BROWNFIELD PROCESS FOR DEVELOPING OF PRODUCT FAMILIES

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ABSTRACT

This paper represents a development process of product families in a case where already available designs are emphasized. This can be called a brownfield process. Tools, which support the individual steps of brownfield development projects, do exist. In this paper it is described how these tools, methods and procedures can be used to cover a whole development process of a product family. The development of a product family was divided into five steps: setting of goals, developing of a generic element model, analyzing the customer requirements, analyzing the minimum variation and describing the resulted product structure. In the first four steps existing tools were used. In the fifth step a new description method, Product Structuring Blue Print (PSBP), for describing a product structure was represented. PSBP shows how items are related in assemblies, how modules include assemblies, how modules are realized, and what customer requirement is connected to each module. PSBP helps in creating the view of the significance of the product structure solution principles. PSPB gives also a response to how product structuring decisions have to be made.

Keywords: Product Structuring Blue Print, variability, product family

1 INTRODUCTION

Many of the product development processes are focused to new product development. There are less product development processes that focus on brownfield processes, where product range and markets are available. The term “brownfield” is used in our paper as it is used in the building industry and in modernisation projects of process facilities. The brownfield process stands for the re-using of available assets and it includes notions that there are limitations to designing and solutions because of existing structures. Old product solutions, product structures or customer requirements limit designing of new products. Because of this, the brownfield process is not the preferred solution from the designer point of view. Old solutions can include waste that has to be cleaned away before the rest of the solutions are useful. In developing product families this means that for example the quantity of parts might be unnecessarily high or that product solutions are not matching against current customer requirements. In the incremental development process the object is developed step by step. One example of incremental development process has been represented in Oja’s dissertation [1]. In many industrial cases though making good use of available products is needed.

New product development or greenfield process (which does not include constraints for development work like brownfield process), has higher risks. Markets usually have dominant designs, which affect the customer behaviour. When a new product has been developed, there is a risk that the customers do not accept it. Investments to infrastructure of the company and existing resources have an effect on the selection of whether to develop current products to higher level or to develop completely new product. Design re-use is one of the most important things that motivate the utilization of brownfield processes. A new product usually includes a set of new requirements to other downstream phases such as manufacturing, maintenance, and sales. These are just a couple of instances why it is unfeasible to start from the scratch.

Tools, which support the individual steps of brownfield development projects, do exist. In this paper it is described how these tools, methods and procedures can be used to cover a whole development process of a product family. Experiences of these tools applied into the case are also discussed. In addition, the tools that were used in this case are analysed in relation to other tools known in the area of developing of product families.

In brownfield processes, it is known that there exist certain product solutions that the customers buy for a specific purpose. The information about the configuration rules is often more unclear. The main challenge in realising product family, which supports customer requirement variation is to develop partition logic. The purpose of the partition logic is to provide rules for selecting the product elements for needed customer variants. The partition logic has to take into account the procurement of elements, and that the elements are suitable for production. In this paper an approach to describe module structures is represented.

The case where product family tools were tested is introduced in Chapter 2. The steps of the brownfield process are explained in Chapter 3. Chapter 4 represents a documenting approach for the product structure. Issues regarding to information management is included in Chapter 5. The results of the research are concluded in Chapter 6. Chapter 7 includes discussion.

2 FINN-POWER OY – CASE COMPANY

The company manufactures production equipment for sheet metal processing. Figure 1 represents an example product of the company. Devices of material management are for example loading equipments, portal robots, tables, carriages and conveyors. Some of these have been illustrated in Figure 2.

Over the years demand has diversified and a quite a selection of different devices for material handling have been developed. The quantity of different alternatives and options has become a challenge for the management over time. Many of the designs have been projects for specific customers. This has led to situations such as that for example the development of certain robot models has gone inevitably on their own paths. Matters have been thought about in different devices in the same ways but requirements have been examined mainly one device at a time.

