Product Platform as a Concept to Increase Production Competitiveness

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Penulis

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Abstract

Dalam era pasar global yang dinamis dengan tingkat persaingan tinggi, perkembangan suatu produk dan proses produksi menjadi perhatian utama bagi perusahaan. Beberapa hambatan yang muncul adalah daur hidup produk yang makin singkat, meningkatnya persaingan internasional, perubahan teknologi dan keanekaragaman pilihan konsumen yang mendorong percepatan proses pengembangan dari suatu produk baru.

Untuk dapat mengelola tingkat kompleksitas keragaman produk yang dimiliki perusahaan untuk ditawarkan kepada pasar, beberapa industri mengaplikasikan konsep Platfomn. Sementara untuk dapat meningkatkan keunggulan daya saing produksi, pendekatan yang digunakan adalah pengembangan produk dengan tingkat kompleksitas rendah dan memiliki tingkat investasi minimal dalam hal perancangan, produksi dan pemasaran.

Konsep Platform produk mengidentifikasi dan menjabarkan persamaan proses/perlakuan terhadap produk, pasar target, proses pengembangan dan pengiriman oleh perusahaan pada tingkat harga yang efisien. Konsep Platform yang dibahas adalah stardarisasi komponen, platform produk, platform proses, platform pengetahuan, manusia dan hubungan antar platform tampaknya menjadi strategi yang berhasil untuk menciptakan berbagai biaya rendah.

Dinamika kekuatan pasar yang mendorong perusahaan untuk mengembangkan produk-produk desainer dengan menciptakan modul standar sebanyak mungkin dari seluruh produk yang dimiliki. Diharapkan dengan menerapkan metode modul standar tersebut membuat perusahaan dapat lebih tangguh bersaing dibandingkan hanya memiliki suatu desain utuh dalam era globalisasi.

Keywords

Product Platform, Production Competitiveness, Modularity Method

INTRODUCTION

Some twenty years ago, customers realized that manual assembly of high-volume products, regardless of any accompanying low labour cost, had become non-competitive. Increasing production efficiency greatly had become a necessity.

Today's market globalization, with its inherent continuous increase in global competition, adds more complexity. Competitive and highly volatile market is redefining the way companies do business. “Customers can no longer be lumped together in a huge homogeneous market, but are individuals whose individual wants and needs can be ascertained and fulfilled” (Pine, 1993) and also Pine attributes the increasing attention on product variety and customer demand to the saturation of the market and the need to improve customer satisfaction:
“Today, demand for new products frequently has to be diverted from older ones. It is therefore important for new products to meet customer needs more completely, to be of higher quality, and simply to be different from what is already in the marketplace.

State of the Art

Product platform concept

The concept of a product platform has been receiving increased attention in product development and operations management. Several authors have recently been concerned with it.

Product platform description and definition

A literature review of the product platform concept reveals a number of definitions and descriptions. They range from being general and abstract in their wording to being very industry- and product specific. Moreover, they tend to differ in scope. Some definitions and descriptions focus mainly on the product, the artifact, while others try to capture large parts of a firm’s value chain in the platform concept.
The streams of product platform definitions that rather narrowly focus on the artifact display several similarities and a high degree of resemblance in both wording and content. A recurrent theme seems to be the notion that the platform is a physical part or a collection of elements shared by several related products. This is one of the reasons leading to the search for adoption of the platform strategy (leading to cost and investment cuts). On the contrary, this approach does not explain other significant advantages of a platform, like the reduction of development lead-time. On this foreword basis, we will define this stream of literature “production oriented”. For example:

- “a product platform…encompassing the design and components shared by a set of products.” (Meyer and Utterback, 1993)
- A platform is the physical implementation of a technical design that serves as the base architecture for a series of derivative products.” (Meyer and Lopez, 1995)
- The platform “…is a collection of the common elements, especially the underlying core technology, implemented across a range of products” (McGrath, 1995)

Product families

Since many companies typically design new products one at a time, Meyer and Lehnerd (1997) have found that the focus on individual customers and products results in “a failure to embrace commonality, compatibility, standardization, or modularization among different products or product lines." Similarly, Erens (1997) states that "If sales engineers and designers focus on individual customer requirements, they feel that sharing components compromises the quality of their products." The end result is a "mushrooming" or diversification of products and parts with proliferating variety and costs." Consequently,"companies *are being faced with the challenge of providing as much variety as possible for the market with as little variety as possible between products."*

Toward this end, the approach advocated in this thesis and by many strategic marketing/management researchers and designers/engineers alike is to, "design *and develop a family of products with as much commonality between products as possible with minimal compromise in quality and performance*

How to make differentiation

The basic rule of the thumb within platform thinking is that everything that costumer cannot see or feel can be largely standardized.

Figure 0.1: Schematic illustration of the product families (Sundgren, 1998)

Since one of the most important features of a product platform is to create product variety, it becomes particularly important to visualize how the product platform actually delivers this variety. The prevailing way to illustrate product architecture in the industry has been focused on what and how many basic modules the product family was built from (see Figure 2.1).

