Effects of product platform development: fostering lean product development and production

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Abstract: In the lean management literature, it is mentioned that product platforms foster lean product development and production. Although product platforms are well known for several effects like reducing costs and attaining multiple product variants, there is still little understanding of how these effects are interrelated and how product platforms support lean product development and production. From a content analysis, we found 27 effects; but only a few effects are mentioned per paper and they vary from paper to paper. Given reasonable indications that common hierarchies and other relationships exist, we define a consistent framework for the effects of product platforms that describes the influence on product development projects and production. An adaptation of this framework to a literature case also illustrates how cost reductions and competitive advantages are achieved. Therefore, the developed framework shows how product platforms' lean thinking helps companies to become more competitive and profitable in the market.

Keywords: product platforms; lean development; lean production; effects; framework; review.

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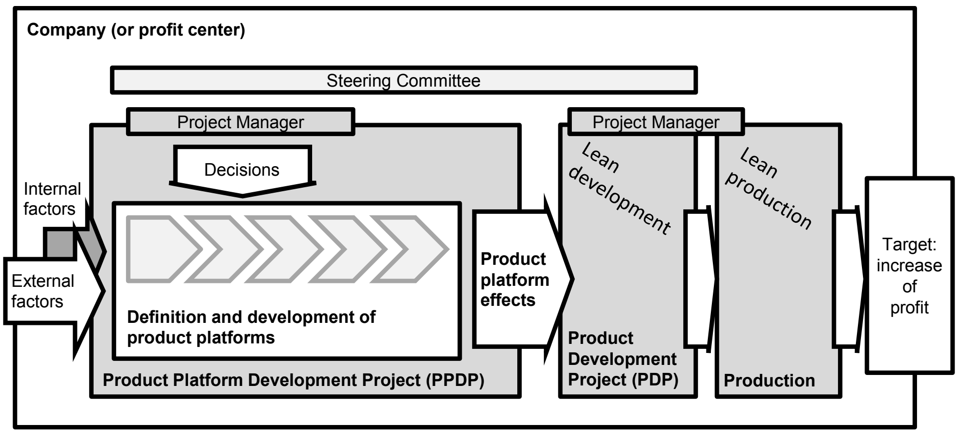
1 Introduction

In several industries, companies are facing increasing pressure in terms of shorter product life cycles, cost competition and diversified demands in the market. In response, they are considering strategies like product platforms to make product development and production leaner (León and Farris, 2011). In the literature, successful product platform stories are presented for companies like Sony Walkman (Sanderson and Uzumeri, 1995), Black & Decker power tools (Meyer and Utterback, 1993), Hewlett-Packard Deskjet printers (Meyer and Lehnerd, 1997; Halman et al., 2003; Chen and Wang, 2008; Farrell and Simpson, 2010) and Intel Microprocessors (Cusumano and Gawer, 2002). Product platforms are defined in various ways, ranging from "collections of the common elements … implemented across a range of products" (McGrath, 1995) and "a common structure from which a stream of derivative products can be efficiently developed and produced" (Meyer and Lehnerd, 1997) to an even broader definition as a "collection of assets that are shared by a set of products" (Robertson and Ulrich, 1998; assets in this wide sense are components, processes, knowledge, people and relationships). In this paper, we define product platforms as the collection of modules or parts that are common to a number of products, and this commonality is developed intentionally to attain certain effects.

The effects of platform-based products are determined by the specific platform definition of a company, which takes various aspects into consideration, like external factors and decisions (Halman et al., 2003). To illustrate this context, Harland and Yörür (2011) proposed a Product Platform Development Project (PPDP) framework (see adapted version in Figure 1).

Figure 1 Product platform development project framework



The core of the PPDP is the definition and development of a product platform influenced by project-internal and project-external factors. The ultimate objective of the PPDP should be to achieve short- and long-term financial success of a company. In this regard, product platform effects are considered to be the positive impacts that will help a company to achieve the goal (Gupta and Souder, 1998; Robertson and Ulrich, 1998; Jariri and Zegordi, 2008) by influencing the way the company runs product development and production (Alblas and Wortmann, 2012). When considering effects we look at the whole life cycle of the platform and the family of platform-based products including the first and all other derivatives.

Womack et al. (1990) described in their book the ideas of lean production and introduced the impact of lean development. The goal of lean product development is to improve return on investment by reducing development time and resources, quality risks, cost overruns and failure and capital costs, while increasing innovation, reusing production systems and parts and improving quality (Ward et al., 2007). In order to achieve this goal, strategies for easier and faster product development with limited errors were developed (Karlsson and Åhlström, 1996; Kennedy, 2003; Liker and Morgan, 2006; León and Farris, 2011). In addition to concepts like the set-based concurrent engineering approach (Ward et al., 1995; Sobek II et al., 1999), product platforms are recognised as one strategy to make the development of derivative products leaner (Cusumano and Nobeoka, 1998; Robertson and Ulrich, 1998; McManus, 2005; Doolen and Hacker, 2005). Liker and Morgan (2011) include the product platform (standardisation of architectures and components) as an important step in the process transformation to lean. In addition, Alblas and Wortmann (2012) show how platform changes have an impact on the lean production system. Even though the literature discusses the positive impact that product platforms have on the implementation of lean management, there is still not sufficient in-depth research on the effects of product platforms per se. This paper tries to fill this gap with the following research questions: which effects of product platforms are described in the literature? How are they interrelated? How do product platforms foster lean product development and production?

2 Methodology

In order to identify the product platform effects mentioned in the literature, we conducted a content analysis of selected papers. We searched for scientific papers related to our topic using the journal search engines of SCOPUS, EBSCO and PDMA (JPIM). The search criterion was ‘product platform’ and the search timeline was from 1997 to January 2012. Some of the articles could not be considered because they did not focus on product platforms. Altogether, 66 papers were selected.

These 66 papers were used to conduct a content analysis for product platform effects. Since the information on this topic is widely dispersed and fragmented in the papers, we used an inductive qualitative approach for the analysis (Elo and Kyngäs, 2008; Thomas, 2006). This approach includes open coding, the creation of categories and abstraction (Elo and Kyngäs, 2008). These papers were read carefully to identify the mentioned effects of product platforms. Double entries in the list of identified effects were deleted, and categories were created with synonymous words. In order to ensure the clarity of the categories, a second coder with evaluation objectives was introduced by Thomas

(2006). In total, we found 27 generic categories of product platform effects (Table 1). To illustrate the significance of the categories, we prepared a statistical evaluation listed by count of occurrence.

Table 1 List of 27 product platform effects found in the literature (sorted by count of occurrence)

Count	*Product platform effects*	*Count*	*Product platform effects*
48	Cover multiple market segments	8	Increase volume
38	Reduce production costs	7	Increase profit
36	Reduce time to market	6	Increase market share
28	Reduce (product) costs	5	Reduce production lead time
28	Increase product variants	5	Increase competitive advantage
27	Reduce development costs	4	Reduce risk
21	Improve design flexibility	4	Reduce logistics costs
12	Reduce customer lead time	3	Increase revenue
12	Cover global market	3	Reduce procurement costs
12	Increase quality	2	Reduce sales, marketing and service costs
9	Reduce design complexity	1	Decrease of investment risk
9	Improve production flexibility	1	Improve global operation
8	Use resources efficiently	1	Improve coherence
8	Reduce production complexity		

In the final step, a framework based on the identified effects was developed according to the inductive qualitative approach (Thomas, 2006). The purpose of the framework of 27 effects is to give an overview of the various effects mentioned as well as to identify hierarchies and dependencies. Afterwards, we created relations between the ultimate goals of the platform development and the major platform effects by using basic economic relationships. Finally, we completed the framework by ranking the effects from abstract to more concrete and added other effects to complete the structure.

