INTERNATIONAL DESIGN CONFERENCE - DESIGN 2016
Dubrovnik - Croatia, May 16 - 19, 2016.

CHALLENGES IN IMPLEMENTING MODULE AND PLATFORM STRATEGIES IN PLANT ENGINEERING COMPANIES

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Keywords: platform strategies, plant engineering, challenge

1. Introduction

Machine and plant engineering is one of Germany's most important industrial sectors. In contrast to series product engineering, it is characterized by individual customer requirements for each particular product. The increasing demand to offer customer-specific solutions forces companies to offer an increasing number of variants of their machines and plants. Modularity is a core challenge for the industry to solve this discrepancy [Vogel-Heuser et al. 2014]. Modules must be identified and combined for each individual project [Feldmann et al. 2015]. The dynamic market with changing customer demands needs a fast adaption of the product portfolio [Feldmann et al. 2015]. In this context, Feldmann et al. [2015] mention new challenges in plant engineering: Increase efficiency, reduce development costs, and manage customer-specific variants.

Another challenge for plant engineering companies is the massively increasing competitive pressure. A study performed by the VDMA (German Engineering Federation) in cooperation with the consulting company maexpartners shows, that consequent implementation of modularization can result in savings up to the double-digit percentage range [VDMA 2014]. An additional study by the VDMA in cooperation with McKinsey&Company points out that for 37% of the considered plant engineering companies, modularization is a highly relevant topic to reduce costs, meet customer requirements and simplify the product development process [VDMA and McKinsey&Company 2014]. Modularization and platform strategies are an increasingly important aspect in plant engineering. But the implementation of such a strategy itself is a big challenge, for instance because of extensive restructuring activities in organization and processes [VDMA 2014].

This paper addresses challenges during the implementation of a module and platform strategy derived from observations in a German medium-sized plant engineering company. The results prepare companies for the implementation of module and platform strategies and make them aware about upcoming challenges during the implementation with the goal to sensitize for consequences.

The paper is structured as follows: section 2 briefly describes the research design and section 3 gives theoretical background about module and platform strategies. In section 4, challenges extracted from literature are presented, followed by the findings of the practical case in section 5. Section 6 discusses the results; section 7 concludes the paper and gives an outlook.

2. Research design

This research is based on two components: A literature analysis and a practical case study. On the one hand, challenges in implementing module and platform strategies in plant engineering have been identified in literature. While only few relevant publications listed in Scopus, Web of Science or Google

Scholar were found, studies by the VDMA provided valuable input. On the other hand, a medium-sized German plant engineering company served as a practical case. The authors accompanied the implementation of a module and platform strategy in the company and provided methodological support through monthly workshops during a time period of one year. Thus, upcoming challenges have been identified throughout the project. The last workshop aimed to derive lessons learned from the implementation project and to reflect on the identified challenges.

3. Background about module and platform strategies

Modularization describes the division of a product or a product group into modules or components [Borowski 1961]. Single modules can be combined in different manners to build a product. The exchange of modules is possible but needs defined interfaces to avoid compatibility problems [Borowski 1961]. Platforms are used to achieve synergies by using common elements (e.g. components, functions, technologies) for several products. A platform can be seen as a combination of economic assets, which are commonly used by product groups [Piller and Waringer 1999]. These economic assets can be components, manufacturing processes or process knowledge. Meyer and Lehnerd [1997] describe a platform as a set of common assemblies, modules and parts, which form a mutual basis. This view can be expanded by four further categories: processes, knowledge, people and relationship [Robertson and Ulrich 1998]. A platform has no differentiating factor and builds the basis for a number of different products. Modules can be added to a platform in order to create specific products [Piller and Waringer 1999]. The product structure can be divided into platform and non-platform elements [Blees 2011].
Hence, product families can be derived from product platforms. Product families group related products to serve a variety of market niches [Simpson et al. 2006]. A further sub-division of product platforms are basic devices, which serve as instance between product family and product variants (Figure 1). Basic devices are distinguished by the variation of a relevant specification of characteristics, for instance performance or dimension [Bauer et al. 2014]. Product variants are single representatives of a product family with the same purpose, but a difference in at least one characteristic [DIN199-1 2002], [Ponn and Lindemann 2012]. The advantage of platform-based product families is that a wide range of products can be offered while achieving economies of scale in design and manufacturing [Bauer et al. 2015].

