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Investigating the Transition towards Changeability through Platform-based Co-development of Products and Manufacturing Systems

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Abstract

Increasing product variety, rapid new product introductions, volatile market demands, and pressure for cost reductions are among the main drivers for developing changeable and reconfigurable manufacturing systems constituting platforms that can be developed and utilized jointly with product platforms. However, methodologies to support platform-based co-development of products and manufacturing systems remain limited in previous research, including lack of knowledge on successful practices for the platform-based co-development project and process. Therefore, the objective of the research presented in this paper is to identify practices for platform-based co-development of products and manufacturing systems through a case study of a company that has successfully transitioned towards changeability through platform-based co-development. The findings cover various aspects of the co-development process and project, providing initial insight into how to enable joint development of products and manufacturing systems, in order to achieve changeability and reconfigurability.

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Keywords: Co-development; Changeable manufacturing; Reconfigurable manufacturing; Co-evolution; Platforms.

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1. Introduction

Changeability is defined as the ability of the manufacturing system to accomplish early and foresighted adjustments of structures and processes in response to change impulses [1]. A continuous adaption of the manufacturing system enables a symbiotic co-evolution between variants, parts, and features in the product domain and processes, equipment, and capabilities in the manufacturing domain [2]. Such symbiotic relations and changes can happen e.g. when a need for higher production volume occurs, when new variants are introduced, or with the introduction of new product families, which requires changes in the manufacturing system to varying extent depending on the magnitude of the change in the product domain [2]. Usually, changes and evolution in the product domain are managed through the use of modular product architectures and product platforms, which to some extent support reuse of processes and equipment across different product variants, thereby increasing adaptability of the manufacturing systems [2, 3]. However, in the manufacturing domain, adaptability can be further increased either through flexibility that is built-in a priori or through reconfigurability that ensures functionality and capacity on demand, as well as provides customized flexibility to reduce the traditional trade-off between scale and scope [4]. In order to achieve this fast adaption, the reconfigurable manufacturing system is built on a modular system architecture and constitutes a platform that can be developed and utilized jointly with the product platforms, which promotes platform-based co-development of products and manufacturing [5]. However, methodologies to support platform-based co-development of products and manufacturing systems remain limited in previous research, including lack of knowledge of successful practices for the platform-based co-development project and process. Therefore, the objective of the research presented in this paper is to identify practices for platform-based co-development of products and manufacturing systems, in order to increase knowledge on how to successfully transition towards changeability and reconfigurability.

2. Related Research

2.1. Product and Manufacturing System Platforms

Platform-based co-development of products and manufacturing systems can be defined as a particular type of co-development, where pre-defined platforms for the product and for the manufacturing system exist and instantiations of these platforms emerge in symbiosis through e.g. reconfiguration, redesign, or new developments [5]. Within the product domain, platforms, modular architectures, and product families have been researched extensively and applied widely in practise for supporting efficient production of variety through reuse of manufacturing processes and equipment across different product variants, thereby increasing adaptability of the manufacturing systems [2, 3]. In the manufacturing domain, changeable manufacturing paradigms have been emphasized for supporting high product variety and volatile market demands, e.g. flexible and reconfigurable manufacturing concepts [4, 6]. The concept of the reconfigurable manufacturing system (RMS) was introduced in the 1990's as an intermediate manufacturing system paradigm in-between the extremes of the flexible manufacturing system (FMS) with general built-in a priori flexibility and the dedicated manufacturing system (DMS) with high efficiency, but limited functionality [7]. The key principles of the RMS are modularity, integrability, customization, and diagnosability, which supports the system being both changeable in functionality and capacity, as well as efficient during operation [7, 8]. Thus, the concept of RMS is closely connected to the platform concept, as the system is built on modular system architecture and as such constitute a platform that can be developed and utilized jointly with the product platform [5].

