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# PROPERTY AND BEHAVIOUR BASED PRODUCT DESCRIPTION - COMPONENT FOR A HOLISTIC AND SUSTAINABLE DEVELOPMENT PROCESS

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## 1. Introduction

Technical development projects became more and more complex through the last years so that a lot of technical disciplines as well as different functional areas of companies have to co-operate. Innovative products make a significant contribution to compete with the global competition, but require close collaboration of mechanical engineering, electrical engineering and computer sciences [VDI 2206]. Of the latter two domains there additionally is, especially with a view to automotive industry, a continuously growing relevance that ends in an increasing proportion of added value concerning product development [Trachtenherz 2009, Benz 2004]. In addition customer requests, becoming more differentiated, cause a more specific market segmentation and, therefore, a disproportionate increase of variants in comparison to the rate of quantity growth.

In general, mentioned increase of complexity leads to ascending developmental periods and costs but is also confronted with decreasing product life cycles and hence, shorter payback periods. Therefore, simple but also effective methods and tools for the development processes are needed to form the stress field consisting of costs, time and quality advantageously in terms of a lean innovation (focusing real added value without wasting activities). These have to provide requested information with necessary quality at the right time to control complexity of the development process and form development progress effectively and efficiently. Within this article necessity and usage potentials of property and behaviour based product description for a multidisciplinary product development is shown. This ensures a holistic view at the product life cycle during the development phase and and additionally recognizes the requirements of the employees from different departments of a company.

## 2. Terminology

### 2.1 Product data model and product model

Although the terms "product data model" and "product model" are used undifferentiated in praxis both have to be distinguished. The "product data model" provides a formal scheme that defines how the data structure is built-on and the way included data correlate [Speck 1997]. Therefore, all relevant data for product description should be represented by a systematic data storage. This formalism is essential to ensure the purposeful use and working up of product information. Is a "product data model" filled with data of a concrete product a "product model" results and can be considered as an instance of the used "product data model", according to [Speck 1997].

An integrated product model provides the integration platform for manifold computer assistance. Therefore, it is the prerequisite for simultaneous engineering and concurrent design. This product model hast to provide an explicit product description including all phases of a product life cycle [Grabowski *et al.* 1993]. This data model shall

- represent product data of all life cycle phases (organizational, technical, technological);
- enable different views depending on field of application and meet the user´s perspective at all product lifecycle phase as exactly as possible;
- and ensure the combination of different physical and technical product properties.

### 2.2 Characteristics, properties, behaviour and function

According to [Weber 2005] characteristics are those parameters that a designer can determine a product with and so directly influence. Characteristics define a product by describing its structure, shape and material consistency. Product properties can be influenced only indirectly by a developer as these result from the product characteristics. When a designer determines geometry and basic material of a component as characteristics, a component´s weight is the logical consequence of decisions made before and can be adjusted only by a modification of characteristics. According to [Roozenburg and Eekels 1995] both characteristics as well as properties can be divided into two different categories (Figure 1). By defining a basic material as a "physio-chemical form" material constants (e.g. density) result as "intensive properties", accordingly. A combination with the characteristic group "geometrical form" (configuration of shape) "extensive properties" like weight or volume as part of the property pattern of a product are determined.
On the basis of a property pattern and in combination with mode and conditions of use a product reveals a certain behaviour (Figure 1). This realized behaviour is the important evaluation criterion as it identifies to what extent a technical system performs its task at given general conditions. The task of a product is considered to meet postulated demands (= functions), therefore, a product´s behaviour can be considered as a specification of its function [Paetzold 2006]. The product´s function shall be deemed to be the intended and deliberately caused ability to bring about a transformation of a part of the product´s environment [Roozenburg and Eekels 1995].