3 Product platform effects in the literature

The 27 categories of the effects of product platforms identified in the content analysis are described below (for reader's convenience we sorted them by resemblance; a full list of synonyms with the possible expressions of the identified effects can be found in Appendix).

Increase volume, revenue, market share and profit: Several authors mention these economic effects with respect to the product platforms discussed in their articles (Meyer and Lehnerd, 1997; Robertson and Ulrich, 1998; Halman et al., 2003; Jiao et al., 2007; Ben-Arieh et al., 2009).

Reduce (product) costs: The 'reduce costs' considered in this category refer to total costs, which is an effect that is mentioned by several authors (Alizon et al., 2006; Ben-Arieh et al., 2009; Lu and Zuhua, 2006). We also found specific reduction effects for costs related to production, procurement and development (as well as others) as a result of product platforms.

Reduce production costs: Production costs are associated with the manufacturing of goods or the provision of services. For tangible goods, it is referred to as manufacturing costs (Hansen et al., 2009). Production or manufacturing costs consist of direct costs for labour and materials as well as overhead costs (Hansen et al., 2009; Kasilingam, 2000). A product platform saves costs because the components are shared among different products in a product family (Suh et al., 2007). As a result of product platforms, production costs can be reduced because companies achieve economies of scale when they produce larger volumes of common parts that share machinery, equipment and tooling (Robertson and Ulrich, 1998).

Reduce logistics costs: Logistics costs are typical costs associated with company's logistics, which include transportation, warehousing, material handling, ordering and inventory carrying costs (Goldsby and Martichenko, 2005). With product platform components and modules, companies can reduce logistics costs sustainably (Riesenbeck et al., 2006). Logistics costs are mostly calculated as overhead costs in traditional cost accounting (Siepermann and Siepermann, 2008). Commonality within a product platform can be helpful in reducing the number of part types in inventory, which in turn can help reduce the costs of warehousing and material handling as well as the complexity of the inventory.

Reduce procurement costs: Procurement costs consist of fixed ordering costs (this includes the costs associated with placing an order, e.g. preparing and transmitting) and the variable costs of procurement, which are basically the purchase price, depend on the order size (Kasilingam, 2000). Platforms allow companies to purchase the components in higher volumes from the supplier, which gives them more leverage in negotiating prices (Lundbäck and Karlsson, 2005). A higher level of commonality within a product platform helps manufacturers to reduce the number of parts in inventory and consequently reduce procurement costs (Lu and Zuhua, 2006).

Reduce development costs: Development costs (or R&D costs) are "expenditures aimed at developing new products and processes or at modifying existing products or processes" (Hansen et al., 2009). Therefore, product development costs "describe the cost and budget estimates associated with designing and developing the product" (Steinhardt, 2010). These costs are usually incurred during the early phase of the life cycle of a product. In the case of platform-based products, parts and assembly processes developed for product variants do not need to be developed and tested for other derivative products; this is an advantage for new platform-based derivative product development (Robertson and Ulrich, 1998). As a result, a significant reduction in development costs can be achieved through a product platform.

Reduce sales, marketing and service costs: Product platforms can help to save costs in sales and service as well as marketing (Robertson and Ulrich, 1998; Sawhney, 1998). Typically, sales, marketing and service costs may include new business development, product marketing, sales as well as service and support (Oliver, 1999). Product platforms help to reduce the costs associated with sales, marketing and service due to the commonality of products. This results in fewer promotional activities (advertisements, flyers, etc.), less training for marketing, sales and service personnel, less support service due to more stable architectures and less storage of spare parts for after sales service.

Increase competitive advantage: 'Competitive advantage' refers to a firm's ability to achieve market superiority (Porter, 1985). Product platforms help to increase competitive advantage by customising designs or helping to develop the appropriate product family to fit the requirements of customers (Halman et al., 2003; Farrell and Simpson, 2010).

Cover multiple market segments: A market segment is "a group of individuals or organizations within a market that shares one or more common characteristics" (Pride et al., 2012). To achieve the benefits of product platforms, companies try to cover more than one specific segment with one platform (Chowdhury et al., 2010). To illustrate the positioning of product platforms within the market, Meyer (1997) first suggested a market segmentation grid that includes the dimensions of the 'major market segments' and 'different tiers of price and performance'. According to Meyer, firms can use one of the following strategies by which product platforms can compete in the market: a 'niche-specific platform' which covers a small segment; 'horizontal leverage' with a platform, which covers some major segments in one price/performance level; vertical scaling of a platform to cover more than one price/performance level; and the beachhead approach starting with one low price major segment.

Cover global market: Global product markets for a company are defined according to the similarities in customer needs and legal issues (Stonehouse, 2004). In cases of heterogeneous requirements, a product platform strategy can help to cover the global market because parts of the global product's final design can be standardised. At the same time, the product platform and its flexibility can fulfil the needs of individual markets (Gillespie and Hennessey, 2011). These heterogeneities in products emerge due to the different regulations and cultural differences (within and outside the company) (Simpson et al., 2006). Therefore, companies should have a global roll-out plan that includes standardised features as well as characteristics that meet country-specific conditions and customer preferences (Halman et al., 2003).

Reduce time to market: Time to market is the "elapsed time from the beginning of idea generation when the firm decided to develop a new product to the moment the product is ready for market introduction" (Langerak et al., 2008). If the 'time to market' is reduced, companies can achieve competitive advantage by penetrating the market as one of the first competitors. Therefore, they have the chance to generate higher revenues with the new product (higher prices at the beginning and longer time on the market). Platforms can reduce the time to market because technology platforms, component designs, manufacturing processes, distribution channels and suppliers can be used again (Sawhney, 1998).

Reduce customer lead time: Customer lead time is "the time from customer order placement to receipt of goods", which includes the elapsed time between order placement and receipt of goods, e.g. customer-specific product development, design lead time, order processing lead time, production lead time, shipping distribution lead time, etc. (Hyer and Wemmerlöv, 2002). In particular, in the case of customised goods and services and/or in B2B transactions, customer lead time can be reduced dramatically by using platforms or building block concepts.

Reduce production lead time: In this paper, production lead time or throughput time means the elapsed time between the start of production of a single product and the end of production of a single product. In other words, "production lead time measures how long it takes to manufacture a product", which includes both value-added time and non-value-added time (Warren et al., 2009). Product platforms help to reduce production time because there are fewer production lines. Also, non-value-added time like material transportation can be reduced due to common parts of the platform products. Also, commonality in the product structure can induce experience curve effects which can reduce production time as well (Alizon et al., 2006).

Reduce design complexity: Authors pointed out that product platform or component sharing reduces product design complexity (Ben-Arieh et al., 2009; Halman et al., 2003; Jiao et al., 2007). Design simplification means reducing unnecessary complexity, parts or design attributes in a product's design. In the case of modular-based product platforms, it is simpler to add, substitute or remove modules (Alizon et al., 2006). Product platforms apply technologies that are already being used, which have demonstrated their usefulness (Lundbäck and Karlsson, 2005). Therefore, products based on existing platform technologies should be more reliable than products based on a totally new technology (Lundbäck and Karlsson, 2005).

Reduce production complexity: Production complexity arises as a consequence of a complex production set-up, or a complex production process, e.g. multiple product lines and overlapping of product lines. Meyer (1997) argued that component variety makes manufacturing unnecessarily complex. Therefore, a platform helps to maintain production processes simple because the components are shared among the various products. Also, production machineries can be used by different product variants to reduce managerial complexity for production (Robertson and Ulrich, 1998).

