Matching Product Flexibility on the Integrated Portfolio of a Product-Service-System

R. Orawski, C. Hepperle, S. Schmitz, M. Mörtl, U. Lindemann
TU München, Institute of Product Development, Boltzmannstr. 15, 85748 Garching, Germany
robert.orawski@pe.mw.tum.de

Abstract

This paper deals with the question, how a product-service-systems portfolio could look like and which approaches in product flexibility are already existing that can fulfil the requirements of such a tool for the early planning. The reoccurring possibility of changed circumstances, known as cycles during the innovation process, are translated into criteria, with which the suitability of the flexibility approaches can be checked. The worked out recommendations are combined to a holistic entity for structuring the various granularities of a PSS referring to the Munich Model of Product Concretization. Thus, this paper sets up a basis for facing the challenge of product flexibility already in the early stages of systematically planned product service systems. This supports a higher degree of flexibility for the stakeholders throughout the lifecycle and thus also allows faster responses to market needs.

Keywords

PSS-portfolio, Product Flexibility, Innovation Process, Integrated Product Development

1 INTRODUCTION

1.1 Motivation

Today's products and corresponding innovations processes are characterised by an increasing level of complexity. The same applies for combinations of products and services and even more for integrated product-service-systems. Proper handling of the design process gets more ambitious with every PSS generation. Further, companies face the challenge to be able to quickly respond to altered market conditions in a fast changing environment. Hence, the new and modified requirements created out of it, have to be adopted in amended product-service-systems. Equally, throughout the same market developments, the planning horizon of a PSS-strategy is shorter and more intricate than several years ago. The amount of different varieties in a company offered to market is increasing exponentially due to diversified market needs and stronger competition. On the one side, customers have the ambition to satisfy their special needs with individual solutions. Beyond, a globally acting company faces the needs of very heterogeneous customer groups. On the other side, stronger competition in a globalized economy pushes companies into market niches in order to reach the broadest diversification for higher turnover.

Hence, the companies have to deal with higher developing costs in order to get these varieties to market. The expenses depend on developing the option itself, the fixed capital deriving from reserved resources i.e. the production tools or service personal and the variety management which has to deal with many different products. Therefore, a key issue of the persons involved in the planning phase is to decrease these costs to preserve the financial flexibility of a company. As new variants costs money in the whole process from a first idea over development, production, utilization to even recycling, it is essential to discover the right choice of products and services which are provided to the customer. Following the creation and concretization of PSS-ideas, the question arises how to deal with them.

1.2 The PSS-portfolio as a solution to changed circumstances

Mass Customization [1, 2, 3] is a well documented approach on this problem. The area of conflict exists in the coordination of mass production efficiency with individualized products. Product flexibility guarantees decreasing the influence of this conflict by analysing i.e. functions or modules, separating and comparing them. Therefore, they provide a method to handle variants regarding commutability, changeability and interconnection.

A difficult contribution to the increasing complexity of products mentioned above is an aspect of the product itself. Products are widely acknowledged as final outcomes of material. This is not sufficient enough anymore. The near past has shown a movement in companies to provide packages including products and services. These so called product-service-systems (PSS) mean new requirements to companies. The point of view got more unclear to the development department. As there was always the distinct imagination of something palpable, now the connections between products and services are abstract.

The idea of a portfolio addresses the need of a representation of the image of all the provided product-service-systems by a company. It must be capable to handle new variants and be able to point out common parts as well as connections between them. As for the early planning, products and services have to be distinguished in their degree of maturity as changes during the development process may occur in different phases. That poses the question how such a portfolio can be structured in order to handle these requirements. A reasonable way doing so can be derived from the well-described approaches for product flexibility which deal with similar requirements. Though, the initial position is a different one. PSS-projects demand different output than provided by most of the methods for product flexibility. This work examines the requirements of PSS represented by the chosen criteria being fulfilled by the examined methods.

Specifying, the approaches to product flexibility need an analysis if the service component fits into the changed requirements of a company as the requirements to product flexibility changed itself. The product spectrum [4, 5] describes an image of the products, which are established in an enterprise. This means the sum of products in market, product concepts in development and the product ideas a company is able to bring to market. With this potent method, there is a way to illustrate the different product varieties with the focus on the product structure and the differentiation within. The considered characteristics reflect several specifications and are shortly outlined in Figure 1 and with an example (car) for better understanding in the following. There are the compulsive parts (chassis), the mandatory choice of parts (engine), optional parts (parking assistant), etc. In other words, a product spectrum is a reflection of the potential of a company.

