Function Oriented Product Descriptions in Product Development and Factory Planning

Daniel P. Politze, Jens P. Bathelt, and Konrad Wegener

Abstract— **In this paper the application of function oriented product descriptions in product development is outlined and extended towards factory planning. Therefore the information sources for building up a function oriented product description are identified and described. Correspondingly, it is shown how the function oriented product descriptions may be exploited by subsequent activities such as: defining subsystems or in the case of factories deriving layouts, processes and selecting equipment. Moreover this work describes how the functional requirements that are contained in such a function oriented product description may be managed and how a performance measurement system can be linked in order to assess the fulfillment of the requirements or to monitor the current state.**

Index Terms— **Customer Needs, Factory Planning, Functional Requirements, Product Development.**

I. Introduction and Related Work

A. Addressing Customer Needs.

Many people have argued that there is more to engineering design than technical problem solving and this viewpoint is also reinforced by recent literature. Especially work in the field of customer-driven design [1] shows that understanding and integrating users in the design process points in a very promising direction. Additionally, it has been recognized, that the quality of a product is mainly perceived by its functionality. Customers demand functions and they think in functions as demonstrated by a simple example: When a customer has a problem with his car he normally complains about defect functionality and not about certain components. In the same way he demands reliable functions, when he is about to buy a product.

B. Functional Modelling.

In the past decades, functions and the modeling of functions became a part of some well-known product design methodologies such as of Roth [2], Pahl and Beitz [3], Hubka and Eder [4], Ulrich and Eppinger [5], Suh [6][7] or Ullman [8]. In order to support a common understanding of functions between all stakeholders in the design process formal function representations and vocabularies have been defined and most of them assume an abstract verb-object representation of functions, as influenced by earlier work on Value Engineering [9][10]

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Unfortunately these methodologies mainly cope with mechanical main functions and corresponding solution principles and do not properly address the rise of electronics, control and optimization functions. But in order to provide high quality product functions, it is not sufficient to bring mechanical, electric/electronic and software components to perfection separately. Fundamental adaptations of the traditional approaches are needed. Most important, the component‘s functional interactions and their contributions to product functions become important and should be considered very early in the design process.

C. Requirements Management.

In order to overcome the above shortcomings and as demonstrated by the automotive industry, a mature management of functional requirements is seen as a crucial activity within the development of high quality mechatronic products [11][12]. Thus, starting from a user's point of view, the intended functions of a new product shall be described and serve as a functional product specification [13] for the subsequent development steps.

D. Factory as product.

Recently the paradigm “factory as product” [14] emerged which regards factories as a new kind of high complex products and thus envisions the transfer of established methods from product development to factory planning. In this context, the description of the intended functionalities of a new factory is also seen as beneficial and serves as a basis for the succeeding planning steps.

II. Scientific Approach

A. Expressing Needs

In today's product development processes a methodical gap can be detected. As it can be inferred from Fig. 1 and [3][15], there exist no clear and persistent linkage between customer needs and the product development process itself. Traditional approaches like the one proposed in [15] use a list of requirements to translate the need into a clear development task. Often this list is not well integrated in the subsequent design process and only reused in the end in order to check the final product against the requirements.

Within this paper a different viewpoint is pursued that proposes a unified understanding of customer needs, requirements and functions. Under the premise that customers demand and think in product functions it is envisioned that their needs should also be expressed in a functional way. Those demanded product functions may then be refined and constitute functional requirements towards the product that shall be developed i.e. they specify the