Improve design flexibility: Design flexibility for product platforms describes the capability of a product platform to adapt to different customer needs. The flexibility to respond to future needs includes "new functional requirements demanded by customers, new technologies, adherence to new regulations or the expansion into new geographical and demographic markets" (Simpson et al., 2006). This scaling up and down of platforms is referred to as business flexibility (Muffatto and Roveda, 2000). As mentioned by several authors, product platforms with modular architectures provide more flexibility (Meyer and Lehnerd, 1997; Muffatto and Roveda, 2000).

Improve production flexibility: Product platforms help to increase the flexibility and reactivity of manufacturing processes (Sawhney, 1998; Robertson and Ulrich, 1998). According to Gupta and Goyal (1989), production flexibility is "the ability of the system to produce a range of products without the need for adding major capital equipment" and production flexibility is determined by factors such as machine size, the variety of machines, material handling and software capability. Product platforms increase the flexibility of a production system because sharing a common structure or components enables the production system to produce variants easily.

Increase product variants: Product variants possess similar architectures but different functional requirements (Fellini et al., 2006). With regard to product platforms, a product family is a set of product variants and these variants are derived from a common product platform (Kumar et al., 2009; Fellini et al., 2006; Abdullah et al., 2008). One of the objectives of a product platform strategy is to increase the number of product variants cost effectively (Ben-Arieh et al., 2009).

Increase quality: Several authors pointed out that introducing product platforms increases quality because the product is free of deficiencies and errors that require doing the work over again (rework) or that are a result of field failures, customer dissatisfaction, customer claims, etc. (Juran, 1999; Krishnan and Gupta, 2001). Product platforms help to increase quality because the underlying platform has been thoroughly debugged and tested (Sawhney, 1998). There is room for improving the architecture and ensuring tighter integration of the components for platform products because with standardisation, firms invest more time and effort in design, development and testing (Krishnan and Gupta, 2001). In addition, performance and perceived quality or brand names are among several of the quality dimensions of manufactured products (Evans, 2011). Standardised and pretested components, as well as the accumulated learning and experience in product platforms, could also result in higher product performance (Halman et al., 2003).

Use resources efficiently (sustainability): Efficient use of resources reduces the cost of a product by decreasing waste generation and has a positive impact on the environment (Wimmer et al., 2010). Meyer and Lehnerd (1997) argued that better utilisation of limited development resources is ensured with product platforms. Platforms help to produce highly differentiated products without consuming excessive resources (Shooter et al., 2005).

Reduce risk: The definition of risk varies greatly depending on the context. In the case of new product development, it could be viewed as "any event that provokes undesirable effects in the process which will finally result in economic losses for the company" (Sorli and Stokic, 2009). Product platforms reduce design risk because they use proven modules that operate effectively or which are known to be used effectively (Abdullah et al., 2008; Gonzalez-Zugasti et al., 2000). At the same time, platforms reuse established processing concepts; in the case of start-ups, this helps to avoid or reduce uncertainty and confusion (Koufteros et al., 2005).

Decrease of investment risk: Platform-based products require less investment because the platform is already developed. This decreases the investment risk for each new product in terms of time and materials (Robertson and Ulrich, 1998). For new products based on existing platforms, a smaller number of variant components need to be developed. Also, commonality in products reduces the need for investment in tools and machinery as the same tools and machines can be used for different platform products.

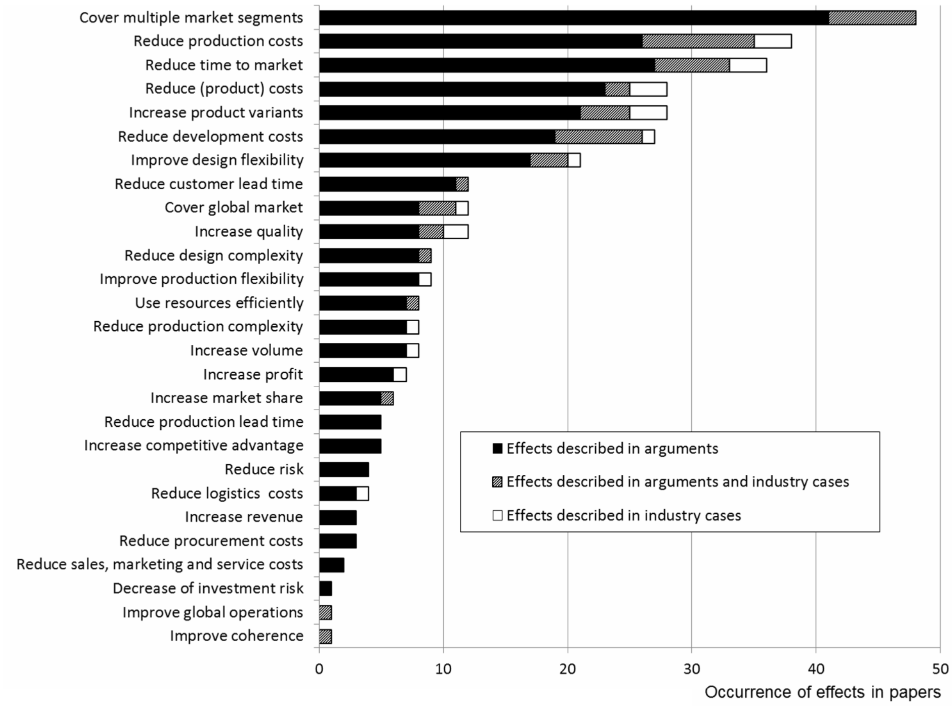
Improve global operation: When production takes place globally, it can be referred to as the global operation of a firm. Using automobile firms as an example, Muffatto (1999) argues that product platform strategies offer greater flexibility between plants because it is easier to transfer platform parts from one plant to another. Therefore, introducing global product platforms might improve global operations in terms of global production or distribution facilities.

Improve coherence: Product group coherence is a decision criterion that focuses on maintaining a relationship across products in terms of design and positioning. Therefore, higher coherence results in higher commonality among the products, which leads to better economies of scale and scope (Sakakibara et al., 1996). Sawhney (1998) uses the term coherence to refer to the benefit of product platforms. Sawhney argued that the offerings of platform-based product families could be extended more logically and coherently to related products, markets and geographical regions due to the inherent similarity among the variants. This could also translate to customer advantages in terms of usage of the product. For example, Airbus standardised its cockpit, which simplified the training of pilots.

To illustrate the significance of the 27 effects identified, the statistical evaluations of the content analysis are briefly discussed in this section. During the analysis of the 66 papers selected, there was an average of five effects found in per paper, with a maximum of 12 and a minimum of 0. The most commonly found examples of product platforms were Black & Decker tools, Sony Walkman and Volkswagen. The computer and electronic product-manufacturing industry, the machinery-manufacturing industry and the transportation equipment-manufacturing industry cover 88% of the industries (classification by NAICS, 2007) that mentioned product platform effects.

The hits were classified by the effects found in the industry cases described in the papers (in case studies or examples), in the argumentation used in other sections of the respective texts or in both (Figure 2; each effect is counted only once per paper when it occurs). The most frequently mentioned effect is 'cover multiple market segments', which is found in 41 papers in the argumentation only and in seven more papers with respect to industry cases as well as in the argumentation. The second most frequently mentioned effect is 'reduce production costs'. A total of 17 effects were mentioned in less than ten papers. The occurrence of effects in the industry cases and the arguments in these cases differ only slightly.