The posed challenge is to include services as a fully integrated product specification unlike an additional option which can be chosen or not. This poses as well challenges on a product spectrum with which it cannot handle. Therefore, a PSS-portfolio is suggested that can provide information in the early phases of development. As service development differs from that of a product, the innovation processes of product and service must be aligned. The second aspect of the PSS-development which has to be satisfied is the consideration of interconnections between steps within the integrated life cycle. I.e. the answer to the question has to be given which cyclic change in the use behaviour – so the utilisation phase of the customers can be anticipated and therefore included already in the early planning and therefore in the appearance of the suggested PSS-portfolio. Because of the absence of an integrated PSS life cycle, there is used a detailed product life cycle [6] which fits the requirements sufficiently. This work is motivated by the participation in the collaborative research centre 'Sonderforschungsbereich (SFB) 768 – Managing cycles in innovation processes – Integrated development of product-service-systems based on technical products'.

The goal is to develop a method that is able to deal with an integrated approach on product-service-systems and to handle changed circumstances in strategic alignments of a company regarding the satisfaction of market needs. The idea is to combine approaches on product flexibility with the product spectrum in order to achieve a method that can master the new complexity of challenges in the early phase of developing product-service-systems including cycles in regard of the SFB.

2 FLEXIBILITY IN THE INNOVATION PROCESS

2.1 Methods of product flexibility in literature

The fundamentals for product flexibility throughout the innovation process should already be stressed in the early phase of strategic product planning. In the past, various approaches in respect to product flexibility have been researched and published. In particular product families, product platforms, and approaches concerning mass-customization and strategies for individualizing products have been analysed in detail and can be found in sufficiently high numbers in literature [7, 8, 9 ,10, 11].

Mass Customization has been a massively developed area in product development since two decades. The advantages of the combination of mass production and individual products are obvious. Diverse approaches concerning product flexibility have been discussed in the industrial and academic world. Product platforms [12] compose the basis for competitive shares of product portfolios. The multiple applications of the same parts allow higher outcome numbers in production. Product families [13] offer the possibility to diversify a certain product in order to satisfy special customer needs without developing completely new products. Modular assembly systems [14] provide specific interfaces between modules. These modules themselves are able to have variants within.

As a general overview, Figure 2 shows an abstract of analysed methods and their time reference. The lines represent the development of a method. The regarded publication is marked with a small box. Boxes without a specific name indicate publications with only small reference or small further development to the methods taken into consideration.