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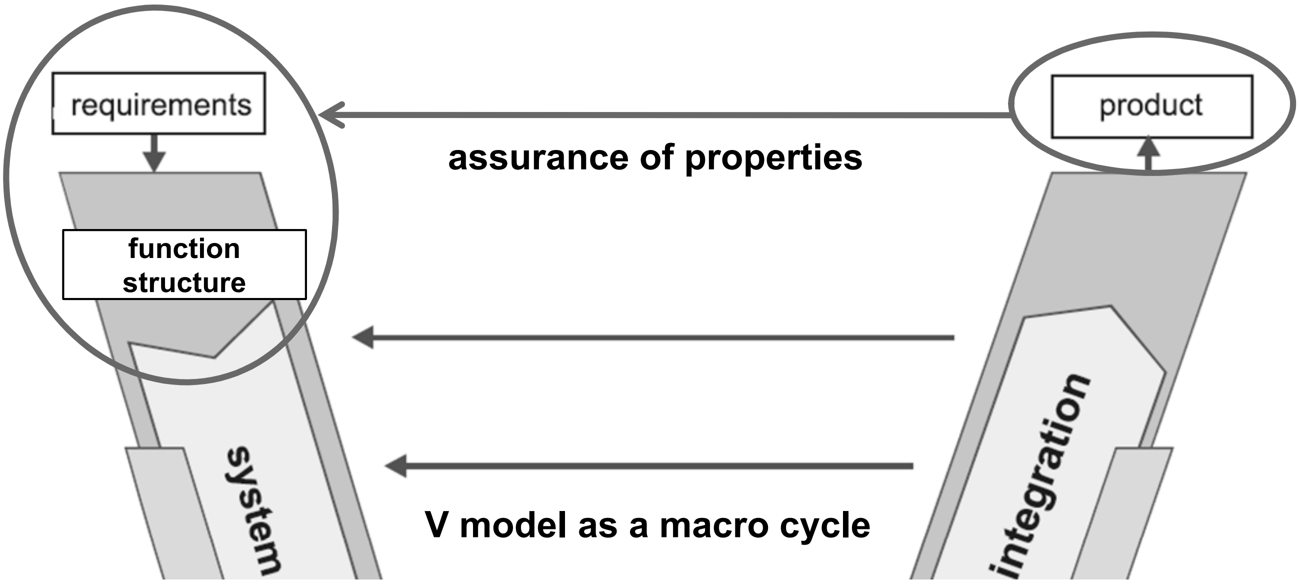

Fig. 1: Function Oriented Product Descriptions in Product Design adapted from [15]

development task. Moreover, these functional requirements serve as a base for traditional functional modeling.

The described approach is depicted in Fig. 1 and strives for propagation, integration and unification of needs, requirements and functions in product development.

B. Function Oriented Product Descriptions

The concept of a Function Oriented Product Description (FOPD) [13] refers to a functional modeling approach that addresses the envisioned integration of customer needs and function structures as described in the foregoing section. The descriptions of functions contained in a FOPD constitute functional requirements that can be refined by more detailed descriptions and have to be addressed by the product to be developed. By combining customer needs, requirements and functions, the FOPD approach aims at a better propagation, improved integration and enhanced traceability for the needs throughout the product development process. Additionally a FOPD is suitable to support the development of high complex and high variant products while maintaining a function oriented point of view. In addition to traditional approaches where a hierarchy of abstract functions is working on flows the inputs and outputs of a function are modeled explicitly. In this way the traditional distinction between function and flow only has been extended by describing their connection with corresponding input descriptors and output descriptors. Moreover a FOPD responds to specific modeling demands that have been identified in the automotive industry [13], such as a notion for pre-conditions, variability aspects, activities and sequences. As mentioned in the introduction, the new paradigm "factory as product" [14] regards factories as a new kind of high complex products, which in turn motivates the application of the FOPD approach not only in product development, but also in factory planning.

C. Performance Measurement for Assessing the Fulfillment of Functional Requirements

Besides the creation of a detailed specification, the function oriented description of products and factories offer a possibility to attach performance indicators (PI) to the demanded functional requirements which in turn allows to monitor the current state and to assess the degree of fulfillment. By measuring the performance through an adequate performance measurement system that focuses on the needs of product and factory design [16][17] the factory's management receives needed information on relevant performance drivers and gets support for efficient and effective decision-making and development. Moreover, the grade of strategic target achievement can be evaluated which in turn provides a valuable feedback on previous efforts and decisions. Within the context of product development and factory planning this approach establishes a new link as depicted in Fig. 1, because the product may now be directly assessed against the top-level functional requirements.

D. Application Context and Interfaces

In Fig. 2 the FOPD approach is presented in its application context. In general, it can be distinguished between incoming, outgoing and bidirectional relationships. At first, there is an incoming link which reflects what sources may be used for the derivation of a FOPD. Then a bidirectional link represents management-related applications that work directly on a FOPD. Finally, an outgoing link stands for several ways of how a FOPD may be exploited for succeeding development steps. All of the introduced links are presented in more detail in the remainder of this paper.

III. Incoming Links: Deriving a FOPD

In this section the incoming link, as depicted in Figure 2, is described in more detail. Although there may exist more sources from which an input may be derived, only the ones are taken into account that will be examined together with industry partners in an European research project.

