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PLATFORM CONCEPT DEVELOPMENT WITHIN THE INTEGRATED PKT-APPROACH

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Abstract

The development of modular product structures and platforms for product families is used more and more in companies to cope with the increasing complexity. Both approaches, modules and platforms, contain the definition of a certain degree of reusable elements which leads to a reduction of the internal variety, e.g. a reduced number of parts.

The integrated PKT-approach is a method toolkit including different combinable method units supporting the development of modular product structures with reduced internal variety. The aim of this paper is to include the specific development of product platform concepts and the evaluation of different concepts regarding complexity costs into the integrated PKT-approach on an exemplary product family.

Keywords: Integrated product development, Product families, Product structuring, Platform concepts, Complexity costs

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1 INTRODUCTION

To cope with the increasing complexity caused by growing diversity in customer demands, regulations and other requirements, companies have to implement appropriate concepts in product development. Beside the use of modules to increase commonality for example to gain scale effects, product platforms are often developed as a common base for product variants. These approaches contain a degree of pre-developed and reusable solutions, which leads to reduction in internal variety, such as a reduced number of parts. This creates considerable potential to reduce complexity costs, even when production costs rise to a certain degree. The integrated PKT-approach aims to develop modular product families with reduced internal variety, while keeping external variety, using combinable, situation-specific method units (Figure 1). It was developed at the Institute of Product Development and Mechanical Engineering Design (PKT) at the Hamburg University of Technology (Krause et al., 2014). The focus of the integrated PKT-approach lies specifically on the variant part of a product family, with systematic identification of standard components to support platform development not integrated explicitly.

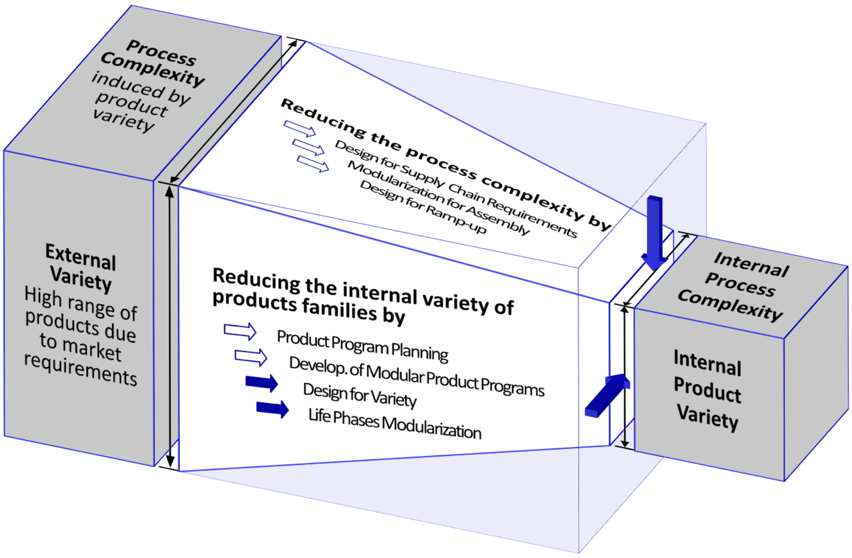


Figure 1. Integrated PKT-approach for developing modular product families (Krause et al., 2011a)

The aim of this paper is to include the definition of platform concepts and their selection in the integrated PKT-approach. The relevant basics regarding platform definition and complexity costs for the approach presented in this paper are described. Adaption of the integrated PKT-approach is explained in Section 3, using a product family of floor cleaning robots. Three concepts with different degrees of commonality are developed and evaluated. Finally, a conclusion is drawn.

2 DEFINITION OF PLATFORM CONCEPTS AND THEIR SELECTION

This section presents the current state of research relevant to the platform concept development approach. It includes the definition and development of platform concepts in the context of modular product structures and their selection.

