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UTILISING THE CONCEPT OF A DESIGN'S BANDWIDTH TO ACHIEVE PRODUCT PLATFORM EFFECTIVENESS

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1 Introduction

Developing complex products based on global platforms is a challenge many enterprises face today. Key factors (motors) for utilising platforms in a global organisation are strong incentives for the introduction of platform-based products, such as: the *economies of scale* by reusing design solutions and minimising bill-of-materials; *customer-oriented offers* with high degree of variety; the *responsiveness* in time-to-market; and the *flexible* utilisation of design and manufacturing resources. It is however not a straightforward process to achieve the expected benefits from product platforms. For instance, to create a configurable platform, that can carry many products, needs more initial resources and time than to create a single product. Thus, one has to make sure that one can utilise the platform as efficient as possible, and get as many high-selling products out of it as possible.

Many strategies have been suggested to reap the benefits of product platforms, such as modularisation, and use of standard components and common parts. However, a core aspect to fully exploit product platforms is the ability to create adaptable and flexible design solutions. In that sense, we can talk about a *design's bandwidth*, i.e. a design solution's ability to fit into/act within/contribute to different products and brands. Naturally, this includes not only the currently planned product range but also future yet unknown product opportunities, in line with Martin and Ishii's spatial and generational variety [1]. The natural question then, is how this bandwidth is designed into the systems solutions being developed and their components. Accordingly, the perspective adopted in this paper originates from the designer doing the actual design work. As a matter of fact, their situation has gradually changed the last decades. For instance, consider the development in the automotive industry, where a designer traditionally developed a single system to fit into a forthcoming product (see Figure 1). Not surprisingly, areas for re-use were found and systems where later designed, were possible, to fit into multiple products. Later, this strategy led to the introduction of platform-based products. Today, with the seemingly inevitable globalisation of the automotive industry, the designer are not only faced with the challenge to design systems that can fit into a platform that serves a product range, but also design systems that can adapt and fit into several products with different brands. This fact, stress organisations to initially put extensive work on specifying required commonality and uniqueness for their platforms, in relation to brand-specific goals. This has resulted in the fact that a platform, in addition to the arguments given earlier in the introduction, also serves as an intermediate means to harmonise brand-specific claims.

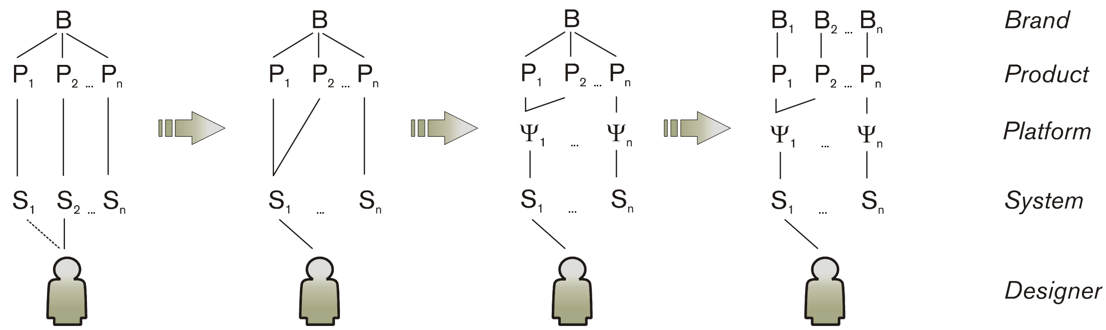


Figure 1. The shift of focus for designers in the automotive industry illustrated.

For the designers, doing the actual design work, this change of focus has not only led to an increased demand to utilise the possibilities of economies of scale, but it has also led to other things, such as:

- more open-ended design tasks,
- the need to understand and care for multiple brands,
- the need for more delicate product differentiations, and
- functional characteristics becoming even more important in multi-brand platform-based products.

Consequently, there is a challenge to avoid making trade-offs between commonality and variety. In this paper we ask ourselves how designers can avoid making these trade-offs.