The theoretical number of products that the schematic product platform can deliver is 72 (4 x 3 x 2x 3 x 1 = 72) different products. This way of presenting the modular product platform, however, does not display how the modules can be mixed and matched together in practice in order to create customized end products. The end products that cannot be built because of restrictions in the product architecture cannot easily be visualized by just displaying the modular platform structure.

Example : The German Volkswagen Group has developed a detailed and explicit definition of what is included in the platform. It is than rather clear that differentiation among individual models is executed through various functionalities and intangible product qualities. Symbolic qualities are of special importance. See Figure 2.2.

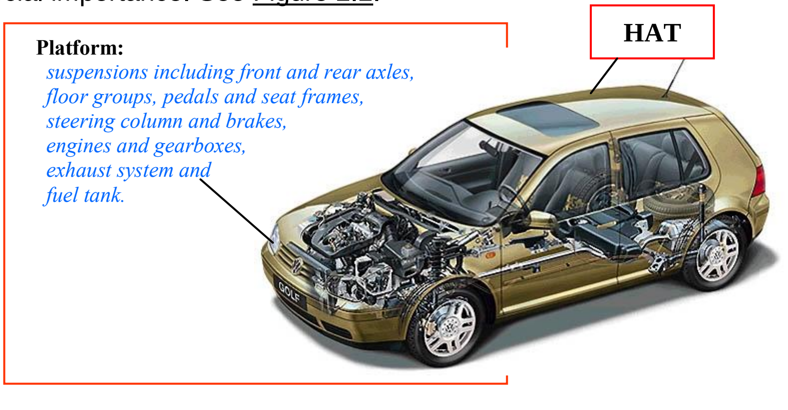

Figure 0.2: Platform and "hat" of Volkswagen Golf (Karjalainen, 2001)

The division of commonalities and variables is rather clear in this case. Platform consists of invisible parts – such as suspension, floor groups, and engine – that do not have a remarkable impact on the cars visual identity. Accordingly, these components can be widely used across the line of derivative products. The prior differentiator is the “hat” that is, also physically, the outer layer of the car. This part creates the personality for the car, primarily through various design elements; regarding both that communalized platform parts are not crucial differentiators from the customer viewpoint.

This detailed description supports the Volkswagen ambition to standardize the platform and its dedicated production equipment across several manufacturing plants in order to gain economies of scale.

Modularity Methods

It is important to view production modularity from the standpoint of creating more modular products. This is quite different from designing products with interchangeable or reconfigurable parts. It is also quite different from maintaining form/function independence. Modular design techniques are the crux of this research. It is the goal of modular design to group all attributes with like processes into a single module and decouple them from all other attributes and processes.

Design methodology for production modularity

Creating modular products involves making sure that, at each level of abstraction; the product’s attributes are as independent from one another as possible for each level of abstraction of the manufacturing tasks. If a dependency does occur, it should occur within a module. In addition, within a module, every manufacturing process should be similar for every attribute.

Part of the goal of modular design for manufacturing involves a one-to-one form/process relationship (independence). This includes maintaining form/form and process/process independence as well as the relationship between the two. Another aspect of modular products is the similarity of how the module and its components are manufactured (similarity) (Gershenson, 1996-2). Similarity is another perspective on the independence between form and process. For each part of the form (module), the entire module must undergo the same production processes. The last aspect of modular design is minimizing the different types of interfaces (interchange ability). This is more easily done and common in industry today.

To increase independence and similarity, a product must be designed with the following facets of modularity in mind: attribute independence, attribute similarity, process independence, and process similarity. The more independent, and unique the components and their manufacturing processes are, the more modular the product is. Attribute similarity is excluded because it is not necessary for modular products as long as attribute independence is preserved. As an example, many different modules can have black components and still remain modular, however, if the components must all match in colour then there is a dependency that reduces modularity.

METHODOLOGY

Design structure matrix

DSM can be used to organize product development tasks or team to minimize unnecessary rework and thus help manage and speed up the development process. The DSM can also be used to define modules within

single product architecture thereby suggesting how they can be improved is the design structure matrix technique (DSM) (Steward, 1981 and Eppinger et al, 1994). The DSM technique uses a form of matrix notation of the relevant variables.
The DSM does not answer *"What other tasks must be accomplished before this one?"* like traditional product development methods such as PERT and Gantt charts; the DSM answers the question *"What information is needed to complete this task?"* (Eppinger, 2001). PERT, Gantt charts and DSMs can all handle sequential and parallel design tasks; DSM can also handle coupled components, or rather coupled design tasks, which the two others cannot. The coupled tasks must be analyzed because they have a significant effect on the system architecture and thereby on the complexity and design process.
DSM is a very versatile technique that can be used on many different problems, e.g. for analyzing relationships between parameters (Steward, 1981), tasks (Smith & Eppinger, 1997) or components (Pimmler & Eppinger, 1994). Another strength is its applicability on large problems, while maintaining a relatively good overview of the model.
The DSM provides insights about how the overall product is working, what components that interact with each other and what changes that can be made in order to make the product structure more efficient. DSM especially highlights issues like dependencies, interactions and modularization.
In a component DSM, the relationships within the product are described in the cells of the matrix. All variables are listed on the x-axis and then in the same order on the y-axis. See Figure 4.1: A cell can hold information about four different kinds of relationships: spatial, energy, information, and material. Each criterion can be positive, i.e. supporting the product functionality, or negative, i.e. detrimental for the operation of the product. If the relationship is *necessary* for the product to work, it is usually given plus two (+2) as a value, if it is *detrimental* to the products function it gets minus two (-2). Desired and undesired relationships get plus and minus One.