2.1 Platform definition

Several definitions of product platform have been made, varying from a basic module used in all variants of the product family (Blecker, 2006; Piller, 2006), over a set of common subsystems (Meyer and Lehnerd, 1997) or a common architecture of a product family (Martin and Ishii, 2002), to a broader understanding, including processes, persons and relations (Robertson and Ulrich, 1998).
Various approaches have been developed that focus on different perspectives of platform development. For example, Robertson and Ulrich (1998) identify the balance of commonality and distinctiveness as a core task in platform development. Therefore they propose the use and iterative refinement of commonality and differentiation plans, as well as a product plan, defining the

introduction of variants. Other approaches focus on the market view and strategies to cover different market segments with product platforms (Meyer and Lehnerd, 1997), or aim for robustness against changes, using for example a Generational Variety Index (Martin and Ishii, 2002).The balance of commonality and variety in the context of product platform development will be included in the integrated PKT-Approach.

To develop a product platform it is important to understand its characteristics, especially compared to standard modules. In the following different characteristics of product platforms are described, which contribute to the methodical approach used in this paper. According to Meyer and Lehnerd (1997), a product platform encompasses the core technologies of a company as a base for efficiently deriving product variants. Schuh (2005) states, that the life cycle of the platform is decoupled from the life cycle of the product variants. Furthermore he describes the platform as a special type of modularization, including all components, interfaces and functions, which can be standardized in a product family. Lindemann (2006) describes the platform as a common base structure that can be configured by adding variant modules and can include modular sub-structures. Elements with high development and test costs should be included in the platform (Lindemann, 2009). Product platforms also support process modularity/commonality and, by defining a basic, common module especially delayed differentiation (Blecker, 2006). The platform and its standardized elements should not be visible to the customer (Ehrlenspiel, 2007), and should be placed preferably in the core of the structure (Lindemann, 2009).

In the context of this paper, a product platform is defined at the level of product structure as a variant-neutral basis for all variants within a product family (platform module). It incorporates particular characteristics that separate it from a standard module. The term 'platform concept' is used to describe not only the platform module, but also the variant modules required for configuration of the platform. The platform concept has to include a description of standardized interfaces and configuration rules to be able to add the variant modules to the platform. The variant modules either offer a low degree of commonality or are individual to a particular variant. For the definition of modules the integrated PKT-Approach provides the method unit life-phase-modularization using technical-functional and product strategic module drivers (Krause et al., 2011b). Other authors propose for example the use of design structure matrices (Pimmler and Eppinger, 1994) or the use of a set of heuristics to identify modules from a function structure (Stone, 1997).

Modularity is a gradual property described amongst others by the level of commonality (Salvador, 2007). Product platforms are defined here in the context of modular product structures; the balance between commonality and variety is a core aspect. Different platform concepts have different levels of commonality and a different impact on the reduction of internal variety. Therefore, it is necessary to evaluate the concepts for selection for variety reduction, which is carried out with the help of complexity costs.

2.2 Selection of platform concepts

Current literature provides several qualitative and quantitative approaches to evaluate product structures. Metrics to measure modularity (e.g. Hölltä-Otto and Otto, 2004) and cost assessment (e.g. Ehrlenspiel et al., 2007) are presented. In the approach described in this paper, a semi-quantitative assessment of modular product structure families using cost, time and quality is sought.

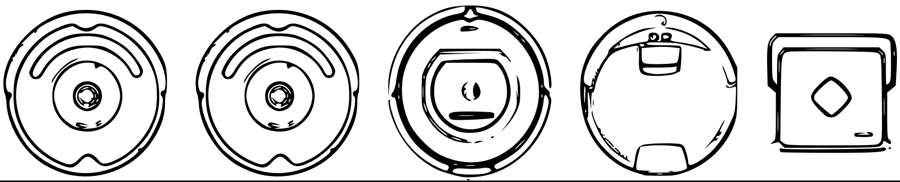
The definition of complexity costs, like complexity itself (Brosch et al., 2012), varies in literature. Definitions include costs that arise in the company from the variety of the product program (Homburg, 1997); costs resulting from product and process complexity (Ehrlenspiel et al., 2007); costs that denote the cost of indirect functions in a company and its suppliers caused by component variety (Thonemann, 1997); and costs that result from variety and diversity of elements and relations in the company (Rathnow, 1993). Complexity costs, as used here, are the changes in costs based on the increase or decrease of the internal product and process variety of the product family relative to the existing state.