The described shift of focus for the design engineer also implies the possibility of the emergence of another, complementary, design task. This design task is primarily not involved in creating the platform, but rather charged with the utilization of design solutions with “high bandwidth” defined by the platform to derive new products based on the platform. The focus in this paper is, however, on the task to define design solutions with “high bandwidth” of the platform.

1.1 Research scope

This study has arisen through our previous work on platform-based products [2], and the insights gained in a global platform development project [3]. Reflecting on the challenges presented earlier, there is a need to support designers to develop system solutions that can fit into/act within/contribute to different products and brands – thus making it possible to achieve product platform effectiveness. This paper will focus on the concept of a design’s bandwidth. We intend to relate the concept of design bandwidth to two interrelated aspects, variety and commonality. We also intend to explore its application to the development of product platforms. In this respect, we ask ourselves, how to define and develop design solutions with appropriate bandwidth? Since the study is explorative in its nature it comprises a literature review in order to find and summarise related research. An ongoing research project together with a Swedish automotive manufacturer serve as a means to identify key factors related to design bandwidth. More specifically, the research project focuses on new methods and tools for developing design solutions with an appropriate bandwidth.

The outline of this paper is as follows; the first section, including this, has opened up the need for the concept of design bandwidth; the second section will summarise related research, mainly research on variety and commonality focusing on issues related to bandwidth; the third section will outline what we mean by product platform effectiveness and presents fundamentals of variety and commonality related to bandwidth; the fourth section will illustrate what characteristics we mean a solution with high bandwidth should have; and the paper will finish with conclusions and some reflections on the implications of bandwidth.

2 Related work

Generally the area of developing platforms consists of three main problem areas: (1) identify the optimal selection of products in a product line based on customer preferences; (2) define and evaluate one or more platforms that can serve this product line; and finally (3) flexible system solutions (product & process) has to be developed to contribute to these platforms.

In the vast amount of research in the area one can identify a lot of research from a marketing perspective supporting the first problem area. A common theme among these is that they are coming from a marketing perspective trying to optimize a product line offer based on customer segments and preferences. Recent contributions within this problem area are trying to integrate engineering and manufacturing costs into the optimization models. For example, Azarm & Li [4], seek the answer to the following key question: How should we generate the design alternatives that are the best possible and devise from them a product line whose market potential is accounted for, given customers' preferences, market competitions, and uncertainties in several parameters? A two-stage approach to model this problem is used. The first stage is the design alternative generation stage. In this stage, the best possible design alternatives for variants that eventually form a candidate product line are generated. The second stage involves product line design evaluation related to the identified customer preferences. In this stage, for each scenario, candidate product lines are formed as a combination of several design alternatives and evaluated with respect to their marketing potential. Other authors model the same problem with a one-step approach [5].

A lot of research in the area of *product variety* or *design variety* focuses on evaluation of variety and commonality in current products and production systems. This includes research on areas such as modularisation, commonality, standardisation, and methods for measuring platform commonality (e.g., Siddique & Rosen [6]).

The third problem area involves research on variety. Early work by Rothwell and Gardiner [7] introduce the notion of *robust product families* that permit economies of variety while at the same time profitability maintaining a central core of economies of scale. The key feature of robust designs is that they allow for change because essentially they contain the basis for not just a single product but rather a whole product family of variants. Rothwell and Gardiner conclude that the basis for robustness appears to vary across product types. In this sense Rothwell and Gardiner's definition of *Robustness* is similar to Siddique and Rosen's [6] *Mutability*, and Jiao and Tseng's [8] *Customizability*.

Jiao and Tseng provides a good illustration (see Figure 2) of the positioning of product and process platforms and that a customization of a functional feature is connected to and impacts other design domains and the customer [8]. According to Jiao and Tseng, a product platform performs as a base product from which product families can vary designs to satisfy individual customer requirements. Corresponding to a product platform, production processes can be organized as a process platform in the form of a bill-of-operations. Customizability analysis necessitates the justification of cost effectiveness of customization around three pillars: the customer-perceived value, necessary design changes, and related process variations.

