How to Combine Artifacts in Product Development for more Efficiency?

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Abstract: In product development, different artifacts, pieces of information, and documents are used at different phases in the development process. In early phases, for example, the Product Profile (PP) is often used. It contains general information about the needs of different stakeholders. In advanced phases, the artifact Development Order (DO) is used. This contains the required information to design the final product and its manufacturing. Although both artifacts are used, they are used separately. Therefore, information is collected for each artifact separately, although it would be available earlier sometimes. We present a possible approach to compare and combine different artifacts like the described ones to use information more effectively and more efficiently. Therefore, product developers will know, from which parts of the individual artifacts, they can use the information for other artifacts. This will increase the efficiency and

effectiveness of information handling throughout the product engineering process.

Keywords: Product Profile; Innovation Management; Knowledge Management; Development Order; Product Development; Product Generation Engineering; Methods; Linkages; Comparison.

1 Motivation

There are many different approaches to product development. Each of these approaches results in individual artifacts – pieces of information. As some approaches focus on the early phases of product development, others focus on later phases. Moreover, those approaches commonly are developed in individual schools, which results in artifacts that aren´t aligned. This causes a loss in efficiency as those approaches and their artifacts are difficult to use combined. To find the relations among the artifacts and combine their advantages to achieve a comprehensive method for better efficiency in product development, these research questions are answered.

In this paper, we propose an approach to combine individual artifacts. Therefore, we use two approaches as examples. An explanation model is the model of PGE – Product Generation Engineering according to ALBERS. It describes that the development of new innovative products is based on references. (Albers et al. 2016) A procedure model is given with the 4-cycle-model of product development according to GAUSEMEIER. It covers methods for the product engineering process (PEP) from strategic product planning to integrative development of market performance. (Gausemeier et al. 2011; Amshoff et al. 2016) Currently, both models aren´t yet aligned with each other. Therefore, information that is available early is not yet used, even if it is needed later. Also, information is missing in later phases of product development, which was not documented at the beginning.

2 State of the Art

This paper is based on artifacts of two schools of product development. The Karlsruhe School of Product Development (KaSPro) and the artifacts of the Heinz Nixdorf Institute (HNI). Therefore, the researched artifacts are described briefly.

2.1 Artifacts of the KaSPro – Karlsruhe School of Product Development

Based on the System Triple Approach of Product Development, the process of product development is a socio-technical system and can be divided into 3 sub-systems (see Figure 1). The Operation System (OS) contains all activities, methods, and processes. It creates the System of Objectives (SoO) and System of Objects (SO). (Albers et al. 2011) The SoO contains all anticipated and planned attributes of the SO, and all objectives, their interdependencies, and boundary conditions. Important to note, that the SoO does not describe the solution itself. During the development process, it permanently is extended and concretized. (Albers 2010) The SO contains all the documents and artifacts. Examples

are physical systems, virtual systems, and all intermediate results of the engineering process like drawings, models, and prototypes. (Albers et al. 2011)

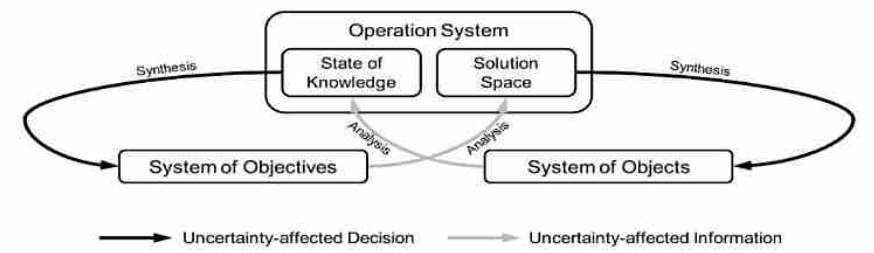

Figure 1: Extended System Triple (Albers et al. 2011)

The Product Profile (PP) is an artifact of the Karlsruhe School of Product Development (KaSPro) and is often presented in form of a poster. Therefore, as an artifact, it is part of the SO. The included information of the PP goes into the initial System of Objectives (SoO) at the early phase of product development. This information contains provider, customer, and user benefit-oriented information and specifies the solution space for the design of a product generation (see Figure 2). According to ALBERS, the "Product Profile is a powerful artifact for the early and consistent integration of the customer into the development process." (Albers et al. 2018)