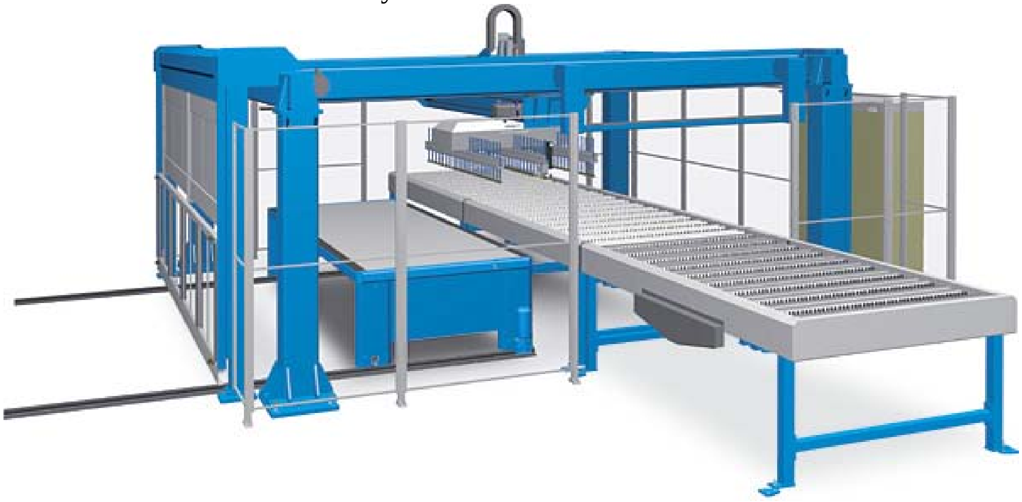

Figure 1. Finn-Power portal robot equipped with a material carriage and a conveyor.

In the year 2006 there was a modularisation project of carriages in the company. In this project, the relation between customer requirements and product properties were managed successfully. The whole product range has not been analysed in regard to modularisation aspects. Commonalities in the product range have been noticed, but the matter has not been effectively improved. There have been different projects, but all of them have not been successful. On the other hand, old projects have served as good learning points for this project. To conclude the description of the current situation, now it was right time to start a consolidating project on the whole product range. The main idea is in the realisation of customer requirements in the whole concept level, not just in one individual product.

This project has many benefits for in the company:

- Comprehensive analysis of customer needs and above all directing of them to the products in a controlled way.
- Managing of variety without losing the management of the whole concept.
- Utilizing the commonality of the product family.
- Speeding up the material management in production.
- Enabling of variation during the production.
- Speeding up the order-delivery process.
- Scaling of the scheme on the whole product concept, not just on single product.
- Simplifying of the product range and elimination of unnecessary combinations.

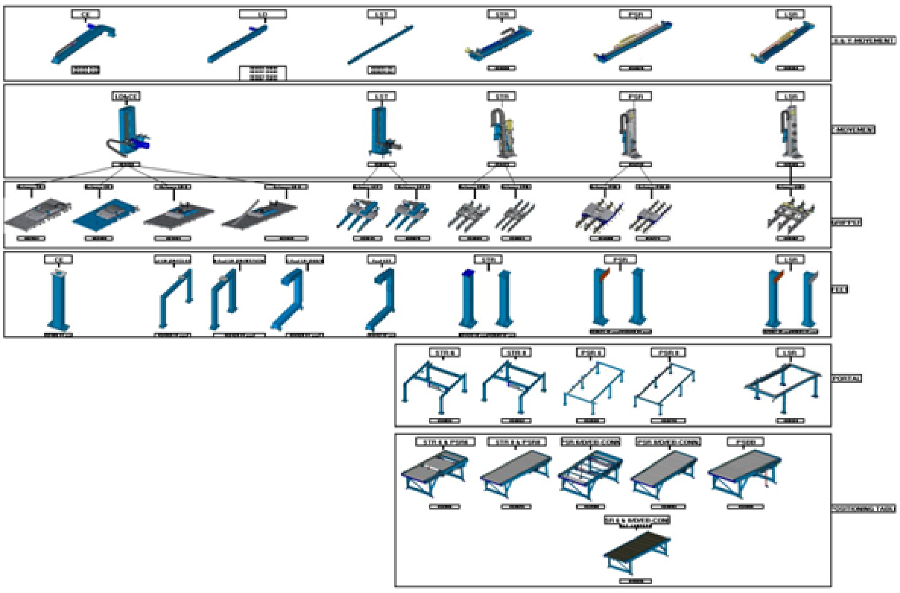

Figure 2. Old elements of the product family. Do we really need all these variations?

Existing products are utilised in the development project although there has been also thoughts that new elements are needed to be developed. Devices to be examined were loading devices, portal robots and discharge equipment where applicable at the beginning of the project.

3 STEPS OF THE BROWNFIELD PROCESS

In this case the brownfield process for the product family development is based on five elementary steps.