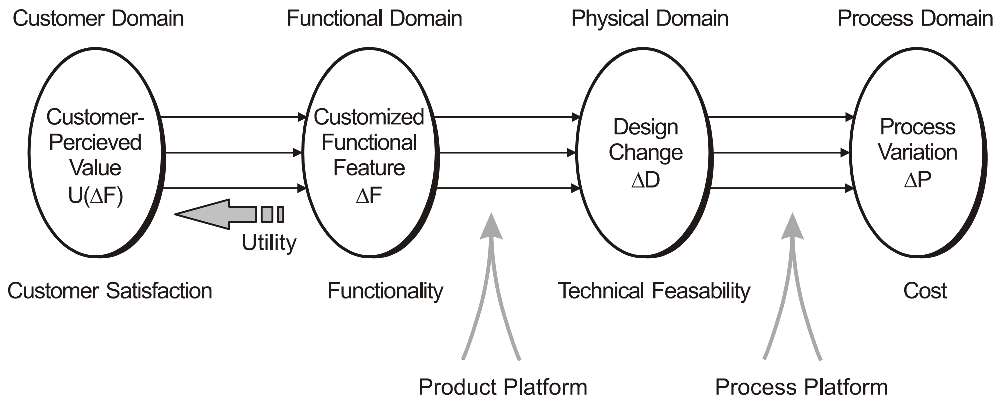


Figure 2. Multiple views of customization (Jiao & Tseng, [8])

To support the development of “robust” solutions Martin and Ishii presents the concept of “Design for Variety” (DFV). Initially DFV focused on measures of the cost of providing variety, representation of variety and measure of the importance of variety [9], but has evolved into structured methodologies to help design teams reduce the impact of variety on the life-cycle costs of a product , . In summary their methodology includes the generation of a *Generational Variety Index* that indicates the amount of redesign required for a component to meet future market requirements, and a *Coupling index*, that indicates the likelihood that a change in one component will require a change in the other. Using these indexes Martin and Ishii provides strategies to change the product architecture in order to develop a product platform that can be more easily applied to future product generations. Consequently, they are retrospective, in the sense that they analyse an existing product in order to determine where to focus efforts when developing a new platform – in other words where to standardise and/or modularise etc.

Olewnik et al. propose a framework for the concept of flexibility in complex system design. Although not with the aim of developing flexible systems to platforms, they provide a method that provides designer(s) an approach to bring flexibility into the design process.

Looking at research there are not much focus on how to develop solutions that are insensitive to variations (*robust*), adaptable to our industrial system (*mutable*), and adjustable to market changes (*customisable*). We have chosen to denote these conformable perspectives a design’s bandwidth, since it highlights that the design solution employs a range of flexibility, when it comes to product functionality and performance, that yields a feasible, validated, and economically sound design solution.

3 Product Platform Effectiveness

We assume that all intended product brands that employ products that are to be derived from the platform is known in advance. Furthermore, we assume that the product lines (and the products) to be delivered from the platform are known in advance. In making these assumptions we formulate the problem as an engineering design problem in the sense that we are seeking the most effective and efficient design solutions that are capable of delivering the defined product range with a maximum of reuse of common design solutions and a minimum of new and product unique design solutions. Or in other words: *How to identify and define effective and efficient design solutions that, taken together, are capable of delivering the necessary design bandwidth to accommodate the variety required from the platform?*