A. Company and Operator Strategy and Goals.

The mission of a company represents its external and the vision its internal goal on a very broad and general level of abstraction. From the mission and vision the main strategic targets may be formulated in a functional way and from

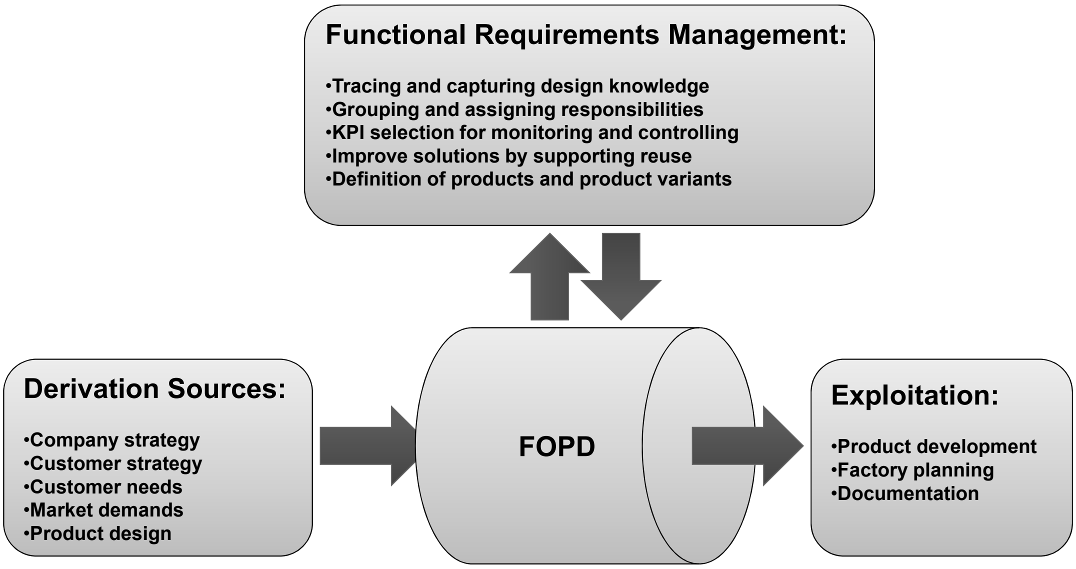

Fig. 2: Derivation, Management and Exploitation of Function Oriented Product Descriptions

these more specific functional requirements may be derived by a step-by-step refinement as proposed in [18]. The application of asking "how and what" may support this activity. In the case of Factory Planning, where a new factory constitutes a product, one further distinction has to be made. In this special case the customer of the product to be produced, the factory provider or OEM (Original Equipment Manufacturer) and the factory operator have to be clearly differentiated, because the strategy of the factory provider and the strategy of the factory operator will differ in most of the cases. Thus, the strategy input, deducted from the mission and vision of both parties, have to be derived and treated separately.

B. Customer Needs and Market Demands.

This input aims at collecting the needs that are raised by the customer and at gathering the demands that come from the market. According to traditional product development methodologies, this can be done by market studies, interviews or with the help of creating a feature list as described in [3]. The collected features may then be reformulated into product functions that constitute functional requirements that have to be fulfilled by the product to be developed. The same approach may also be used in the case of factory planning.

C. Product Design and Documentation

Especially in the case of Factory Planning, the design of the product to be produced has also to be taken into account. Therefore the product documentation serves as an input for the derivation of a FOPD. Typically this form of documentation consists of assembly- or part-drawings and a BOM (Bill of Materials) and allows the retrieval of production functions and assembly functions according to those that have been described in [19].

IV. Bidirectional Links: Working with a FOPD

In this section the bidirectional link which aims at management-related applications, as depicted in Figure 2, is described in more detail. It is envisioned to have a tool support that supports the following use-cases that are entailed in the FOPD approach.

A. Tracing and capturing design knowledge.

As stated earlier, the descriptions of functions contained in a FOPD constitute functional requirements that can be refined by more detailed descriptions and have to be addressed by the product to be developed. This means a FOPD contains detailed descriptions of technical solutions, starting from a very abstract level to a very detailed and specific view. In this way the product designer's knowledge of the solution is captured and documented. Thus, all product functions and their technical solutions become traceable which in turn allows the detection of redundant developments and provides a base for arguing about specific solutions.

B. Grouping and assigning responsibilities.

Since the data contained in a FOPD may become very extensive, it is important to allow different views on it. In [20] several aspects have been identified that lay out a base for defining appropriate subsets of functional requirements that enable easier work and also to address organizational aspects e.g. the assignment of guarantors, function owner, function developers or other responsibilities for specific product functions.

