ASSESSING THE FINANCIAL POTENTIAL FOR MODULARIZATION: A CASE STUDY IN A GLOBAL OEM

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Abstract

Assessing the financial potential of implementing a strategy, based on sharing of key modules and interfaces across a portfolio is difficult. However, this is a critical input when deciding strategic direction in industrial organizations. Through a case study, this paper gives an example of how to map and evaluate the architectures in a portfolio to identify the financial potential for implanting a platform-based modularization strategy. The approach has been applied in a global world-leading OEM with 50.000+ product variants and a turnover of USD 3,5b (2015). The results show a potential for reducing the cost-base by up to 15% through systematically sharing of key design principles across 80% of the company's portfolio. This has supported the discussion of adjusting innovation strategy in the organization. The core contribution of the paper is the operational application of the systematic Architecture Mapping and Evaluation approach (AME) and discussion of how it can support strategic decision-making related to modularization. The approach builds on the understanding that a top-down assessment can give a starting point for implementing a level of modularity across a portfolio.

Keywords: Platform strategies, Product architecture, Case study, Decision support

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1 INTRODUCTION

Industrial companies (i.e. a organization developing, manufacturing and distributing physical products) are faced with the challenge of continuously improving their business. Introducing new products to increase turnover and/or reducing the internal cost-base are two ways to achieve this (Dobni et. al. 2015; Kester et. al. 2013). Defining and deciding on a strategic direction for business improvements implies evaluating one strategic initiative against another. In a situation with changing market requirements, increasing global competition and unpredictable technological development this can be a complex task, but non-the less, critical for the success of a business.

This paper presents a case study focused on the application of the Architecture Mapping and Evaluation (AME) approach presented by Mortensen et. al. (2016). The AME approach is meant to support industrial companies in assessing the financial potential of introducing a strategy based on shared modular platforms and architectures, in this paper referred to as a modularization strategy. The approach is based on elements found in existing literature and is a step-based operational method, which is aimed at practitioners working within the field of modularization and strategic decision-making.

The case company is a large and global OEM with operations in Europe, America and Asia. They design and manufacture industrial products and the portfolio includes 50.000+ product variants. Yearly turnover in 2015 was approximately USD 3,5b. Through a systematic application of the AME approach a potential for reducing the company's cost-base was identified. Potentials related to sharing of selected key design principles across 80% of the portfolio. This supported decisions related to changing the innovation strategy in the company. The core contribution in this paper is an example of application and evaluation of the proposed approach. Furthermore, the paper supports an interesting discussion of the financial benefits of introducing modularity in industrial organizations. An area, which is difficult to quantify and has had limited focus in existing literature (Campagnolo and Camuffo, 2010). First, the paper will describe the theoretical basis for the AME and the related research. Next the case study is presented and, finally, results are discussed.

2 RELATED WORK

The AME approach (Mortensen et. al. 2016) draws on classic System Thinking (Klir, 2001), Theory of Technical Systems (Hubka and Eder, 1988) and elements from the Product Family Master Plan (PFMP) (Harlou, 2006), and is primarily a tool to visualize high-level potentials for shared modular architectures. It focuses on the three dimensions: The market, the product and the manufacturing dimension. Industrial insights obtained through research activities and working as professionals in industry, have inspired the tool. Being able to, up front, assess and indicate the financial potential for implementing a platform-based modularization strategy was in several cases identified as a desire in industry. Thus, the approach is thought to act as decision support on a strategic level. The case study will be used to describe the different steps in the AME approach in detail.

The next sections in this paper will briefly describe what is understood as platforms and architectures and show two state-of-the-art examples of existing research related to evaluation of the financial benefits of modularization. When looking at existing research, it is to a large extend focused on situations where companies have already decided to adopt a modularization strategy or elements of one. The result is, that existing methods are technical in nature and not directly operational in the early stages of defining a strategy for modularization. This is why the application of the AME approach provides some interesting input to decision making related to modularization.