2.2. Platform-based Development and Co-Development

Platform-based product development including modular architectures and product families have received extensive attention in previous research [9], e.g. how to develop modular products [3], development and visualisation of product families [10], and holistic development for product families [11]. Likewise, on the manufacturing side, the design of platform-based manufacturing systems has received attention as well, e.g. design of changeable and reconfigurable manufacturing systems [12-14], development of modular manufacturing [15], and development of classification schemes for manufacturing as a basis for process platform identification [16]. Nevertheless, research within each of these domains does not explicitly focus on co-development and on how to successfully develop platform-based systems in concert with each other. In regard to this, Michaelis and Johannesson address the importance of modelling interfaces and interactions in the product and manufacturing system domains, as well as between the two domains [5]. In line with this, Michaelis et al. [17] propose an integrated platform model for product and manufacturing to support development and Levandowski et al. [18] propose a set-based approach for development of an integrated product and manufacturing system platform. The modelling of products and processes was also addressed by Brunoe et al. [19] using a product-process ontology. The concept of co-evolution, which can be enabled by platform-based co-development, was introduced by ElMaraghy and AlGeddawy [2]. Accordingly, a methodology for co-platforming was introduced by ElMaraghy and Abbas [20, 21] for synthesizing manufacturing systems through mapping product platform and non-platform features to platform and non-platform machines and capabilities using matrix formulation and manipulation and optimization. Tolio et al. [22] propose a model for co-evolution of products, processes, and manufacturing systems that can be used for analysing the level of integration and evolution of a company's configuration approach in each domain, considering the impact of the structure of the organization.

2.3. Methodology for Platform-based Co-development

A design methodology is usually considered as containing knowledge in three areas to support practitioners: 1) models and rationalizations of the design and development process including activities and their sequence, 2) methods, tools, and techniques to be used within the process, and 3) corresponding terminology and concepts [23]. As described above, methodologies exist for both design and development within the domains of platform-based products and manufacturing. However, methodologies for platform-based co-development that cover the three aforementioned aspects are limited, as most related research cover methods and techniques to support the co-development process. Systematic methodologies including steps, activities, and their sequences to be conducted in practice appear limited. Moreover, in previous research, co-development is largely approached solely from the process perspective, while both process and project perspectives on development are important determinants for success, as the process has to be appropriate for the task and the development project has to be designed accordingly [23].

Conducting platform-based co-development is fundamentally different from traditional "over-the-wall" product and manufacturing development [17], which emphasizes the need for not only addressing co-development as a development process, but also as a project, e.g. how to organize the project in terms of length, size, organizational structure, resources, team composition, management, planning, decision-making, and task division. Consequently, the objective of the research presented in this paper is to identify practices for platform-based co-development of products and manufacturing systems, considering both the overall approach and supportive tools, as well as the organization of the development project.

3. Case Study Methodology

In order to address the research objective, a case study was conducted within a large Scandinavian company that has recently transitioned towards changeable and reconfigurable manufacturing systems through platform-based co-development. The company has several customer segments and a broad product portfolio covering a range of product families for different applications. The company has various manufacturing and assembly sites worldwide. Recently, the company introduced a global strategy of increasing profitability, growth, and sustainability by developing common product architectures with shared technology based on standardized assembly processes, considering both current and future products and how to enable changeable multi-product assembly platforms. The company initiated product and assembly co-development in 2010 and successfully launched the first platform-based assembly line in 2017. The journey in between the project start and the launch of the new changeable assembly lines is the unit of analysis of this paper. In order to collect data, a case study protocol was developed containing procedures for on-site data collection and interviews in three areas: 1) the co-development process including applied methods and tools, 2) the organization and structure of the development project, and 3) the output of the co-development initiative, e.g. the final changeable setup and the product platform. In each area, further details were included regarding in which aspects and dimensions to seek data. Multiple sources of information were used; 1) semi-structured interview with one of the managers involved in the conceptual development, 2) archival records, incl. project documentation, meeting documentation, project presentation, etc., 3) semi-structured interview with project manager at specific site where detailed development and implementation was conducted, and 4) on-site observation at the new assembly line. In the following, the findings of the case study are presented.

