approximately 50%) and is found on a component level (e.g. switches, motor, bearings, electronics). Platform thinking in this company therefore relates to 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 (consisting of e.g. a set of 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 as much as possible the same technical components. Figure 2 shows the relationship between components, commonality within the same and between different types of power tools and brand segmentation.

Figure 3 shows how SDI develops 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 is therefore 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 General Purpose Modules (GPMs) have been developed, which are used in different products using this technology. 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 only been used for products for the textile market; however, applications for the graphic arts are on their way. Applications for a totally new market, the photo printing market, are being investigated based on the new possibilities offered by the Array technology. The platform concept appears during the concept generation phase, where arrays of products are defined based on a similar underlying technology. New product ideas are in first instance only screened on their technological feasibility and link to customer needs. During design and development the focus is on keeping as many modules the same among the different applications. The products belonging to the same product family, either textile or graphic arts market, are up to 70 to 80% similar, with just small differences in size, color, inking components or frame.

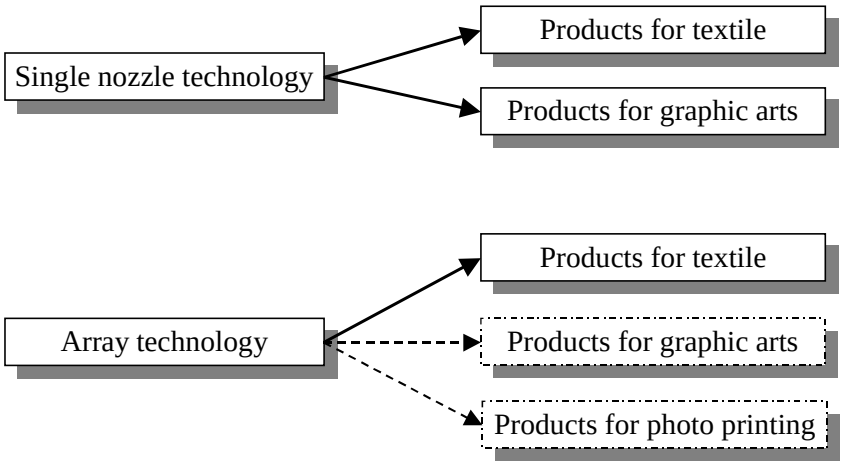

Figure 3: Platform driven development within SDI.

Monitoring product families in practice
Just like single products, product families have a limited lifetime that needs to be managed and monitored. 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 a new product family, and where to best allocate scarce resources. Clear metrics or designated methods to take these decisions, as discussed in literature, were not mentioned during any of the interviews. For ASML, the technology road map and the capability of the current platform are the factors that drive changes. For each platform, performance targets are clearly stated during the development phase. Based on the then known capabilities (and limits) of the platform, an array of products is planned. This way it is known in advance when a platform is reaching its technological limits, and therefore when it is time to move on to a new platform. This approach assumes a reliable forecast of the market needs for the coming years. Since platform thinking at Skil relates to the reuse of single components, monitoring takes place on a single product basis (e.g. effects of reuse on sales and profit margins). Monitoring of families of products takes place on a marketing level and is primarily based on experience and intuition. No formal methods are used to monitor the contribution of a family to the performance of the company as a whole. On a family level a similar picture was found for SDI. In this company however the capability of the current platform (i.e. can it still be used to develop new products), technology road maps (i.e. what technology to use, what technology will probably become the industry standard), and business road maps (i.e. future customer needs) play an important role in decision making related to product development.

Perceived risks related product family development in practice
Developing product families not only provides opportunities for companies; there are also risks involved. As stated earlier, product family development is more strategic and long-term in nature than single product development, focusing less on single opportunities. 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 customers' demands. Table 3 gives a summary of the risks and problems facing platform and product family development, as perceived by the interviewees.

	ASML	**Skil**	**SDI**
Risks	• Get platform to work • Development time and costs of platform • Restrictions on use of new technologies • Rigidity in design • Incorrect forecast of future user needs	• Failure to forecast customer needs correctly • Developing families as a goal in itself	• Development time and costs to meet specifications of both markets • Development process becomes more complex • Selecting the right platform

Table 3: Perceived risks related to product family development.