The next section shows how platform concepts with varying degree of commonality are developed and evaluated by complexity costs, using the example of a product family of floor cleaning robots.

3 USING THE INTEGRATED PKT-APPROACH FOR PLATFORM CONCEPT DEVELOPMENT

In this section, the integrated PKT-approach is used to develop and evaluate three different concepts for a family of floor cleaning robots. The integrated PKT-approach is a method toolkit and its basic method units are the development of variety-optimized component concepts and life-phase modularization (Figure 1). Balancing commonality and variety in platform concept development is included in the integrated PKT-approach here. For this purpose, a platform heuristic is applied after the design for variety step as an add-on to the life-phase modularization step. Two approaches are used to predict the complexity costs of the platform concepts. A family of floor cleaning robots is used as an example to demonstrate the application of the method (Table 1).

Table 1. Product family of floor cleaning robots



variant	SR400	SR500	SR1000	WR600	WM2000
cleaning principle	vacuum	vacuum	vacuum	scrubbing	mopping
control concept	buttons	buttons	touchpad	buttons	buttons
discharge bin sign	no	yes	yes	yes	no
dirt detection	no	yes	yes	no	no
filter type	standard	standard	HEPA	standard	-
volume per cycle	60000 pc.	50000 pc.	25000 pc.	55000 pc.	50000 pc.

The product family consists of five product variants for different applications. The first three variants use brushes and a vacuum system to clean floors. They vary in the user interface or the filter. The fourth variant is used for scrubbing smooth floors using a cleaning fluid. The last variant is a mopping robot, which only uses a dry or damp cloth for cleaning smooth floors. The robots have the ability to clean predefined spaces autonomously, while detecting and avoiding obstacles. The methodical approach, including the adaption for platform concept development, is shown in Figure 2. For all three developed concepts, the first method unit was used to create variety-optimized component concepts with the variety allocation model (VAM), which shows the dependencies between the differentiating properties, the functions and the variant components (Blees et al., 2010). This leads to a redesign of the components to isolate each differentiating property to one variant component. For the third concept, c, a platform concept for all variants of the product family is defined, using a heuristic as part of the Life Phases Modularization.