Figure 2 Effects found in industry cases or arguments in the selected papers (n = 66)



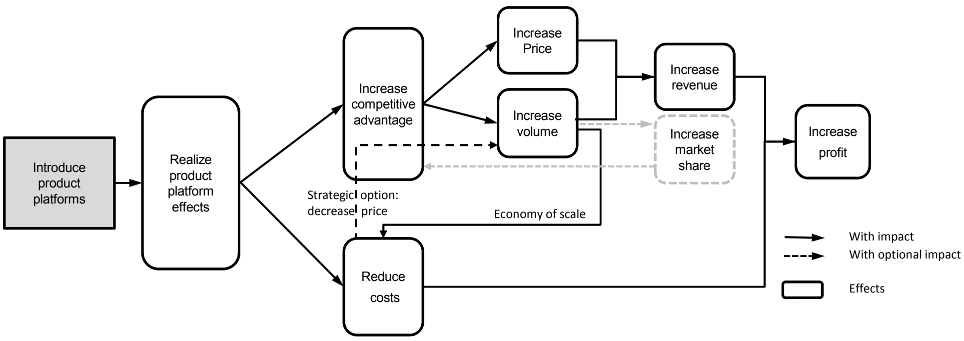
Surprisingly, we do not get a clear picture of the relevant effects. In most papers, only a few effects are mentioned, however, these effects vary from paper to paper. We assume that this is not only reasoned by volitional or non-volitional negligence of effects by other researchers. The mentioned effects might also have influence between each other. They might be defined more direct or more indirect, respectively, more abstract or more precise. There might be structural reasons in the coverage and hierarchies of different identified effects. In summary, we found that most of the papers only focus on a few effects, even though other effects are obviously relevant. Therefore, in the next section we provide a framework for product platform effects in order to reveal the relationships involved.

4 Framework of product platform effects

As previously assumed, the identified effects could influence each other; therefore, they are part of a logical system. In this section, we develop a framework by merging the identified effects and linking them with the ultimate goal of introducing the platforms ('increase profit'). The profit that a firm makes with its products is the difference between revenue (sales of products = price per unit × number of units) and the production costs (Harshbarger and Reynolds, 2009; Francis, 2004; Mankiw, 2011). Therefore, either a decrease in costs and/or an increase in revenue could increase profit. Revenue can be increased by any increase in unit price and/or any increase in sales volume. In addition, an increase in volume can reduce production costs due to the 'economies of scale' effect (Robertson and Ulrich, 1998). For example, this effect can be achieved when companies introduce product platforms to produce larger volumes of common parts.

Companies are pursuing product platform strategies not only to reduce costs but also to gain competitive advantage by having greater product variety (Huang et al., 2007; Muffatto, 1999; Ramdas, 2003; Shooter et al., 2005). Therefore, having a competitive advantage allows companies to increase the price and/or give them the chance to sell higher volumes. The relationships and hierarchies mentioned above are summarised in Figure 3.

Figure 3 Relationships between the introduction of a product platform and the achieved profit



In three additional steps, we integrated the product platform effects identified into the basic framework as shown Figure 3: the effects were integrated with a direct link to costs, competitive advantage, and the remaining indirect effects.

4.1 Cost composition

We found six types of cost-related product platform effects in the literature. The 'reduce (product) costs' effect consists of all the possible costs and their reduction. Therefore, it is represented in the framework as an overall cost reduction consists of specific costs (e.g. 'decrease production costs', 'decrease development costs and sales', and 'decrease marketing and service costs'). The remaining two cost effects ('decrease procurement costs' and 'decrease logistics costs') are covered by 'decrease production costs'. According to Porter (1985), cost leadership is one of the major parts of competitive advantage. Therefore, cost reduction can enhance the competitive advantage of a company. Companies can also consider a *decrease in price strategy* as an option to increase volume and consequently gain more market share.

Influences on 'reduce sales, marketing and service costs': Product platforms help to simplify marketing, sales and service activities through more coherent products as well as product commonality (e.g. less spare parts inventory, less requirement for training, experience curve effect). Simplifying these activities will result in cost savings in the respective branches. According to Juran (1999), when higher quality means that a product is free of deficiencies (i.e. free of 'errors that require doing work over again (rework) or that result in field failures, customer dissatisfaction, customer claims' etc.), in this context it usually 'costs less'.

Influences on 'reduce development costs': Platforms are known as a successful strategy to create product variety by using resources efficiently and they also help to reduce resources (e.g. cost and/or time) at all stages of product development (Halman et al., 2003). Hence, efficient use of resources can reduce the time and costs associated with product development. These are the key aspects of lean development. We consider both influences as optional impacts because time pressure can also increase costs.

Influences on 'reduce production costs': According to the definition of procurement costs and logistics costs, we consider them as a part of production costs. We found five effects that have an influence on the reduction of production costs. They are as follows: 'use resources efficiently', 'reduce customer lead time', 'improve global operation', 'increase quality' and 'decrease of investment risks'. Halman et al. (2003) considered time as a resource for platform strategies and that customer lead time can help to reduce production costs if it is seen as a resource (e.g. concept design time, machine time, working time). Otherwise, it can increase costs if it is considered as a pressure. For a global operation, greater flexibility between plants is achieved by transferring production between plants as a result of introducing a product platform (Muffatto, 1999). This can help to reduce production costs by transferring production to plants where it is cheaper. After the successful development of a product platform, a lower investment is required for leaner development of derivative products, which in turn reduces the investment risks for each product (Robertson and Ulrich, 1998). The lower investment in production (e.g. sharing machinery and components) will help to reduce production costs.

4.2 Composition of competitive advantage

Besides cost-related effects, there are eight effects of product platforms that have a direct impact on competitive advantage.

Improving coherence through product platforms helps firms through the logical extension of products or maintenance of integrity (Sawhney, 1998). Since coherence has an influence on the marketplace and leads to better diffusion of the products, it also results in a competitive advantage for the company.

For the *market segmentation* strategy, developing specific marketing 'mixes' for each market segment targeted is one of the ways that firms can achieve a competitive advantage (Hunt and Arnett, 2004). The individual parameters (i.e. variant parts) of platform-based products can be customised to satisfy individual customer needs (Gao et al., 2009). This means that platform-driven firms can meet the requirements of customers over time better than competitors because they offer a large variety of products

(Halman et al., 2003). Product platforms make product families more cost effective and faster to market, which in turn enhances the competitive advantage of the products in the *global market* (Simpson et al., 2006).

Due to sharing common components or modules, servicing platform-based products are more standardised and consumes less warehouse space for spare parts. The sales person feels more confident and it is easier to convince customers of the platform-based products because of the similarities among the variants. In addition, less marketing initiatives are required for the platform-based products because they already have a brand identity in the target market. As a result, product platforms help to simplify the marketing, sales and service activities of companies. With the *simplification of marketing, sales and service*, firms can better penetrate the market or increase sales volume. Furthermore, easy access to after sales service can help to win and retain customers. Thus, it increases competitive advantage. We added this effect to link the indirect effect of 'reduction of complexity' with the 'reduce sales, marketing and service costs' effect.

Martin and Ishii (2002) consider *reduction of time to market* as a part of a company's competitive advantage. Since product platforms help to reduce the time to market, the competitive advantage of companies is increased.

Reducing customer lead time through product platforms allows companies to meet the requirements of customers faster. Compared to competitors, this can increase the competitive advantage of the firm because it strengthens the bond between the company and customer. In a product platform strategy, there are three types of lead times: i.e. *quotation lead time*, *customising lead time* and *production lead time*. Quotation lead time and customising lead time were not explicitly found in the product platform literature; however, we added them to give a more complete picture as we see especially in B2B businesses advantages for companies having a product platform.

A *global operation* helps a company save on production costs and increase its competitive advantage. It also helps companies implement a simpler and more cost-effective product delivery system, become more familiar with the respective cultural and social system of a country, present the brand and product as its own brand, create value by enhancing the production as a contribution to the economy of a country, etc. Since a product platform makes a global operation simpler, it also contributes to competitive advantage (Muffatto, 1999).