C. KPI selection for monitoring and controlling

The functional requirements, their functional descriptions and the dependencies that are captured in a FOPD may be analyzed for the definition of suitable KPIs (Key Performance Indicators) which allow a goal-oriented monitoring and controlling. Functional requirements that are heavily cross-linked or those that constitute important strategic goals may be seen as a first input for the KPI selection.

D. Improve solutions by supporting reuse.

Appropriate tool support and a versioning system may enhance the degree of reusing existing functional descriptions which in turn allows the evolvement of the

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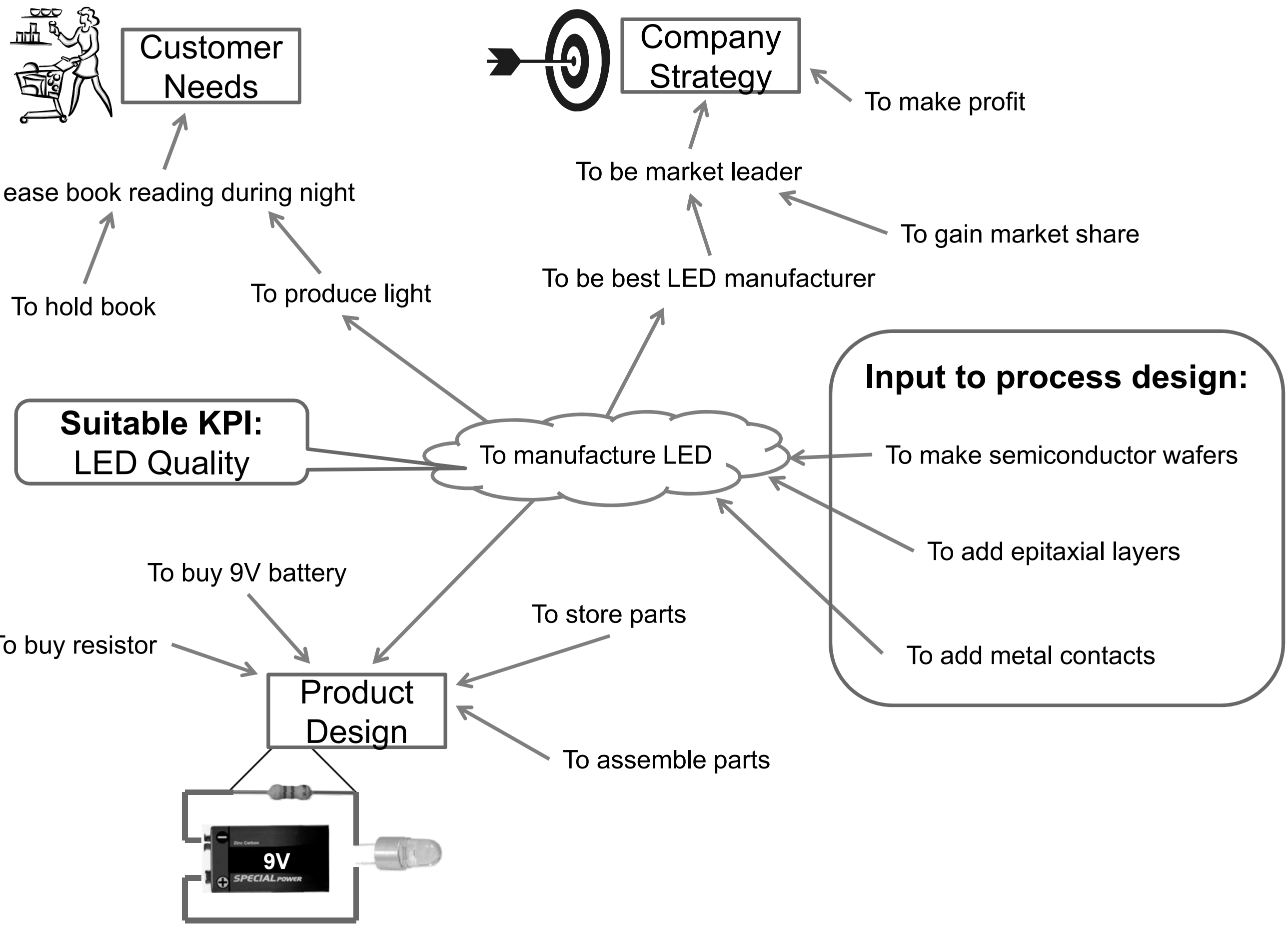

Fig. 3: Example of Expressing Functional Dependencies and Selecting a KPI by Using a FOPD

descriptions to a mature and reliable functional specification of the product. This allows to capture the lessons learned from past development projects and supports the idea of continuous improvement and ensures and tracks the specification quality in new projects. Thus the application of a FOPD helps to reduce development time while supporting the realization of high quality product functions.