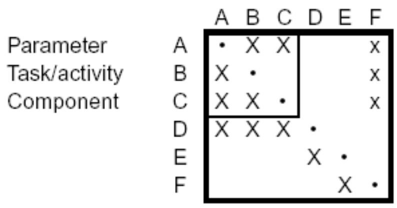

Figure 0.1: Simple DSM example. adapted from Eppinger et al, 1994

An example of a sequential task is building a house: the foundation has to be built before the walls are put up. Parallel tasks can be performed simultaneously, e.g., installing windows, wiring and plumbing. Coupled tasks are not common in construction but always exist in product development. Coupled tasks are tasks where learning is required, e.g., if it is discovered that a change in the foundation could improve the house, when the walls of the house have already been built. It is then necessary to first redo the foundation and then rebuild the walls. The evaluation of how different products and system architectures affect the design process would not be possible without considering the coupled design tasks, which consume the most resources.
Listing all design tasks that are needed to develop a product creates the DSM or system and arranging them in the same order vertically and horizontally. The diagonal in the DSM does not carry any information since this would indicate that each design task requires information from itself. Reading along the rows, the crosses indicate which design tasks that the design task on the row requires information from, e.g., B requires information from A, G, and J. Reading down the column, the crosses indicate which design tasks the task in the column needs information from, e.g., B supplies information to E, H, and J.

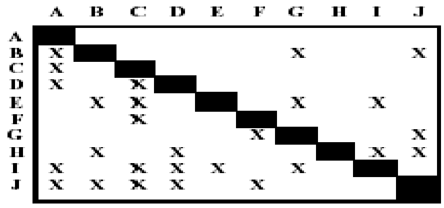

Figure 0.2: A design structure matrix.

In order to exclude the skill of the design task planner from the study of the different architectures and thus get an objective analysis a formal method, Steward's method (Steward, 1981) is used to optimize the design task sequence. The result of the method applied on the DSM in Figure 4.2 is seen in Figure 4.3

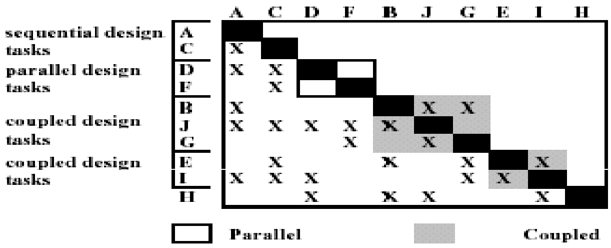

Figure 0.3: Optimized design structure matrix

All crosses beneath the diagonal indicate feed-forward information. Feed-forward means that information from the design tasks performed before is needed to perform the coming design task, this gives a sequential design. The crosses above the diagonal indicate feedback information. This means that design tasks performed previously are in need of information that is created in design tasks performed later, e.g., design task B needs information from design task G. These are coupled tasks because when information is finally available, it may be necessary to change B, and the development process has to be performed again from B; i.e., an iteration. Compared to feedback couplings, the feed-forward couplings are significantly easier to handle in design.

VDI design method

It is one of popular modularization method is VDI (The Society of German Engineers devised a methodology (VDI 2221) described in great detail in "*Engineering Design: a systematic approach* " by Pahl and Beitz.

The authors describe four stages including a number of steps guiding the design of a product from scratch to full specification, as illustrated in Figure 4.3. The stages are planning and clarification of the task, conceptual design, embodiment design, and detail design. There will be a particular focus on the conceptual design phase where the concepts of functions and working principles are defined in detail.

Planning and clarification of the task

This stage starts with an incentive, bringing a new product to the market that has to be attractive in terms of market conditions and company strategy, and concludes with a list of requirements that need to be fulfilled by the new product. To that end the company will conduct an extensive analysis of the marketplace and situation of the firm and subsequently set a process in motion where product ideas are generated and selected. The most promising idea is then refined by formulating a product proposal that clarifies the product's task. Finally, the company creates a list of product requirements that in turn is used to set the next stage of the design in motion.

Conceptual design

The conceptual design stage produces the principle solution required to establish the product requirements. The stage begins with an analysis of the main problem that needs to be solved to satisfy the list of requirements created in the previous stage. The following steps are then taken:

- Construction of the function structure
- Searching for and selecting working principles
- Combining the principles into a working structure

These steps determine the main product structure and will be paid special attention. A designer first needs to formulate an overall product function. A function describes the relationship between inputs and outputs within a system. These inputs and outputs can be categorized into three types: flows of energy, flows of material, and flows of signals (information).

When the overall function is clearly specified, the design evolves to the stage of decomposing the overall function into smaller functions. These functions are again transformations of energy, material, and information, but at a lower level of complexity. The resulting set of functions can be arranged in a function structure, such as is shown in Figure 4.4. The structure indicates that all functions are part of the overall function and can be connected to each other. The output of the one function becomes the input of the other function. All of the connected flows together constitute the input and output of the overall function.