4. Case Study Findings

4.1. Platform-based Co-Development Project

The company in which the case study was conducted is a market leader within its industry. Recently, the company initiated a new global strategy for product and manufacturing development, which involved joint development of platforms, in order to deal with increased variety and complexity in e.g. product volume, mix, sizes, parts, as well as in assembly tasks and tooling, thereby improving lead-times, increasing changeability in operations, and reducing development costs. To support this strategy, a global central project was initiated in 2010 with the aim of developing the concept for new changeable assembly setups built on a shared technology platform, in order to produce any existing and new variant of the product platform. This initial concept development project was conducted as a joint effort between product and manufacturing, aiming at developing a modular product architecture and platform, as well as increase changeability within assembly and logistics through a shared technology platform. The project commenced in different phases and lasted from 2010-2016 before the platform concepts were finally handed over to specific assembly sites for detailed development and implementation. The initial global co-development project consisted of members from product development, technology, manufacturing, finance, and a notable number of participants from academia such as researchers with expertise on product realization, platform-development, and changeable manufacturing. Moreover, the overall project was divided into parallel sub-projects within different specialisations, e.g. development of modular architecture or development of manufacturing concepts, however, extensive communication and joint involvement occurred in order to address interfaces and interactions in the product and manufacturing system domains. The primary outcomes of this initial global platform-based co-development project was aligned concepts for a modular product architecture with defined standard interfaces including design guidelines for new products, and a concept for a manufacturing platform of standard technologies and enablers to deal with change and complexity. In 2016, these concepts were handed over to selected global sites for detailed development and implementation. In each of these sites, local projects were initiated with the aim of changing existing sites and assembly systems towards changeability through adaption of the product in accordance with the new product platform concept and implementation of the shared technology enablers. In the first site to launch these new platforms, the local project organization was led by an external project leader, hired with limited previous experience from the company. During the whole project a supporting organization was created and both blue and white-collar workers participated in strategic development tasks and operational tasks, which created a positive attitude towards the project. Planning was made in three dimensions, daily, weekly, and long-term. One long-term plan that affected the project was e.g. dismantling a part of the warehouse to give space for the future line, which in the end proved to be crucial to finalize the project in time.

In Fig. 1, an overview of the platform-based co-development project in the case is presented from initial central project start to implementation.

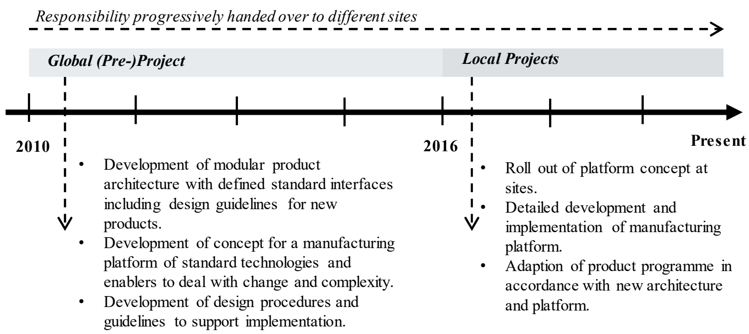

Fig. 1. Overview of the platform-based co-development project in the investigated case

4.2. Platform-based Co-Development Process

In the studied case company, the goal of the co-development process was to eventually transition from multiple dedicated assembly lines into fewer changeable assembly lines, by the use of shared technology platform and a common modular product architecture with standard interfaces. Thus, a high degree of joint development activities was needed, as both the existing product and assembly concepts needed to be revised in accordance with each other. As described previously, the entire co-development project was roughly divided into two sequential project phases, where the first had a global scope and covered all main modules of the final product being assembled at different specialized sites, whereas the last co-development phases were conducted as local projects at the different sites.

The aim of the initial co-development project was to develop the concept for a generic product architecture and platform across existing variants and create the concept for a shared technology platform to accommodate changeable and multi-product assembly lines. Thus, the product platform was developed particularly for the purpose of accommodating generic assembly sequences and interfaces, and the assembly concept was developed as a technology platform of enablers to deal with different types of product-related change drivers. Moreover, the initial project defined a development methodology for subsequent local development projects, regarding how to adapt the product to manufacturing and vice versa.

In the local projects conducted at the different assembly sites, the development process can be described as follows: 1) specification of objective and requirements for the product and manufacturing domains, 2) analysis of existing products and re-design into a generic modular product architecture with increased commonality across variants and standard interfaces, including definition of common assembly sequences, 3) analysis of existing assembly lines, including existing layout, equipment and tools, content of work, part presentation, and review of current performance, 4) identification of requirements for redesign to accommodate the new product concept e.g. need for different tooling, need for layout change, or need for accommodating varying work content, and 5) development of assembly concept built on common technology platform and enablers, such as reconfigurable fixtures, flexible tools, etc. to manage variation and complexity. Within this development process, product and manufacturing development were conducted jointly and each activity required both information sharing, collaboration, overlapping activities, and joint decision making across both domains. Specific methods and supportive tools used for this include interface mapping, process mapping, product grouping matrices based on e.g. dimensions, tooling, sequence, and discrete event simulation. Moreover, in local projects, paper sketches and models were used to communicate future results between product development, project management team, and assembly operators. At present, several sites has successfully developed and implemented changeable manufacturing systems based on the common product architecture and manufacturing platform concepts. As such, each assembly site has instantiated assembly lines from the common technology platform, as well as adapted existing products to the new modular architecture. For instance, the assembly site specially investigated for this research, transitioned from three dedicated assembly lines to one changeable multi-product line with an increased efficiency of more than 8%. Products were assembled in a mixed flow with three main variants that differed both in size and components. This was realized by a main line with low variations and high stability, as well a different sub-flows. Handling, positioning, and tightening were performed in the same way on all variants due to standard product interfaces, and generic modular tools could be used as well. Moreover, volume increases and uncertainty were dealt with by pre-assembly stations and scaling of operators. In Fig. 2, an overview of the platform-based co-development process conducted in the case is presented.