2.1 Platforms and architectures in product development

The classic way of developing products, one-at-a-time is costly and can ultimately result in a high number of unique designs. Starting from zero every time a development process is initiated can increase time-to-market and unique designs are seen, where using a standardized solution could have saved resources and significantly reduced developing time (Meyer and Lehnerd, 1997; Harlou, 2006; Simpson et. al. 2014). Product family design, based on modular platforms and architectures, describes a way to organize products as a set of modules that can be designed independently and through combination, can provide a variety of product variants. The method is often seen as a way to enable cost-effective mass-customization as companies can deliver a wide product assortment based on sharing of standardized modules (Jiao et. al. 2007; Gonzalez-Zugasti et. al. 2001; Hvam and Ladeby, 2007). Other benefits are generally recognized as the ability to reduce time-to-market and reduce cost for new product introductions (Harlou, 2006; Simpson et. al. 2014). A modular approach can also be seen applied to the manufacturing domain to achieve similar benefit (Campagnolo and Camuffo, 2010; Sanchez, 2008).

The terms platforms and architectures are often used in different contexts and can be found to have different meanings and interpretations when looking into existing literature (Campagnolo and Camuffo, 2010). The part of the AME approach which focuses on architecture mapping is based on the understanding, that a product or manufacturing architecture describes a structured arrangement of functional elements, the allocation of these functional elements to physical components and the definition of the interfaces between these interacting physical components (Ulrich, 1995; Harlou, 2006). The architecture defines the basis for variant creation towards (1) the market side, to satisfy a variety of customer needs, and (2) the operational side, e.g. technical variants aimed at reducing internal cost or time-to-market (Erens and Verhulst, 1997).

The benefits of platforms and architectures can be said to exist in the dimensions of rationalization and innovation (Mortensen et. al. 2012). Rationalization focuses on benefits related to the optimization of the existing business e.g. increased standardization and effectiveness in production. The innovative dimension focuses on the future of the business, e.g. improved ability to reach out to new markets, rapid new product development based on a reuse of standard designs, and leverage of core technologies in new business areas (Harlou, 2006; Meyer and Lehnerd, 1997). Even as the methodology is well established in research and industry, it can be argued that the understanding of the strategic implications of implementing a modular strategy is still relatively limited (Sanchez, 2013). However, modular architectures and platforms from which several product variants can be developed, can be said to give an organization the foundation to execute multi-product plans focused on strategic market differentiation (Simpson et. al. 2014). The approach presented in this paper includes a market segmentation, which is based on the mapping concept presented by Meyer and Lehnerd (1997), where the market is divided into homogeneous groups of consumer preferences to create a number of market segments. Understanding the market dimension is a fundamental aspect of defining the criteria for development of product platforms and architectures (Hansen et. al, 2012). The AME approach links the architectures to the market segments and includes sales volume to understand how the current portfolio fits the market situation. This overall mapping of the current market, product architectures and manufacturing architectures is considered an important step towards identifying the financial potential for implementing modularity into a portfolio. Jiao et. al. (2007) argues, that future research related to modularization lies in this holistic and system-wide solution-oriented approach. This includes the establishment of a closer relation between the market, product and manufacturing domains. The approach applied in the case study draws on the architecture definition described here and focuses on both rationalization and innovation potentials related to modularization.

2.2 Financial evaluation

Several methods exist to assess the financial value of e.g. a developing project. This includes different variations of assessing Net-Present-Value, Internal Rate of Return, Discounted Cash Flow Analysis or determination of Estimated Commercial Value etc. (Cooper et. al. 2001). These methods give a relative simple indication of the value of a project and can be used to make decisions when planning how to optimize the value of a portfolio. Methods to assess the value of a platform initiative based on sharing of common modules can also be found in the literature. However, research is limited within this area.

Gonzalez-Zugasti et. al. (2001) present an approach to valuation of a platform design for a product family. The method is based on the understanding, that subtracting the needed investments from the sum of benefits related to a modular platform design, can define the value of implementing a platform strategy. They present a two-step model. The first step focuses on the technical design of different platform alternatives for a product family. The second step goes into evaluation and selection of the most valuable/robust product family/platform design. The approach requires a number of alternatives to be evaluated. Thus, the method implies that a company has already committed to the development of these platforms.