1. Defining (business) targets.
2. Drafting the proposed module architecture using mainly old solutions and components.
3. Updating and rationalising the market and customer requirements.
4. Creating module architecture with minimum scale of variation. Defining the amount of new design needed.
5. Documenting the reasoning behind the selected module architecture.

At first the targets of the development process were analysed. The purpose of the first step was to give a clear picture of why the development work should be done and what benefits the results could bring. After analysing the drivers to the development process it was time to model the entity of products and to sketch the generic element model in step two. The generic element model describes the design rationale and the intent of product realisation. The element structure alone is not sufficient enough for developing of product variants. The product variants have to match customer needs. The customer needs were examined in step three. The minimum scale of variation was analysed in the fourth step. These steps are explained in more details in the following subsections. The fifth and the last step includes description of the formed product structure. Actually a sixth step is also needed, because the cost and income effect of the selected solution must be validated against the original business targets. However this step must be taken in any development project. Because it is not specific for brownfield process, it is left outside the scope of this paper.

3.1 Target setting

At first the business goals for the development project have to be discussed. In this case the target setting was done based on the benefits of systematically variable products, which are illustrated in Figure 3. This figure helped to find answers to the question “Why to design variety with commonality for a technical system?” The primary goal was detected; the cost reduction of operating expenses. At this point, the pilot product was chosen. It was discussed that the suitable approaches to facilitate this goal would be 1) form a common architecture for product family and 2) the development of the elements (i.e. modules) as different streams, explained in “Dynamic modularisation concept”, see Figure 4 and references [2], [3].

The case specific targets for the product structuring were:

1. Common architecture: the product variants should have a common architecture, as large part as

possible.

2. Common modules: the architecture should be made in such a way, that as many as possible of the modules could be shared between the variant customer products in the product family.
3. Elimination of unnecessary variants: the variations, which do not add customer value or facilitate the production or long term development of the product, should be eliminated.

These goals leads to a modular product family, that is able to fulfil the customer needs without extraneous quality and is made out of a minimum inventory of different modules. Naturally, the modules must be real modules with unbreakable and manageable interfaces in mechanical, electrical and information domains [4].

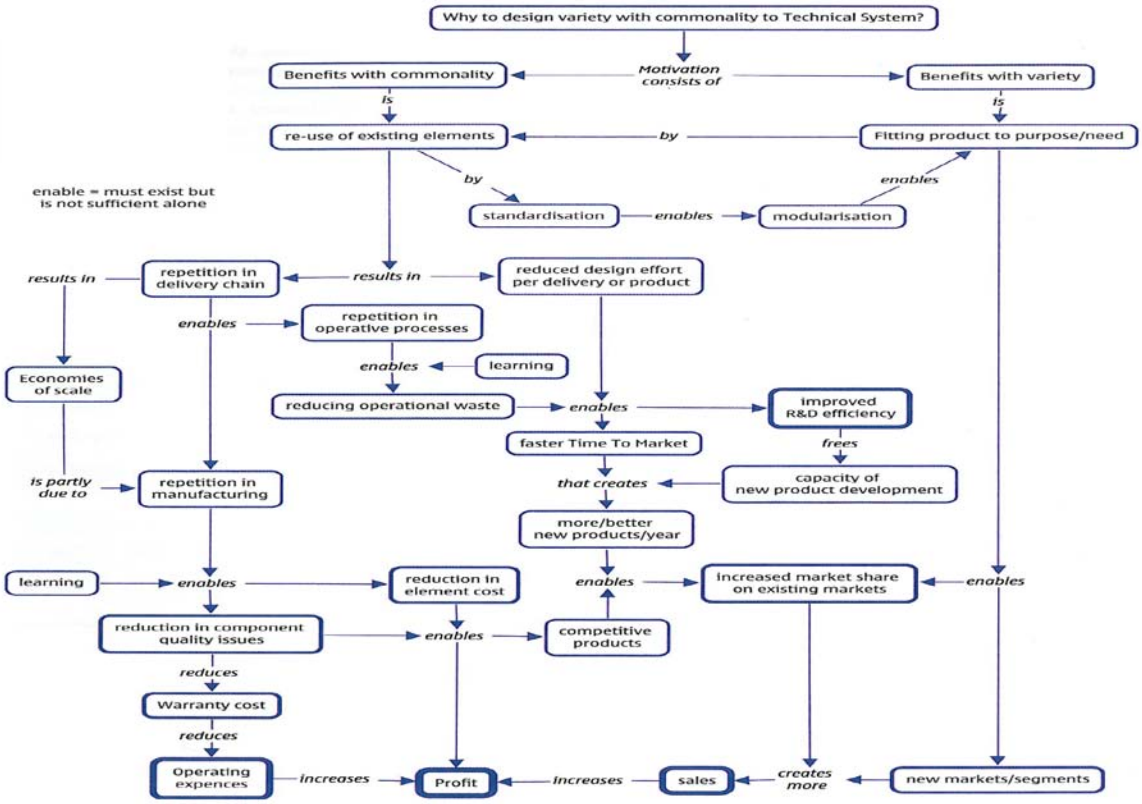

Figure 3. Cause-effect chain of benefits using commonality and variability [5].