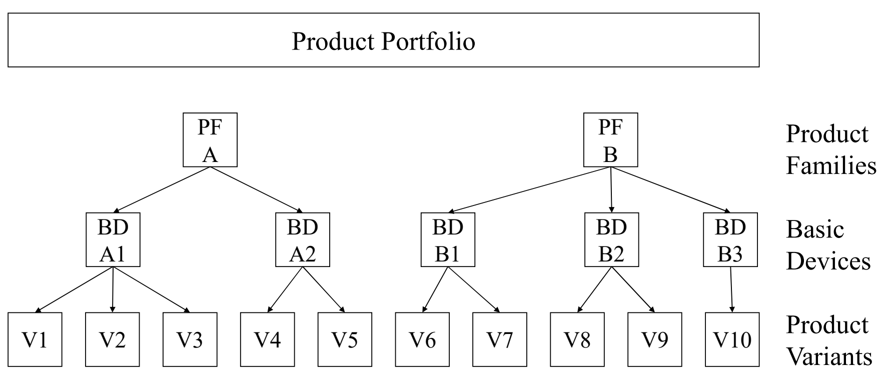

Figure 1. Decomposition of a product portfolio [Bauer et al. 2014]

Product variants can be grouped into model series, whereas the included product variants have the same qualitative functions and are designed similarly - they only differ in dimensions (size) and performance data (quantitative functions) [Ehrlenspiel 2003].
The implementation of modularization offers financial advantages for a company. Figure 2 points out the influence of modularization on the different aspects of plant engineering companies' profit and loss statement. These findings are based on a study by the VDMA in German plant engineering companies [VDMA and McKinsey&Company 2014]. The 'Material costs' and 'Sales and administrative costs' show the highest saving potential, whereas 'Research and Development' and 'Depreciation and other indirect costs' show an additional but minor potential.

Improvement potential in 3-5 years

P&L of a Plant Engineering Company	**Modularization strategy**
Turnover	↗
Material costs	⬇
Sales and administrative costs	⬇
Research and Development	↘
Depreciation and other indirect costs	↘

⬇ Major factor ↘ Additional factor

Figure 2. Potential effects of modularization on a profit and loss (P&L) statement of a plant engineering company [VDMA and McKinsey&Company 2014]

4. Challenges from literature

This paper particularly focuses on challenges that arise during the implementation of a module and platform strategy in plant engineering companies. Challenges identified in literature are presented here in order to deepen the understanding of currently known aspects and to obtain a knowledge base for the practical case.

Feldmann et al. [2015] present the following challenges for modular engineering in machine and plant manufacturing: managing interdisciplinarity; managing inconsistencies; differentiating project-independent and project-related activities; and managing variants and versions. Typically, machines and plants are interdisciplinary systems. Hence, engineers from multiple disciplines are involved in the development process. Consequently, different disciplines are involved during the implementation of modular strategies. Those disciplines need to be represented in an adequate manner [Feldmann et al. 2015] and interdisciplinary modelling support is necessary [Thramboulidis 2013]. Herzig et al. [2011] further mention a more general topic: Adaptions of engineering solutions during the design process are often not synchronized across different models, which causes inconsistencies that have to be managed [Feldmann et al. 2015]. In addition, the differentiation between project-independent and project-related engineering activities is a highly relevant aspect. It supports the efficiency and reuse in engineering [Maga and Jazdi 2012]. Project-independent activities aim to shorten project duration and to reduce engineering costs. Project-related activities focus on the fulfillment of customer needs [Feldmann et al. 2015]. Last, customer and system requirements change continuously in plant engineering and a multitude of solutions exists simultaneously because of the required variability in the engineering solution. This leads to a multitude of variants. Their evolution over time results in different versions of these variants [Vogel-Heuser et al. 2014]. Following this argumentation, Feldmann et al. [2015] identified the need for mechanisms to support the management of variants and versions.