Moon and Simpson (Simpson et. al. 2014) introduce a method based on a module instance matrix to valuate modular platforms in product family design. They introduce the expected platform strategy cost function and calculate the expected cost for a specific platform strategy, as the sum of additional design cost per product, plus the expected cost for a given strategy. The strategy cost relate to the cost of redesign of components, creating convenient interfaces and having some components overdesigned so that they can be shared between several variants within the product family. They then valuate a platform design based on the net benefit, related to the volatility rate, the changing demand rate, the cost saving of family design, and the identified additional cost. The approach differs form Gonzalez-Zugasti et. al. (2001) by including a level of risk and uncertainty in the valuation e.g. by taking into account the possibility for market changes. Being able to present the expected cost and a valuation of a platform strategy gives a company the ability to make decisions related to modular family design.

Both approaches compare different platform alternatives or platform strategies to support the selection of the best possible option. This is a valuable input when making decisions regarding modularization. However, they consider different platform alternatives within a product family and they imply that an organization has already, to some degree, committed to designing a level of modularity into their products. Introducing modules, which are shared across one or several product families, can be argued to be seen more as a portfolio management task (Krishnan and Ulrich, 2001) and room exists for an approach to valuate modularization across several product families and the related manufacturing landscape. Furthermore, support related to identifying a holistic strategic direction for modularization within a portfolio is needed.

The approach presented in this paper builds on similar elements as the two existing methods i.e. the possibility of valuating modularization by subtracting needed investments form potential benefits. However, the approach holds two dimensions (1) identifying rationalization potential based on the existing situation in an organization and (2) identifying potentials for platform innovation through windows of opportunity in the company roadmap. The sum of contributions from the two dimensions indicates the financial potential. The AME approach gives a high-level valuation of a platform initiative, which can be used by organizations when making decisions related to defining a strategic direction. The approach is a top-down assessment, which can support identification of areas within a portfolio where the largest benefits can be harvested. This is believed to be an important step before going into the process of designing modularity into a portfolio or a product family.

3 RESEARCH APPROACH

The presented research is the outcome of a comprehensive case study where we had the opportunity to apply the AME approach in a global world-leading OEM. 40 days were spent in the case company, working with the AME as reference model. From August to December 2015 we supported an internal project team in the effort of developing a strategy for modularization. The team consisted of resources from production, R&D and business development. The thoroughness of the study allowed presentation of results consolidated within the company and milestones were presented to top management. The goal of the study was to use the AME approach as tool to define focus areas within the company's portfolio for platform design and to define a financial goal setting for modularization. A high level of uncertainty was identified in the process of assessing the financial potential and the goal was not to provide an exact number and disregard this uncertainty, but as far as possible, to provide a fact-based argumentation for implementing a modular platform-based innovation strategy. The AME approach was introduced through weekly work session and results presented in visual models. Figure 1 and 2 show representations of some of these models. Finally looking at the current situation, the rationalization potentials were assessed across the portfolio, and potentials for platform innovation identified by looking at windows of opportunities. In the end a financial potential based on a holistic portfolio-wide approach was presented. This served as financial goal-setting and starting point for implementing a modularization strategy within the case company.

4 ARCHITECTURE MAPPING AND EVALUATION IN GLOBAL OEM

The AME approach proposes that it is possible to assess the financial potential by applying a holistic and top-down perspective across a portfolio. This includes assessment of the current situation (as-is) in a company and outlining a modular platform-based innovation strategy (to-be). Comparing the two scenarios and taking the sum of all rationalization and innovation potentials and subtracting the investments needed, indicates the financial potential. The approach is relatively simple and is based on the understanding that a new "to-be" scenario can be benchmarked against the current situation to indicate the potential for changing strategic direction. The AME approach should be seen as decision support. It includes a number of steps, which are primarily described through a number of visual models including (1) mapping of the market and global requirements, inspired by Meyer & Lehnerd (1997), (2) the product architecture mapping and (3) manufacturing architecture mapping, inspired by Harlou (2006) and Bruun et. al. (2014), (4) the architecture evaluation, which is a cost/performance evaluation, (5) identification of a "to-be" scenario, (6) a roadmap dimension and (7) the assessment of the financial potential for implementing a modularization strategy. One of the values of this approach is to allow companies to evaluate the impact of modularization relative to other strategic initiatives in the organization e.g. cost reductions through optimization of procurement or a new market entry. The next sections will describe operational examples of the different steps and results from the case study.