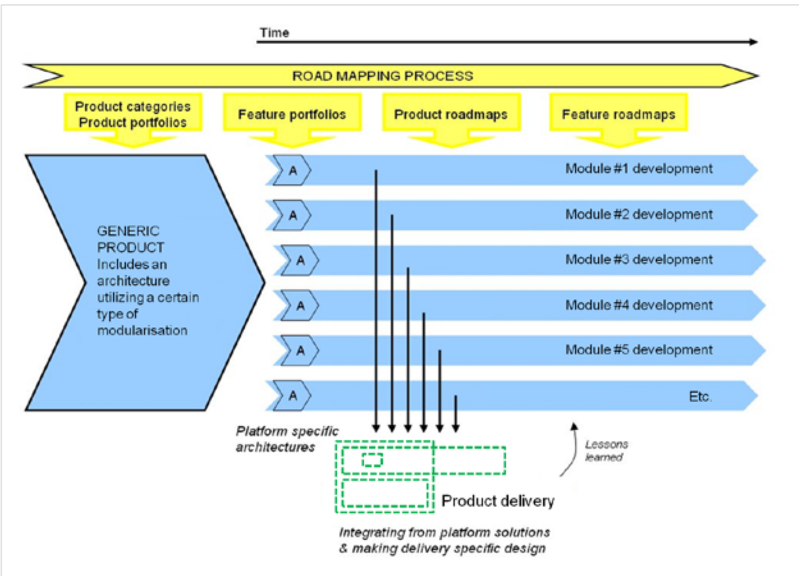

Figure 4. Dynamic Modularisation concept is a R&D method, in which everything is being developed as modules that fit into the common product range architecture. All the products are assembled from those modules. [6].

3.2 Generic element model

The formulation process of a generic element model includes several steps starting with the brainstorming session having participants from various functions such as sales, product development, mechanical, electrical and software engineering.

In this case, the individual work was done first in a brainstorming. During the common session, the participants formed pairs and tried to find a common understanding on terms and connectivities in this particular design. The session resulted in five proposals for a general element model candidate of the future product family. The proposals were all analysed based on the groups of cross-disciplinary expertise.

Due to the fact that there were experts from different areas of the company; the proposals differed a great deal from each other. This was seen extremely beneficial. During the presentation and discussions, the facilitator made a collection of the proposed elements on the white board. After all there were 37 elements on the white board. In addition to written elements there were more than one element, that should be divided further. The software elements were still excluded at this point and there was a separate proposal including a dozen of software elements.

The previous product structuring division could not fulfil case targets completely and so invention of something new was also reasonable. Again brainstorming session was held. In this session everyone was asked to describe his idea of the elements that will be building blocks in the new product architecture. In the beginning of this stage the proposals for the quantity of elements were seven or fourteen and so on. However later on it was discovered to be a too small number. In the end there were several tens of elements. As the final conclusion a combined generic element proposal was accepted by all parties as a work draft for developing the modular architecture.

3.3 Customer requirements

The brownfield processes have existing designs in the background which means that old products have been manufactured for some customer requirements. These requirements can include out of date information and traditions, which are based on old technological realisations. The challenge is to grab the customer requirements according to real customer needs, not according to old products. The validity of customer requirements was analysed using the Gripen method. This is a method inspired by the rationale how the product structure and configuration in Scania trucks were realised [7],[8]. The starting point in this method is the process of customer - what is customer doing. Process can be for example forming of sheet metal products. A handful of master questions, the questions that are most important in for the process of customer are found out. When the customer’s preferred ways of working and processes are understood they are segmented in to specific groups and solutions. These groups and solutions have to meet the requirements of a certain customer segment. The most important questions are those that determine in which segments the customer belongs.