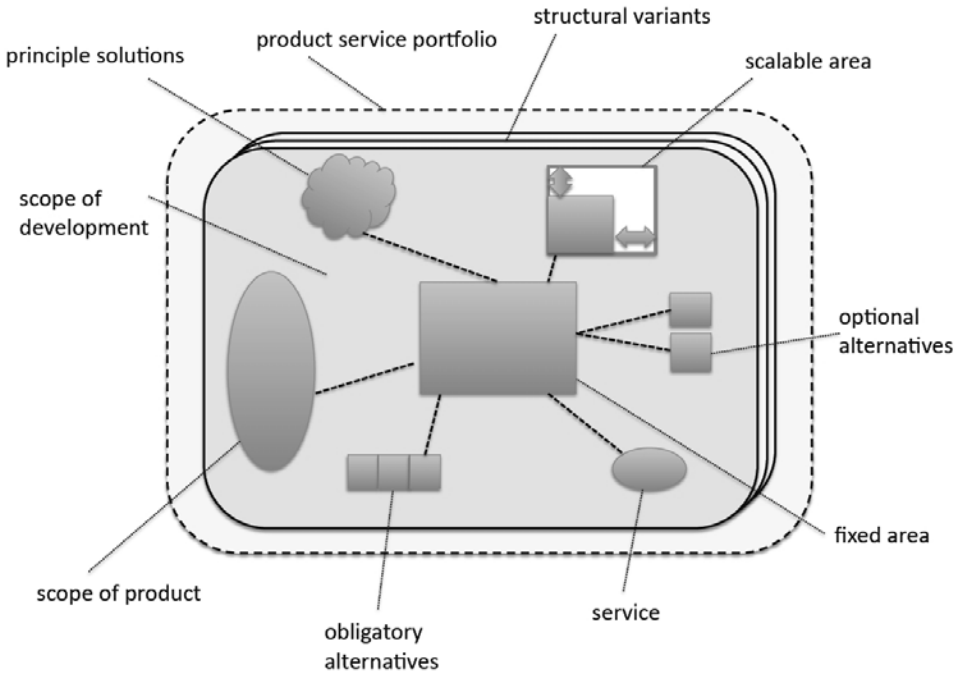

Figure 1: The product spectrum with its dimensions [5]

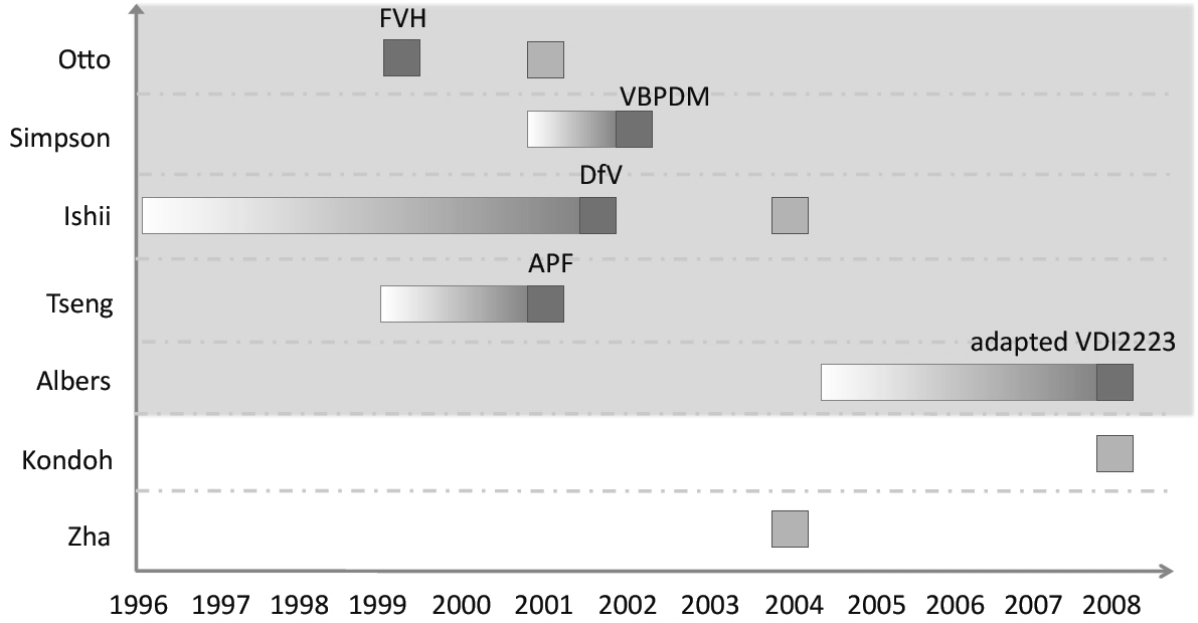

Figure 2: A chronology of product flexibility

The four methods which are taken into account in this paper give an overview regarding the steps of planning of a product. These five examples which only represent a small part of the published work in this research domain represent work which has its foci in different phases of the innovation process. From the requirements level through the function and behaviour level to the structure level in the Munich Model of Product Concretization model [15], each method represents a concretion level.

Focusing on the function level, Zamirowski and Otto [16] are introducing the function variety heuristics method (FVH) dealing with functions and possible modularization of them. Combining costumer needs with product function architecture, the authors propose to develop monolithic product architectures. With the overview of all functions, one can identify product modules which are separated from the product platform.

Martin and Ishii [17] introduce a method for standardizing and modularizing product platform architectures. Existing products are analysed and improved with a focus on the design for variety (DfV). The detailed work presents two indices with which it is possible to identify decoupled architectures with lesser design effort for new generation products. The generational variety index is a measure for the effort which is needed to develop new generations of products. The coupling index is a factor for the interactions of the individual components of a product.