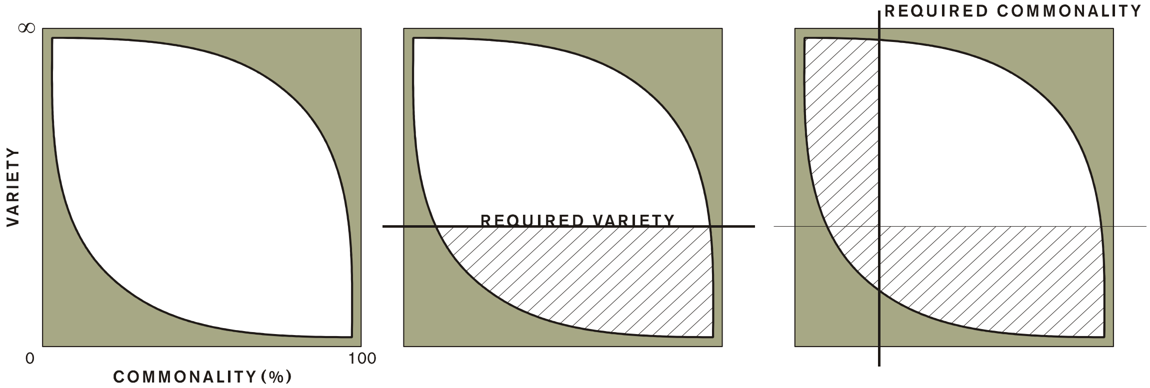


Figure 3. Variety and Commonality – Design (VC-D) space illustrating the effects of the relationship between variety and commonality.

3.1 Fundamentals of Variety and Commonality

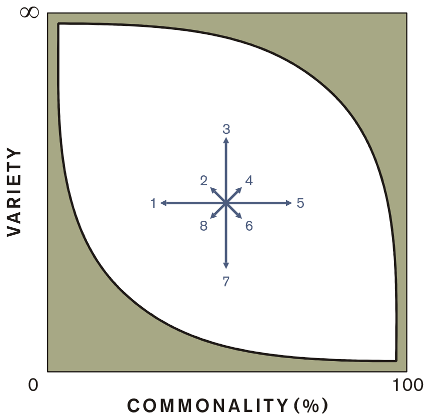
For our purposes, we view *variety* as a consequence of the existence of different functions and differences in their functional characteristics that are embodied in a systems design properties (surface, dimensions, form, tolerance, structure, material, and manufacturing method) [13]. The *variety dimension* has two extreme points. No variety at all meaning zero variety (i.e., no function at all), and endless variety (i.e., any and every function and functional characteristic).

Further, for our purposes, we view *commonality* as the utilization of an existing resource (possibly in a new context) to realize new functional characteristics and/or functions. We do not limit ourselves to the reuse of physical artefacts in this definition. A design solution that is used in a modified way or context to achieve new functional characteristics and/or functions is also considered a contribution to the level of commonality. The *commonality dimension* can be thought of on a scale from zero to 100 %, where 100% is complete reuse of existing resources (which would also imply no new variety added) and 0 % is creating everything new, that is from scratch.

The two dimensions variety and commonality as defined above are illustrated in Figure 3. The shadowed area illustrate that it is impossible to conceive any design solution in that area. Of course, the shape of the borderline between the area of possible design solutions and the area of impossible design solutions is only conceptual and illustrative. However, the figure clearly illustrates the existence of a borderline between the two regions.

In our context – where we consider development of platform-based, modular, high-variety, and multi-branded products – the developed design solutions must deliver a certain level of variety (referring to the situation depicted in the right side of Figure 1). In Figure 3, this is illustrated as a lower boundary representing the *required variety*. This lower boundary further limits the region of possible design solutions to a smaller area representing design solutions that are both possible and acceptable. The acceptance criteria established in this case is the *required variety*.

Furthermore, in order to limit the necessary amount of resources required for the development of the products a certain level of reuse or commonality is required. In this perspective commonality is used as a means to uphold and leverage investments already made. In Figure 3, this is illustrated as a lower boundary, representing the required commonality. Again, this lower boundary further limits the region of possible and acceptable design solutions. This



1. Reducing commonality
   e.g. introducing new processes or suppliers in the manufacturing process.
2. Reducing commonality while increasing variety
   e.g. unique solutions are introduced to create new functionality.
3. Increasing variety
   e.g. New applications for existing solutions are found.
4. Increasing variety and commonality
   e.g. utilising synergies and function-sharing to create new options.
5. Increasing commonality
   e.g. standardisation of components such as fasteners.
6. Increasing commonality while reducing variety
   e.g. reduce the number of model-specific options to reduce over-head cost.
7. Reducing variety
   e.g. specialisation to reduce over-head cost.
8. Reducing commonality and variety
   e.g. introducing unique solutions that do not add a variety value.