One policy of the Gripen method is that instead of selling individual components, larger assemblies or “solutions” are offered, since it is easier to be sure of the compatibility and correct functioning of limited amount of layout variants than compatibility or correct functioning of remarkable amount of single pieces. The Gripen method includes also a thought that individual components are sold only when they are important elements for the customer alone.

In the discussion about the Gripen method, mainly catching of the understanding of customer needs, both pros and cons were considered. Generally the approach was highly regarded as a rational approach to this case and it was decided to give it a try. However there is one point that should be noted. It is possible to develop unnecessary variation. A care should be keep that the level of variation is sufficient enough but not too wide. This is due the fact that it is usually easier to define two solutions that one that fits on the requirement. The issue of minimizing the level of variation has been discussed in the next step.

The focus in customer requirement mapping is to get out of the product orientation and to move on to analysing variability from customer perspective. Giving up on product names and naming products based on configurations can be one helpful approach to this because this helps to get out of a feeling of product specific parts. This has been done for example in Scania 4-series models [7],[8].

3.4 Minimum scale of variation

In the fourth step the suggested element groups, which can form modules later on, of the product are compared against the customer requirements. The objective is to find the minimum quantity of variation that fulfils the customer requirements.

Product Family Master Plan (PFMP) [9] was used for analysing the minimum variation of product family. PFMP includes customer, engineering and part view of the product family.

At first the elements of the generic model were written in the middle of the white board on purpose. Now, there was room for drawing of empty domains and relations on the both sides of the elements. On the left hand side there was the domain of customer need. On the right there was the domain of parts.

On the side of customer needs the "use case" needs were listed. Relations were drawn between customer needs and generic elements. The relations formed visible route from customer needs to existing parts. This method illustrates the formalisation of the product family described above. The formalisation gives possibilities to see certain solutions as well as problems and enables the participants to ask important questions relating to specific relations.

For example in the part domain, the real parts of the product family were arranged according the elements in which they were supposed to be part of. This enables designers to see clearly the feasibility of the elements as modules in the sense of commonality. If an element has parts set, which could be formed with small amount of standard bill-of-materials (BOM), it is a good candidate for a module, where variation is achieved by selecting a suitable module. Similarly if major amount (weighted with a price more than a item number) of the parts of the element could be standardized and only minor part is varying, it could be a configurable element. Naturally there must exist a remarkably large "base unit", which is a standard module. Figure 5 represents examples of PFMP workshop.

