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Future-robust evolution of product portfolios: Need for action from theory and practice

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Abstract

The evolution of products is driven by changes in the economic and technical environments through cycles of varying speed. But companies must not consider each product in isolation, but as a part of their product portfolio to reflect cross-product dependencies and interactions, as they are highly interconnected. As a result of these changes, companies face manifold challenges in the future-robust evolution of their product portfolios in a disruptive environment. A volatile environment requires the overarching and resilient design of products and related production systems. This article addresses the research question: What are the theoretical challenges and need for action in the evolution of product portfolios? How do they compare to the articulated challenges and need for action from practice? We conduct a systematic literature review to identify the challenges from a theoretical perspective and compare the results with the insights of an interview study. Overall, a need of action for the development of methods, processes and models to support the evolution of resilient product portfolios emerges. Based on the identified research gaps and the concrete challenge fields, a systematic for future-robust product portfolio development will be developed in the following work.

Keywords: Product Generation Engineering; Strategic Product Planning; Product Portfolio; Product Portfolio Management; Corporate Foresight;

1. Introduction

The further development of the product portfolio is a task that contributes to the long-term success of the company [1]. Such a task is characterized by challenges such as shorter product life cycles, complex networked products, customizable products and a volatile business environment [2]. These challenges can soon no longer be met with conventional methods [3]. An interview study with seven companies showed that despite existing models and methods, challenges and needs exist in practice regarding the development of product portfolios [4]. Examining the current situation in practice, a consistent methodical approach to the further development of product portfolios is needed to address the current challenges [4]. MEYER et al. have specified that a descriptive model as well as a corresponding procedure model are necessary for consistent modelling [4]. The descriptive model has to be able to describe several generations as well as different development steps and the use of already existing systems, partly also retrospectively [4]. The procedure model has to enable the synchronization of the development of the product portfolio at all levels and align it to a common goal [4]. DOORASAMY also acknowledge that approaches are needed to develop the product portfolio at the various levels across multiple generations [5]. The present contribution extends the findings from the interview study with company focus as presented in [4] by the problems and challenges from theory. In order to be able to develop suitable methods for the development of product portfolios, existing approaches, from the fields of investigation, as well as resulting challenges have to be considered.

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2. Theoretical Framework

A model that represents a descriptive character for the development of products and systems is the model of SGE - System Generation Engineering according to ALBERS that can be used to describe any type of product development [6]. The model is based on two hypotheses: (I) Every development is based on a reference system. The reference system for the development of a new system generation is composed of elements of already existing or planned systems [7]. (II) The development of a new system generation is based on the reference system through a combination of three types of variation [6,8]. Furthermore, there are descriptive models for the structuring of product portfolios. According to KRAUSE and GEBHARDT product portfolios are divided into the levels product line, product family and product [9]. Models such as the PSM-Program Structuring Model according to JONAS provide a basic structuring of the product portfolio, but do not focus on the relationship and further development of the portfolio elements on different levels [10].

As MEYER et al. stated, the descriptive model alone is not sufficient. It also requires a process model for the further development of product portfolios [4]. The requirement here is a reference process that provides information about tasks and activities in the derivation of goals for the further development of product portfolios. For the derivation of future relevant properties to specify the system of objectives of an individual product, models also already exist, such as the reference model of strategic planning and integrative development of market offerings according to GAUSEMEIER [11]. Strategic product planning (SPP) represents the first step in product development according to the reference model of GAUSEMEIER. SPP is further subdivided into three main tasks; foresight, which aims to identify future needs; product discovering, which forces the derivation of initial product ideas; and business planning, which addresses the accompanying business models [11]. The strategic product planning specifies various tasks and activities with the aim of specifying the system of objectives in the early phase of product development. Approaches exist for the further development of product portfolios, such as the strategies in product portfolio development according to ANDERSSON [12]. The strategies include initial recommendations as to whether a portfolio should be expanded or reduced [12]. Approaches such as the "procedure for the sustainable product portfolio planning" according to SÖLLNER combine steps in the development of product portfolios based on scenarios as an element of the methods of foresight [13]. DÜLME, has developed an approach for the future-oriented consolidation of multi-variant product programs [14].

These approaches focus on strategic development but do not take into account the impact of various influences on the overall portfolio, such as new technology trends or legislation. In addition, the aforementioned approaches largely do not consciously work with reference-based development of products, as would be conducive to efficient development. The resulting need for investigation can be concretized for the systematic literature review on the three relevant fields of investigation as shown in figure 1.