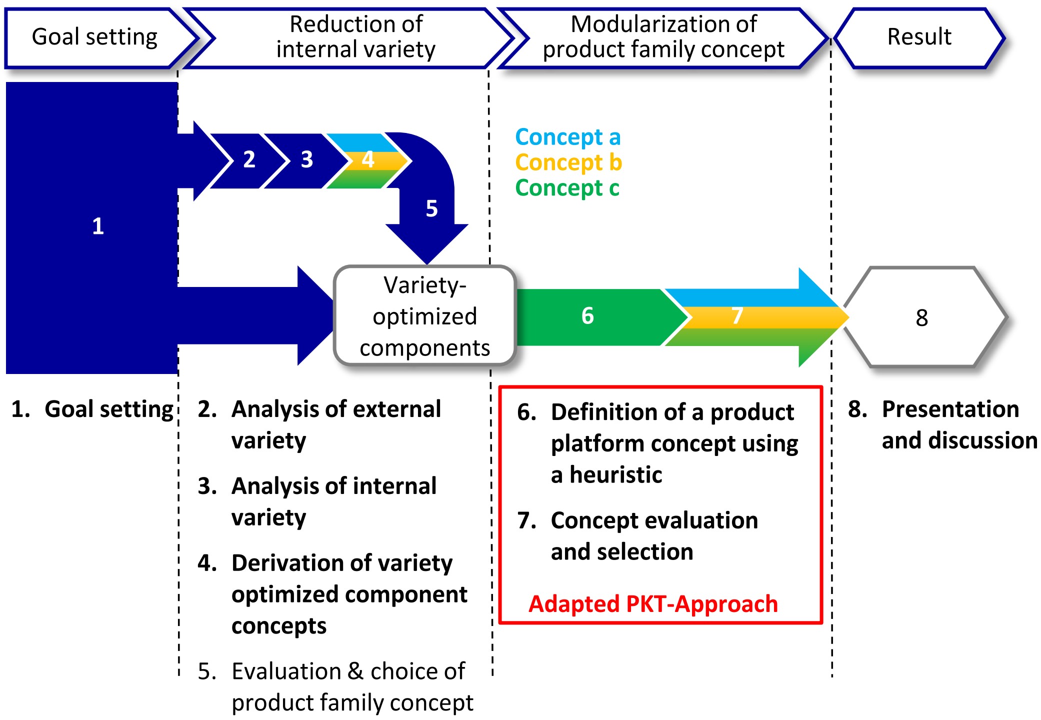
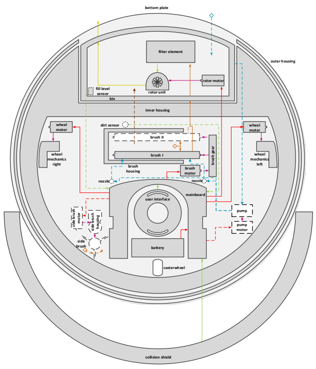
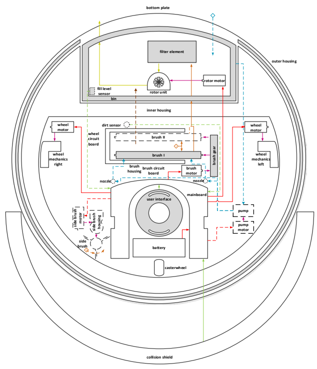
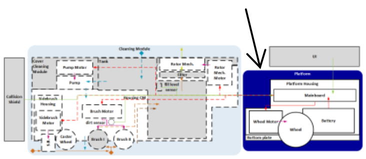


Figure 2. Adapted Integrated PKT-approach (based on Krause and Eilmus, 2011)

The concepts are shown in Table 2. In concept a, the variants were optimized separately for their cleaning function (vacuum-cleaning, scrubbing, mopping). The result of this concept is a reduction in the number of variant components; the degree of commonality between the variants is still relatively low. The second concept, b, focuses on finding commonality between the vacuum-cleaning and scrubbing variants, leaving out the mopping variant. This leads to a high degree of commonality between the variants, but an overall medium degree of commonality. With the development of a platform concept for all variants (c), the aim is to achieve the highest overall degree of commonality.

Table 2. Concepts a, b and c

Concept a	Concept b	Concept c
Separate improvement	Combination of SR and WR	Platform for all variants
		Platform  *Lateral view*
Low level of product commonality	Medium level of product commonality	High level of product and process commonality

Standard component   Variant component

The development of platform concepts is one focus of this paper and, in the following section, the approach for platform concept definition is explained using the example of concept c.

3.1 Development of platform concepts

To minimize internal variety and its associated complexity costs a platform concept definition aims to find a common basis for a product family that is not influenced by product variety. In this case, the common basis is defined with the help of product family properties, functions and components, as in the VAM. To find these platform elements and to support clear differentiation between commonality and variety, a heuristic based on the characteristics of product platforms (Section 2.1) derived from literature is used to adapt the integrated PKT-Approach for product platform concept definition.

Heuristic supporting platform definition:

- Include core technologies
- Find basic/common characteristics/functions
- Provide basic structure
- Include technologies with long innovation cycles
- Include elements with high costs (e.g. development & quality control)
- Remove variant dependency
- Provide sufficient differentiation (visual, functional, etc).

Based on the integrated PKT-Approach, the general steps are:

- analyse external and internal variety
- develop variety-optimized component concepts (design for variety)
- define platform concepts, using:
  - the *platform heuristic (new step)*
  - module drivers (life phase modularization)
- *evaluate cost (new step)* to support concept selection.