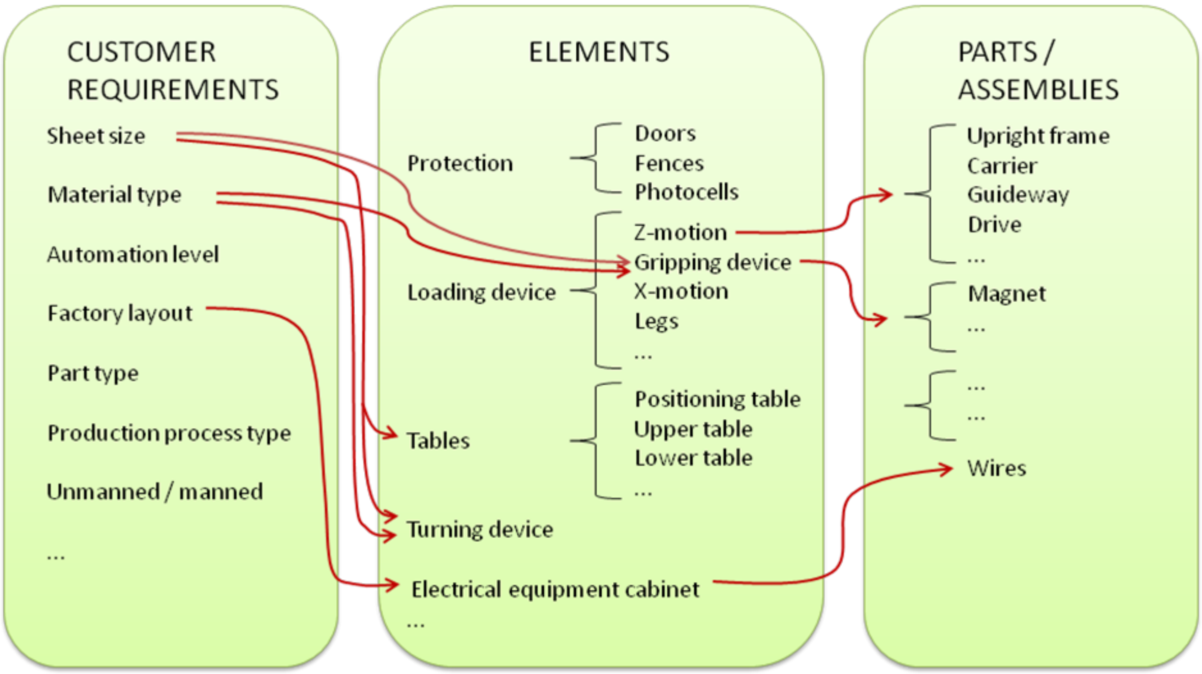

Figure 5. Example of relations between customer, element and part view in PFMP.

In examination of proposed structure the goal was to find or to create a commonality between product variants. This addresses the need for standardisation. Standardisation forms the bedrock for modularisation and thus there must be commonality between X and Y or the goals will never be achieved.

If any kind of standardized BOMs for an element are not generated, element as a future module is evidently challenging to be realised. In this case the suggestions would have been:

- Divide it further.
- Change the element division.
- Consider of changing the technical solution.

- ...and if nothing helps, consider if this is an feature which should not be part of this product family (divide the product to families, remove this element from standard product).

With the use of PFMP it is also possible to discover unnecessary internal variation. Every variant part/module should have a connection to a specific customer need that tells why there has to be variation. Only exception to this rule is that there may be a really good reason for variation coming from own processes of company. It is also possible to check, whether there is possibility to use the same parts or assemblies in elements that as a whole serve different functions.

Configuration knowledge was clarified with the help of the K- & V-Matrix method [10]. In this case we emphasised the use of K-Matrix that included analysis of customer needs against the proposed element structure. This matrix tool helped in ensuring that the elements the configurable product consists would be feasible in production and delivery network. The original K- & V-Matrix method does not consider variation strategies. This missing knowledge was added to solution principles of product variation next to proposed elements of the products to the matrix. These solution principles described that how the variation is done in each element. For example the element could have three options to certain customer requirements.

4 DOCUMENTING THE PRODUCT STRUCTURE FOR DESIGNERS

After four steps that have been demonstrated in Chapter 3, the plan of the product structure exists. This product structure is based on the existing solutions mostly but matches with minimum scale of variation and in reasonable way to the customer variation. The next step was to design elements according to the new product structure. This development needed suitable documentation that represents partition logic of the product and objectives the solutions will provide. In this case these matters were represented with the help of graphs, which were called the Product Structure Blue Prints (PSBP).

The idea in representing module structures using PSBP description was to make the blueprint drawing to show what elements have to be developed or exist and which customer requirement is connected to that element.

The syntax of the method is represented in Figure 6. The left most side includes name of the element (from generic bill of materials) in the product family. Next to it (when moving towards the right hand side) is a description of what kind of modules the element consist of. In this case the generic modules are mostly functional modules that are linked to solution principles of product variation. The solution principles of product variation describe the structure of items in the final assembly. Five different strategies of product structuring can be seen behind the solution principles.

1. Standard component that is included every time.
2. Module that is interchangeable without layout change.
3. Module that is interchangeable with layout alternatives.
4. Module with parametric variation.
5. Element that requires delivery specific design (these should be avoided).

These strategies have been marked with numbers in the generic example represented in Figure 6. Effects of the product structuring strategies on value creation (value chain), procurement and production can be estimated and with the help of this the product structure can be validated. The right hand side of the Figure 6 represents the relation between customer requirements and actual modules (solution principles of product variation).

The Figure 6 shows, for example, that the Beta module includes solution principle Eta to product variation and that the Eta is solved with standardisation. The Gamma module answers to the Customer requirement #9 through the Eta solution principle of product variation.