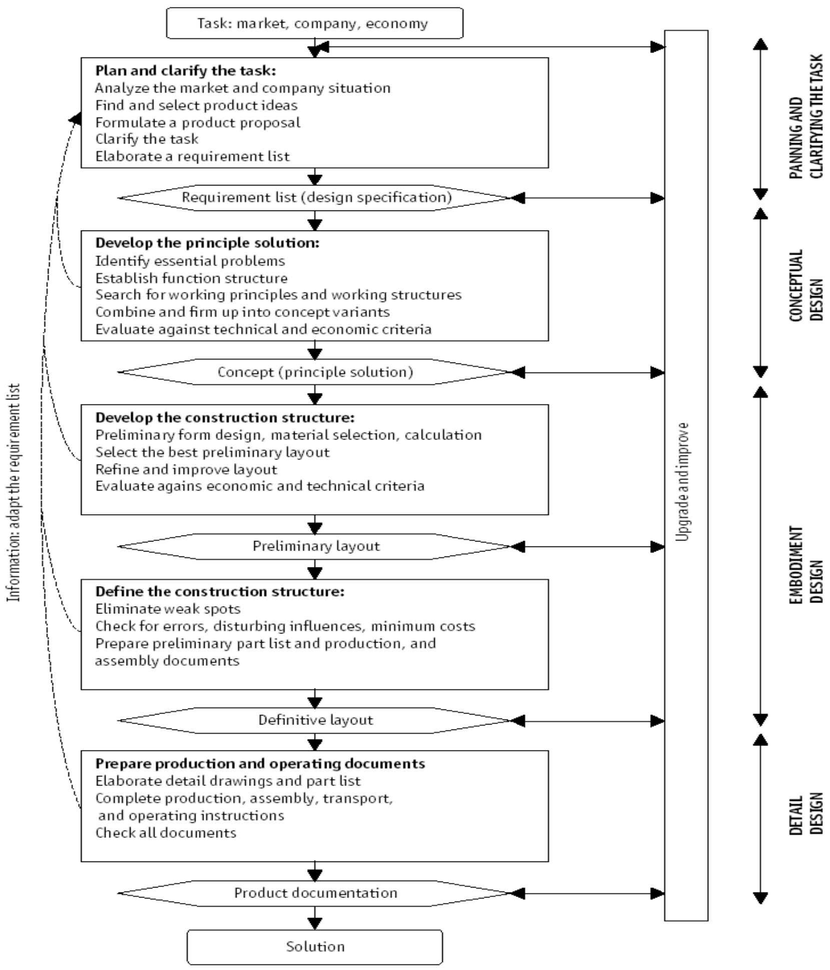

Figure 0.4: Steps in a design process (Pahl & Beitz, 1996)

A function thus expresses a transformation of energy, material, or information. Functions are preferably described as a verb-noun pair without a preconceived idea of the solution.
In addition, Pahl and Beitz classify functions as being main or auxiliary (as can be seen in the function structure depicted in Figure 4.4). They state that the main functions contribute to the overall function directly, whereas auxiliary functions have a more supportive character and contribute to it indirectly.
Second, once the functions have been specified, the search for appropriate solutions can start. The final solution for the overall function is obviously not directly available and has to be created step-by-step, piece-by-piece. Hence, the role of the function structure is to guide the search for solutions. It enables problem decomposition and facilitates the recognition of parts for which the solutions are known or available. The level at which the decomposition has to take place depends on the level at which the search for solutions for each sub function seems most promising. When existing physical solutions can be assigned directly, the decomposition may end at a relatively high level. For totally new design, the decomposition has to be performed until levels of much lower complexity are reached.

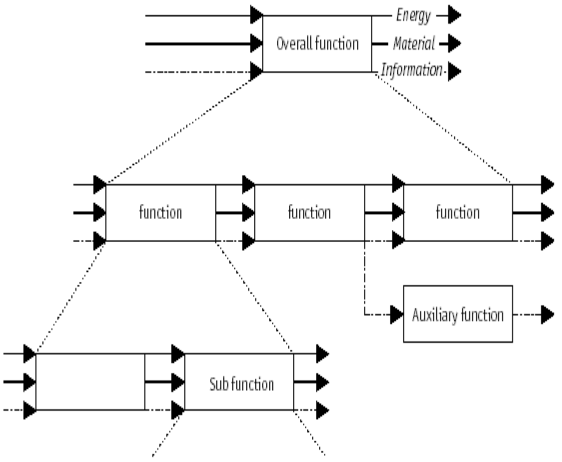

Figure 0.5: Function structure (Pahl & Beitz, 1996)

Third, once the functions are clearly specified, the search for solutions can be dealt with concurrently. A working principle has to be chosen for each function. A working principle expresses basic physical characteristics (geometry or material) to realize a physical effect that is needed to perform a given function. For instance, a working principle may be depicted as a rough sketch of a leverage that is based on the leverage law (physical effect) realizing the function ‘amplify force’. Mapping each function in order to develop a working principle may be guided by a morphological scheme. For each function, collection of several alternative-working principles is considered, from which the most appropriate one is selected.