4.1 Market segmentation and identification of key design driving properties

The case company designs, manufactures and distributes products, which include an electronic control box (CB). This CB has been the main focus of the study. The core markets are Europe, Americas and China and includes both OEM and wholesale customers. The CB is generally made up by a number of printed circuit boards (PCB) encapsulated in either a composite or metal casing with one or more I/O functions. The CB is responsible for the majority of the total unit cost and is one of the main drivers for product differentiation. The strategy has, historically, been to develop the CB at product family level, with one or more assembly lines dedicated to the specific family. This has resulted in a high level of capital investments and relatively low utilization of the assembly lines. In the first part of the case study the current market situation was mapped and trends and key properties driving CB designs were identified (see Figure 2). The market analysis was the result of a series of semi-structured interviews with key stakeholders in the organization. Several rounds of interviews were held and between these a visual representation of the market segmentation was updated and used as reference for the next round. In collaboration with market and technical specialists the number of key design driving properties was limited to 6. P1: product power requirements, P2: ambient temperature requirements, P3: need for human-machine interface (HMI), P4: serviceability of the product, P5: electromagnetic compatibility (EMC) and P6: The need to live up to international approvals. In Figure 1 these are represented as P1-P6. Each property was evaluated in the segments, creating the profiles seen in the charts. Figure 1 shows an excerpt of the full market segmentation.

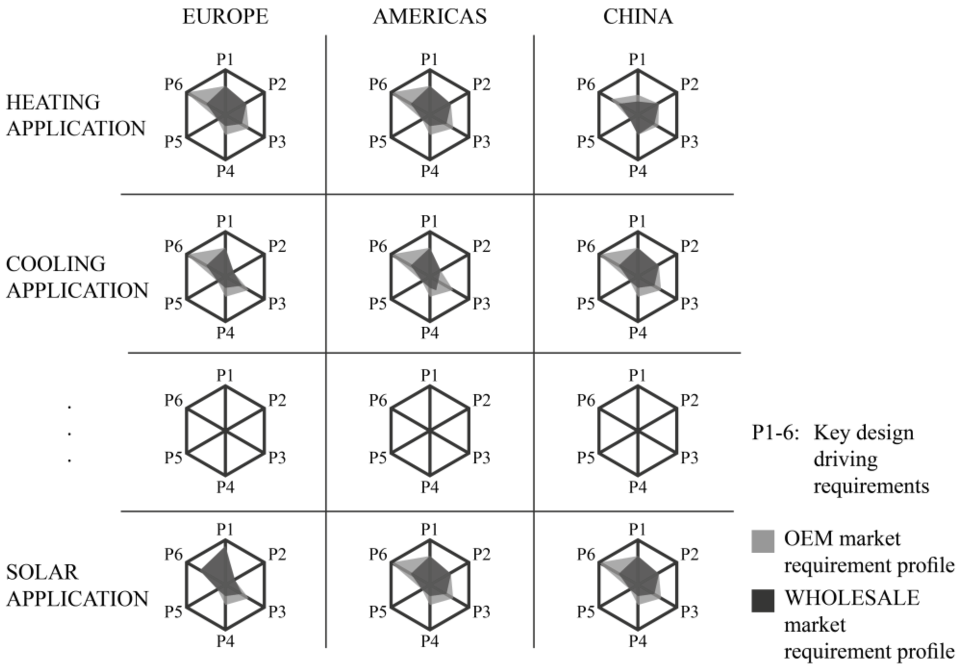

Figure 1. Example of market segmentation and evaluation of key design driving properties

The approach was to focus on the key market segments and key requirements (Mortensen et. al., 2011; Mortensen et. al., 2016). This resulted in a number of segmentations defined by strategic geographical core markets and core application areas. The goal was to show how the existing architectures fit the market and through a top-down reasoning argue for a changed approach if needed. This level of detail gave enough input to show that the existing strategy in the case company resulted in added cost being transferred from low volume segments to the core segments responsible for approx. 90% of the sales volume. The conclusion was, that elements in the current strategy compromised the overall competitiveness of the portfolio.