E. Definition of products and product variants.

A FOPD allows the management of variability information. In addition to that, the existing product functions are made explicit in a FOPD. Both can be used to define products or even specific product variants for development.

V. Outgoing Links: Exploiting a FOPD

In this section the outgoing link, as depicted in Figure 2, is described in more detail. Therefore each keyword that is part of the figure will be addressed and explained.

A. Product Development.

The contents of a FOPD (i.e. the functional descriptions and their dependencies) may be exploited for the development of high complex and high variant products. As described in [21] the FOPD seamlessly connects to common product development methodologies by allowing the derivation of an extended function structure. Besides, a FOPD may be used to determine a function oriented product structure that

B. Factory Planning.

A FOPD is also exploitable towards factory planning and offers some useful inputs to performance planning, process design, equipment selection and layout planning. The selection of KPIs from analyzing a FOPD may not only be used for monitoring and controlling, but also for planning the performance of a new factory. Thus, target values may be defined that determine the expected performance. In addition to that, the functional requirements and the descriptions regarding the manufacturing process may be used as an input for process definition and equipment selection. The first one may be achieved by interpreting the functional requirements as process activities. The latter one can be realized by grouping and filtering specific functional requirements i.e. those that start with “to weld sth.”, “to mill sth.” or “to transport sth.”. Similar to that, an input for the layout planning can be generated, since each of these process activities needs to be allocated to a location in the factory layout.

C. Documentation Generation.

Since a FOPD contains detailed descriptions of technical solutions and thus captures the product designer’s knowledge i is also a good source for deriving documentation. Either this could be a detailed function-oriented description of the product to be produced or it may serve as an input for creating a user manual, since it addresses all product functions that are comprised by a specific product or product variant.

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VI. Example

For this example a startup company is assumed that recently finished the design of its first product, which consists simply of a battery that is connected to a resistor and a LED (Light Emitting Diode). In order to manufacture this new product in future, this company seeks to build up a new production site that is in line with their goals, their values and their product to be produced.

A. Derivation of an initial FOPD.

As displayed in Fig. 3 the initial functional requirements have been derived from the customer needs, the company strategy and the product design. Specialists from Management, Product Design and Marketing then helped to refine these functional requirements into more detailed function descriptions by providing relevant sub-functions.

B. Selection of suitable KPIs.

As a result from analyzing the functional requirements, their descriptions and their dependencies the startup company found that "to manufacture LED" is very critical and thus important to achieve. In order to be able to monitor the current state and to control the fulfillment of this functional requirement they defined a corresponding measure "LED Quality" which shall play a crucial role in future reports and hence serve as a base for a better decision-making.

C. Exploitation in the Factory Design Procedure.

Regarding the planning of the new production site, the existing functional requirement and its description regarding the activities for manufacturing a LED can be exploited. In this context, they serve as an input for process design which is a typical step in a factory planning procedure. Based on that input the sequence in which these activities have to be performed is properly defined and also the equipment that shall be used for the manufacturing process can be pre-selected. At all times the defined KPI measure helps to evaluate alternatives.

VII. Summary and Outlook

This paper presents the concept of applying a FOPD within product development and factory planning. Therefore the FOPD approach is introduced and explained on a theoretical base. Then the incoming and outgoing informational links are described and the possibilities on how to manage and to work with a FOPD are sketched. Finally a short example which illustrates one intended way of using a FOPD is given in the end of this paper. It can be concluded that the FOPD approach helps to find and maintain the right balance between strategic company goals, customer-orientation and production while supporting mature development process and contributing to an efficient controlling. Furthermore the application of a FOPD contributes to a better propagation and traceability of customer needs in product development and factory planning.

Until now, the conceptual approach presented in this paper has been implemented in parts and its applicability was shown in several industrial cases. In a next step success evaluation is envisioned. It is assumed that better propagation, improved integration and enhanced traceability for the customer needs leads to a higher degree of knowledge about these needs throughout the development process. In order to show that, a study is currently conducted that aims at examining the existence of clear links from the development steps to the customer needs.

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