Once a working principle has been chosen for each function, the challenge is to combine these working principles such that they together fulfil the overall function of the product. The combination of working principles is primarily based on the input-output relationship established clearly in the function structure. That is to say, each working principle has to realize its corresponding functional inputs and outputs. However, this is generally not sufficient. The compatibility of working principles is often strongly affected by physical and geometrical considerations. Alternative combinations of working principles have different effects on technical and economic criteria. Making a selection of physically feasible and technically and economically favourable combinations is generally a hard task for designers. Taken together, the choice and combination of working principles results in a specification of an overall solution principle that is the starting point for the next stage.

Method and procedures

Figure 4.6 presents the systematic MFD, Modular Function Deployment method and procedure. The tools needed in each step are entered in the figure, consisting of some well-known design tools and some newly developed.

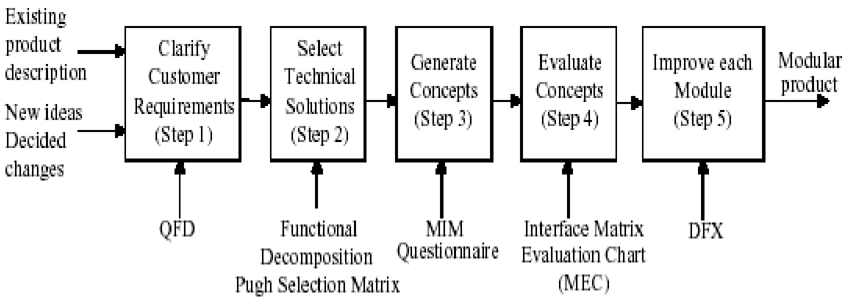

Figure 0.6: Modular function deployment method and procedure.

The MFD-method and procedure consists of the following steps:
1. Clarify Customer Requirements
The first step in any method for product design has to ensure that the appropriate design requirements are derived from the customer/market needs. The customer requirements have to be clarified, such that, the specification of the product to be designed must be formulated. QFD applied in a multi-disciplinary team has turned out to be well adapted for this task, (Tipnis,1994). Our experiences have also shown that QFD is well adapted to ensure that the right input data from the customer (user) is derived. Considering the objectives here, our contribution to the usual QFD matrix is to put "modularity" directly in as the first "how" (design requirement). This is preferable in order to get the right "mind set" of the participants in the team already from the start. This way of acting at an early stage, in which creativity and free minds should prosper, can be criticised. Case experiences have, however, shown that it actually encourages creativity and gives new dimensions to thinking.

2. Select Technical Solutions
Design requirements derived from QFD will have a strong market and customer focus. In order to proceed with the design a more technical view of things is needed. Looking at the product from a functional standpoint does this. The latter consists of the identification of a number of functions and sub-functions, in the products, which fulfill the demands and the selection of the corresponding technical solutions (function carriers, organs, means, design parameters, etc.).

This breaking down of the product into functions and corresponding technical solutions is normally referred to as a functional decomposition. Such decomposition shapes the basis for the creation of a good modular product design. By going through the functions for all the parts contained in a product, or system, a mutual understanding within the design team of how every part contributes to the whole, can be achieved. A good product design begins with a good specification and a good decomposition. Fine and Whitney(1996) argue that the ability to decompose a product or a system, top-down, is a basic strategic skill that may even be considered a core competence of a company.

3. Generate Concepts
A number of different driving forces behind modularization studies, (Östgren,1994) and (Erixon,1996). These criteria, termed are found along the entire product life cycle as below:

Product development and design

Carry-over: A sub-function can be a separate module when its technical solution can be carried over to new product generations. Technology evolution: A sub-function can be a separate module if there is a risk that the technologies have to be changed during the product life cycle. Planned design changes: A sub-function cans a separate module if it is the carrier of features that will be changed according to a plan.

- Variance

Technical specification: It might be suitable to concentrate variant changes into one module. Styling: A sub-function can be a separate module if it is influenced by trends and fashion in such a way that form and/or colour has to be altered frequently, or may be used for focusing the product towards different segments.

- Manufacturing

Common unit: A sub-function that has the same technical solution in all product variants can be a separate module Process /Organization: Reasons for a separate module could be when a sub-function:

- Has suitable work content for a group.
- Fits to our know-how.
- Can be arranged in an easy and pedagogical assembly structure.
- Has a manufacturing lead-time that differs extremely from other modules in the product.

- Quality

Separate testing: A sub-function should be a separate module when its function needs to be tested separately.

- Purchasing

Purchase: A sub-function that can be delivered as a “black box” in order to reduce logistics cost. Additionally, the manufacturing capacity of the company can be utilized better focusing on unique differentiating components.

- After sales

Service and maintenance: Service and repair can be easier if a sub-function becomes a

Separate module.

- Upgrading

If upgrading is foreseen, it can be easier if the sub-function is a separate module.

- Recycling

It can be an advantage to concentrate pollute (or easy recyclable) material in a separate module.