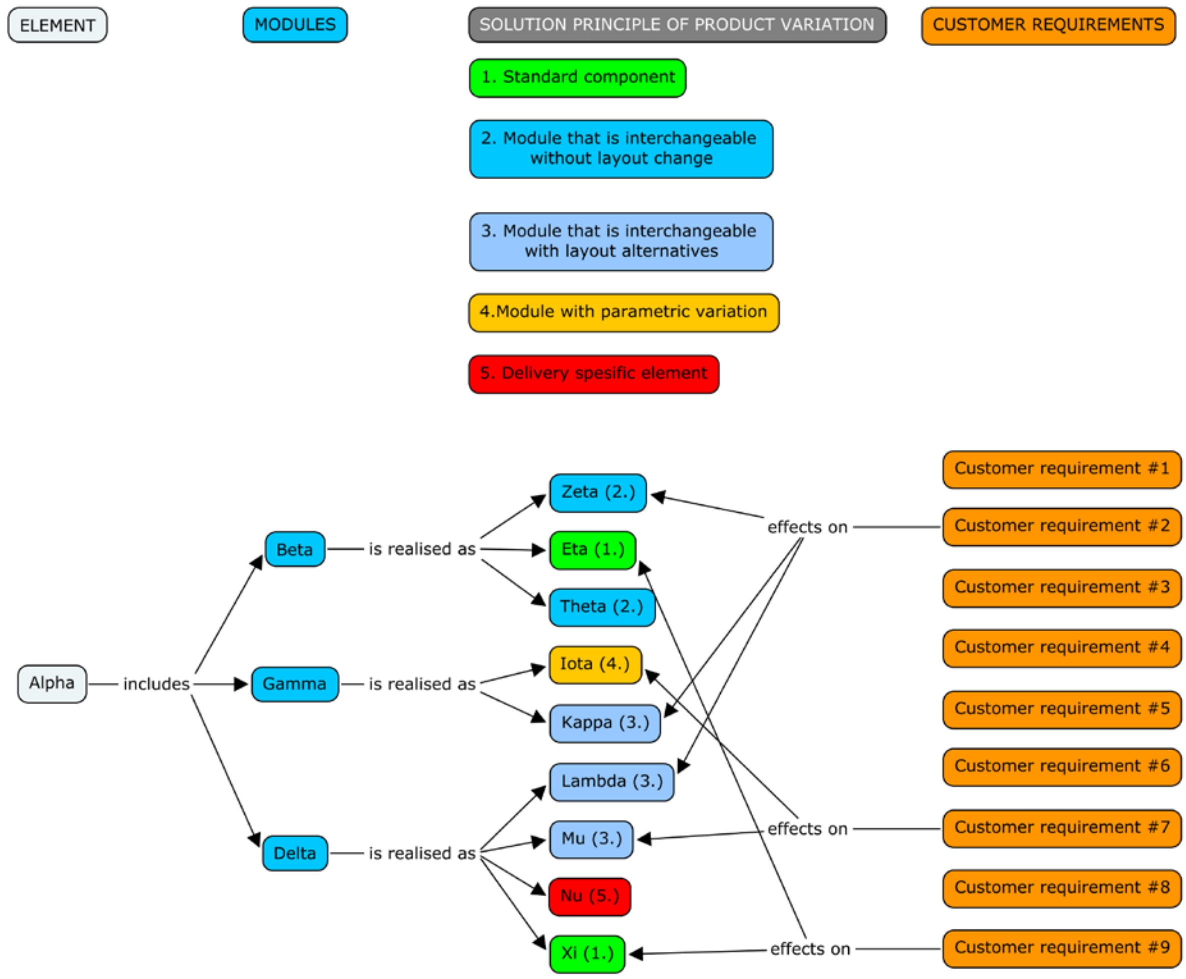

Figure 6. Product Structuring Blue Print (PSBP) for representing of module structures.

5 DIGITAL PRODUCT PROCESS REQUIREMENTS

In today’s product development environments the data and information related to a product and its processes are managed in many different systems, often with little integration and with a great deal of data redundancy. The modelling of complex products and their production processes and systems is typically done by multi-disciplinary, often multicultural and geographically distributed teams, working in collaboration. The cooperation required between the teams and each individual member of the team is heterogeneous because of the different platforms and each member’s specialization and tasks. Therefore a great number of different types of CAx systems are used throughout the whole life cycle of the product. This heterogeneity affects the communication both between humans and information systems [11].

For example, engineering drawings and product models may be maintained in a proprietary CAD system format, whereas the information on materials, surface finishing, packaging, electrical connections, assembly processes and sequences, resources, and so on are contained in various dispersed documents and stored in a variety of formats. What is common for these documentation formats is the lack of computer interpretable meaning of data [11].

The use of multiple proprietary formats forces the experts to serve as a manual human-machine interface between different systems, causing a vast amount of manual work and the possibility of human errors. After each life cycle phase of the product the different design teams create the models again from their own perspective. Also during these remakes the model gets filtered, because the current phase does not need all the information that was needed in the previous development phase, or because the transfer format does not support all the data types of the original model. The filtering leads to the “snapshot” approach where the product information is reduced to a screen-captured picture in the end forming a cartoon like design documentation [11].