A study by the German Engineering Federation [VDMA 2014] identified high saving potentials for plant engineering companies through consequent modularization. Moreover, in the context of the study, essential challenges such as restructuring in organizational and business processes were identified. Particularly, processes concerning engineering and preparation of offers are highly relevant. Furthermore, the study proposes the need for a general rethinking and breaking up historically grown structures. For instance, the sales department is often used to offer customer specific solutions, which complicates the consequent usage of standards and produces a lot of variants.

Another study by the German Engineering Federation in cooperation with McKinsey&Company [VDMA and McKinsey&Company 2014] lists main aspects of a successful modularization strategy:

- Optimum degree of standardization
- Integrated concept along the entire value chain
- Pricing for non-standard solutions
- Structures and processes

Not all of these aspects are relevant for the implementation process, since the focus is rather on the design of the modularization strategy on a business level. It is challenging to find the optimum degree of standardization for each component and thus optimize the balance between cost saving equality and customizable flexibility. Furthermore, the complete cost savings could only be achieved if the modularization is realized along the entire value chain. Often, only pilot projects or single process steps are standardized [VDMA and McKinsey&Company 2014].

Plant engineering companies are often characterized by a customer-oriented corporate culture, which must not be in contrast to standardization. They often feel compelled to offer customer-specific solutions, which leads to a multitude of variants. An upcoming challenge is the reasonable pricing of additional efforts and risks. An institutional integration of the standardization must be implemented in structure and processes to support the cultural rethinking [VDMA and McKinsey&Company 2014].

In summary, the implementation of module and platform strategies in plant engineering companies faces similar challenges as the implementation of these strategies in general. However, the necessary cultural change seems to be the major challenge especially in plant engineering. Instead of seeing every product as a unique customer-specific solution, product variants should be derived from standardized platforms and modules. This requires major rethinking in engineering departments as well as in sales departments.

5. Practical case

5.1 Observed company

The observed partner in this study is a medium-sized process plant engineering company located in Germany. Major goals of the company are permanent high quality, optimal process control, and fully automatic and low-maintenance operation. Increasing market competition and planned market expansions require radical cost reductions in order to offer attractive purchase prices. Generally, the machines are offered under different boundary conditions. Not only the application case and the customer-specific situation differ fundamentally but also the required solution scope to fulfill the task varies from supplying only a subsystem to offering a whole solution system. In the past, this resulted in a multitude of individual adjustments, which led to many internal and external variants. Consequently, this customer-oriented culture resulted in high efforts for adjustments, high costs to manage variants and increased production costs.

Accompanied with the design of a new plant generation, a module and platform strategy has been elaborated to handle the balancing act between customer-specific solutions and internal standardization. The strategy incorporates aspects of cost reduction as well as functional improvements and supports standardization of components and the usage of common and repetition parts. The whole system solution usually consists of a core system and several peripheral subsystems for pre- and post-treatment purposes. On this level, the system is already modularized to a high degree. While the main function of the core system always stays the same, elements of the core system need to be adapted for different applications, which was a big driver for variants in the past. This is why the system of interest for this research was only the core system.

The critical factor for the definition of the platform is the achievable throughput per time. Consequently, the platform consists of parts, which are similar for a couple of offered throughput rates. This approach supports the standardization of components and parts. The parts that have to be adjusted to particular throughputs are aggregated to several modules. The modules are categorized by their specific function in the process. Some of the modules are basic parts of the system, other ones are customer-specific and consequently optional.

5.2 Identified challenges

Gawer and Cusumano [2008] classify actions for companies that aim to become platform leaders. On the one hand, they differ between technology and business actions and on the other hand between creating a platform and building market momentum with an existing platform. They mainly focus on electronic companies, but the classification of technology-based and business-based actions can be adopted to the field of challenges in this research. In the context of this paper, business-based challenges are those with the main responsibility in the business disciplines. We define structural, administration, economical and management topics as business-based challenges. All aspects concerning organizational change management are also assigned to the business discipline. These challenges primarily address the implementation of the strategy. The technology-based challenges focus on the target state of the product. They concern the machine in a technical way or the main responsibility is in one of the technical disciplines.

In addition to the discipline, a second classification criterion is used: the level of action. This describes where the main field of action was in context of the studied practical case. A four level top-down classification is used: (1) The cultural level on the top, concerning the complete company culture and corporate thinking. (2) A process level, which addresses not existing or not suitable processes. (3) A methodological level, which describes an identified insufficient methodological support for each challenge and (4) the tool level, where specific tools hinder the implementation of a module and platform strategy.