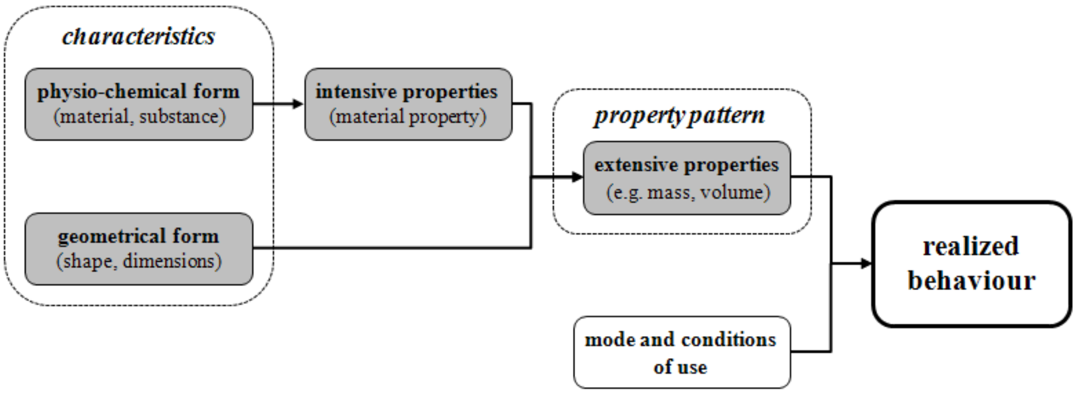


**Figure 1. Product´s behaviour according to [Roozenburg/Eekels 1995]**

## 3. Multidisciplinary product development

Mechatronical products provide the potential for success, but are marked by high complexity because of their networked interaction between different domains of knowledge [VDI 2206]. The development is executed separately in involved domains and is based on established and specific development tools that are affected by typical mindsets and vocabulary of concepts. Starting from a concrete development order a system design for an interdomain solution is designed, afterwards specifically substantiated by every involved domain and finally linked by systems integration to an overall system. Last step is a property validation relating to requested product functions.

### 3.1 Synthesis and analysis as steps of development

Mechanical engineering as the basic domain of product development shows two fundamental kinds of process steps that are executed alternately (Figure 2): synthesis and analysis. Synthesis` results are

characteristics that are in turn necessary input for analysis, analysis´ results are characteristics again. Hence, product data emerge from both kinds of process steps, but are saved by different product models resp. data storages. In this connection the following difficulties can be recognized: a return of data from analysis to synthesis is difficult because of different used data types resp. finally an own step of synthesis is necessary to return which cannot be automated in many cases.
To a certain extent characteristics can be considered as original data that are determined by the designer and form the basis for different methods of analysis. Depending on the properties to describe corresponding characteristics are composed and weighted concerning their importance. Storage is provided by classic product data management systems, basis for the necessary classification is the product structure in general. Properties can also be found in product data management systems, but just as a kind of semantic information that cannot be used for analysis.