A commercial solution for capturing the meaning of models and documentation does not exist. In other words “the meaning of” is not implemented into the IT-systems. In academic circles some approaches have been utilized for adding the computer interpretable semantics into the models. These technologies include use of logical representation such as first-order-logic and description logic, light-weight ontologies and semantic web technologies. Unfortunately, these have not yet been accepted into the solutions of software vendors.

As the technology rarely solves the underlying problem, it has been proposed that the companies should concentrate on the knowledge preservation through daily interactions. In this case the interactions would be the cooperative design procedures and definition where the information comes from and where the knowledge is used later on. It is a known fact that once the designers know the meaning of their work and its impact to colleagues work, the amount of errors and short-cuts tends to drop [11].

6 CONCLUSIONS

Development process in the case of a product family can be identified to be an business-oriented process. It means that it is most important to think of the business profits that the results could realise first. This is why the process does not give any modularity type until the goals have been set.

The product family concept has been defined in the company. The next steps are in designing each section. Design work is done in mechanical, electrical and software disciplines. At this stage, it has been estimated that the project would last about one year. Also a technical innovation will be tried in the form of a prototype. If results of the testing are positive and it looks promising to be developed further, the innovation will be adapted to the whole concept.

The PFMP is a powerful although a little laborious tool. However, a lot of information can be extracted from the company’s IT-systems. Use of only PFMP can result in products that are not configurable or configuration rules are not unambiguous. Because of this, other tools are needed in addition for detecting the configurable parts from which the product is assembled.

K- & V-Matrix method is not as visual method as PSBP. And the deficiency in the former is that it does not include the production point of view.

Both pros and cons can be recognised about using the PSBP description approach. The final element structure of the products can be hard to piece together from table tools like MS Excel. Standardised elements are viewed fairly well in customer requirement - module relation. The idea is that the product does not include anything that has not been modelled. One question is that is the quantity of variants sufficient?

If modules of the product are explicit, they have been validated and all the customer requirements can be fulfilled with them, realistic product structuring plan of the item is ready. The developer group can be given a drawn PSBP as a work instruction in designing of the part. If in the developing work solutions have to be changed. It can be seen from PSBP immediately where the changes have effects and what estimates must be redone. One challenge is the fact that the method is new and not yet established among the industry. The PSBP can be therefore be drawn how it is wanted, not necessarily how it is supposed to be drawn in the first place. To improve this, information systems should have support for this kind of a description method.

When modules are known from the product structuring strategy point of view, the basis for validation exists. It is possible to estimate or to calculate what advantages in the processes and networks of the company this module structure brings to us. In our example case, the expected benefits were calculated using activity based costing approach. The cost savings and added value differed highly from activity to activity. Because the product was not completely re-engineered, the expected savings on material and components were moderate. But the effects on company operational costs were in this example remarkable high. In certain cost topics they came up to near 40 %, which could be considered a good result even for Greenfield project.

7 DISCUSSION

Other methods and approaches could have been used instead of using methods represented in Chapter 3. Selection of product structuring solutions like modularity without evaluation of business objectives is possible but then the outcome is not very likely an optimal from the company effectiveness point of view.

The research group of Ishii [12] has developed calculation models for optimizing the quantity of product variants. There is evidence that these models can result in the most optimal solution but this means also that all of the existing variants need to be developed again. Main challenges of these kinds of greenfield processes were discussed in Chapter 1.

Erixon [13] has represented Module Indication Matrix (MIM) where module drivers are checked against function carriers. This method starts from existing components or modules but does not consider is it possible to reduce amount of modules by standardisation. In spite of this the tool can be considered as a possible tool variant also in a brownfield process.

There are many methods that say that modules should be treated as functional ones [14]. Adapting of function based module structure leads to good results only if recognised variation is only functional. The Gripen method that we used helps to identify the importance of functionalities in variations.

Quality Function Deployment (QFD) [15] does not include alternatives of product structuring strategies but concentrates on handling of product properties. The essential contribution of this paper stays outside of QFD studies. QFD is not a tool which is sufficiently design oriented. Currently the mere control of requirements does not help. It must be possible to design a product family which meets the customer requirements and the own requirements of the developing of the operation.

Brownfield method offers a process and a formalised way to rationalise existing product range. This kind of an approach is useful because in projects where it is not possible to develop new products, it might be hard to decide a good starting point and direction for the development work.

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