In the example, the heuristic was applied to the modularization step after redesign of the components for variety optimization (which is not necessary but recommended). Analysis of the variety and decomposition at the functions and components level of the product family is needed for input. The definition of platform concepts is divided into two steps that have to be repeated iteratively. The first step is searching for the part of the product family that can be standardized; the second step is to define the variant parts. The second step is carried out using module drivers, as proposed in the life-phase modularization. Both steps balance commonality and variety, based on the idea of Robertson and Ulrich (1998). To integrate the idea of a clear differentiation between standard and variant elements into the integrated PKT-approach the following two steps are used. The application of the steps is visualized in Figure 3. The upper part incorporates the first new step, which defines the platform using a heuristic, and the lower part incorporates the second step, which includes the definition of variant modules as in the life-phase-modularization.

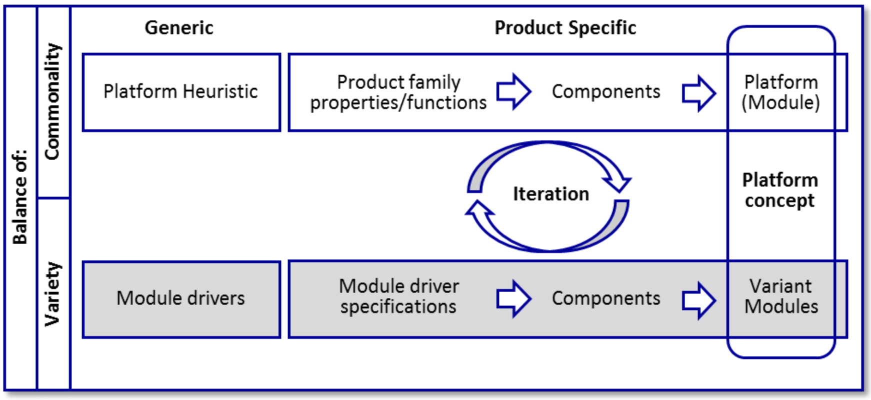


Figure 3. Definition of platform concepts

Step 1 - Platform definition with a platform heuristic

The application of the platform heuristic can be compared to the use of a commonality plan, because it leads to description of the standardized elements of the product family. It not only describes the platform, it also provides a generic guideline for decision making to define the platform. In comparison to module drivers, which lead to the definition of different modules, the heuristic is cumulative. It aims to extend the platform as one entity, not to define different parts. This heuristic can be used to translate the platform characteristics into a product structure. As in the VAM structure, basic product properties and their corresponding functions have to be found with the help of the heuristic before connecting them to suitable components. This allows for more efficient optimization, because it supports the creation of new concepts at an abstract level (like the VAM) and the redesign of components. The result of the first step is definition of the product properties, functions and components included in the platform.

Step 2 - Definition of variant modules

The second step can be seen as a reference to the differentiation plan, because the necessary product family variety is defined in the shape of variant modules or components. For this purpose, module drivers are used, as in the standard integrated PKT-approach using the life-phase-modularization (Krause et al., 2011b). The definition of modules with module drivers is used to validate the previously defined platform for the necessary variety. The module drivers and platform heuristic have to be weighed against each other, balancing commonality and variety, to find an overall improved product structure. The module drivers can be chosen using assessment of best applicability to the specific context. Instead of this simplified approach, the platform definition can be included in the life-phase-modularization using module drivers from all life phases. In this case, the defined platform has to be compared to the modular structure of each relevant life phase.

The result of the iterative refinement using the platform heuristic and the module drivers is a platform concept composed of the platform itself and the variant modules necessary for differentiation.