4.2 Map current architectures

Next, existing architectures were mapped. Identifying the number of architectures in the portfolio, was, to some extend, a pragmatic exercise. As benchmark, an architecture was considered unique if less than 90% of interfaces were shared with other architectures. Software features and minor variance e.g. colouring, was not considered. The 90% benchmark, allowed differentiating product variants. For example, within a certain product family redesign of a single variant had led to a number of interface changes and thus, due to the 90% benchmark, several different architectures were identified within that product family. Through a number of iterations, 24 different product architectures distributed over 8 product families and 20 different manufacturing architectures were identified. The challenge in this process was to be systematic in the identification of the architectures and input from several product and manufacturing specialists was required. The conclusion was, as in average 3 different product architectures existed within each product family, that too many unique architectures existed in the portfolio. Examples of different architectures within the same product family were e.g. different product structures for the American and European markets and different building principles for OEM customers and wholesale customers. At interface level this could be different ways to connect an upper and lower cover of a CB, or different ways to mount a PCB in the lower cover e.g. press-fit, snap-fit or mounting with screws. Only interface variations, which were not directly linked to a customer requirement, were regarded as non-value adding. Cost and sales data for each architecture were analysed i.e. material cost, labour cost, yearly sales volume and full-cost. For the manufacturing architectures each process step was analysed and grouped into three overall categories: Handling, processing and quality control & programming. This indicated core differences between line architectures. Again, core data was identified i.e. cycle time, capacity, investments, footprint and overall equipment effectiveness (OEE). Figure 2 gives a visual representation of the architecture mapping and shows how the production landscape was related to the 24 product architectures.

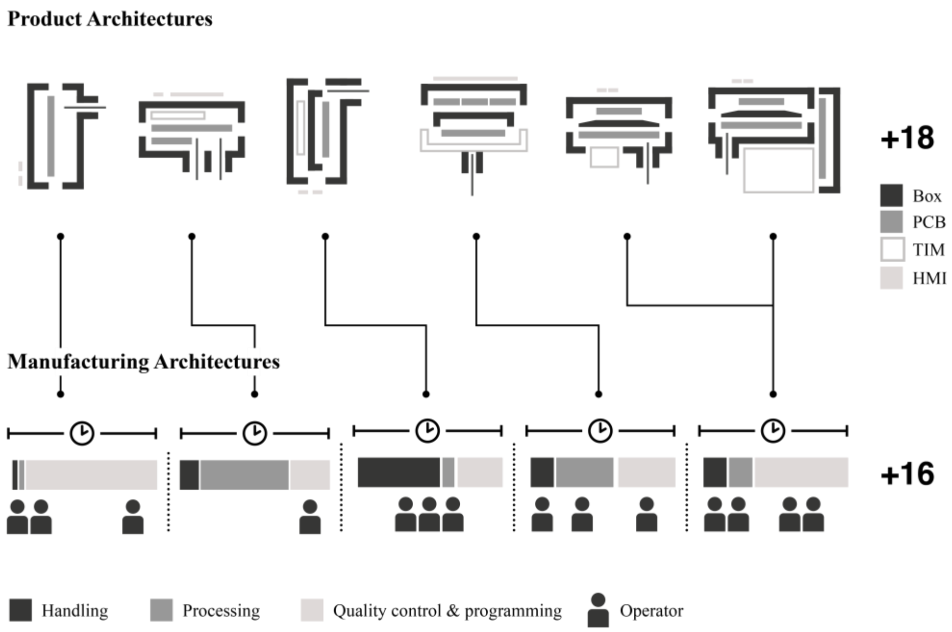

Figure 2. Example of architecture mapping

Differences between product architectures are in figure 2 illustrated by different representation of the main subsystems of the CB i.e.: the encapsulation (box), the printed circuit boards (PCB), the thermal interface material (TIM), which allows transportation of heat away from mainly the power module, and the human machine interface (HMI).