Figure 4. Navigating in the Variety – Commonality Design (VC-D) space.

illustrates the effects of the relationship between variety and commonality, although on a conceptual level. Furthermore, it illustrates how variety and commonality combined makes the design task more and more difficult.

3.2 Navigating in the Variety and Commonality – Design space

Assume that we have a certain design solution that we want to extend with a couple of new functions. Further assume that we want to provide each of these new functions with different functional characteristics in order to satisfy different customers. The functions and their characteristics are not important for our reasoning here. We want to use this situation and our diagram on variety and commonality to explore how this design task can be addressed and how different approaches would be illustrated using our diagram (see Figure 4).

A straight forward approach to add new functions and functional characteristics would be to add new design solutions to the currently existing. In our diagram a starting point for reasoning about how to create new variety can be in the lower right corner. In a real situation, the starting point can be located anywhere within the region of possible designs. The approach to add new design solutions in order to increase variety is, in our diagram, equal to following the lower boundary curve between possible and impossible design solutions. Another approach would be to define a design solution that is capable of delivering more than one function and that can be tuned to deliver a range of functional characteristics. In our diagram this approach would be a vertical line where the commonality is constant and we increase the variety.

Intuitively, adding new design solutions will increase the cost of the design. Cost can be viewed based on the source for the cost. Spending time in the search for and definition of a design is one source of cost. Using a defined design solution to produce an artefact is another source of cost. In both approaches described above we spend time in search of and definition of the design solutions. However, in the second approach where we increase variety through envisioning a more capable design solution with several functions integrated and the functional characteristics tuneable, we probably need to spend more time in doing the design tasks. Thus, the second approach will cost more in terms of design work. Using the design solutions to produce artefacts was the other source of cost. In the first approach where we add new design solutions to increase variety, we can expect the production costs to increase rapidly since we both add the costs for the specific artefacts and through the introduction of more items to manage in the production system we also increase the system cost and complexity.

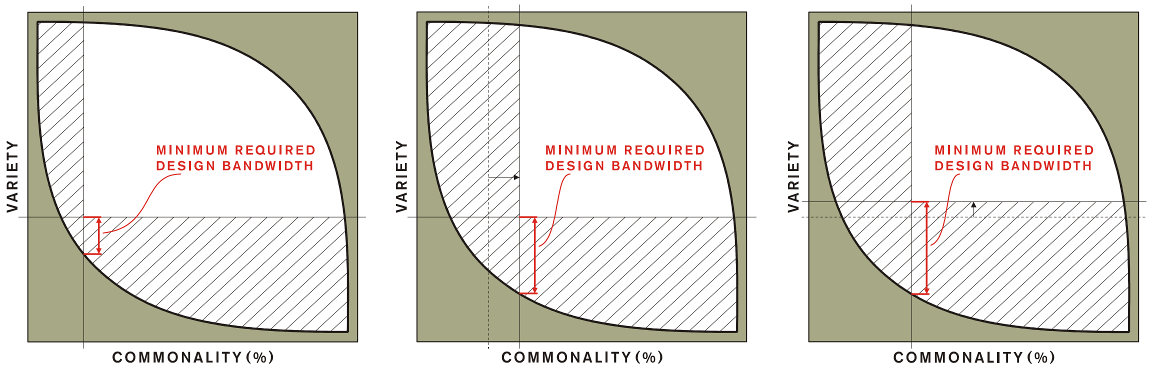


Figure 5. Design bandwidth illustrated in the VC-D space.