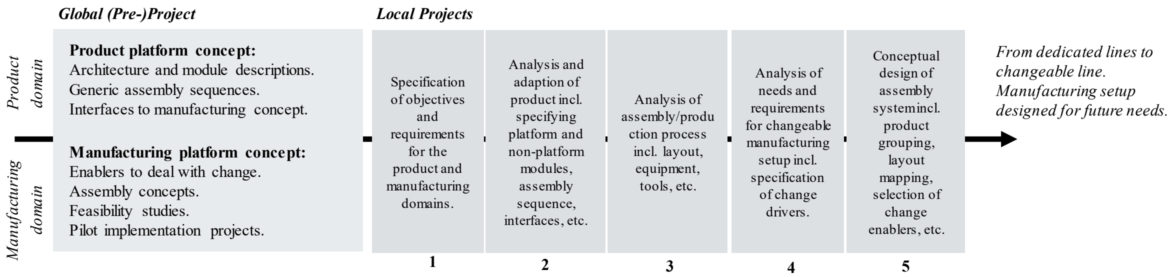

Fig. 2. Overview of the platform-based co-development process in the case.

In Table 1, a summary of the case findings is presented.

Table 1. Overview of findings from case study on practices applied for conducting platform-based co-development.

Practices in case	
Project	Central/global project for concept development: • Task: develop methodology for implementation of platform-based co-development globally and develop concept for generic modular product architecture and technology platform for assembly. • Scope: all existing and future products across entire product range, including all main product modules and global assembly sites. • Team: product development, technology, manufacturing, and extensive involvement from academic experts. • Length: 5 years for development of product and assembly platform concepts. Local projects at sites for detailed development/implementation: • Task: Redesign product module in accordance with specified generic architecture and interfaces, and implement technology platform/generic enablers to deal with required change and complexity. • Scope: Specific product module and assembly site. • Team: External leader, local engineering functions, and high operator involvement. • Length: Initiated after global project, implemented within app. 1 year due to high project prioritization.
Process	Process for co-development conducted at sites: • Analysis of requirements for the product and production domains. • Analysis of existing products and re-design into a generic modular product architecture. • Analysis of existing assembly lines and design of assembly concept built on common technology platform and enablers. • Performance evaluation. Supportive methods: • Interface mapping, process mapping, product grouping matrices, and discrete event simulation.

5. Conclusions

In this paper, a case study was presented with the aim of identifying successful practices for platform-based co-development of products and manufacturing systems. In the studied case, a largely structured way of working was present in the platform-based co-development project, and responsibilities were redefined in the organization to accommodate the new way of making product and manufacturing development. The specific development process required not only coordination between product and manufacturing domains, but rather required joint design due to tasks being highly interdependent between design domains. Moreover, the process methodology applied in the case company shares similarities with design methodologies for changeability and reconfigurability, which center around analyzing drivers of change and implementing enablers of changeability, utilizing a high degree of product commonality. Moreover, in the case study, some challenges regarding conducting platform-based development of products and manufacturing were highlighted, e.g. training of operators for new changeable setup and work content, need for redefining organizational setup, and need for redefining organizational responsibilities. Likewise, the need for including knowledge and competences from central platform project in later detailed design and implementation projects was highlighted as a success factor.

The findings reported in this paper represent initial insight on how platform-based co-development can be successfully conducted considering both the overall approach and supportive tools, as well as the organization of the development project. However, future research should focus on this in a broader context, as significant differences in approach to co-development is expected across different types of companies. Furthermore, while this research highlights some practices for platform-based co-development that have been applied in real-life, other approaches and methods related to platform-based co-development can be identified in previous research. Thus, determining best-practices or different maturity levels of platform-based co-development could be a viable future research direction, as well as the creation of generic methodologies specifically targeting the joint development of product and manufacturing system platforms.

References

[1] ElMaraghy, H., Wiendahl, H., 2016. Changeable Manufacturing, CIRP Encyclopedia of Production Engineering, p. 1-7.