Application on the family of floor cleaning robots

The application of the platform heuristic on the family of floor cleaning robots is shown in Figure 4. Based on the platform heuristic, the basic properties and functions of the floor cleaning robot family were identified. In this case, the basic property of all robot variants is autonomous navigation. Each variant is able to systematically clean, avoiding obstacles. The core competence of the company is the software that controls robot navigation and the cleaning process. Because of the variant cleaning principle, only the associated software can be standardized and activated, according to the variant. Regarding the navigation the hardware can also be unified for all variants. To define the platform at technical and abstract levels, all necessary functions that serve the basic property have to be found. Module drivers were chosen to provide the necessary variety. For simplification and because of the focus on platform definition, only two module drivers are shown in Figure 4 and complete life-phase-modularization was not carried out. The use of module drivers leads to reconsideration of whether the collision shield should be established as a separate module because of visual differentiation, particularly in the case of the floor-mopping variant. Visual differentiation also leads to decoupling of the user interface as a variant-specific module. The technical specification driver leads to the definition of a cleaning module that includes all relevant components required to realize the main differentiating property, the cleaning principle. The result of this method step is the definition of a platform concept that provides the basic building principle, including a common platform module, for all robot variants and a variant cleaning module, as well as a sensor and UI module to configure variants. Finally, concept c was visualized using a module interface graph (MIG) (Figure 5). The MIG analyses the components of a product family for variety, spatial arrangement and connecting flows (Gebhardt et. al., 2014). In the cleaning module, there is significant difference between the vacuum cleaning/scrubbing variants and the mopping variant. The mopping variant consists of a simplified housing and a cloth instead of the brushes. There is more potential for commonality between the other variants, as analysed in concept b. For example, the housing, caster wheel and brush motor were standardized for these variants, while the side-brush with motor and housing form a module for the vacuum cleaning variant. In this way, concept c has the highest overall commonality while the other two focus on optimization of specific variants. The influence that the different degrees of commonality have on cost is shown in the next section.