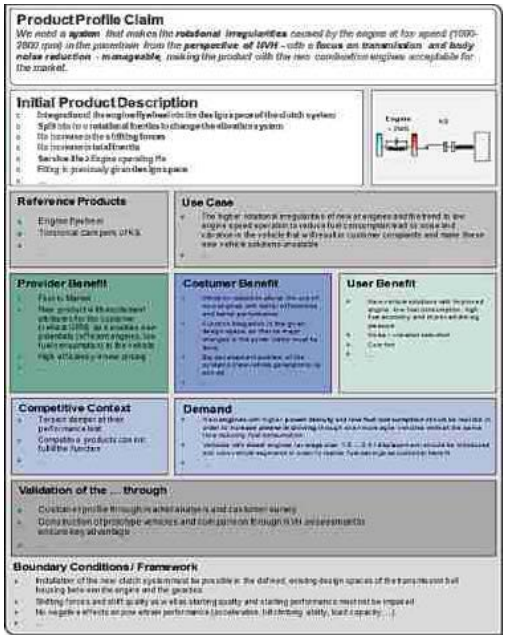

Figure 2: Example of a Product Profile for a Dual Mass Flywheel (Albers et al. 2018)

Defining the Product Profile is the starting point of product generation development. A PP contains essential elements such as objectives, requirements, and boundary conditions of all relevant stakeholders as well as product properties, central functions, and application scenarios of the product generation. (Albers et al. 2018) The initial development of one or

more Product Profiles and their initial evaluations together form the complete initial SoO. (Albers et al. 2017) In this context, SoO has a higher degree of concretization than PP.

2.2 An Artifact of the Heinz Nixdorf Institute (HNI) – The Development Order

The Development Order (DO) is an artifact of the HNI at the beginning of product development. It contains relatively concrete and more specific information, which are not considered in PP, such as the planned development process, schedule, etc. (see Figure 3). (Amshoff et al. 2016)

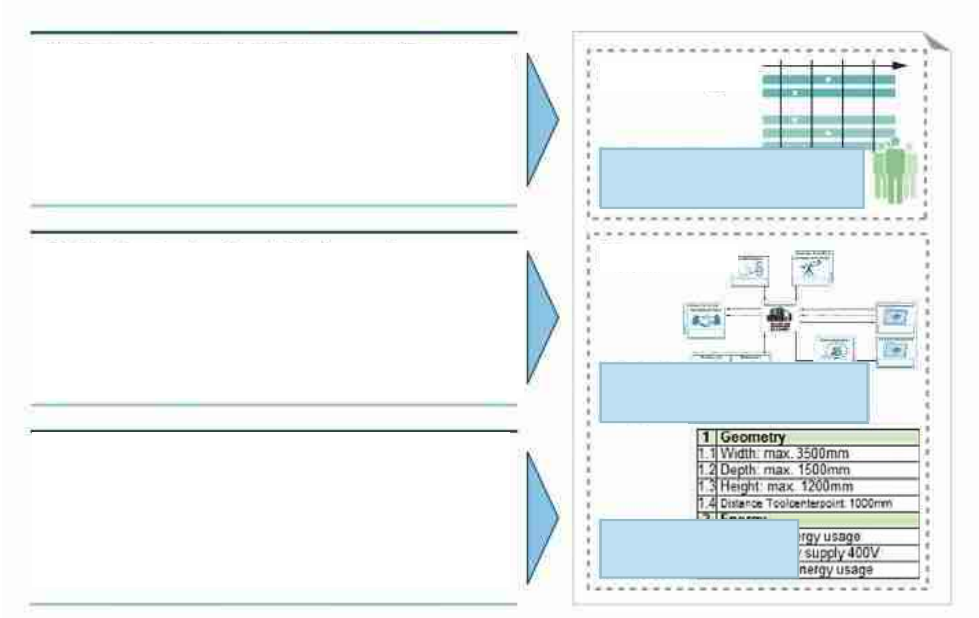

Figure 3: Structure and Content of the Development Order, translated (Amshoff et al. 2016)

Compared with SoO and PP, DO contains on the one hand, a wider range of information such as the determination of quantities, manufacturing costs, development time, on the other hand, more concret and more specific product specifications with solution approaches. (Echterhoff 2016; Gausemeier and Plass 2014) In this context, DO has an even higher concretization level than SoO. Thus, PP is the most abstract, and DO is the most concretized among the artifacts.