[2] AlGeddawy, T., ElMaraghy, H., 2011. A model for co-evolution in manufacturing based on biological analogy, International Journal of Production Research 49, p. 4415-4435.

[3] Ericsson, A., Erixon, G., 1999. *Controlling Design Variants: Modular Product Platforms*, SME.

[4] Wiendahl, H., ElMaraghy, H.A., Nyhuis, P., Zäh, M., Wiendahl, H., Duffie, N., Brieke, M., 2007. Changeable manufacturing-classification, design and operation, CIRP Annals-Manufacturing Technology 56, p. 783-809.

[5] Michaelis, M.T., Johannesson, H., 2011. From Dedicated to Platform-Based Co-Development of Products and Manufacturing Systems, in *Enabling Manufacturing Competitiveness and Economic Sustainability* H.A. ElMaraghy, Editor. Springer, New York, USA, p. 196-202.

[6] ElMaraghy, H., Schuh, G., ElMaraghy, W., Piller, F., Schönsleben, P., Tseng, M., Bernard, A., 2013. Product variety management, CIRP Annals - Manufacturing Technology 62, p. 629-652.

[7] Koren, Y., Heisel, U., Jovane, F., Moriwaki, T., Pritschow, G., Ulsoy, G., Van Brussel, H., 1999. Reconfigurable manufacturing systems, CIRP Annals-Manufacturing Technology 48, p. 527-540.

[8] ElMaraghy, H.A., 2005. Flexible and reconfigurable manufacturing systems paradigms, International journal of flexible manufacturing systems 17, p. 261-276.

[9] Jiao, J.R., Simpson, T.W., Siddique, Z., 2007. Product family design and platform-based product development: a state-of-the-art review, Journal of Intelligent Manufacturing 18, p. 5-29.

[10] Harlou, 2006, Developing product families based on architectures: Contribution to a theory of product families.

[11] Simpson, T.W., Jiao, J., Siddique, Z., Hölttä-Otto, K., 2014. Advances in product family and product platform design, New YorN: Springer.

[12] Andersen, A., ElMaraghy, H., ElMaraghy, W., Brunoe, T.D., Nielsen, K., 2017. A participatory systems design methodology for changeable manufacturing systems, International Journal of Production Research, p. 1-19.

[13] Andersen, A., Brunoe, T.D., Nielsen, K., Rösiö, C., 2017. Towards a Generic Design Method for Reconfigurable Manufacturing Systems - Analysis and Synthesis of Current Design Methods and Evaluation of Supportive Tools, Journal of Manufacturing Systems 42, p. 179-195.

[14] Rösiö, C., Bruch, J., 2017. Exploring the design process of reconfigurable industrial production systems: Activities, challenges, and tactics, Journal of Manufacturing Technology Management.

[15] Joergensen, S.N., Schou, C., Madsen, O., 2014. Developing Modular Manufacturing Architectures–An Industrial Case Report, in *Enabling Manufacturing Competitiveness and Economic Sustainability*. Springer, p. 55-60.

[16] Sorensen, D.G.H., Brunoe, T.D., Nielsen, K., 2018 (In press - 51st CIRP Conference on Manufacturing Systems). A classification scheme for production system processes.

[17] Michaelis, M.T., Johannesson, H., ElMaraghy, H.A., 2014. Function and process modeling for integrated product and manufacturing system platforms, Journal of Manufacturing Systems 36, p. 203-215.

[18] Levandowski, C., Michaelis, M.T., Johannesson, H., 2014. Set-based development using an integrated product and manufacturing system platform, Concurrent Engineering 22, p. 234-252.

[19] Brunoe, T.D., Sorensen, D.G.H., Andersen, A., Nielsen, K., 2018 (In press - 51st CIRP Conference on Manufacturing Systems). Framework for Integrating Production System Models and Product Family Models.

[20] ElMaraghy, H., Abbas, M., 2015. Products-manufacturing systems Co-platforming, CIRP Annals - Manu. Technology 64, p. 407-410.

[21] Abbas, M., ElMaraghy, H., 2016. Functional Synthesis of Manufacturing Systems Using Co-Platforming, Procedia CIRP 52, p. 102-107.

[22] Tolio, T., Ceglarek, D., ElMaraghy, H., Fischer, A., Hu, S., Laperrière, L., Newman, S.T., Váncza, J., 2010. SPECIES—Co-evolution of products, processes and production systems, CIRP Annals-Manufacturing Technology 59, p. 672-693.

[23] Bellgran, M., Säfsten, K., 2009. *Production development: design and operation of production systems*, Springer-Verlag, London.