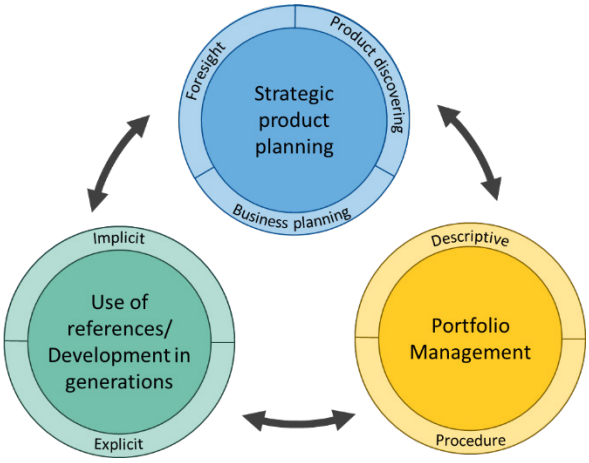

Fig 1. Relevant fields of investigation

3. Research Design

The literature review aims to identify the challenges and needs for action from theory and to cluster them into key challenge fields. Existing approaches are to be compared with the fields of investigation based on the identified needs for action from practice [4]. The research process is based on the approach of WEBSTER & WATSON as shown in figure 2 [15].

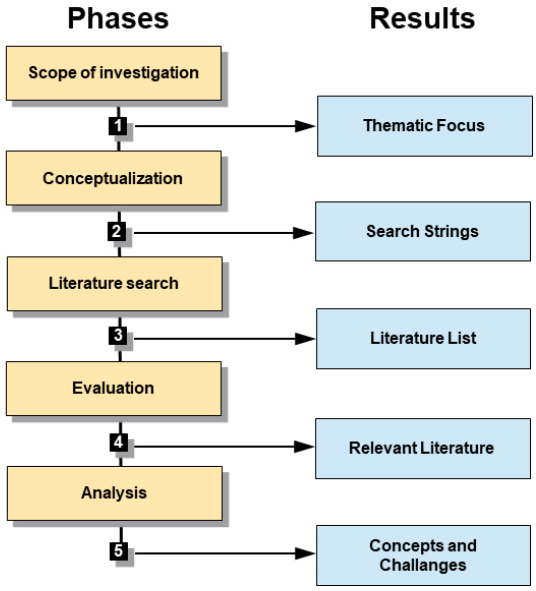

Fig. 2. Phases and results of the literature review [15]

At the beginning, the scope of the literature search was defined. By means of an initial literature scan, it was agreed to consider product portfolio management in the context of strategic product development and generational development, as stated in the theoretical background. After defining the scope, a search string was defined:

"Future Robust Product Development" OR "Product Generation Engineering" OR "System Generation Engineering" OR "Product revolution" OR "Strategic Product Planning" OR "Product Portfolio" OR "Product Portfolio Development"

At the beginning of the third phase the search string is used to perform a literature search in the Scopus database. The initial

result was 1429 articles. After eliminating duplicates, non-specialized, and non-German or non-English titles, 901 articles remained. These 901 articles where then evaluated independently by two persons. In the first step, the articles were filtered on title level. The relevance of the articles was rated on a scale of 0-2; 0 points: Not relevant; 1 point: Potentially relevant; 2 points: Relevant. The result of the first iteration provided 126 articles that were (potentially) relevant at title level. Subsequently, the results were evaluated at abstract level in the second iteration. For this purpose, the abstracts were each read twice and then classified as relevant or not relevant. The second iteration yielded 60 articles that were relevant for the full text analysis. For the full text analysis, the fields of investigation mentioned at the beginning were used again. The articles were read and it was seen whether the content of the text coincided with one or more of these terms. After full text review, a base of 43 relevant articles remained.

4. Results

The results of the literature review are evaluated in table 1 according to the fields of investigation derived in chapter 2. The share at the end of table 1 shows the contributions that meet the category based on the field of investigation.

Table 1. Evaluated literature in the analysis

	References/ Generations		Strategic product planning			Portfolio Management		
	Explicit	Implicit	Foresight	Product discovering	Business planning	Descriptive	Procedure	
1	✓							[16]
2	✓							[17]
3	✓				✓			[18]
4						✓	✓	[2]
5					✓	✓	✓	[19]
6						✓		[20]
7					✓	✓	✓	[21]
8							✓	[5]
9				✓	✓	✓		[22]
10	✓		✓			✓		[23]
11					✓	✓		[24]
12						✓		[25]
13					✓	✓		[26]
14					✓	✓		[27]
15					✓	✓		[28]
16					✓	✓		[29]
17					✓			[30]
18					✓	✓	✓	[31]
19					✓	✓	✓	[32]
20						✓	✓	[33]
21						✓	✓	[34]
22					✓		✓	[35]
23					✓	✓		[36]
24					✓	✓	✓	[37]
25					✓			[38]
26				✓			✓	[39]
27					✓	✓	✓	[40]
28					✓		✓	[41]
29					✓	✓		[42]
30						✓		[43]
31					✓	✓	✓	[44]
32		✓		✓				[45]
33					✓			[46]
34					✓	✓	✓	[47]
35		✓		✓				[48]
36		✓				✓		[49]
37					✓	✓		[50]
38					✓	✓		[51]
39					✓	✓	✓	[52]
40					✓	✓		[53]
41						✓		[54]
42					✓	✓		[55]
43				✓		✓		[56]
Share	9%	7%	2%	12%	63%	72%	37%	