3 Method for Aligning Artifacts

To find the relations among the artifacts and combine their advantages to achieve a comprehensive method for better efficiency in product development, these research questions are answered.

- What relations exist among the respective model elements of SoO, DO, and PP models?

- How can the exclusive model elements of individual models contribute to the other models?
- How to integrate the models considered with the advantages of other models to achieve a comprehensive result?

To answer these research questions, a result-oriented retrospective comparison-and-supplement-approach was conducted in three Macrosteps (see Figure 4). In the Macrostep 1, the respective model elements of SoO and DO models are compared. Each Macrostep is divided into three Microsteps (see Figure 5). In the first Microstep, the linkages and differences are discussed. In the second Micro Step, the exclusive model elements are identified and analyzed with their advantages and capabilities of supplementing the other model. In the third Micro Step, the suitable model elements, as well as relevant analytical perspectives, are picked out and adapted to the other model. This results in an extended model, in this example the Extended Development Order (EDO).

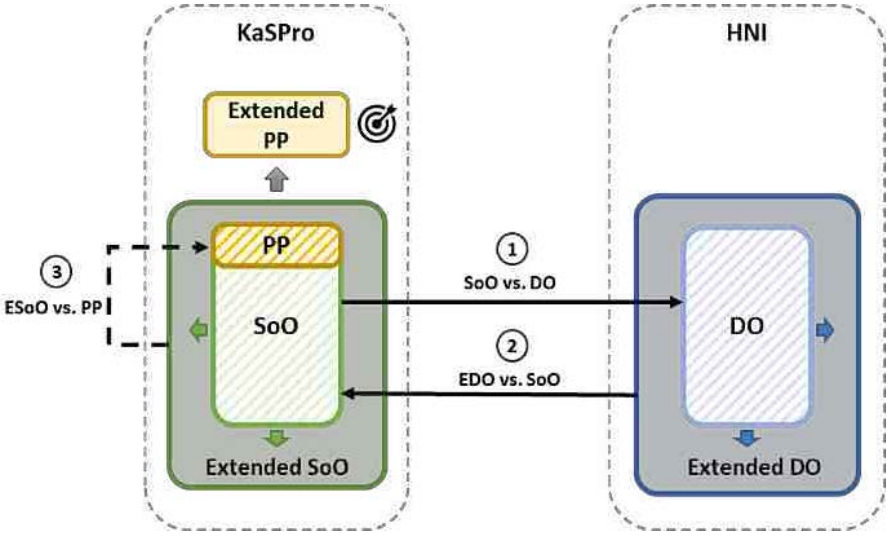

Figure 4: Result-Oriented Retrospective Comparison-and-Supplement-Approach

Analogous to Macrostep 1, the second comparison and supplement procedure between EDO and SoO models are made by applying Microsteps in step 2, with the extended SoO model (ESoO) as a result. Finally, the model elements of ESoO and PP models are compared in step 3. An Extended PP model is obtained as the result (see Table 1).

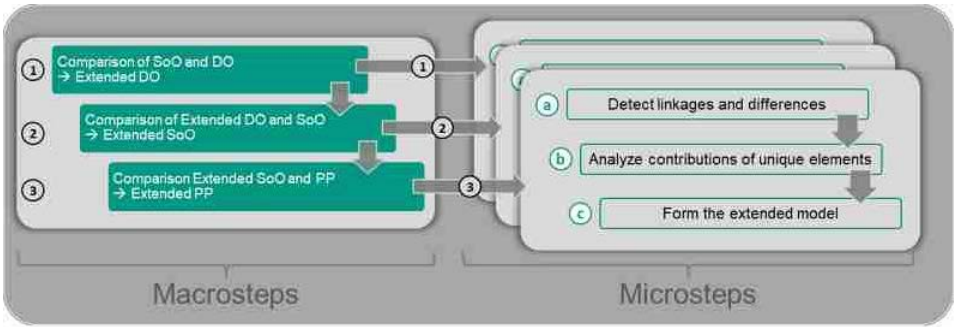

Figure 5: Macro- and Microsteps of Comparison and Supplement Process among models

The process of comparing and supplementing starts with the analysis of possible linkages. The linkages consist of two parts, which are similarities and relationships (see Figure 6). When the compared model elements contain identical, similar, or comparable contents, the linkages in between can be defined as similarities. When the compared model elements are bound up with each other, the connections can be generalized as various relationships. Based on the findings of comparisons and the analyses of the unique model elements, supplements to the model elements and models will be proposed. In conclusion, an extended model results after each model comparison. This extension of the models leads to a better alignment. Thus, information relevant to product development in PP, SoO, and DO is accumulated in the extended PP model to be considered right from the beginning of product development.