With the described interest in early planning methods, the work of Albers et al. [18] gives an interesting approach on modularization adapting the German guideline VDI 2223 [19]. The interactions between the components are analysed and clustered. The clusters feature a small number of intercluster connections and a high number of intracluster connections.

Du et al. [20] provide a conceptual approach on architectures of product families (APF). The described characteristics and procedures supply designers with a tool for the improved design of product families. The proposed Generic Product Structure is explained as a platform for adjusting products to individual customer needs. The well-elaborated state of the art review provides the reader with an interesting overview of research work done in the last years in this field.

3 EVALUATION OF APPROACHES ON PRODUCT FLEXIBILITY REGARDING THE IMPLEMENTATION IN A PSS-PORTFOLIO

3.1 Approach

In order to extract a sophisticated method to analyse given models of innovation processes, there has been developed a selection of specific criteria, which help to appraise in which way and to which extent the analysed model can be helpful in solving the problem discussed before. The paper compares and opposes in how far the existing approaches are suitable for consideration in the context of early planning of integrated product-service-systems. Thereby, it is focused on if these methods are suitable to represent integrated product service systems, i.e. if the existing methods on product flexibility are capable of representing both products and corresponding services. Further, it is analysed how different aspects from the various lifecycle phases of a product service system can be considered within the respective approaches. For example, it is of interest to which extent the they are able to take various specifications concerning the development, production, distribution, utilisation, maintenance, modernisation, recycling and disposal of the product service system into account. Thereby, it is also analysed in how far cycles (i.e. recurring processes and artefacts) within the lifecycle phases can be represented within the different methods concerning product flexibility. Besides the consideration of cycles within the lifecycle phases, the comparison of existing methods is also directed on the cyclic behaviour in dealing with the process steps within the methods itself. Thereby, it is of interest how often and to which extent representation models of the respective approaches have to be adapted due to new and changing market needs and corresponding product potentials and product ideas. It implies the answer to the question, to which level and to which frequency, the connection between strategy phase, planning phase and design phase has to be considered in

the innovation process.

3.2 Introducing criteria for the PSS-portfolio

For evaluation of the regarded methods, there were gathered 45 criteria, which represented the characteristics of a suitable approach for a PSS-portfolio. These criteria strongly correlate with the requirements of a robust product service portfolio as introduced before. After identifying and weighing these criteria, they were combined into six clusters, which shall be presented as follows:

1 The initial criterion 'Categories' is meant to structure the methods according to their focus and their aim. The main question to be answered here is: Why and what for is the method being used?

2 The 'Point of View and Time' covers the different perspectives of the method. Namely ranging from the level of abstraction the level of detail, the development stage to the consideration of cost, this cluster combines all these in order to help to classify the methods even when using several different and independent methods.

3 The 'Input and Origin' cluster regards the question, where the information which is required by the method is coming from and how concrete it is. On the one side, information as input of a method is considered and checked. On the other side, the origin of a new planning process is taken into account.

4 The section 'Implementation' deals with the integration of the method especially with the procedure and the flexibility of the method.

5 The cluster 'Flexibility' only regards the category which deals with the product design. It does not cover the flexibility of the method since that is part of the implementation process. Here, adapting and adding functions are specified since they can measure the flexibility of the product design.

6 The final category 'result oriented" rounds up the list of criteria to evaluate the methods. It deals with the effort of the documentation process and the results of the methods in general.

3.3 Matched correlations of method for product flexibility and PSS-portfolio

The evaluation of the considered methods shows a shared optimum between the four concepts. Hence, there is no method which meets the requirements of the chosen criteria in all categories. The four most interesting methods shall be displayed regarding their performance in each of the clusters.

1 Almost all methods can deal with the product, service and both at the same time. The adapted VDI 2223 is the only one that cannot deal with the service due to the mathematical approach for the generation of a product service portfolio or due to a too low level of abstraction.

2 As expected, all methods can easily handle the requirements as a level of abstraction. The requirement level is mentioned in every single method. Almost the same status can be found for the functional level. All methods can perfectly handle the functional level of abstraction. This trend continues for the behavior and the structure.