5. Discussion

(1) Product portfolio structure

A fundamental challenge is how a product portfolio is described. According to ESMAEILI und ARJMAND a successful product portfolio combines the views of marketing view and engineering view on a product portfolio [24]. This requires a close discussion between marketing and engineering issues, referred to as customer engineering considerations [57,58,59] [24]. LATHINEN distinguishes by R&D or NPD portfolios. [60], [61,37]. Within these views, the product portfolio is divided into different levels. According to LAHTINEN into product lines [62] or product families [63,37]. This view is in line with the results of the interview study [4]. Subdivision by principal layout, architectural-, functional- and physical variance is also possible. [52]. Analogous to this, levels of abstraction can also be subdivided [53]. According to MORGEN and REGO the size of a product portfolio is defined by the number of variants [64,56].

(2) Forces triggering product portfolio evolution

Product portfolio development is a dynamic decision-making process [65]. Four main goals of product portfolio management (PPM) are summarized by COOPER: "(1) Value maximization, (2) Strategic choice, (3) New product and technology choices and (4) Balancing resources" [40]. Central forces for further development of product portfolio are technological and market-oriented uncertainties to be handled [16]. New technology often results in the adaptation of subsystems. One challenge here is the integration of the new technology into adjacent systems [45]. In B2B markets, decisions were mostly based on organizational needs and objective criteria and continuous technical improvement [66]. Completely newly developed releases as well as technologies are rare and cannot be considered as continuous development. [47]. Technology thus represents one of the main triggers for further development, such as the enhancement of physical products with IoT [11,25]. Two approaches are important to address the triggers, the dynamic interactions of competing firms in a market as well as the organizational competencies of a company [56].

(3) Product portfolio evolution process

HARKONEN et al. propose an approach to productization, this is usually interpreted as the process of transforming customer needs into a saleable product offering [67]. The productization with the product structure concept has been studied for manufactured products [68] and for service products [67,69,37]. The further development of a product portfolio should be supported by targets and KPIs. monitored by tracking the number of items on each level. Increases or decreases of items would indicate the direction of the company's product offering. The goal is to reduce internal diversity while maintaining external diversity. This is enabled by focusing on the most essential and profitable functionalities [37]. It is not only the number that is decisive. Developing new products by adapting existing products as far as possible can reduce development risk and associated costs [70,71]. ECKERT and ALBERS point out that product development in most cases consists of improving existing products [71,17,18]. Functionality and architectures often do not change significantly over product generations, while detailed designs may [72,73]. With a modular approach, modules can therefore evolve independently and be replaced by upgrades as needed [74]. One approach for standardization in the context of design is to define a product architecture and create multiple variants from the same base product. [75,52]. The use of established product portfolio management methods is useful for the simultaneous assessment of strategic, market, technology and risk factors as well as the economic return of the product portfolio [76]. It is important that the use of these methods is easy to understand and apply [31]. Current literature defines PPM as managing to prioritize investments and resources for the highest-potential product development [51].