Figure 3 structures the identified challenges and barriers. The challenges are manifold and go beyond the pure definition of the machine platform and modules. Nevertheless, a core challenge is a) the definition of the standard machine (basic device) and to clarify which parts, functions and features are included. Especially in plant engineering, the customer requirements and boundary conditions are very specific and a standard machine cannot cover all customer-specific application cases. It is categorized as both business and technical based, because there is a trade-off between technical feasible and economically reasonable arguments. The challenge is to implement a corporate thinking of standards and to support the definition of standards methodologically. Another challenge in this context is to find the balance between an as large as possible coverage of application cases with the standard machine and reasonable sales prices. The more functions are included in the standard machine, the more expensive it is. All potential variants, exceptions and complete model series must be planned in an early project phase. A major challenge in the observed implementation projects was the missing definition of some of these aspects in the previously defined strategy. From a system requirements perspective, the handling of all these different system levels were challenging. Requirements concerning the standard machine, variants (i.e. international requirements) and the entire model series (i.e. performance parameter) already have to be considered during the design of the first machine.

	Discipline		Level			
	Business	Technical	Culture	Process	Method	Tool
a) Definition of standards	x	x	x		x	
b) Adaptation of system peripherals		x			x	
c) Adjustment of corporate strategy	x		x			
d) Definition of model series boundaries		x			x	
e) High uncertainties in sales volume	x				x	
f) Adjustment of process management	x			x		
g) Adjustment of IT infrastructure	x					x
h) Management of older machine generations	x			x	x	x
i) Integration of stakeholders	x			x		

Figure 3. Categorization of identified challenges

In the observed company, some advantages of the module and platform strategy only come to full effect when peripheral systems are involved. The clarification and definition of the interfaces between the basic device and peripherals in an early project phase was challenging (b). This aspect is closely related to the definition of standards.

A challenge on a higher level, but also closely related to the definition of standards, is c) the adjustment of the corporate strategy. This brings the 'thinking in standards' to the entire company and is project independent. As previously mentioned, the plant engineering sector developed customer-specific solutions for years. With a module and platform strategy a change of policy needs to be done towards a focus on core business and hence higher sales volumes of standardized machines. A specific challenge is the change of the mind-set of the sales department aligned to this strategy. A general rethinking concerning sales behavior is necessary. In frame of this corporate rethinking a new assessment of existing strategies (i.e. Make-or-Buy) is recommended.

Further, e) high uncertainties regarding estimated sales volumes are seen as challenging. The observed company noted high fluctuations in the numbers of sold machines for each particular size. This complicates the definition of standards across the model ranges. Moreover, this uncertainty leads to challenges in preliminary calculation and reduces the planning reliability regarding supplier negotiations. Not exclusively, but also this uncertainty makes the definition of model series boundaries (d) difficult, because future sales figures cannot be reliably planned. Consequently, it is unclear how to achieve optimal volume effects with standardization and modularization. For both challenges d) and e), insufficient methodological support was identified. They are strongly connected, whereas the high uncertainties in sales volumina challenges the business disciplines, the definition of model series boundaries is the counterpart on the technical side.

The change in strategy also requires adaptions in process management (f). A new sales process needs to be developed with the focus to offer standardized machines and avoid individual solutions. But also internal processes are affected, like order processing or project planning. Here, high efficiency potentials thanks to the modularization exist; e. g. cycle times from offer to delivery could be reduced.

To meet the needs of the changed processes, g) an adjustment of the IT infrastructure is necessary. Tools supporting the processes (i.e. ordering process) must be optimized and adjusted to the equal parts strategy. Furthermore, a limitation of the available master parts for the machine design is required to effectively handle the parts in the product lifecycle management systems.

Another challenge with regards to the digitally represented master parts is h) the management of previous machine generations and "old" parts. Those should not be used in the new modularized and standardized machine generation, but must be kept as spare parts for the maintenance of "old" machines. The specific challenge is to reasonably represent this part structure in an IT system, so that only the appropriate parts are used in the development of the new machine generation. In order to address this challenge, adjusted processes, methodological support and the implementation in a tool is needed.