As can be seen in table 3, 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. Respondents from ASML also mentioned that 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 lifecycle (i.e. does not match with the platform), rigidity in design when a lot of choices have to be made in a very early stage, and failure to forecast future user needs correctly. Interviewees from Skil stressed that product platform

development should not be a goal in itself. Developing a product platform should only be considered when there are clear views on reuses in future products. Besides that, forecasting future consumer needs was considered a risk. For SDI, the increased complexity of the platform (in order to make it suitable for a wide range of products) and the correct choice of the platform were seen as major risks of product family development.

Discussion

The objective of this study was to explore the actual use of platform and product family concepts in practice and to compare this with the current state of platform and product family development literature. When comparing the theoretical and practical perspectives, several observations can be made.

The concepts related to product family development (e.g. product family, product platform) are not clearly defined and agreed upon in the companies investigated. When asked for definitions, all respondents had to think of one on the spot. The result was as many definitions as there were respondents, however, with clear overlap in the underlying meaning of the definitions. The list of definitions did not reveal any disciplines in the development process to be more or less knowledgeable about the discussion on product family development in literature. Lacking clear definitions of and consensus about the concepts used, one might wonder whether the concepts could be adopted, implemented and managed as effectively as discussed in literature.

The definition of what constitutes a platform has a much wider meaning in literature than encountered in our case studies. According to literature, a platform can be related to product technology; sourcing, manufacturing and supply processes; customer segmentation, brand positioning or even people and relationships. In our case studies, respondents predominantly associated this concept with product technology and in a limited way with customer needs and branding. The interviews did not reveal any structural or planned use of sourcing, manufacturing and supply processes as a base for platform development, which highlights opportunities to further benefit from the principle of platform thinking.

Monitoring of platform and product family development as found in literature was not encountered in anyone of the companies involved in this study. Products are monitored individually (i.e. sales and profit margins), and in two companies the extent to which the existing platform was still suitable for developing new products was checked. However, in none of the cases it is monitored whether platforms are indeed leading to a more effective and efficient development process of follow-on products. The real benefits of platforms and product family development therefore remain unknown to the companies involved. This is particularly worrisome since data collected by Hauser [6] at one firm over a five-year period showed the platform-based development approach to be negatively correlated with profitability.

The companies involved in the study do acknowledge risks as well as opportunities when developing product families. The majority of the risks mentioned relate to increased development times and costs of the initial platform and the uncertainty whether the right platform is chosen in order to develop enough follow-on products to gain back these extra expenses. No clear suggestions were given how to manage these risks effectively. Along the product family development process many decisions have to be made, which in the end may appear to be the wrong ones. Take for example a product family based on a product platform, as is the case in all the companies of this study. Choices have to be made related to the technology. Should this platform be at the cutting edge of new technology development and risk high investments and development times which may not pay back in the end, or build further upon existing knowledge and risk inability of the platform to meet future customer demands? Should the platform allow a maximum of flexibility in product design and risk

being too expensive in the end, or focus on efficiency in product design and risk not being able to meet future customer demands? Choices have to be made also related to the definition of the products of the product family, and the market segment(s) to address. Aim for effectiveness (i.e. meeting customer demands) in one market segment and risk low returns due to low volumes, or aim for efficiency through high volumes in more than one market segment and risk low sales due to products that do not fully meet customer demands? Choices have to be further made related to brand positioning. Products might help to build a strong brand, but sharing of components can also increase cannibalization, creating revenue interactions between "look-alike" products [17]. It still remains difficult for companies to oversee the consequences of these and many other risky choices in advance.

Taking 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. Besides a poor knowledge transfer, when seen from applying the concepts in practice, also several white spots in literature became evident. 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 successful options for platform and product family development that are useful in practice given a specific context.

The study showed further 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 develop and manage product families effectively. 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 mostly focused 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. Academic scholars should focus also on how to transfer their developed knowledge in a way that is easy accessible and acceptable for practitioners.

The study at hand resulted in an enriched vision about platform and product family development in practice and clearly showed that, although widely discussed in literature, it is still only a young emerging field, both in theory and in practice.

Acknowledgements

The authors would like to thank the three companies who participated in this research for their support, in particular Bert Koek of ASML, Sjeng Houben of Skil and Jacco Diederen of SDI for their contribution and for their help in organizing the interviews. We also acknowledge the contribution of Elena Insúa Ortega who participated as a graduate student in this research project.

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Appendix 1: Definitions of product families and platforms as found in our case studies.

Co.	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.

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