Quality is considered as an important source of competitive advantage because each of the six characteristics of having a strong competitive advantage relates to quality (Evans and Lindsay, 2008). The core idea of product platforms is to reuse several parts, components or modules. This helps to gain experience (learning curve effect) and encourages firms to invest more time and effort to create the components that lead to a better architecture and component integration (Krishnan and Gupta, 2001). Increasing quality helps to achieve competitive advantage through product platforms.

4.3 Influence of abstract (indirect) effects on direct effects of product platforms

By indirect effects of product platform, we mean all the effects have an indirect impact on competitive advantage and the costs of a product platform. They are more abstract in nature and are organised on the left side of the framework:

Influence of 'increase product variants': Platforms are used to provide a large number of product variants to address multiple market segments (Gonzalez-Zugasti et al., 2000). Each of the product variants are meant to fulfil the specific customer needs of that market segment (Jiao et al., 2007). Therefore, an increase in product variants can help to fulfil the requirements of customers both nationally and globally and thereby achieve better coverage in multiple market segments and the global market.

Influence of 'improve design flexibility': Flexibility in a product platform helps to satisfy different market niches by developing different product variants (Fung and Chong, 2007). According to Thomke (1997), a more flexible design technology requires less investment of resources. Thomke also argues that when design flexibility is high, modifications require less time and cost. It is obvious that if a design is flexible it will require less time to prepare a quotation and that product development or customisation will also require less time. It is clear that design flexibility might help cover multiple market segments and the global market. In addition, it will contribute to using resources more efficiently, as well as to reducing customisation lead time, quotation lead time and time to market.

Influence of 'improve production flexibility': According to Gupta and Goyal (1989), "production flexibility is strategic in that it allows new products to be introduced in a relatively short period of time". Production flexibility helps to introduce new product variants very quickly (Gupta and Goyal, 1989). Therefore, platform-dependent production flexibility reduces production lead time.

Influence of 'reduce design complexity': Unnecessary product design complexity leads to more resource consumption, longer production cycles and increased costs (Smith, 2007). Therefore, reduction of design complexity helps to use resources more efficiently and reduces production lead time (Drury, 2006). Customisation time will be shorter because a simple design is easy to understand and modify. A reduction of complexity also simplifies marketing, sales and service because these activities require customer interaction, and a simple product design is easier to demonstrate and learn. Product simplification helps to eliminate the risk of mistakes and errors. Therefore, it is one of the most effective measures of quality (Hinckley, 2001). Similarly, quotation time will be shorter due to easier interpretation of the product.

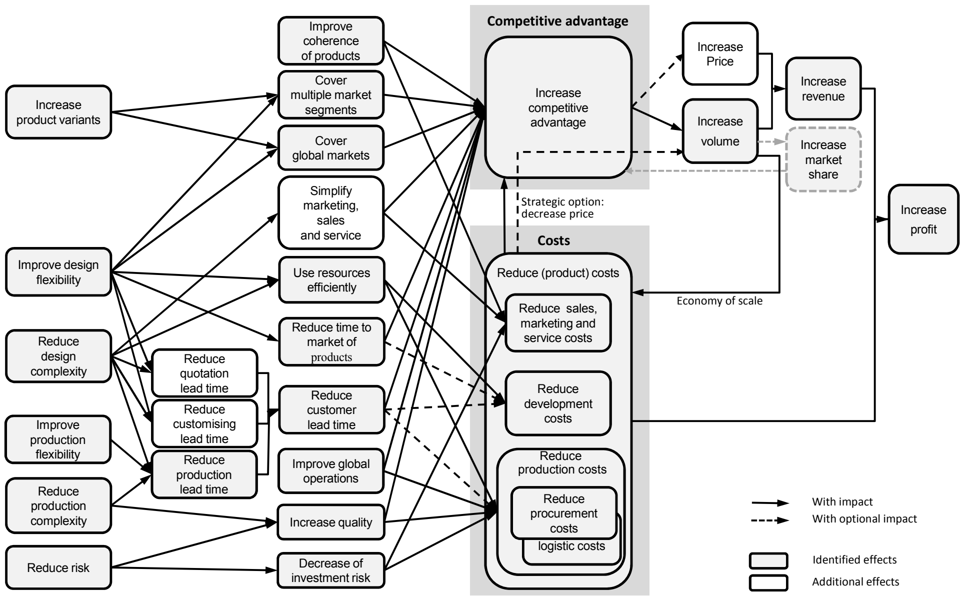
Influence of 'reduce production complexity': More complicated manufacturing settings require more elaborate and sophisticated control and costing systems (Kaplan, 1990). Kaplan (1990) used a lead time variance (which depends on actual and expected lead time) to measure production complexity and argued that more complex productions result in greater lead time variances. Therefore, we can predict that reducing production complexity will also reduce production lead time.

Influence of 'reduce risk': Product platforms help to reduce design risks because they use proven modules that operate effectively (Abdullah et al., 2008; Gonzalez-Zugasti et al., 2000). By reducing risks through product platforms, firms also increase the quality of their product. Also, by using common components and modules, product platforms reduce the need to invest in new machinery and storage. This is referred to as decreased investment risk by Robertson and Ulrich (1998).

Finally, we integrated the identified relations into one framework of product platform effects (see Figure 4). In addition, we introduced the framework to six experts in the field of product platforms (academic experts, platform product managers and platform project managers) as well as to 15 participants of a product platform workshop in an

R&D department. All of them stressed the importance of the contribution for a holistic understanding of product platform effects as well as its considerable benefits in terms of future research and its practical implications.

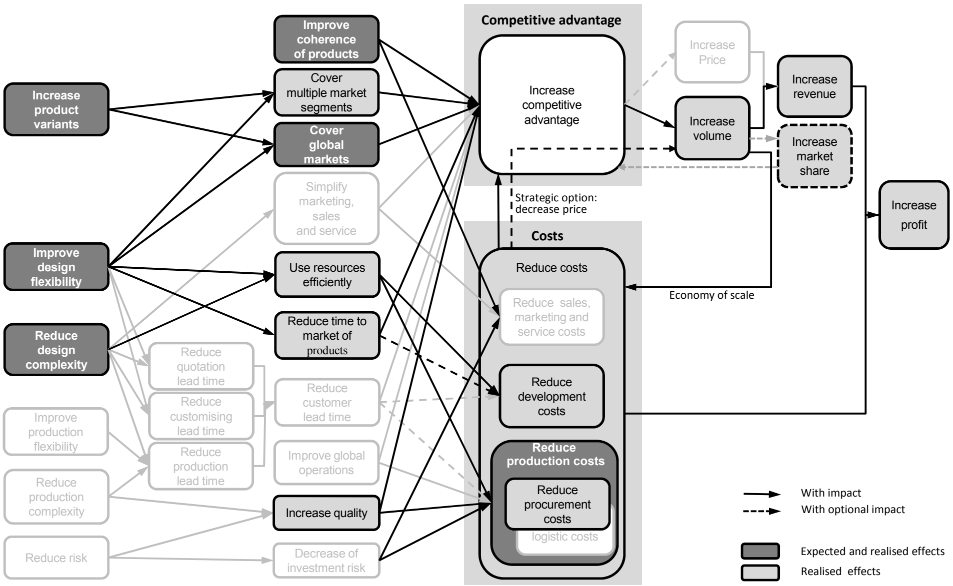
Figure 4 Framework of product platform effects



5 Adapting the framework to the example of Black & Decker

In this section, we illustrate how our proposed framework can be adapted to a real environment. To do this, we used the case of Black & Decker power tools. It is one of the most cited and most elaborately described examples of product platforms by Meyer and Lehnerd (1997). In 1970, Black & Decker had 122 different power tool models. These models required 30 different motors and each model was manufactured by a different set of tools. A total of 60 different motor housings, 104 different armatures and dozens of different operating controls were needed for these tools. These required large storage spaces and hundreds of people to manage them. Since each unique product design required a dedicated production line, the process was very labour intensive. Up to that point, the company had not paid much attention to commonalities. Since new regulations requiring the addition of double insulation affected almost all of the products anyway, they had a chance to develop platforms for all of the products. They defined the project objectives, which were to develop a 'family look' for their product (i.e. coherence), simplify the product offering (i.e. design simplification), reduce manufacturing costs, make it possible to add features (i.e. design flexibility) and make global products to be able to react to overseas competitors. They were happy that they could not only realise all the desired effects but others as well (see Figure 5).