3 For most methods, it is difficult to deal with or aim for undefined customer wishes. However, the method FVH is using market research and surveying techniques. This shows the intended importance of identified costumer needs. Therefore, FVH awaits an input on the highest level of abstraction. DfV is also able to handle soft and unsharpened customer wishes with which the development team has to deal further. Undefined wishes can be translated to formulate statements that are necessary for the further development. In comparison to the rest, the adapted VDI 2223 has the lowest possible input compared to all other methods. It is waiting for a specific behavior, given parts or a sub-assembly. Hence, the input for the method already is already a basic solution.

4 The category implementation focuses on the procedure and aspects of the method itself rather than the PSS-portfolio. Thus, the procedure of the method as well as its flexibility and adaptability are covered here. The first two attributes cover the polarity of simplicity and complexity. The APF, DfV and adapted VDI 2223 are well explained, deal with known information only and have no or not much internal dynamics. The FVH is a more abstract method that processes everything on a higher level. In order to stay on track, it is important to follow the steps accurately. Therefore, this method is a slightly complex one.

5 A central point for the PSS-portfolio is the adaption of functions which has to be possible in order to handle a progress through time and changed requirements. DfV and the adapted VDI 2223 only need a decent amount of work load to change the functions of an existing structure. The influence of parts and functions from or on other parts cannot be proven in the APF and the FVH. DfV is the most prominent example for this attribute using the so called coupling index between the parts and functions. The adapted VDI 2223 knows what functions or parts affect each other due to the use of a design structure matrix for displaying dependencies.

6 The FVH and adapted VDI 2223 are the only ones that need to be interpreted. For FVH the result is complex, thus, not visible straight away. Albers et al. show a matrix combined with a graph, that needs interpretation and verification before the development of the product can start due to a possible misleading of the modularization process. On the other hand, the generic product structure discussed in Du et al. gives all information in a compact figure. DfV does not miss to give the developer the results of the generational variety index but suggests concrete options of how to continue. It is positive to see, that all authors reflect on the method and highlight this by a perspicuous example. However, plausibility checks with the results are missing. Not every method guarantees a continuous work with its result. The DfV method leaves the user with several options that are not part of the method anymore but have to be performed in order to continue the development process.

The question about the possibility to add functions to the product service portfolio plays an important role for its success. However, it is the most difficult question to answer as many papers don't mention a lot about it. Initially known functions can be added fairly easy to the product service portfolio as they have been kept in mind and considered all along the product planning and product development and design process. The amount of effort is higher than the effort to adapt a function, but it is still manageable. However, if functions are initially unknown, it is impossible for any of the five methods to add a new one without having to rerun the method. In this case a new product service portfolio has to be generated and the entire process starts over again.

3.4 Combining the analyzed methods to a heuristic approach

As the results have shown, a single product flexibility approach appears not to be sufficient to meet the

demands of a PSS-portfolio. It is shown, that different methods comprise different foci during product planning and are therefore not redundant or superior to one another but rather ancillary. Taking the phases of product planning into account like they are introduced by Ponn and Lindemann in the Munich Model of Product Concretization with its generic classification of different levels of abstraction during the planning of product-service-systems, each of the analyzed methods arranges itself differently in the levels function, behavior and structure.

The method of function variety heuristics meets the requirements of the abstract level of the planning process. The functions are still neutral and can be filled unrestrictedly with various technical and service solutions. As functions are the direct interpretations out of the requirements level, handling them suits better to the FVH than to the other analyzed methods and are therefore chosen as the beginning method for the classification of a PSS-portfolio. Regarding the requirements of a PSS-portfolio, the stage of a structured portfolio during the early planning phase of a function structure is given by the FVH.

As for the behavior level, the Design for Variety method is chosen. The focus of this method is the handling of technical and service solutions. With the various indices that describe the interconnections between components and the behavior of single components, the DfV is a powerful tool, to build an image of the existing PSS-portfolio at this level of abstraction. Again, regarding the requirements of a PSS-portfolio during the planning phase, in which the behavior structure is compiled, the DfV acquires an entire image of the technical or service solutions available.

The adapted guideline VDI 2223 by Albers deals with the structuring of the very specific properties of a PSS. As the method is very potent in characterizing different variants regarding i.e. the package size or the performance value, the usability is restricted to the product side of a PSS. The service side is hard to divide in numbers or values and is therefore, mostly, not suitable for a modularization of service parts of the PSS. Nevertheless, there can be entire PSS-concepts with reasonable need for the adapted VDI 2223.