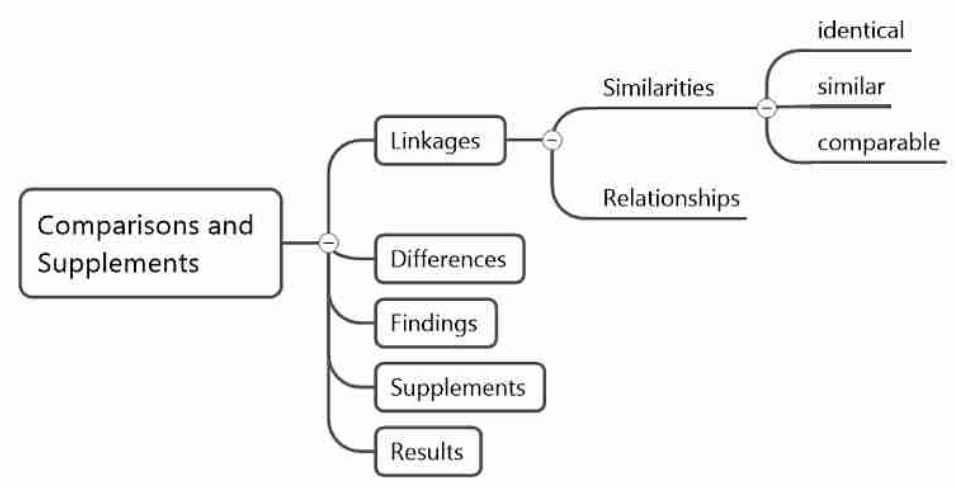

Figure 6: Components of Comparison and Supplement Process

4: Example for Linkages between SoO Model and DO Model

The first Macrostep of the comparison and supplement process for the two analyzed approaches starts from the SoO model and compares against the DO model (see Figure 7). The remaining SoO partial models which have no relations found with DO model constructs are the unique model elements of SoO model. To these unique model elements

of the SoO belong for example use cases, embodiment/implementation, phases, and product development activities.