Figure 5 Framework of the product platform effects adapted to the example of Black & Decker



Therefore, the effects of the platform development projects were robust. Production costs were reduced significantly due to savings in labour, materials and overhead expenses. Standardisation of the products and the elimination of extra connectors increased the supply volume, which made it possible to procure quality materials from the best suppliers at a good price. This enhanced product quality (e.g. the failure rate in the hand of the consumer was 6–10% after implementation of the product platform). The rate of new product introductions was an average of one per week for several years because the cycle time for the new derivative product was greatly accelerated. Furthermore, due to standardisation of the new product platforms, much of the work in design and tooling was eliminated. Since designers only had to concern themselves with the 'business end' of new products, they were able to reduce the development costs for each new product. Also, standardisation of the interfaces and components helped to reduce waste materials and use resources more efficiently.

All of these realised effects ensured increased competitive advantage in the market. At the same time, competitive advantage was also boosted by being able to lower prices due to cost savings. In some instances, the company was able to reduce the price up to 50%. As a result, Black and Decker became the market leader in power tools and the estimated breakeven period of seven years of the project was reduced to three and half years.

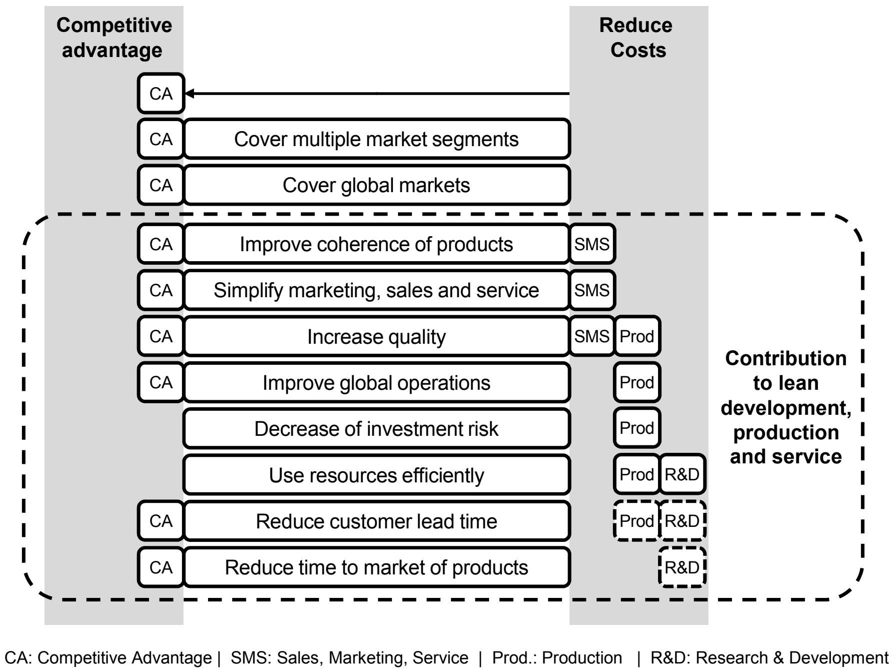
The above analysis of a practical example shows how product platforms support lean concepts in both product development and production. The case study complements the concept developed by Liker and Morgan (2011) that standardisation of the component and subsystem contributes to the lean process. Furthermore, using resources efficiently, reducing time to market and increasing quality with product platforms are core concepts of lean development in terms of creating value for customers through waste reduction (Womack et al., 1990; Karlsson and Åhlström, 1996; Liker and Morgan, 2006; Sobek II et al., 1999; McManus, 2005). This adaptation of the framework also shows how cost reductions and competitive advantages are achieved by Black and Decker. Therefore, it shows how product platforms' lean thinking helps companies to become more competitive and profitable in the market.

6 Conclusions

This paper presents the versatility of product platforms by exploring and identifying 27 effects of product platforms in the literature. In most papers, only a few effects are mentioned, however they differ from paper to paper. The developed framework fills a gap in the literature by showing the hierarchical nature and interdependencies of the product platform effects used in the argumentation and case studies in recent papers. A few other effects were also added to the framework to improve the structure.

A simplified version of the framework is shown in Figure 6. It considers only the effects that have a direct impact on costs and competitive advantage (the indirect effects were left out because they contribute to the direct effects). Obviously, the majority of the product platform identified effects seem to contribute to lean thinking and its application to product development, production and service (e.g. cost and time reduction, efficient use of resources, etc.). The previously discussed example of Black & Decker illustrates the idea of product platforms in terms of how they foster lean product development and production.

Figure 6 Contribution of product platform effects to lean development and production



The framework has managerial implications for senior managers as well as the project team in terms of providing motivation because outlining the possible effects of having a product platform can result in greater transparency and broaden the scope of the business. It is like a 'blue print' of possible product platform effects in a company. Later on, especially the simplified framework could be also used in evaluating the realised effects since the indirect effects of the complete framework were removed. Management can use these outcomes, develop product platforms as a resource (Harland et al., 2013) and incorporate them into their lean product development and production. Even by pressing ahead with product platform modification or expansion, management might complete the product development strategy by addressing previously neglected product platform effects; thereby the contribution of their PPDP can be enhanced.

The findings of the effects and the consistent framework developed broaden the field of product platform research because it is now possible to view product platforms as more than just a strategy for cost or time effective variant production. The findings can be considered a basis for investigating unexplored phenomena in relation to product platforms (e.g. effect of product platforms on logistics, procurement or sales and service). In the lean development and production literature, this research fills the gap of how product platforms foster the concept of lean production in firms.

However, the present work also has several limitations. In practice, there might be additional effects and relationships. Moreover, only positive effects are considered here; product platforms could also have a negative impact with respect to innovation risks or having too much commonality (e.g. lack of distinctiveness within a product family). Also, the possible external and internal factors and their influence on the expected effects are not considered. The research explains the link between product platforms and lean thinking, but it does not show how value is created for the customer.

Future research can be done to clarify the different product platform effects and the impact that they have in their respective areas (e.g. logistics, service). In addition, the framework can be tested and adapted to certain market situations. A classification of product platform project types could be useful for researchers and R&D managers to develop a better understanding of the potential benefits of product platform development. Finally, we see a better understanding of the impact of decisions in PPDP on the effects identified in the paper as a challenging target for future research.