4 SUMMARY

4.1 Conclusion

Connecting three methods together to get an integrated and continuous portfolio, there has to be a tool, with which the parts can be aligned. During research, the analysis has shown, that the also examined method of architecture of product families has the characteristics of a meta method. It provides the language for the other three methods to define incoming and outgoing information and therefore joining them into a whole consistent method. Figure 3 outlines the arrangement of the analyzed methods. As the characteristics used by APF, the other three methods have to be adapted in order to meet these requirements. This will be part of future work. The common language is necessary to develop analysis and controlling tools within the portfolio as same as between various portfolios.

Configurating an image of the aligned balance of the potential of a company and the needs of the customer, the portfolio describes an important instance during the PSS-planning process. With it, it is possible to estimate the effort which is required to change an existing potential of a company in bringing a PSS to market and the work that has to be done in order to fill the white gaps, which are not covered by resources, knowledge or capacities in the company.

Along, the impact of specific changes coming from cyclic interconnections can be damped, because it is more obvious to the planning team where this impact takes place. Even more, anticipated changes will be already included in a continuously updated PSS-portfolio. The result is the reduction of time pressure in the development process, because expansive iterations will be avoided and further, aberrations of PSS are minimized.

4.2 Future Work

As mentioned before, the four identified methods are building a base for the structure of a PSS-portfolio. Though, it is necessary to define exactly the information which is handled between the three stages of function, behavior and structure and shall be part of future work including an example from an analyzed portfolio in the industry.

Further research will take the results in this paper into

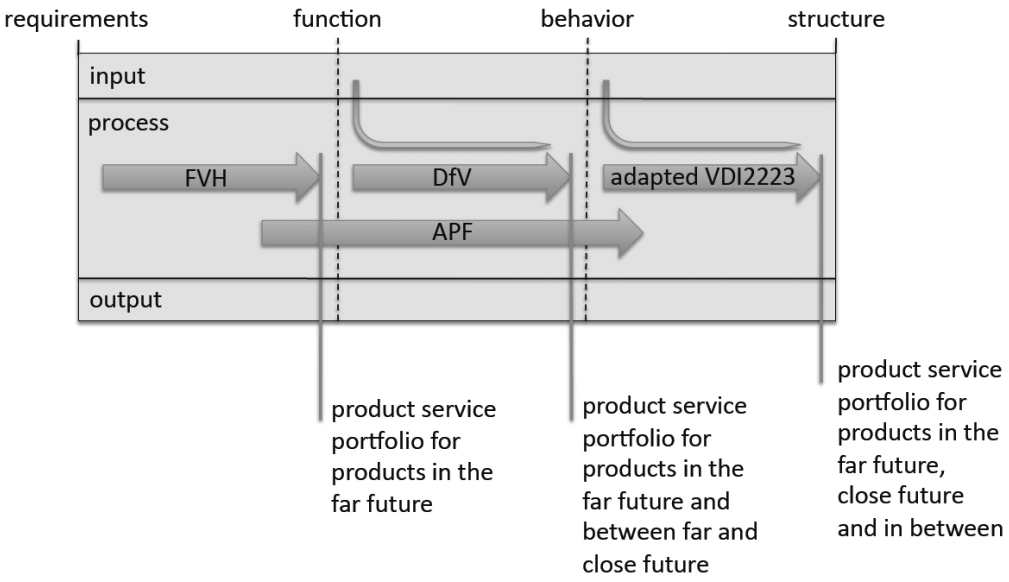

Figure 3: Adapted approaches on product flexibility

account and develop special indices, out of which it will be possible to guide an innovation process. It is planned to monitor the process at every desired time and give a respond on the extent of flexibility in every step of the design process. Therefore, it will be feasible to estimate the degree to which a project is suited for further changes along the early stages of the product life cycle. With changed market conditions in a running design process, the indices shall be capable of providing definite directives to confront fulgurous market events. A possible enhancement of the PSS-portfolio could be the inclusion of manufacturing requirements and the interconnection of PSS and production.