4.3 Evaluate performance across portfolio

Having established an understanding of number of architectures in the portfolio, cost and performance for the individual solutions were evaluated. For example, looking at cooling solutions across the portfolio, it was clear, that several different technologies with different realization and cost structure existed. In a similar way, looking at test and programming equipment across assembly lines, large deviations in cost/performance were identified. The complete evaluation included systematically going through key functional parts of the architectures and comparing cost/performance across the portfolio. The analysis supported the important discussion of which parts of the portfolio should build on in the “to-be” scenario and which parts should be “killed”. This type of evaluations was only possible by applying a portfolio-wide perspective and gave the first indications on the rationalization potential. Examples of findings from the evaluation phase were that comparable product solutions differed in cost by up to a factor 2, as different design solutions had been applied to deliver similar product properties. On the manufacturing side, product dedicated test procedures were driving cost. Furthermore, it was observed that copying line designs, or parts of it, provided up to 20% reduction of investments and procurement time.

The 24 unique product architectures and 20 unique manufacturing architectures were related to the market segmentation in Figure 1. This allowed rationalizing across the product, manufacturing and market domains to assess the optimal number of architectures in the portfolio able to cover the market. The assessment showed that roughly half of the existing architectures were enough to cover the market segments. This was an estimation based on the input from the AME approach and conclusions were that the number of current architectures exceeded the optimal. These examples give an idea of the type of top-down reasoning behind the financial estimates presented in this paper.

4.4 Conceptualizing “to-be” scenario and financial assessment

Mapping and evaluating the current market situation and existing product and manufacturing helped to identify a number of potentials for rationalization of the current situation. Next, the roadmap for new product projects were scrutinized to identify windows of opportunity related to modularization. This could e.g. be a new product able to carry a new standardized cooling solution, which then could be implemented across the portfolio for comparable products. Three projects, all in an early development stage, were identified to serve as lead projects. For each project sales forecasts, product, and production concepts were analysed. The “to-be” scenario was conceptualized based on the input from the former four steps in the AME i.e. market segmentation and analysis, architecture mapping of product and manufacturing, evaluation of cost/performance across the portfolio, and the roadmap. The “to-be” scenario formed a holistic picture including a definition of optimal number of architectures to accommodate market demand, modularization of these architectures and the identification of where standardization could be financially beneficial. In collaboration with the specialists involved, the “to-be” scenario was benchmarked against the “as-is” situation and all potentials were summarized. Table 1 shows an excerpt from the total list and illustrates potential finical gain and needed investments for seven rationalization initiatives. Each potential was consolidated and reviewed within the team working with modularization in the organization. The financial numbers are displayed in Mill. USD. The needed investment is indicated with zero, if no or a neglectable direct investment was anticipated to obtain the potential gain.

Table 1. Examples of rationalization potentials

Rationalization potentials		**Investment needed**	**Potential gain**
1	Kill redundant product architecture	0	5
2	Apply best cooling solution for comparable architectures	1,5	3,5
3	Use best solution for quality control	0,3	1
4	Move product from one to another assembly line	3	8,8
5	Implement standard solution for PCB assembly	0	3,2
6	Implement standard solution for box assembly	0	5
7	Run-in of product on existing assembly line	0	2,9
Total		**4,8**	**29,4**

Benchmarking the sum of all financial potentials with the total cost base for the CB (as-is) indicated a potential reduction of material cost by 10%, labour cost by 15% and investments by 35%. In total, the final assessment showed a potential reduction of the total cost base by 15%, by implementing elements of a modular platform-based innovation strategy for the control box. Applying the AME approach helped the case company to define a goal setting for modularization, and the results served as a starting point for realization of a platform-based innovation strategy. Applying the AME and using it as decision support related to modularization, initiated a discussion in the case company to extend the scope and apply the approach to the complete products assortment.