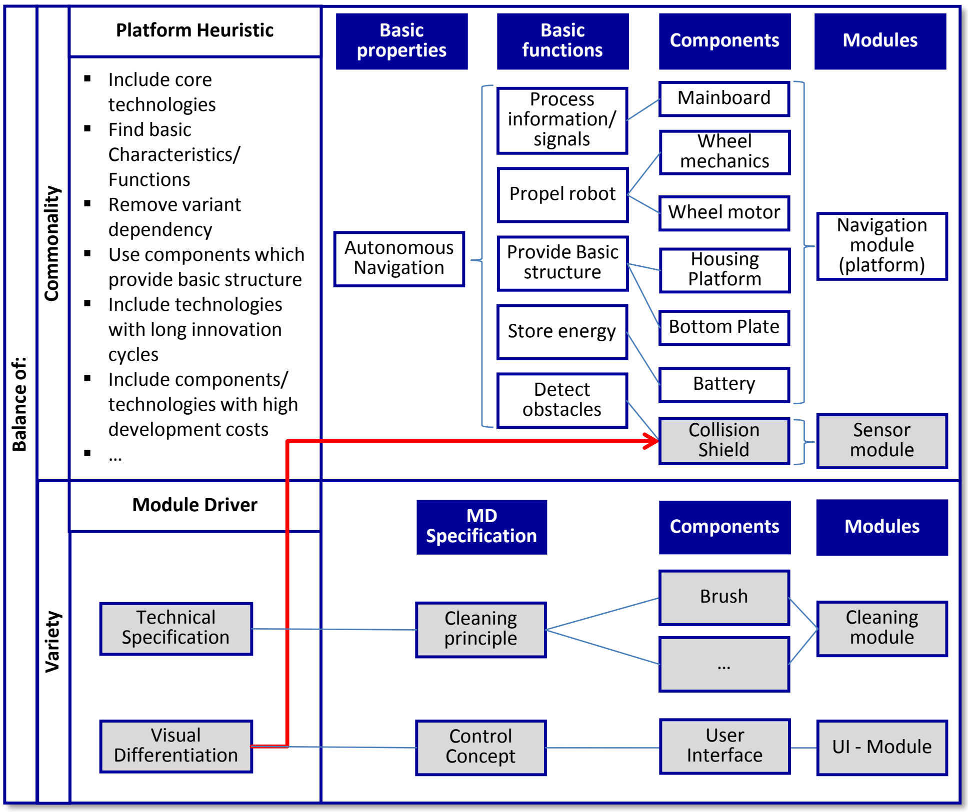


Figure 4. Balancing Commonality and variety - defining platforms and modules

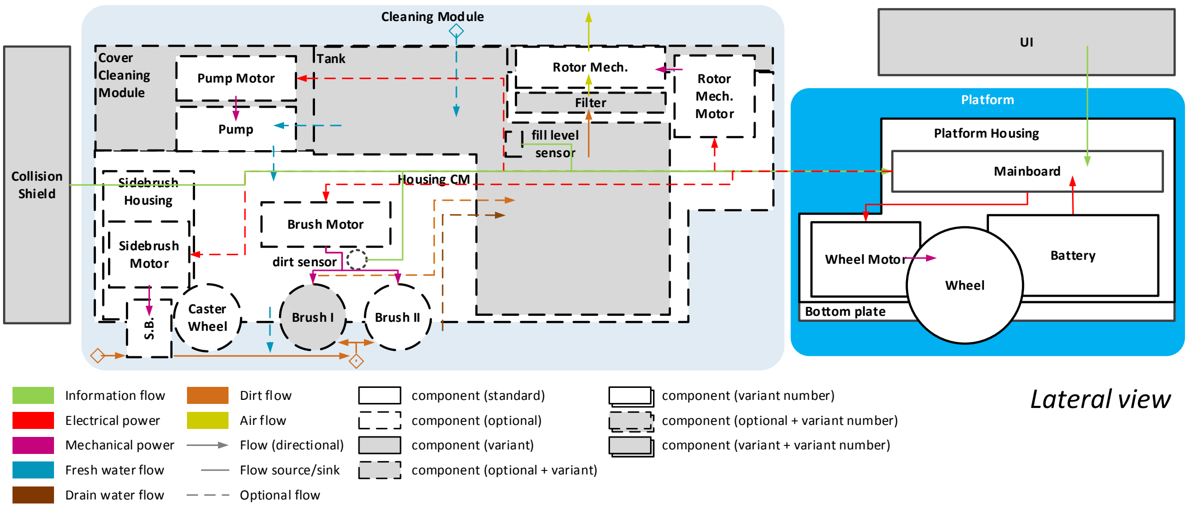
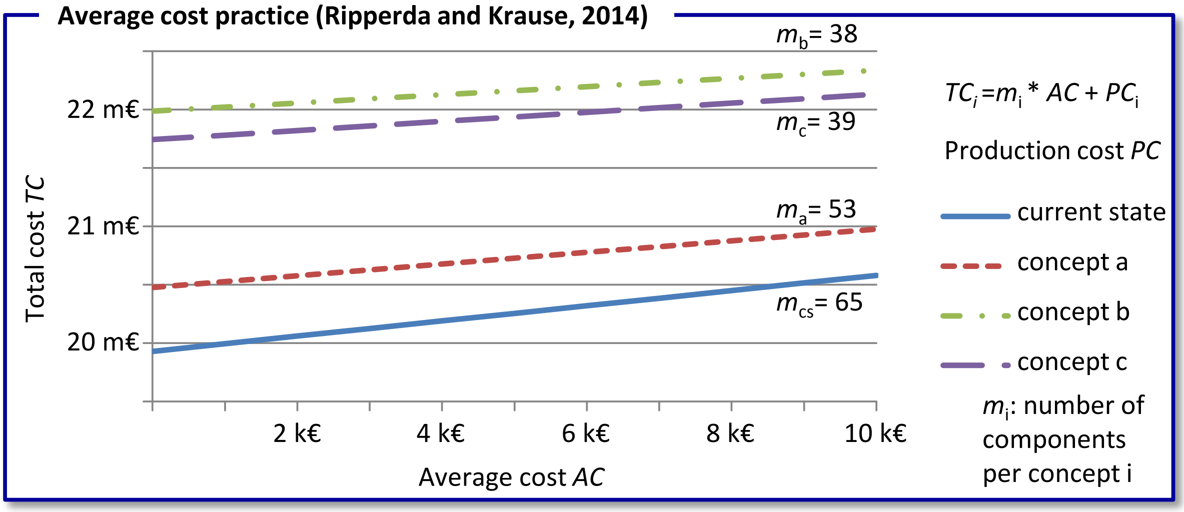
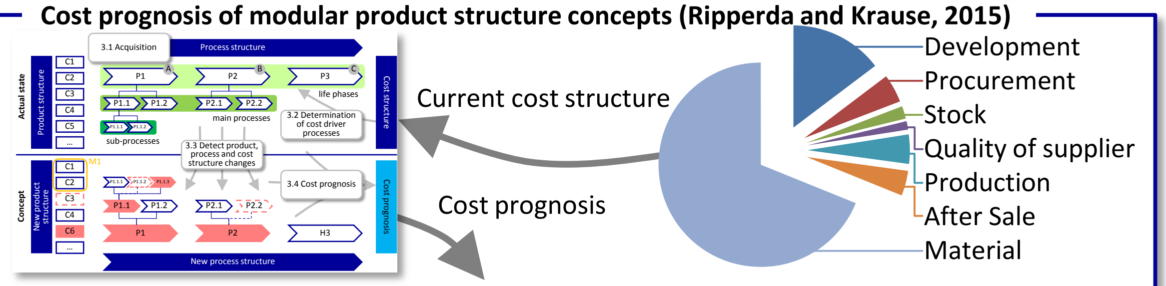