These drivers may be seen as generic, but may be complemented by company specific ones such as: strategy, financial limitations, legal restrictions, etc.

No other phase determines a product’s success or failure more than product strategy formation and product planning. Product strategy formation should be deployed for individual or series of product generations. (Clark & Fujimoto, 1990) discuss the concept of product integrity, i.e. the quality, or state, of being complete or undivided: completeness. Thus, ”*there are some companies that consistently develop products that succeed with customers, and what differentiates them is integrity*”. Every product reflects the organization and the development process that developed it. Product integrity, or differentiation, depends on how well strategic choices are made and on which technology is chosen to develop and invest. (Erlandsson, 1993) suggests that the product development process should be divided into primary development (new strategies, technologies, materials, etc.) and product delivery (industrialization) in order to render the control of development projects easier. This is simpler to achieve from a modular product platform.

In order to handle product variation and customization effectively one should strive to allocate all variations of a technical specification for variants, to one or, a few parts of, the product. The variations should not be allowed to spread throughout entire product. Parameterization in one or a few of the modules may be one-way doing this. Also, it will be advantageous to make the variation adaptation as late possible in the production chain. To keep the product generic as long as possible improves inventory savings, customer service, and lowers overall costs.

4. Evaluate Concepts

When some new modular concepts have been generated, the arising questions are many; i.e. - which one of the new concepts should we select? Which effects do we get in the production or in the development? How much better is the new modular concept compared with the existing design?

There is a need to further evaluate and/or measure the resulting effects in order to assess the proposed changes and to compare with the earlier situation. As discussed before, during a development process, there are many crossroads to pass and choices have to be made. An evaluation can also serve as a feedback to earlier phases in the process. For a modular design, the interfaces between modules have a vital influence on the final product and the flexibility within the assortment. Thus, firstly, an evaluation of interface connections will be the important factor for the selection of the concept.

5. Improve each module

The MFD-method should not be considered as a replacement for, or competitive to, design improvements on part level. It is important to emphasize the necessity of such work within every single module in order to secure the final result. The MIM now works as a pointer for what is important for each module respectively: e.g. a module that is chosen mainly for service and maintenance reasons should be designed to ease disassembly. The work required to improve a product design may take place at different levels: product range (assortment) level, product level and part level. The work on product and part level has been extensive and great lengths have been written about it, which will not be repeated here. However, one interesting aspect will be treated here.

Namely, the number of different parts used to build up a product or a product range. Many to be an important driver of costs in a company have identified the numbers of different parts in a product. Costs that are difficult to calculate or judge e.g. (Zenger & Cafone, 1991) and (Nilsson F, 1990). Material, labour and tooling are the most visible components of the part cost, but they only represent a part of the total true cost for the company.

Many other cost components are driven by the part number count. These components, which normally do not show up in the traditional calculation system, are overhead costs, and have to be traced through e.g. activity, based costing techniques (Beavers & Cafone, 1991) and (ABC, 1991).

In reality, however, the design work very seldom starts from the first specified Steps in a method, continues through every single step in the right order, and ends with the final step. Starting points vary and much iteration is needed before the end is reached. Vital, however, is that, in the end necessary steps and/or stages have been gone through in order to reach an acceptable solution. The presentation of the MFD method will nevertheless follow an ideal working manner from step 1 through to Step 5.

Hierarchical product platform realization method (HPPRM)

Kjartan Pederson in his thesis describes another methodology for platform product. It calls Hierarchical product platform realization methods (HPPRM). Basic idea is framework of the bottom-up approach is rooted in the product platform design. HPPR methods are trained and educated to break up problems that are too complex into smaller ones that can be solved. HRPPR method wants to create products 'that work.
This implies that there is something that products 'do' and this 'doing' is nothing else than the function of the product in technical terms. Implement current technologies in the new way. HPPR methods consist of a three phases: (Figure 4.7).

Phase I: DEFINE (from a 'path-dependence' perspective)
This methods start by '***structure of the past***', i.e., they acknowledge *path dependency*. Which done of Numerical Taxonomy, a stand-alone method hypothesized as a viable approach to analyze what standardization potential is present in an existing design portfolio. Also gather data consist with the entire task from defining what data to gather, to making them available for computer manipulation, and how to process the information. The next identifying data using dendrograms, where each junction of designs (or clusters of designs) represents a unique Taxonomic Level (TL), or better, a unique set of product families. If these dendrograms are found to be satisfactory in terms of representing reality, they are passed on to the second phase.