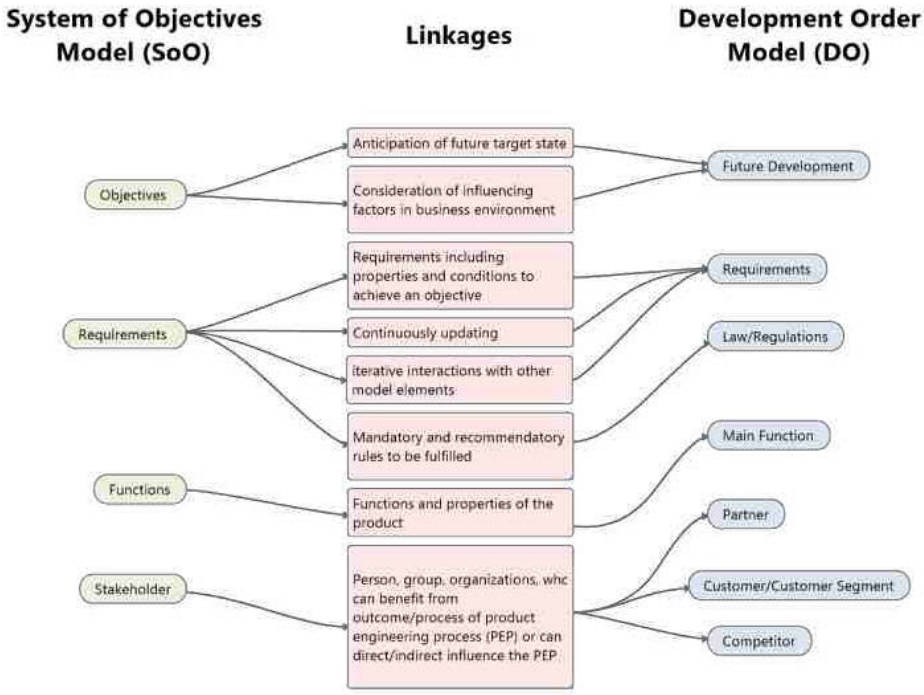

Figure 7: Examples for Linkages between SoO Model and DO Model

Since the model-based Development Order serves as a basis for communication and cooperation between the participants from strategic planning and development (Amshoff et al. 2016), taking the above-mentioned product engineering process related analytical perspectives into consideration will help to enrich the Development Orders, thus they are proposed to be added to the extended DO model as supplements. Accordingly, Macrostep 2 and 3 were carried out. As a result, the most abstract Product Profile scheme is linked with the most concrete Development Order model, and the original Product Profile scheme is expanded with supplements related to the internal and external environmental influences of the company and PEP-related influencing factors. The Macrostep 3 results finally in the Extended Product Profile Scheme.

5: Extended Product Profile Scheme

An extended Product Profile scheme is obtained on the bases of the Product Profile scheme and was supplemented as a result of the comparison and supplement process of the ESoO model and PP scheme (see Table 1). On the example of an instant hot water kettle, it is possible to interpret the extended Product Profile scheme. For each model element, one or two examples of practical applications are described. The term “module” is used to refer to all the partial models, model constructs, and modules.

Table 1: Applications in Extended Product Profile Scheme

Modules	Examples
Product Profile claim	"We need a system that makes the control of water temperature manageable via mobile APP."
Initial product description	adjustable water temperature, mobile APP control, low noise level,
Provider benefit	First to market, new attributes and modes in water boiling lead to a new pricing
Customer benefit	Low noise level (under 50dB), accurate water temperature adjustment enhances user comfort and efficiency
User benefit	Low noise level (under 50dB), accurate water temperature adjustment enhances user comfort and efficiency
Competitive context	Competitive products have a lower price
Use case	Users use the kettle to prepare coffee or tea. For specific users e.g., moms, can use the temperature control functions to get accurate and proper water temperature to dilute milk powder for the babies fast and conveniently.
Reference products	Normal electric kettle, other Intelligent home appliances
Demand	Short time in water boiling, water temperature control,
Picture	"Sketch, photo, CAD model or other graphic representation"
Validation of the … through	Customer profile through market analysis and customer survey
Boundary conditions/framework	Standards (ISO 9001:2015),
Supplements	
Future Development	Increasing digitalization in the household electrical appliance industry
Opportunity/Potential for Success	New business due to lifestyle change: smart home
Danger/Risk	Expiration of own patents leads to loss of competitive advantages
Strategic framework condition	Fundamental entrepreneurial decision: focusing on major customers (global key accounts)
Partner	Sales partner, service partner
Phases and Product engineering activities	Concept phase, construction phase, production phase
Milestones and deliverables	Construction approval, construction release, start of production (SoP), market launch

6 Discussion

The presented figures of the linkages between different artifacts enable product developers to derive artifacts later of later phases more easily from artifacts of earlier phases. Due to

the described linkages, they can easily spot possible origins of the required information. But as there are so many linkages, the figures became messy. Therefore, we propose to use tables with filters instead, where you can choose, what you are looking for. The table would then present you, where you can get all the required information from.

The comparison-and-supplement approach provides a reference process for further studies on the alignment of different models for product development and shows a possible example of establishing the further relationships, interfaces, and ontology in between.

At the beginning of the PEP, the extended PP model provides developers with the essential elements of the products, which include not only customer, user, and provider benefits, but also extensive strategic planning and PEP-related factors, to generate the comprehensive Product Profile and improve the efficiency of product development.

7 Outlook

Based on the results of this research study, further research works can be carried out in both, the short and long term.

In the short-term, the extended models derived from the comparison and supplement process should be validated, by applying e.g., survey questionnaires, empirical case studies, expert interviews, etc. Furthermore, an explicit guideline for comprehensive information at the beginning of the PEP based on the extended models should be derived. Moreover, possible software tools based on the related guideline can be developed.

In the long-term, the alignment of the model of PGE and all phases of the 4-cycle model is worth investigating. The applicability of the reference research process of this study – the result-oriented retrospective comparison and supplement approach could be a base for that.

8 Acknowledgments

The authors gratefully acknowledge the support of the research project "Future Robust Product Development: Systematic Extension of the Model of PGE - Product Generation Engineering by Adaptation of Methods of Strategic Product Planning" with the project number 437943992 by the funding of the German Research Foundation (DFG).

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