In Figure 4, approaches for navigating in the variety, commonality – design space is illustrated, we do not argue that some approaches are better than any other, they all have their applicability. However, according to the scope of this paper, we will try to support designers moving in the fourth direction, which is to both increase variety and commonality.

4 Design Bandwidth

In Figure 3 we introduced the two criteria of required variety and required commonality. Assume that our analysis of our market has resulted in knowledge that a certain amount of variety in our product range is required. This will result in an establishment of the required variety level in our diagram. Without any additional criteria established on the required commonality we could go ahead and simply create the necessary amount of design solutions required to meet the required variety. If we, however, assume that we want to leverage our investments (either the existing or the new to be created) we must define a criteria level on the required commonality. In doing so, we put a requirement on some of the design solutions to carry a certain amount of flexibility (adaptability, mutability, or customizability). The leftmost part of Figure 5 illustrates this scenario. Since we have defined the design bandwidth to be a measure on the flexibility of a design solution we can use the diagram to illustrate the required design bandwidth for the platform that is charged with the task to deliver the required variety.

In the middle part of Figure 5 we illustrate the effect on the design bandwidth if we decide to increase the level of required commonality. The figure clearly illustrates the increased level of difficulty for the design engineers. They must find more flexibility in the design solutions from an available design space that is substantially smaller. In the right part of Figure 5 we make it even more difficult for the designers by increasing the level of the required variety from the platform. Similar to the effects of requiring an increased commonality the required bandwidth for the design solutions increases while at the same time the available design space for finding acceptable solutions becomes even smaller.

Based on the presented illustrations on the effects of required variety and required commonality it seems obvious that there is a great need for new and improved design methods and tools that can support the designers in this rather new and emerging difficult design context. In order to facilitate the development of such methods and tools we want to increase our understanding about the sources for variety and mechanisms to deal with variety in the definition of new design solutions. Figure 6 presents a tentative approach to understand the sources for bandwidth and how to embody it into the product itself.

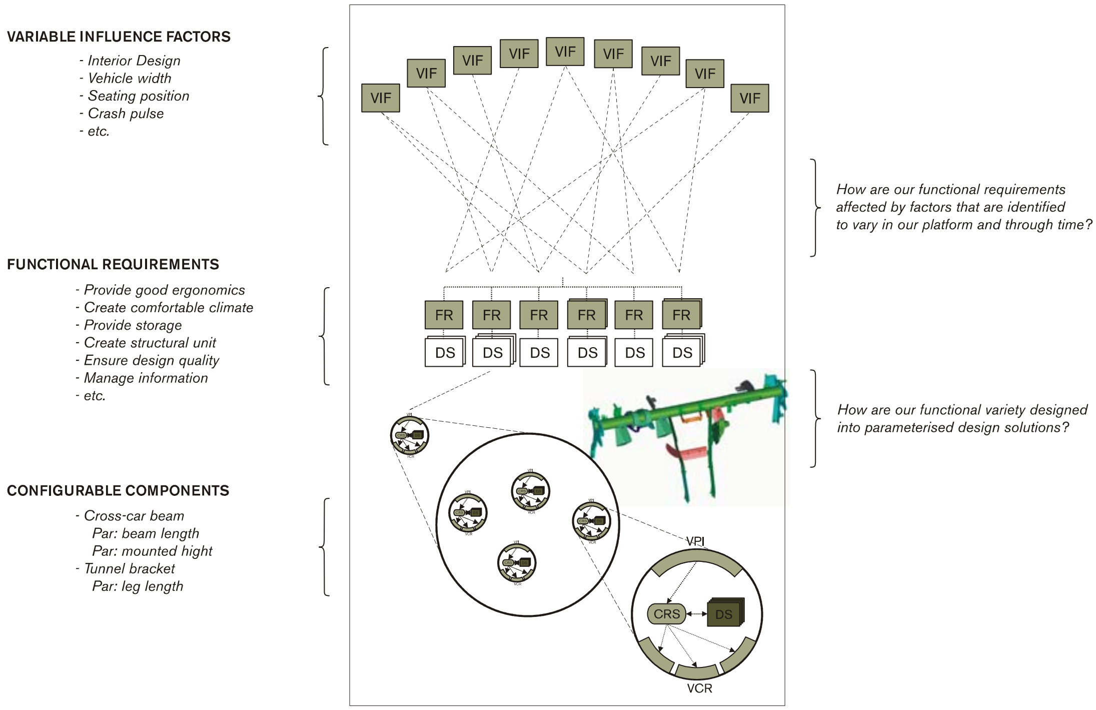


Figure 6. Sources of and embodiment of variety.