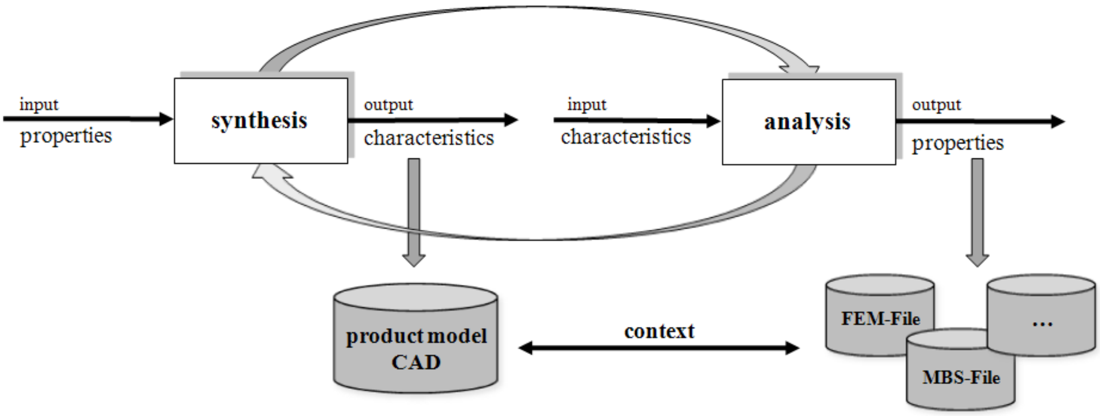


**Figure 2. Main process steps and data storage concerning mechanical engineering**

Basic set-up shown in figure 2 keeps validation for electrical engineering and information technology supported development as well. There is no common formalized standard in case of electro-technical development, but especially with a view at automotive engineering a V-Model, based on V-Model ´97, as a frequently used process model can be recognized [Benz 2004]. V-Model ´97 is a standardized method of project management for software development orders. In V-Model any step of development is opposed to an equivalent test step whereas a in-plane connection between development steps and test steps clarifies test-reference [Benz 2004]. The previous statement shows that steps of synthesis and analysis are executed alternately in this case as well. However, in case of a domain specific carry-over figure 2 has to be modified concerning used data storages and structures as well as required input of custom-designed tools resp. their characteristical output.

### 3.2 Characteristics and properties from a domain specific viewpoint

Following statements are initial idea to carry over the mechanical engineering originated vocabulary of concepts concerning characteristics and properties (chapter 2.2) to the other domains in the development processes. Explanations shown here only describe approaches for the upcoming research, a collection of domain specific aspects at large within this article is not intended. To get the carry-over across the already mentioned viewpoint of mechanical engineering is shortly outlined once more: when a designer determines a basic material (physio-chemical form) density (intensive property) is a resulting element. In connection with the design of shape (geometrical form) weightiness of a component (extensive property) is a logical consequence of decisions made before. The realized behaviour of a product is the result of combination of built property pattern and influence of mode and conditions of use.

#### *3.2.1 Electrical engineering*

At the beginning of every system development requested system functions and all non functional basic conditions are defined on basis of the system requirements [Benz 2004]. First step of the system design is a functional concept whereas the overall function is defined and structured. In planning the system architecture the system is split into sub-systems, followed by an apportionment of function in hard and software. Therefore, you can see a basic focus on functions. Only a closer look enables to recognize characteristics and properties: e.g. the electro-technical component plate capacitor, as a passive electrical component for energy storage, is with a view on mechanical engineering a comparable standard element (pinion, gearshaft,…). Material between conductor plates can be called "physio-chemical form" in a figurative sense and determines the range of approachable capacities, an "intensive property". Specification of its geometry ("geometrical form"), face and distance of plates, determines a maximum of possible capacity ("extensive property"). A fundamental aspect concerning functional quality of electro-technical elements is mode and conditions of use, electromagnetic compatibility mentioned for example. The aimed condition that technical equipment is not influenced by electro-magnetic perturbation depends on a spatial arrangement of electro-technical components to each other. This results, among others, from the spatial design of the available design space. In case of electro-technical developments such considerations have minor importance, tests and property validation are rather based on behaviour observations. Herefrom, a relationship to constructive characteristics (dimensions of design space) resp. properties (volume of design space) is resulting.

*3.2.2 Computer sciences*

Within the design stage of software development the system gets structured by several steps into decreasing sub-systems and interfaces as well as behaviour of sub-systems are specified [Trachtenherz 2009]. Realization of required system functions and system behaviour via source code can be considered as the core aspect of the developmental task. Therefore, software behaviour and its way to interact with its environment is rigorous. On the lines of mechanical engineering there is a number of standard elements at the software engineer´s disposal: manifold source code libraries can be used for the source code creation (e.g. algorithms). These are the "physical-chemical forms" in the figurative sense. Modified resp. filled with adequate parameters the "intensive properties" of the analog standard element are received. Combination with further modified components (generally a source code consists of a multiplicity of parameterized standard elements) generate the "extensive properties" of the developed system. Application under mode and conditions of use shows an appropriate system behaviour. This is especially important when embedded systems are subject of development, that regarding innovative functions like anti-lock brake system (ABS) or electronic stability program (ESP) the automotive industry could not do without it.
Also considering interaction and communication between software systems and software users by image guided components it may be recognized that different used objects represent characteristics in this context (boxes, buttons,...), that show certain properties (colour, size,…) by their design.