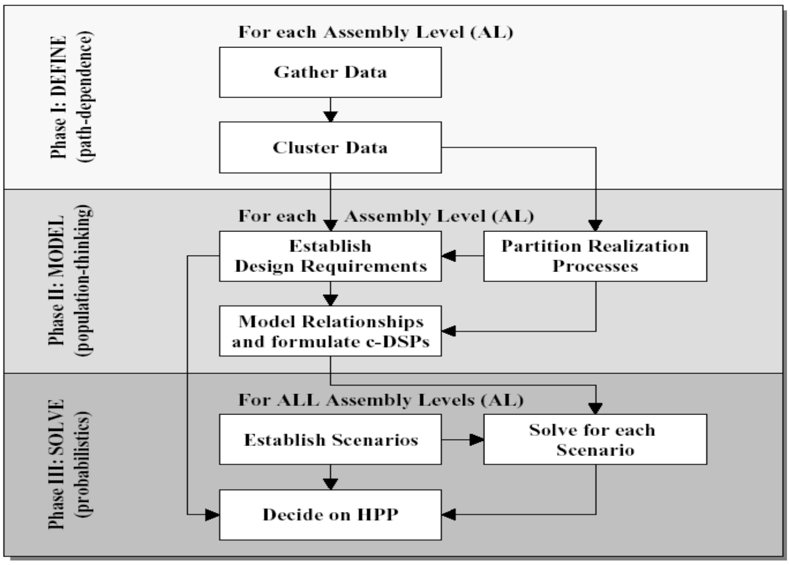

Figure 0.7: **The HPPRM phase (Pederson, 1999)**

Phase II: MODEL (from a 'population-thinking' perspective)

In the second phase identifying are '***bridging the past and the future***'. In this step is done by evaluating the 'structure of the past' in terms of its applicability for present and anticipated future conditions. This is the procedure for defining which product families at each Assembly Level are promising from a standardization perspective, and what design criteria and realization processes are applicable. In the latter, *population thinking* 'dictates' variation which implies inclusion of alternative processes. The performance of the alternative processes is discounted according to the Technology Diffusion concept, which is hypothesized as a viable discounting approach. This is the basis for establishing relationships between product families and processes at each Assembly Level on the one hand, and the operational performance, time and cost of the total system on the other hand. Then a series of c-DSPs are formulated, which is hypothesized as a viable approach to enable designers to minimize the distance to their goals for the total system with respect to operational performance, time and cost. The tested model is 'sent' to the third and final phase to be solved.

Phase III: SOLVE (from a 'probabilistic' perspective)
Final phase is to define the '***direction into the future***' by solving the model for a series of scenarios to gain appreciation about the problem. This is done acknowledging the *probabilistic* nature of the model, i.e., that the information is incomplete and that the future most certainly will invalidate one or more of the assumptions upon which the model / scenarios rest. The scenarios are based on estimating present and future customer / public / own preferences in terms of system-goals and the relative importance associated with each goal. Each scenario is represented by an objective function which is minimized (solved) according to an archimedian and / or preemptive scheme. The wanted solution is the set of product families and processes that gives the best compromise between operational performance, cost and time for the total system. All phases and procedures product family is coined a "Hierarchical Product Platform".

Comparison of modular methods

The compare started by decomposing all the product architectures and building function structures. First steps built functional block diagrams (function structures) for the product architectures. Decomposed the products to the assembly level of the production. Then represented all the connections between the components or sub-systems with material, energy, and information flows. For example the motor torque going to the transmission was represented with an (mechanical) energy flow of torque/rotation.

Function structures are not required for the MFD, the HPPR, and the DSM methods, but they start with a functional decomposition. The function structure representation of a product is all that is needed to apply VDI Design method. For the DSM method, the function structures need to be converted further into a design structure matrix. This is done by listing the product functions as headers in the rows and columns of a matrix. Interactions between functions are marked in the corresponding intersecting cells of the matrix. For the MFD method, the function structures are converted in a similar manner to a so-called module indication matrix. In a module indication matrix, the column headers represent the product functions, whereas the row headers represent the various module drivers for modularizing the product. The next step of MFD, where module drivers are mapped against the products.

HPPR consist that humans are at the center of decision making, and an evolutionary approach acknowledging the importance of historicity (heredity), variation (population thinking), and probabilistic decision (natural selection) in modularization.

Further, the component based DSM (can be assigned the same interactions as Pahl and Beitz's function structures) except for an additional spatial relationship that is added to the DSM cells. This difference can be removed when one takes the approach of Otto and Wood and augments the function structure with force flows of gravity through the function network, thereby creating an isomorphism between a function structure representation and a DSM representation. The chosen algorithm, however, does not separate between different interactions. Furthermore, since Kurfman *et al.* have shown function structures to be reasonably repeatable the function structure and its functional decomposition, identical for each method, are used as a starting point for all three methods in this study. All products are decomposed to approximately the same level and the same functional basis terms are used when possible.

VDI Design method, DSM, HPPR methods and the MFD, given identical inputs, produce different results. This is due to the different viewpoints and application areas of each method. The VDI Design method considers the functionality of the product and interface simplicity whereas the DSM considers only the interface simplicity but it can be combined with other strategic matrices to take also other company issues into account. The MFD, on the other hand, focuses on various strategic issues leaving the decisions about the functions and interfaces of the product to the designer.

As assumed, all methods give different suggestions for possible modules. This is due to the fact that each method has been designed to optimize a different factor. VDI design method minimizes interactions between the modules and finds conversion components. The DSM method also minimizes the module interactions but does not separate main flows as VDI design method does. The MFD, on the other hand, looks into a few chosen strategic factors and leaves module interaction choices to the designer.