4.1 Understanding the sources for bandwidth

Of vital importance when designing solutions with a suitable bandwidth is to understand what factors is driving variety. Using Martin and Ishii's notion of spatial and generational variety one must understand both the differences between the thought products on the product line that the platform should serve (e.g. product size, functionality, performance, and use), and understand how these and more market-related factors could vary throughout time (e.g. changing customer-preferences, new legal requirements, and new technology introduction).

In our approach, for finding sources and embodiment of variety (see Figure 6), a functional representation has been chosen since it has been recognised as a core activity to understand and develop conceptual layouts of a product. The function, in this sense, embodies the reasons for the product being designed (e.g. provide storage, create structural unit, create comfortable climate, etc. for an instrument panel). The functions are also further specified with functional related properties (e.g. air volume, air flow, temperature interval, etc. for create comfortable climate). However, the functions and their properties in itself, do not embody the reasons for creating a bandwidth. Thus, we focus on identifying influence factors that varies (spatially and/or through generations) that are crucial to understand where to put effort on creating bandwidth. This is not a straightforward issue, understanding these factors and how they relate to our product functionality determines our possibilities to arrive at a flexible solution, which can effectively and efficiently serve our product platform. Consequently, this approach requires that the rationale behind decisions regarding issues such as product-differentiation, functionality, performance, and solutions are transparent and readily available. Mainly, because identifying parameters that should be considered when creating a certain bandwidth means understanding what different stakeholders requires and would like, and making and justifying decisions about product flexibility, uniqueness and commonality. These decisions specify needed bandwidth on identified parameters that system solutions should fulfil.

However, this is not necessarily a top-down approach. Using the concept of *Configurable Component* to define design solutions and embody bandwidth will certainly reveal opportunities for building in bandwidth in certain parameters, and the work to achieve this will reveal sources of design bandwidth. Methodologies to construct product platform models using the concept of configurable components that capture both functional behavior and embodiment of design solutions as well as the operative component structure in a configurable system product are further elaborated in Johannesson and Claesson [12].

4.2 Embodiment of variety

Traditionally, detailed design methods have been focused on the design of a single product. Mass customized products, however, require the detailed design methods to provide support for the realization of product variants. One way to provide for definition and management of design solution variants is to use *configurable components* [2]. Primarily, this concept has been proposed as an extension to the function-means methodology [13] to enable support for handling design solution variants (see Figure 7). The introduction of Variable Influence Factors (see Figure 6) provides a means to define sources of variation in the opportunities, needs, an problem definition in Figure 7. Referring to the Theory of Domains [14], the concept is positioned as an additional model construct linking organs to their physical realization in a parameterized way that can accommodate different realizations of a basic design solution concept (organ or function carrier).

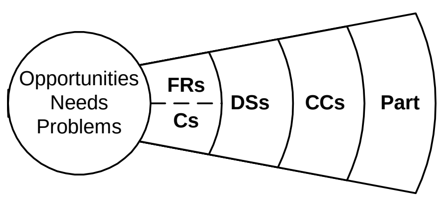


Figure 7. Extended function-means based approach.