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Appendix

No	*Effect*	*Synonymous word groups in papers*	*Reference*
1	Increase volume	(a) 'ramp up volume' (b) 'increased production volumes' (c) 'higher volumes' (d) 'high volume'	(a) Halman et al. (2003), (b) Jiao et al. (2007), Park et al. (2008), Zacharias and Yassine (2007), (c) Lundbäck and Karlsson (2005), Muffatto (1999), (d) Robertson and Ulrich (1998)
2	Increase revenue	(a) 'revenue enhancing' (b) 'maximise revenue' (c) 'increases revenues'	(a) Ben-Arieh et al. (2009), (b) Luo et al. (2010), (c) Ramdas (2003).
3	Increase market share	(a) 'increase market share' (b) 'takes away market share from competitors' (c) 'market share gains' (d) 'expand its market share'	(a) Kang and Hong (2009), (b) Chowdhury et al. (2010), Robertson and Ulrich (1998), Simpson and D'Souza (2004), (c) Johannesson and Claesson (2005), (d) Park et al. (2008)
4	Increase profit	(a) 'optimising profit' (b) 'increased profit', (c) 'maximise profits'	(a) Ben-Arieh et al. (2009), (b) Chowdhury et al. (2010), (c) Halman et al. (2003), Jariri and Zegordi (2008), Luo et al. (2010), Robertson and Ulrich (1998), Suh et al. (2007), Zhang et al. (2008)
5	Reduce (product) cost	(a) 'deduct cost to market', (b) 'reduce cost', (c) 'lower cost', (d) 'cost saving', (e) 'reduced cost', (f) 'reduce total cost' (g) 'low cost' (h) 'keeping cost relatively low' (i) 'cost reduction' (j) 'benefit in terms of cost' (k) 'cost advantage' (l) 'reduce cost by leveraging product' (m) 'product cost' (n) 'lower per product cost' (o) 'cost leadership'	(a) Abdullah et al. (2008), (b) Alizon et al. (2006), Ben-Arieh et al. (2009), Lu and Zuhua (2006), Qin et al. (2005), (c) Bhandare and Allada (2009), Lundbäck and Karlsson (2005), Qin et al. (2005), Meyer (1997), (d) Farrell and Simpson (2010), (e) Ye et al. (2009), Kumar et al. (2009), Li et al. (2008), (f) Khajavirad et al. (2009), (g) Liu et al. (2010), (h) Luo et al. (2010), (i) Muffatto (1999), (j) Olivares-Benitez and Gonzalez-velarde (2008), (k) Park et al. (2008), (l) Alizon et al. (2010), (m) Chowdhury et al. (2010), (n) Chowdhury et al. (2010), (o) Meyer (1997)
6	Reduce production costs	(a) 'produce product at low cost', (b) 'reduce production cost', (c) 'reduce overhead', (d) 'reduce manufacturing cost', (e) 'cost reduction in production', (f) 'minimising production cost', (g) 'cost saving in terms of material and scope', (h) 'reduction of cost in goods for product line'	(a) Abdullah et al. (2008), Gao et al. (2009), (b) Ben-Arieh et al. (2009), Simpson et al. (2006), Farrell and Simpson (2010), Alizon et al. (2010) (c) Chowdhury et al. (2010), (d) Farrell and Simpson (2003), Gonzalez-zugasti et al. (2000), Jariri and Zegordi (2008), Muffatto (1999), Meyer (1997), (e) Karlsson and Sköld (2007), (f) Ben-Arieh et al. (2009), (g) Otto and Hölttä-Otto (2007), (h) Meyer and Dalal (2002)

No	*Effect*	*Synonymous word groups in papers*	*Reference*
7	Reduce logistics costs	(a) 'lower cost in logistics'	(a) Robertson and Ulrich (1998)
8	Reduce procurement costs	(a) 'reduce procurement cost', (b)'significant economies in the procurement of components and materials'	(a) Lu and Zuhua (2006), (b) Meyer (1997)
9	Reduce development costs	(a) 'save the cost of redeveloping', (b) 'reduce development cost', (c) 'better leverage investment in product design', (d) 'reduce product development cost', (e) 'reduce cost in new derivative product', (f) 'develop product cheaper', (g) 'reduce fixed cost of developing'	(a) Abdullah et al. (2008), Gonzalez-zugasti et al. (2000), (b) Alizon et al. (2010), Ben-Arieh et al. (2009), Simpson et al. (2006), Chen and Wang 2008, (c) Halman et al. (2003), (d) Muffatto and Roveda (2000), (e) Muffatto and Roveda (2000), (f) Robertson and Ulrich (1998), (g) Krishnan and Gupta (2001)
10	Reduce sales, marketing and service cost	(a) 'lower costs in sales and service', (b) 'save significantly in operating, and marketing costs of new products'	(a) Robertson and Ulrich (1998), (b) Sawhney (1998)
11	Increase Competitive advantage	(a) 'creating a competitive advantage', (b) 'substantial competitive advantage', (c) 'offer competitive advantages', (d) 'enhance competitiveness', (e) 'ensure companies' competitiveness'	(a) Farrell and Simpson (2010), (b) Halman et al. (2003), (c) Ye et al. (2009), (d) Huang et al. (2007), (e) Liu et al. (2010)
12	Cover multiple market segments	(a) 'cover multiple market segments', (b) 'leverage strategy in different market', (c) 'satisfy a variety of market niches', (d) 'different market segment', (e) 'various market segment', (f) 'satisfy variety of customer need', (g) 'market segment grid to satisfy various customers need', (h) 'different market niches', (i) 'satisfy diverse customer needs', (j) 'satisfy different set of customers', (k) 'wide range of market segment', (l) 'variety of market niches', (m) 'diverse market niches', (n) 'satisfy diverse customer requirement', (o) 'other market segments'	(a) Alizon et al. (2010), (b) Ben-Arieh et al. (2009), (c) Simpson et al. (2006), Khajavirad et al. (2009), (d) Simpson et al. (2006), Bhandare and Allada (2009), Chen and Wang (2008), Gonzalez-zugasti et al. (2000), Halman et al. (2003), (e) Bhandare and Allada (2009), (f) Chen and Wang (2008), Gao et al. (2009), Jiao et al. (2007), (g) Fung and Chong (2007), (h) Liu et al. (2010), (i) Lu and Zuhua (2006), (j) Luo et al. (2010), (k) Park et al. (2008), (l) Shooter et al. (2005), Simpson and D'Souza (2004), (m) Wei et al. (2009), (n) Zha and Sriram (2006), (o) Meyer (1997)
13	Cover global market	(a) 'marketplace globalization', (b) 'international company to market their product', (c) 'globally rolled out product', (d) 'market place globalisation', (e) 'global market', (f) 'global market place', (g) 'international customer segment', (h) 'global marketing of product'	(a) Simpson et al. (2006), Chen and Wang (2008), (b) Simpson et al. (2006), (c) Halman et al. (2003), (d) Ye et al. (2009), (e) Karlsson and Sköld (2007), Qin et al. (2005), Zhang et al. (2008), (f) Kumar et al. (2009), (g) Sawhney (1998), (h) Sawhney (1998)