Another difference between the DSM and the VDI design is that the former, being a computerized algorithm, can handle complex problems quickly but may suffer from lack of the flexibility and reasoning of a human mind and suggest some irrational modules. To modularize a product family, the family VDI methods are the only reasonable choice, since they are the only tools designed for that purpose. The MFD has a common unit driver to handle product family issues, but it is only one of many drivers.
It was presumed that even though the methods are very different, they should find some common module boundaries in a product since the fundamental goal of each method is the same. This however was not true and leads to a conclusion that no method is perfect and the choice of method to use depends on the case in hand.

The MFD is best suited for strategy-based modularization, to define design variants and decide on buy-make decisions, for example. To decide on the exact module boundaries i.e. to minimize the interactions at each boundary the function structure heuristic method is the best choice. It helps the engineers design fairly independent modules, that is, modules that if changed, they will not affect the rest of the system too much.

The DSM can also be used to simplify the module boundary interactions. It is best suited to modularize a more complex system where there are too many interactions for a person to handle. The DSM can also be used for organizing product development teams and tasks.

The cases when one should apply each method are different, which leads to a conclusion that none of the methods should probably be used on its own. A solution could be to start with one method and check additional factors with another method. One could for example run an MFD on a product and use the VDI Design to define the final module boundaries. Another example could be to use the product family heuristics on a plat forming case to identify common modules across the products and then continue modularizing the rest of each product with another method.

The MFD is the least favourable method for a complex product and the DSM the most favourable. Again VDI design method between the two. HPPR suggest adapting large and complex made to order system by stabilizing the product and changing the product realization processes.

No method dominates the others. The choice of which method to be used and when should be done case by case. MFD is suitable for forming customer modules, the other methods for more technical modules; maybe for sub-modules of customer modules. Choosing a modularity method depends on the modularizing objectives.

CONCLUSION

Although technology influences all activities in a company's value chain, in platform concept may affect a company's competitiveness in the field of production. Product manufactured and sold to the customer, processes used to make the products, and information systems to integrate the various areas of a company are each part of the technology in use and are expected to show an impact on the performance of the production system. Hence, effective implementation and use of platform concept is to be seen as a strategic weapon in the battles of a company against competition in global markets.

Company can operate with more flexibility, because platform concept enable to:

- manufacture more varied products in small or large volume,
- bring products to market quickly and manufacture cost-effectively even during a short product life cycle.
- platform concept are based on standard assembly platforms and extensive development experience for industries around the world,
- platform concept can be adapted readily as throughput requirements change,

Advantages of modular system for manufacturer:

- Documentation readily available for tender
- Additional design effort only for unforeseeable orders
- Improved production planning and delivery dates
- Short execution of orders through parallel production of modules
- Simple calculation
- Modules can be manufactured for stock independent of order
- Favourable assembly conditions when product is modularized appropriately

Client:

- Short delivery times
- Better exchange possibilities, easier maintenance, better spare part service
- Possibility to change functionality and extent the range
- Fewer failures thanks to well-developed

Also, platform concept can have a significant impact on a product's life-cycle and its development time. Platform concept allows for easy disassembly upon product retirement and allows for wide product variety. By using similar modules from one generation to the next, product development time can be reduced and modules can be used across product lines to reach different niche market.

The development cost can be reduced by reusing different assets between the products tailored for different market segments. If these products have a common architecture they can more effectively share parts of a design and implementation. Because each product has its own set of requirements, a careful analysis of these requirements is needed to design the family architecture and to develop new provides traceability of requirements and allows tools to support graceful evolution of the system throughout its life cycle.

But some limitation of modular system for manufacturer:

- Adaptation for clients not as easy as with individual design.
- Product changes are only economical when considered at long intervals
- Increased assembly effort

- Difficult to determine an optimal modular system taking into account client and manufacturer needs and preferences
- Rare combinations of modular systems can be more expensive as individual, special purpose solution

Client:

- Special wishes cannot be met easily
- Certain quality characteristic can be less satisfactory than with special purpose solution
- Weight and volume usually greater than with special-purpose solutions

A number of methods for defining a product's modular architecture exist in the literature. Most of the methods have been derived from function diagrams developed by Pahl and Beitz (VDI Design method, 1996). Function diagrams show the flow of energy, materials, and signals between sub-functions and in and out of the system boundaries. VDI Design method gives a rough definition and guidelines to define a product's modules, but does not explicitly define this process. Basic idea of Hierarchical product platform realization methods (HPPRM) is framework of the bottom-up approach. It is rooted in the product platform design.

Ulrich and Tung (1991) give a good overview on the different types of modular and integral architectures. These methodologies tend to fall into two categories, function-based and matrix-based methods.

All of these methods: VDI Design method, DSM, HRRPM and the MFD, given identical inputs, produce different results. This is due to the different viewpoints and application areas of each method. The VDI Design method considers the functionality of the product and interface simplicity whereas the DSM considers only the interface simplicity but it can be combined with other strategic matrices to take also other company issues into account. The MFD, on the other hand, focuses on various strategic issues leaving the decisions about the functions and interfaces of the product to the designer. HPPR consist that humans are at the centre of decision making, and an evolutionary approach acknowledging the importance of historicity (heredity), variation (population thinking), and probabilistic decision (natural selection) in modularization.

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