## 4. Holistic oriented product data model as a potential for success

### 4.1 Challenges of multidisciplinary product development

The integration of multidisciplinary components in mechatronical systems demands an interdomain cooperation between all involved disciplines to achieve a common imagination of the prospective product and to procure an overall optimized solution [VDI 2206]. A transition from considerations of a complete system to considerations of sub-systems and back again to considerations of a complete system is shown as a formal procedure. However, it doesn´t arise from VDI 2206 how an integration to an optimized overall solution in avoidance of interface difficulties can be explicitly executed.
In component development of mechanical engineering interface difficulties are ubiquitous. An updated study concerning the cooperation between construction and calculation shows that already within the domain of mechanical engineering exists significant potential to optimize communication processes [Herfeld 2007]. Certainly, differentiated demands and storages of information concerning product data as well as different viewpoints concerning the product to be developed can be considered as a starting-point to approve results of that study. Mostly, these interface difficulties are met with structural thinking but this alone is not sufficient enough. A multiplicity of modern tools of information technology enable an early model technical representation of mechatronical systems, but these are insufficiently integrable and create interface difficulties in addition [VDI 2206]. This fact adds further

interdomain problems to already existent intradomain problems. Development disruptions can be considered as the final consequence and have to be avoided.

*4.1.1 The problem system in a multidisciplinary product development process*

The approach to display the difficulties in integration of construction and calculation shows the main objects "product", "data", "tools", "process" and "man" [Herfeld 2007]. The basic problem system of multidisciplinary product development is split analog, but is valid beyond the domain mechanical engineering for all domains of knowledge and includes all corporate functional areas (Figure 3).

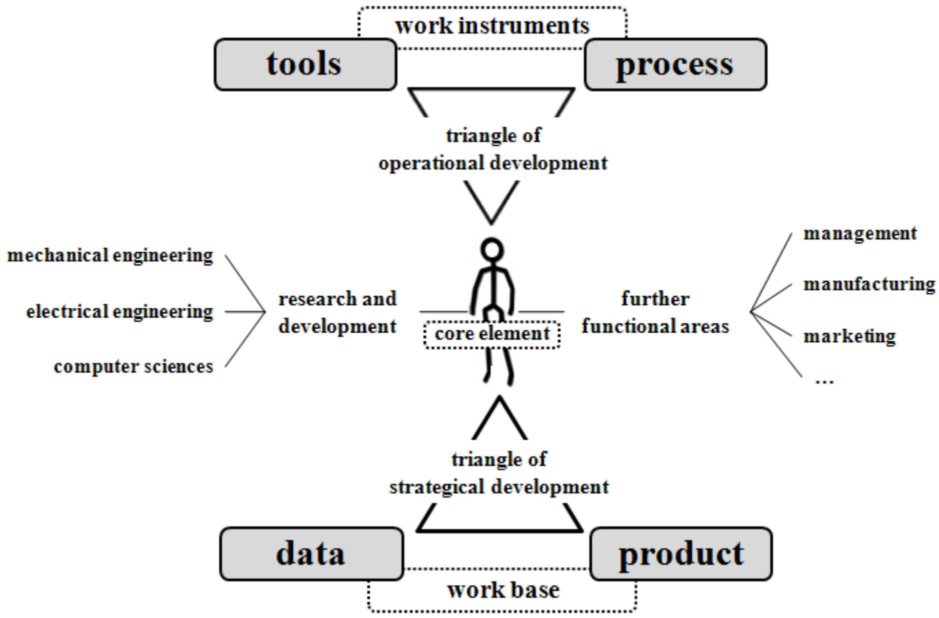


**Figure 3. Multidisciplinary problem system**

The design of Figure 3 mustn´t be interpreted hierarchically – it simply serves as a sensible drawing of focused objects concerning a multidisciplinary problem system:

- **work base:** the product in terms of a development order provides both business background and the core of corporate activities. Especially data are in close connection with the product. These can be direct necessary data for the determination of essential product characteristics in a development process as well as information like market research for a better comprehension related to the importance of singular functions to create a successful product. Data have to be available at an adequate level of quality and quantity at every time. Product and data are relevant work base for different user groups inside a company. This work base has strategic relevance as potentials for success are searched resp. generated here.
- **work instruments:** tools and processes as work instruments modify the work base to systematically achieve company goals. Tools give the correlation between input and output regarding a computer-based development process, require a certain data quality, but also have to provide these for the following process steps. Processes secure the organizational structure and procedure and have to be purposefully oriented to the company structure and resource management. Work instruments have operational character as the potentials for success resulting from the work base have to be exploited at the best.
- **core element:** man as equivalent for all user groups is the core element of the problem system and constitutes in combination with the potential for the success generating work base a triangle of strategical development (in German: "entwicklungsstrategisches Dreieck") and in combination with the potential skimming work instruments a triangle of operational development (in German: "entwicklungsoperatives Dreieck"). Man acts as a kind of navigation component, has to use and define work instruments efficiently to realize the aimed potential for success. In context to this problem system the term "development" should not

only include the classic view on development divisions, but contain other functional areas of a company that have a share in a holistic oriented product development as well.

This interpretation underlines the importance of a holistic oriented product data model especially with regard to the necessary integration of different disciplines in and their specific views of the adding value process. It provides a future-oriented work base at which development processes can be adjusted more effectively to carry out cycles of innovation in a more economic and time-saving way.

*4.1.2 Core demands to an multidisciplinary product data model*

As already argued in chapter 2 and 3 there are different data models in a multidisciplinary product development and this fact causes development disruption as follows: when the work base is made up from different product models and data basis depending on user groups, then the deciders from different functional areas have heterogeneous information. Therefore, it is questionable whether decisions (work packages,…) of multidisciplinary teams that emerge from an inconsistent and heterogeneous data basis have an ideal drive for results. Additionally, an exchange and carry-over of data is hindered due to interface difficulties. In comparison to mechanical systems the complexity of mechatronical systems is based on a higher quantity of connected elements that are additionally realized by different disciplines [VDI 2206]. Accordingly, these elements are developed resp. administrated by different systems. However, the very work-sharing and organizational splitted development process is marked by a high degree of cross-linking – therefore, a product representation has to fulfill needs of all stakeholders to be a sustainable support. Present product data models cannot ensure the integration of multidisciplinary product data. Thus it is necessary to find a new way to represent in a product development process all arising product data in one product data model according to described demands to an integrated product data model by [Grabowski *et al.* 1993].

**4.2 Context of multidisciplinary product description**

In mechanical engineering´s classic product data management system elements (parts resp. components) are recorded and their correlation is fixed. But this systematic can´t be taken over directly to build on a property oriented product data management as on the one hand product properties can´t always be directly ascribed to product characteristics and on the other hand mostly several components have to be combined to reach a certain product property. In fact there are n:m-relations between characteristics and properties. Hence, a context has to be found that ensures representation of property oriented hierarchies resp. dependencies.