No	*Effect*	*Synonymous word groups in papers*	*Reference*
14	Reduce time to market	(a) 'deduct time to market', (b) 'reduce time to market', (c) 'decrease in time to market', (d) 'shrinking of design cycle', (e) 'shortening product development cycle', (f) 'time-cycle low', (g) 'positive impact on development time' (h) 'increase speed of new product development', (i) 'faster time to market', (j) 'reduce time', (k) 'reduce product development lead time', (l) 'speed up development', (m) 'reduce development time', (n) 'lead time reduction', (o) 'increase speed in product development', (p) 'reduce time in new derivative product', (q) 'benefit in terms of time', (r) 'launch new product variant quickly', (s) 'faster market response', (t) 'develop product faster', (u) 'reduce product development time', (v) 'decrease in development time', (w) 'new products can be developed more rapidly'	(a) Abdullah et al. (2008), (b) Ben-Arieh et al. (2009), Chen and Wang (2008), Martin and Ishii (2002), (c) Simpson et al. (2006), (d) Chandrasekaran et al. (2004), (e) Gao et al. (2009), (f) Fellini et al. (2006), (g) Johannesson and Claesson (2005), (h) Karlsson and Sköld (2007), (i) Koufteros et al. (2005), (j) Lu and Zuhua (2006), (k) Lundbäck and Karlsson (2005), (l) Lundbäck and Karlsson (2005), (m) Luo et al. (2010), Wei et al. (2009), (n) Muffatto (1999), (o) Muffatto and Roveda (2000), (p) Muffatto and Roveda (2000), (q) Olivares-Benitez and Gonzalez-velarde (2008), (r) Otto and Hölttä-Otto (2007), (s) Qin et al. (2005), (t) Robertson and Ulrich (1998), (u) Sawhney (1998), (v) Suh et al. (2007), (w) Meyer (1997)
15	Reduce customer lead time	(a) 'decrease lead time', (b) 'shorten lead time' (c) 'shorter lead time', (d) 'deliver them to customer as soon as possible'	(a) Alizon et al. (2006), (b) Kumar et al. (2009), Li et al. (2008), Wei et al. (2009), (c) Bhandare and Allada (2009), (d) Gao et al. (2009);
16	Reduce production lead time	(a) 'reduce the time to manufacture', (b) 'produce products at shorter time', (c) reduce production time	(a) Chandrasekaran et al. (2004), (b) Abdullah et al. (2008), (c) Alizon et al. (2006)
17	Reduce design complexity	(a) 'simplify design', (b) 'complexity reduction', (c) 'simplify conceptual design', (d) 'advantage of simplicity', (e) 'reduce complexity', (f) 'reduce complexity in product design', (g) 'minimising manufacturing complexity', (h) 'reduce managerial complexity', (i) 'product line complexity are decreased'	(a) Ben-Arieh et al. (2009), (b) Simpson et al. (2006), (c) Chandrasekaran et al. (2004), (d) Chen and Wang (2008), (e) Halman et al. (2003), Jiao et al. (2007), Krishnan and Gupta (2001), (f) Halman et al. (2003), (g) Kumar et al. (2009), (h) Muffatto and Roveda (2000), (i) Qin et al. (2005)
18	Reduce production complexity	(a) 'reduce system complexity', (b) 'reduce systemic complexity', (c) 'reduce development system complexity', (d) 'components variety makes manufacturing unnecessarily complex'	(a) Jiao et al. (2007), (b) Lundbäck and Karlsson (2005), Muffatto (1999), (c) Luo et al. (2010), Wei et al. (2009), (d) Meyer (1997)

No	Effect	Synonymous word groups in papers	Reference
19	Improve design flexibility	(a) ‘design flexibility’ (b) ‘flexibility capability into product styling’, (c) ‘flexibility of the subsystem’, (d) ‘designed with flexibility’, (e) ‘flexibility in product design’, (f) ‘reduce design effort for future generation product’, (g) ‘flexible product family architecture’, (h) ‘flexibility maintain on model change’, (i) ‘more flexible.. modular architecture’, (j) ‘improve business flexibility through scaling up and down’, (k) ‘flexible product design’, (l) ‘promote flexibility during change’, (m) ‘flexible design for product variety’, (n) ‘enhance product flexibility’	(a) Simpson et al. (2006), (b) Fung and Chong (2007), (c) Gonzalez-zugasti et al. (2000), (d) Halman et al. (2003), (e) Halman et al. (2003), (f) Martin and Ishii (2002), (g) Liu et al. (2010), (h) Muffatto (1999), (i) Muffatto and Roveda (2000), (j) Muffatto and Roveda (2000), (k) Suh et al. (2007), (l) Wie et al. (2007), (m) Zhang et al. (2008), (n) Zha and Sriram (2006)
20	Improve production flexibility	(a) ‘increase flexibility of manufacturing process’, (b) ‘enhance flexibility of manufacturing process’, (c) ‘improve ability to update products’, (d) ‘increase flexibility’, (e) ‘flexible manufacturing process’, (f) ‘increase flexibility and responsive of their manufacturing process’, (g) ‘increase flexibility and responsiveness of their product realisation process’, (h) ‘flexibility of the assembly and manufacturing process’, (i) ‘greater flexibility’	(a) Chowdhury et al. (2010), (b) Jiao et al. (2007), (c) Lundbäck and Karlsson (2005), Luo et al. (2010), Wei et al. (2009), (d) Luo et al. (2010), (e) Sawhney (1998), (f) Robertson and Ulrich (1998), (g) Shooter et al. (2005), Simpson and D’Souza (2004), (h) Zha and Sriram (2006), (j) Meyer (1997)
21	Increase product variants	(a) ‘several variant’, (b) ‘increase variant’, (c) ‘increase product variety’, (d) ‘large number of product variant’, (e) ‘enhance variant’, (f) ‘increase variety’, (g) ‘high variety’, (h) ‘several different models’, (i) ‘wide variety of variants’, (j) ‘wide variety of product’, (k) ‘large product variety’, (l) ‘company introduces streams of new products’, (j)’numerous derivative products’	(a) Ben-Arieh et al. (2009), (b) Simpson et al. (2006), (c) Chen and Wang (2008), Kumar et al. (2009), Shooter et al. (2005), (d) Gonzalez-zugasti et al. (2000), (e) Koufteros et al. (2005), (f) Li et al. (2008), (g) Liu et al. (2010), Sawhney (1998), (h) Lundbäck and Karlsson (2005), (i) Johannesson and Claesson (2005), (j) Zha and Sriram (2006), (k) Zha and Sriram (2006), (i) Meyer (1997), (j) Meyer (1997)
22	Increase Quality	(a) ‘high quality’, (b) ‘higher quality’, (c) ‘convey quality message of product brand’, (d) ‘significant effect on performance/quality’, (e) ‘increase product reliability quality rise’, (f) ‘benefit in terms of performance’, (g) ‘results in better architecture’, (h) ‘improve design quality of new product’, (i) ‘improve product performance’	(a) Bhandare and Allada (2009), (b) Koufteros et al. (2005), Qin et al. (2005), (c) Johannesson and Claesson (2005), (d) Liu et al. (2010), (e) Muffatto and Roveda (2000), (f) Olivares-Benitez and Gonzalez-velarde (2008), (g) Krishnan and Gupta (2001), (h) Sawhney (1998), (i) Meyer (1997)

No	*Effect*	*Synonymous word groups in papers*	*Reference*
23	Use resources efficiently (sustainability)	(a) 'better utilisation from limited resources', (b) 'full advantage of existing product resources in re-design', (c) 'utilise limited development resources', (d) 'efficient use of resources (cost & time)', (e) 'efficiency', (f) 'sharing existing resources', (g) 'without consuming excessive resources'	(a) Abdullah et al. (2008), (b) Gao et al. (2009), (c) Gonzalez-zugasti et al. (2000), (d) Halman et al. (2003), (e) Koufteros et al. (2005), (f) Park et al. (2008), (g) Shooter et al. (2005)
24	Reduce Risk	(a) 'reduce development risk', (b) 'marketing and technical uncertainties are lower', (c) 'lower risk'	(a) Gonzalez-zugasti et al. (2000), Jiao et al. (2007), (b) Koufteros et al. (2005), (c) Robertson and Ulrich (1998)
25	Decrease of investment risk	(a) 'The lower investment results in decreased risk'	(a) Robertson and Ulrich (1998)
26	Improve global operation	(a) 'greater flexibility between plants', (b) 'international operation'	(a) Muffatto (1999), (b) Muffatto (1999)
27	Improve coherence	(a) 'improve coherence'	(a) Sawhney (1998)