Last, the interdisciplinary aspect in plant engineering requires i) the integration of several relevant stakeholders, which is challenging. Especially the integration of the sales and service department and their experiences in everyday business proof to be valuable in the observed implementation project. The coordination of the strategy with the sales department is necessary to meet the relevant customer requirements. The integration of the service department delivers information for the machine handling, long term behavior and customer-specific situations. The challenge is to get the relevant individuals together and to develop a common understanding of the new strategy and machine.

6. Discussion

The identified challenges have different validity. Basically, the focus is on the sector of plant engineering and some of them are probably valid for this sector in general. However, others might be only suitable for specific cases. One has to keep in mind that the challenges are identified in one particular use case and hence their transferability and generalizability is limited.

The goal of this research is to sensitize companies for the extent of consequences when implementing a module and platform strategy. The challenges are manifold and go beyond the pure definition of the machine. They address different disciplines and require actions on different levels. The challenges derived from the use case partly correspond with literature but also expand the list. Topics like the adjustment of processes and organizational structures match in literature and in the practical case. Also the challenge of interdisciplinary communication and integration, the need for methodical or tool support and the challenge of defining the standards already mentioned in literature were observed in the practical case. Further, a general rethinking of the corporate mind-set is proposed in literature, which was also proven to be important in the practical case. It is worth to point out this aspect, because it is an ongoing protracted process. Hence, modularization needs good preparation and should not be started ad-hoc. Companies have to be aware about consequences of modularization and have to find the balance between risks, efforts, chances and potentials.

The identified challenges showed different time dimensions. Some of them could be handled with short-term actions, some require long-term measures. For instance, the integration of sales and service departments could be realized in relatively short-term actions, whereas the adjustment of the corporate strategy towards a sales behavior with focus on standard machines requires a long-term rethinking.
To efficiently implement a platform and module strategy in plant engineering a reasonable IT-infrastructure is an important enabler. This should include a consequent management, description and connection of all relevant data. On the one hand, this is needed to manage all technical aspects of the machine and on the other hand to support the processes. Therefore, the consequent use of a product data management system is highly advisable. On the process side, a structured and professional change management supports all process and cultural based topics.
In context of the presented practical case, the need for methodological support to handle the challenges was identified. For instance, a support to manage different levels of requirements in the requirements documentation is needed. This aims to design the current machine in preview of the entire model series in order to reduce late changes. Furthermore, a methodical support in building a "volume model" of the future sales figures would be beneficial. This could reduce uncertainty and put the entire modularization and platform strategy and the definition of model series boundaries on a more reliable basis.

7. Conclusion and outlook

Module and platform strategies are a more and more important aspect for plant engineering companies in order to face upcoming challenges. This contribution focuses on the identification of challenges in implementing module and platform strategies in plant engineering and sensitizes companies for the extent of upcoming tasks. Relevant challenges extracted from literature are presented.
In addition, practical insights are provided based on a case study with a German medium-sized plant engineering company. To handle the balance between customer-specific solutions and internal standardization, a module and platform strategy was integrated in the design of a new machine generation in the observed company. Challenges are identified and classified according to discipline and level of action. The challenges are manifold and span different dimensions. They affect companywide organizational structures, processes and cultural aspects as well as technical, infrastructural, IT and business aspects. Particular challenges require long-term strategies and a basic rethinking process in the corporate strategy.
Implementing a module and platform strategy needs structured preparation because it goes beyond the sole standardization of components. Companies must be aware about the consequences of modularization. Major aspects are the necessary IT-infrastructure and a professional organizational change management. The results of this research prepare companies for the implementation of module and platform strategies and make them aware about upcoming challenges during the implementation.
For future work, further studies and use cases with detailed analyses are needed to gain a better understanding of the challenges' background. The presented use case is one specific case with a limited transferability and generalizability.
During the accompanied implementation project, the need for advanced practical methods was identified. This again corresponds with literature, which demands for modelling and tool support. In this specific case, the need for methodical support regarding the management of different levels of requirements and the support to build a reliable "volume model" of future sales figures stood out.

Acknowledgements

We would like to thank our partner company and its employees who made this research possible.

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