The structure of a PSS-portfolio is developing over time. Today's portfolio is displaying the resources and potential of a company. Including methods of early planning, there is the opportunity to develop future portfolios regarding middle-and long-term targets which are influenced by the strategic orientation of the management of a company. It will be possible to analyse the costs and therefore the effort needed for the changes regarding meeting the strategic goals. By tools coming from systems engineering [21, 22], the structures can be analysed and decisions can be made. I.e. the future work in this topic will focus on minimizing the change of structure. The middle-term structure of the PSS-portfolio shall be aligned to long-term goals in order to avoid unnecessary efforts which are not helpful in the long-term perspective.

5 ACKNOWLEDGEMENT

We thank the German Research Foundation (Deutsche Forschungsgemeinschaft – DFG) for funding this project as part of the collaborative research centre 'Sonderforschungsbereich 768 – Managing cycles in innovation processes – Integrated development of product-service-systems based on technical products'.

6 REFERENCES

[1] Pine, P. J., 1993, Mass Customization The New Frontier in Business Competition, Harvard Business School Press, Bosten

[2] Gräßler, I., 2004, Kundenindividuelle Massenproduktion. Springer Verlag, Berlin

[3] Piller, F., 2001, Mass Customization, DUV, Wiesbaden

[4] Baumberger, G., 2007, Methoden zur kundenspezifischen Produktdefinition bei individualisierten Produkten, Technical University Munich: Dr. Hut, PhD thesis

[5] Lindemann U., Reichwald, R., Zäh, M. F., 2006, Individualisierte Produkte – Komplexität beherrschen in Entwicklung und Produktion, Springer, Berlin

[6] Hepperle, C., Thanner, S., Mörtl, M., Lindemann, U., 2009, An integrated product lifecycle model and interrelations in-between the lifecycle phases, 6th International Conference on Product Lifecycle Management.

[7] Nayak, R., Chen, W., Simpson, T., 2002, A variation-based method for product family design, Engineering Optimization 34: 65-81.

[8] Robertson, D., Ulrich, K., 1998, Planning for Product Platforms, Sloan Management Review, Vol. 39, No. 4: 19-31.

[9] Zha, X., Sriram, R., Lu, W., 2004, Evaluation and selection in product design for mass customization: A knowledge decision support approach, Special Issue: Platform product development for mass customization Cambridge: Cambridge University Press: 87-109.

[10] Kondoh, S., Masui, K., Hattori, M., Mishima, N., Matsumoto, M., 2008, Total performance analysis of product life cycle considering the deterioration and obsolescence of product value, International Journal of Product Development 6 3-4: 334-352.

[11] Tseng, M., Jiao, J., 2001, Mass customization, Handbook of Industrial Engineering. Edition 3,. New York: chapter 25

[12] Meyer, M. H., Utterback, J. M., 1993, The Product Family and the Dynamics of Core Capability, Sloan Management Review, Vol. 34: 29-47.

[13] Erens, F. Verhulst, K., 1997, Architecture for product families, Computers in Industry 33: 165-178.

[14] Meyer, M., Lenhard, A., 1997, The power of product platform: building value and cost leadership, New York: Free Press

[15] Ponn, J., Lindemann, U., 2008, Konzeptentwicklung und Gestaltung technischer Produkte, Berlin

[16] Zamirowski, E., Otto, K., 1999, Identifying product portfolio architecture modularity using function and variety heuristics, Proceedings of the 11th International Conference on Design Theory and Methodology, ASME Design Engineering Technical Conferences.

[17] Martin, M., Ishii, K., 2002, Design for variety: developing standardized and modularized product platform architectures, Research in Engineering Design, Vol. 13: 213-235.

[18] Albers, A., Burkardt, N., Sauter, C., 2008, A modularization method in the early phase of product development, International Design Conference – Design 2008: 253-260.

[19] German Industry Guideline, 1999, VDI-Richtlinie 2223: Methodisches Entwerfen technischer Produkte, March

[20] Du, X., Jiao, J., Tseng, M., 2001, Architecture of product family: fundamentals and methodology, Concurrent Engineering: Research and Application 9, No. 4: pp. 309-325.

[21] Browning, T.R., 2002, Applying the Design Structure Matrix to System Decomposition and Integration Problems – A Review and New Directions, IEEE Transactions on Engineering Management 48: 292-306.

[22] Lindemann, U., Maurer, M., Kreimeyer, M., 2004, Intelligent strategies for structuring products, Knowledge based intelligent information and engineering system, International Conference: 1157-1163