Figure 5. Concept c visualized using a Module Interface Graph

3.2 Cost prognosis

In this section, the costs of the three concepts of the product family floor cleaning robots are predicted to support concept selection. Depending on predefined goals, additional criteria (e.g. time or quality) for concept evaluation can be considered. The cost prognosis is shown, using the average cost practice (Ripperda and Krause, 2014) and the cost prognosis of modular product structure concepts (Ripperda and Krause, 2015). The average cost practice considers production cost and average cost of the concepts in terms of indirect costs that occur for one type of component in all life phases. The cost prognosis of modular product structure concepts is a clustered, time-driven, activity-based costing approach that detects the product, process and cost structure changes of the concepts, and predicts their cost based on the existing cost structure. The results of both approaches are shown in Figure 6.





		Stock			PC	CC
103%	91%	96%	90%	99%	98%	**97%**
104%	74%	90%	89%	98%	97%	**94%**
105%	73%	88%	75%	95%	93%	**89%**

Relative cost per life phase of concepts a, b and c compared to current state (100%)

Figure 6. Comparison of the results of the average cost practice (Ripperda and Krause, 2014) and the cost prognosis of modular product structure concepts (Ripperda and Krause, 2015)

From a monetary perspective, the results of average cost practice point towards keeping the existing state concept. The cost prognosis of modular product structure concepts suggests a change in the product structure to concept c. Comparing the approaches, the first overly generalizes so that the effects of greater commonality only result in higher production costs due to over-dimensioning of components. The second approach provides more differentiated cost information, which means greater effort is required to perform cost prognosis. The existing cost structure shows that material and development are the main cost centres. The relative costs of concepts a, b and c compared to the existing state necessitates an increase in development costs because new components are required. A decrease in cost is predicted in procurement, stock, production, after sale and material due to scale effects of commonality. In this example, production costs (PC) and complexity costs (CC) decrease relatively equally. A reduction of eleven percent in relative cost is predicted when commonality in the product family of floor cleaning devices is increased.

4 CONCLUSION

This paper describes how platform concepts can be developed and evaluated using the integrated PKT-approach and a new platform heuristic. It presents the literature, relevant for the presented approach, and a combined approach, using the example of a product family of floor cleaning robots. Three concepts with varying degree of commonality are developed, using the method units of the integrated

PKT-approach. A new platform heuristic was used to support the systematic definition of the platform. A basic and an advanced cost prognosis are used to forecast the concept costs to support decision making. The results show that the integrated PKT-approach can be used for systematic platform development. Comparison of the two cost prognosis approaches showed that detailed cost analysis is necessary to predict the effects of modular product structures.

The approach will next be applied in the development of a modular entrance area of an aircraft. Further research is needed in the field of platform concept development and evaluation. In particular, the characteristics of product platforms have to be studied in more detail to extend the platform heuristic. Additional verification of the cost prognosis unit needs to be carried out in projects with varying levels of internal variety and cost structure.

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