(4) Internal and external challenges

TOLONEN has listed some of the current challenges, for example undefined product portfolios, lack of portfolio level business case thinking, unplanned product lifecycles leading toward portfolio explosion and classified five groups: 1) generic, 2) target setting and KPIs, 3) ownership and governance models, 4) processes and methods and 5) data availability [77,37,51]. The biggest challenge for manufacturers is to strike a balance between resource constraints and customer preferences [5,24]. Further triggers are considered as a result of the systematic literature search. **Customer requirements:** Customer wants the price as low as possible but many functionalities. On the other hand, developers need resources to implement the functionalities [43]. Companies have to address customer needs in order to survive in the face of competition. In line with the environment, the product portfolio is becoming more dynamic and tends to be deeper, while complexity is continuously increasing [44]. At the same time, however, a wide range of variants can confuse the customer [22]. The need for mass customization is increasing [47,44]. This trend is countered by unnecessary growth of many different variants [78,79,55]. **Complexity**: Products with a large number of subsystems and interdependencies between technology and market create a high degree of complexity [2]. The challenge is that there are too many projects for different parts of the product portfolio. As a result, projects are often understaffed, receive too few resources or the time to market is too high [19]. The goal, therefore, in a complex portfolio with a limited budget is to maximize capacity saturation, customer attractiveness, and profit [2]. **Knowledge in product development:** Gathering and processing external knowledge for product development is a challenge [41]. Lack of knowledge leads to an inability to assess the value of product opportunities and allocate resources to projects appropriately [21]. PPM without data utilization can lead to an portfolio explosion, cannibalization and financial failure [27]. A scattered data base makes it difficult to identify commonalities in product lines, families [52]. The scattered data base sometimes leads to a lack of understanding and visibility of the interrelationships of the technology. This in turn results in engineers designing new components and modules for new products instead of relying on existing technical elements. There is a need for a uniform system for the use of references [37]. **Measurement and decision making:** The prioritization of the strategic fit is unclear or ignored in some places. It makes sense to take a broad view of KPIs [37]. 58% of development projects fail, due to wrong decisions in the earlier development phase [19]. Executive teams indicated that there are often no serious criteria for a "go/kill" decision. As a result, companies cannot make targeted decisions about the number and priority of projects [5]. Volatility complicates investment decisions for development projects [19]. Increased number of internal variables for "go/kill" decision due to increased number of products, attributes and levels requires complex modeling [20]. **PPM effort:** Many of the theoretical methods have not been applied in companies due to their complexity [31]. PPM has to fulfill three basic goals: strategic alignment, balance, and maximized portfolio value [32]. Integration of PPM represents increased effort for larger companies because e.g. multiple departments are involved [33]. The dimensions cover methods, organization and strategy [31]. However, in some places methodology is neglected in portfolio decisions [32]. The concept of PPM as well as the difference to product management is not properly understood and implemented in the companies [55]. **Product life cycle**: Monitoring of the product life cycle is neglected in the later stages, which has a negative impact on productization [37]. In addition, the lifecycle costs can often not be determined precisely [29]. Costs such as life cycle costs are determined by product diversity: Accordingly, greater product variety leads to higher costs [36]. **New technologies:** New technologies can come from outside or from the company's own inventions [18]. Digital transformation and continuous validation are key challenges in the further development of product portfolios [23,16]. The product complexity and networking to manufacturing processes often require a simultaneous development of product and production system to realize the potentials [17]. Therefore, there is a need for synchronization of portfolio management over lifecycle phases [51].

(5) Strategies for overcoming challenges

According to PORTER, there are two main strategies companies can follow: differentiation or cost leadership to avoid being "stuck in the middle" [80,36]. Product portfolio management is more demanding to handle than single product development due to the consideration of multiple products at the same time [40]. Strategies in managing product portfolios are, for example, prioritizing products using the horizon approach.

Short horizons are financially motivated and longer horizons are strategically motivated [34]. Prioritization of products via batch sizes [46] or standardization methods with regard to modular platform-based designs are also common [49]. Especially then formalization is an important influencing factor in product evaluation [33]. For Example BERTSIMAS and SIM introduced a general formulation for robust optimization [81,26]. The complexity in product portfolios often requires the support of mathematical approaches to optimize the portfolio [50]. With regard to the challenge of digitizing product portfolios, ECHTERFELD shows four phases and combines proven methods such as scenario technique, customer value analysis and roadmaps for digitizing portfolios [23]. One concrete approach is the "Regret Minimization Approach" to calculate the probable losses of each possible portfolio and pick the best portfolio according to the lowest loss [24]. Strategic variant management methods can be used as a steering and control instrument for the further development of product portfolios [44]. The central objective of variant management is to determine the optimum number of product variants [47].

6. Conclusion and Outlook

The systematic literature review and subsequent discussion of the identified papers screens the existing methods and challenges in the further development of product portfolios and complements the challenges identified in MEYER et al. to the need for action from theory by five fields of challanges. In the systematic literature review 1429 papers were evaluated using the rating scheme; 0 points: Not relevant; 1 point: Potentially relevant; 2 points relevant. The 43 relevant papers were considered according to the relevant fields of investigation derived in the theoretical background based on the interview study (figure 1): use of references/development in generations, strategic planning of products, and considering multiple products in terms of portfolio management (table 1). During the review of the relevant 43 papers, we identified further challenges and needs for action. These were divided into the fields of: (1) product portfolio structure, (2) forces triggering (3) product portfolio evolution, (4) product portfolio evolution process and (5) strategies for overcoming challenges.

The systematic literature review shows that, using the search string provided, no approach could be identified that met the criteria of using references, strategic planning activities, and an overarching approach to description and process model. At the same time, the need for action in the development of methods for the development of product portfolios was specified and extended by five challenging fields. Based on the findings in this paper a systematic for future-robust product portfolio development will be developed in the following work.

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