Main question is on which basis this holistic oriented product representation has to be configured. Depending on the customer´s viewpoint product properties and behaviour have to be considered as essential purchase criteria. Inferential, a holistic oriented product data model must be based on extensive properties resp. use them as basis for evaluation in development progress (degree of maturity by way of example). Finally, the customer concerning conformance to requirements decides about a product´s success. As shown in chapter 3 product properties and behaviour can be considered as the single identical evaluation criteria between different domains of knowledge and affirm aimed product representation. Heterogeneous and in particular domains used structure of their developmental tasks can be seen as a further reason. In addition the V-Model includes a clear reference to property validation [VDI 2206]: a design progress must be continuously controlled regarding specified solution and requirements whereas conformity of realized and desired system properties must be ensured. Furthermore, viewpoints that don´t attract interest within aspects of customer requests can be used as a context in a holistic oriented product data model. For example a context reference based on "Design for X" (DfX) approach enables inclusion of requirements relevant to manufacturing as well as tracing of corporate strategical orientation. DfX guidelines offer potential to include manifold aspects. At this juncture verification resp. modification of these guidelines with regard to necessary viewpoints and mindsets of other domains have to be considered.

Certainly, property orientation must not replace classic product structuring entirely. A connection between both points of view has to be established to show a developer the correct parameters to achieve improvements to optimize developmental periods by purposeful iterations and to raise developmental quality in a sustainable way.

## 5. Increased information quality for different functional areas within a company

Product description based on product properties and behaviour can be among research and development departments also useful for other functional areas within a company to perform their specific range of tasks superiorly (Table 1). In principle, characteristics as well as properties can be of interest to different user groups, but with a differentiated focus: by way of example management divisions are more interested in the relative and temporally proceeding fulfillment of requested product functions than in several product characteristics within product structure. However, quality control occupied with purchased parts has to control property pattern of incoming charges, but needs information concerning essential product characteristics for control as well.

**Table 1. Exemplary information benefits**

| division | focus | usage |
|---|---|---|
| management | properties | degree of maturity estimation of different sub-projects by validation of actual properties with required properties<br>resource allocation to sub-projects is more efficient, market entry planning,...<br>… |
| purchasing and inbound logistics | characteristics (and properties) | characteristics like basic material or dimensions for distribution and storage planning<br>required property pattern of purchased parts<br>… |
| manufacturing | characteristics (and properties) | detailed construction data necessary: characteristics like size or surface finish<br>… |
| marketing | properties | comprehension for innovative product properties and inclusion in sales approaches<br>… |
| distribution and outbound logistics | characteristics (and properties) | coordination of distribution referring to product characteristics (dimensions, basic material,...) and properties (e.g. weight)<br>… |
| after-sale service | characteristics (and properties) | survey of product structure and components<br>networked product properties for defect analysis<br>… |

In addition it is noted that the definitions of characteristics, properties and behaviour were formulated from a development´s viewpoint. In a continuative step it is rather useful to question vocabularies of concepts of several functional areas more closely. Logistics can be mentioned exemplarily: When a product includes glass components the common used characterizing property "fragile" can be sufficient enough to fullfill given tasks (packaging, transport,...). Gained knowledge has to be connected with the development oriented definitions to provide a targeted product description. Starting-point for this purpose can be tasks as well as the specialist area of corresponding divisions.

## 6. Summary

This article is based on an upcoming research project that uses given approaches as a thought-provoking impulse and starting basis. Certainly, former statements overlap pure development aspects. Reflection of pure development aspects is not advisable as the customer requests more and more an overall package (best product offering, service,...) as only the product by itself.

The objective is a product data model that provides in combination with classic custom-designed data management systems user oriented information for multifarious tasks within a company as well as supports the fulfillment required product properties, functions and behaviour. As shown, a holistic and multidisciplinary approach for product description is a necessary basis to be up to current and future challenges of product development. A product representation on basis of product properties and behaviour provides a consistent data basis and avoids occurrence of development disruption. Besides an effective and efficient organization of development processes as a core aspect, such a product representation is also useful for other functional areas in a company. Therefore, one can easier cope with the stress field consisting of costs, time and quality concerning corporate level to offer the best possible overall product to a customer.

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