A *configurable component* (see Figure 8) is an abstraction of a design concept that represents a functional (sub-)system of the product design. The component is configurable if it is defined using parameters. Three different kinds of parameters are recognized: design parameters, performance parameters, and variant parameters. The *design parameters* (DP) are those design characteristics that can be determined directly by the designer. Note that this is the reason for why we have chosen to refer to *Design Solutions* (DS) in Figure 6 and Figure 7 instead of naming these entities *Design Parameters* (DP) which is the traditional name used in axiomatic design. The *performance parameters* (PP) are primarily the parameters representing the required quality or utility of the design solutions. Finally, the *variant parameters* (VP) are a convenient mechanism that can be used to group different sets of design parameter values that in a certain combination will deliver a configured design solution with certain quality and utility characteristics.

A set of product variants is represented by a configurable component. The variety provided is exposed to a user of the component through a *variant parameter interface* (VPI). The component itself is defined both with its own internal design definitions and through references to other configurable components that are used by this component (a *composition set*, CS), i.e. a system component *is composed using* (ICU) other components as sub-systems. Through these references a structure of configurable components are defined that more or less corresponds to a traditional product structure. The difference being that the configurable

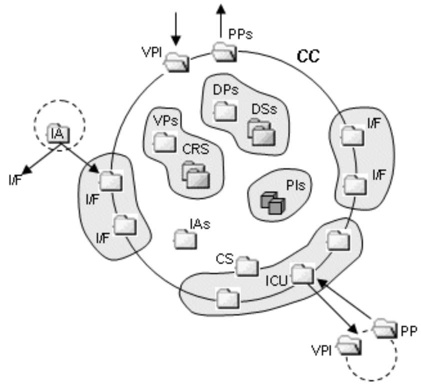


Figure 8. Illustration of a configurable component and its main information elements.

component structure is a definition of a whole set of products rather than one product or a few product variants.

A configured component (i.e., a component where a sufficient set of variant parameters has been given a value and all internal design rules are satisfied) may constitute a design definition of an artefact that can (or shall) be *physically realized* (i.e., result in a *physical item*, PI). The effects of assigning values variant parameters of a component are, in turn, propagated to the components used thereby causing these components as well to respond to the applied configuration.

The concept of configurable components and how it is applied to define and manage reuse, commonality, and product variety is described in more detail in [15].

5 Conclusion

5.1 Summary

In our exploratory approach to improve our understanding on how to perform and utilise platform-based product development we have found that previous research can be categorized into three main problem areas as describe in section 2. We furthermore found that the majority of the research work has been on the two first problem areas mentioned, whereas few contributions has put the designer and the design engineering task itself in focus. Reflecting on the situation for the designer and the design engineering task revealed a pattern of a slowly changing situation for the designer as described in Figure 1.

There are two main contributions in our work presented in this paper. The first is the identification of a need for, and definition of the concept of design bandwidth and the relation between design bandwidth and requirements for product variety and solution commonality. The framework presented as the Variety/Commonality – Design space leads towards an understanding of that there might not be a need for the traditionally expected trade-off between variety and commonality (the “carry-over trap” or “badge engineering”). Rather we will seek “high bandwidth” design solutions that deliver according to both criteria. The second is that we present an initial attempt to a design method that will enable the designers to more easily identify and define these “high bandwidth” design solutions and refine them into platform definitions including the definition of the delivered product variety.

The paper has hopefully managed to highlight the role of the designer and the slowly changing environment and requirements put on the designers in a platform-based design context. The identification of this changing pattern put emphasis on what kind of design methods and tools are needed in order to successfully support the design engineering in this new, emerging, and challenging environment.

Our continued work will include further refinements of the concepts introduced in this paper as well as application of the proposed approach to industrial cases for improved understanding and validation of the applicability of the framework presented.

5.2 Reflection

There seems to be great potential in developing smart and flexible solutions that do not only carry a single products attributes but can deliver different functionality and performance to different products and brands. This is probably a necessity if one is going to be successful of reaping the benefits of (multi-brand) platform-based products. This does not only apply to the automotive business, but also in other areas such as kitchen appliances, electronics, etc. However, this approach might lead to that one cannot become best on every performance level, i.e. the search for high bandwidth leads to trade-offs regarding other performance levels.

Acknowledgement

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