5 DISCUSSION AND FURTURE RESEARCH

So, is it possible to get anything beneficial out of estimating a financial potential based on other estimates of rationalization and innovation potentials at architecture level across a portfolio? As indicated in the case study, putting in the effort, it is possible to get an outcome, which on a high level can indicate if a company can get anything out a modularization initiative. The intention is, that the result of the AME should be used as decision support for top management to answer whether to proceed or not. Based on input from the AME approach the case company has put an effort into pursuing the identified potentials, has initiated similar AME analysis for all product areas, and has put resources into conceptualizing and operationalizing the "to-be" scenario for modularization of the CB. This is considered to validate the value of the approach.

The approach highlights the importance of understanding the current situation before going further into the definition of a platform-based strategy. Specialists in the case company commented in the early phases, that resources was wasted putting so much effort into mapping and detailing the current situation. However, as this mapping served as benchmark for the future modularization efforts, the value became clearer along the process. A fundamental assumption in this paper is that we cannot ignore the current situation. Good product and manufacturing solutions exist across the portfolio, which should be carried into the "to-be" scenario. Very few situations are "green field" and the AME approach seeks to connect future modularization initiatives with the existing portfolio and gives an assessment of how these two situations can be merged in the most optimal way to harvest a financial potential. This is why the AME approach can provide an important input for decision-making regarding modularization in an industrial context. The overall point for this assessment is to bring the discussion of modularization to a strategic level. If we are not able to assess the financial potential, the discussion of platforms and architectures is believed to often remain an R&D task, and be constrained to specific project contexts. The top-down approach presented in the AME showed a positive result and has brought the discussion of modularity to a new level in the case company. A major challenge related to the approach applied in the case study, is the collection of data. Collection of data e.g. cost data, market data and production data, must be performed so stakeholders are confident, that correct conclusions are drawn based on the AME approach. Extensive effort was put into validating data study and several iterations of mapping cost structures of the existing architectures were needed. As each company context is different, research effort should be put into systemizing the data collection process related to the AME approach. This could strengthen the approach and improve the operational use.

As seen in related methods to valuate modularity in product families (Simpson et. al., 2014), a high level of uncertainty exists in this type of assessment e.g. in market changes and internal cost variations. The uncertainty presents a fundamental challenge for the AME approach. However, and as the case study showed, the AME approach should indicate if a financial potential for modularization exists and in which range this potential should be expected. Not to give an exact number. It is up to management, with input from the AME to dictate the strategy for modularization in the organization.

For future research activities related to decision support in the early stages of developing modularization and platform strategies, focus should be on how to systematically approach the data collection to the extend it is possible. A more systematic overview of data needed to execute an assessment based on the AME approach would be valuable. This could improve the operationalization of the approach. One of the main challenges is that every company context is considered to be different. Further research activity should also be put into how the "to-be" scenario for modularization is defined. In the current application of the AME approach, this scenario is developed, adjusted and verified in collaboration with specialists from the case company. An overview of dimensions to be covered in this scenario could also increase the operational use of the approach.

6 CONCLUDING REMARKS

In the paper we show how the AME method has been applied in a large global organization to assess the potential for introducing a modular platform-based strategy across several product families. The results show a significant potential for rationalizing across the existing portfolio, and when looking into the roadmap and identifying windows of opportunity, also for a standardization of new product and manufacturing solutions. The main contribution of this paper is the example of application of the AME approach, which can give input to practitioners and serve as inspiration for executives who want to investigate the potentials of applying a platform-based strategy across a portfolio. The top-down and holistic approach presented in the paper allowed generating results within the case company in a relatively short time frame and at a level of quality able to support strategic decision-making concerning modularization. Results from the case study are believed to indicate the validity of the approach, in spite of a high level of uncertainty associated with the assessment.

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