

IMPROVING DECISION MAKING IN THE EARLY PHASES OF CONFIGURATION PROJECTS

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During the early phases of configuration projects very important decisions are made which will heavily influence the performance of the company, benefits in different functional areas (production, sales, purchase, product development, service etc), maintenance of the configuration system and quality of the dialogue between the configuration system and the users. Today there exists very sparse tools and procedures which can assist the early phases, i.e. conceptual modeling of the products and product assortment. This paper presents a five-phase procedure for conceptual modeling in configuration projects. Each of the five phases is supported by a set of tools. The main idea of the procedure is utilization of a so-called Product Family Master Plan, which is a formal description of the product assortment and its variation. The procedure has been tested at one of Baan's (SSA Global) customers with very convincing results.

Significance: It is well known that important decisions are made in the early phases of projects. This paper proposes an operational method which supports decisions making in the early phases of product configuration projects

Keywords: Product configuration, early phases, modeling, product variety, visualization.

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1. GROWING PRODUCT ASSORTMENT

In many companies the product assortment is growing quickly due to an increased number of customer specific product variants. There are many "good" reasons for that, e.g.:

- When a customer is on the phone and wants a new feature included, it is difficult to say no.
- No one in a company dare to cut variants.
- No one dare to say no to a great new product invention.
- Resources utilized for maintaining the product assortment is not measured and visible.

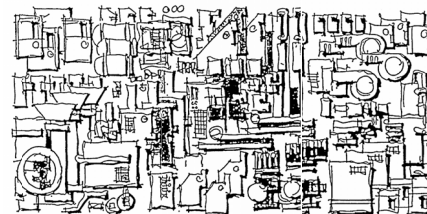


Figure 1. Complex product assortment

The growing product assortment normally leads to an increased turnover but not necessarily to increased profit. The reason is that all new parts or products become tasks in all functional areas in the company. Someone has to purchase, storage, produce, market, sell, ship etc. the new variant. The company might be trapped, thus the majority of resources are spent on maintaining the big complex product assortment and the ability to innovate and develop new product are dramatically reduced.

Now one could argue that it is not difficult to see the problems, but what about the solutions? A main challenge is to master the right balance between variance and commonality Andreasen & Hein (2000), Sanchez (2004). The product assortment shall show variance from a market point of view, and show commonality from a company point of view. Variance of the product assortment is a relational property between the product assortment, competitor products and customers. Commonality is a relational property that at least two products have in relation to a functional area. If e.g. two machine parts can be manufactured by the same lathe then they possess commonality from production point of view. Commonality ensures reduction of complexity in all activities carried out in a company.

How shall a company handle the right balance between variance and commonality? There exist two very powerful alternatives, namely application of modularization Sanchez (2004), Otto (2001), Simpson (2006) and configuration, Hvam (2006), Hvam and Pape (2006). Modularization is a way of structuring the product assortment and configuration is way of handling knowledge about the product assortment. Configuration and modularization can be applied individually or in combination. Sometimes products are not configurable and therefore modularization is a prerequisite for obtaining a product assortment, which is configurable.

This paper is treating configuration – more specifically the conceptual phases in a configuration project. The next section will briefly explain the reasons for doing conceptual modeling in a configuration project, and then a procedure and toolbox for conceptual modeling will be presented. This procedure and toolbox has been tested at one of Baan's customers and experience from application will be explained.

The work is done within Baan Development now SSA Global, which is currently developing a new powerful language for configuration. This procedure for conceptual modeling is targeted at the new configuration language. This modeling language will be so flexible that an approach taking the need of the company as starting point is possible rather than taking the starting point in the modeling language and tools.

2. REASONS FOR CONCEPTUAL MODELING

When a company has finished modeling the product assortment, very important decisions have been made. It is decided which product variants that shall be offered to the market and thereby which products and subsystems that shall be manufactured (purchase, logistics, transport, service etc). This means that both turnover and costs are influenced directly by the contents of the configuration system. It can therefore be argued that deciding on the structure of the configuration model is a business decision rather than a configuration technology decision. Making a constraint may seem innocent but may be a very crucial decision.

Like in any other projects important decisions are made in the early phases of a configuration project, i.e. the phases where the model structure in the configuration system is decided. Experience shows that when 10-15% of the resources are consumed 80% of costs, maintainability, efficiency and effectiveness etc are disposed.

Today there only exist sparse results from the early phases of a configuration project. Often there is a jump from specification to typing in the attributes, constraints, resources etc in the configuration system, see figure 2. This is an unfortunate situation because the domain experts, e.g. sales, production, purchase, product development have difficulties on seeing what decisions are made and they can not react.

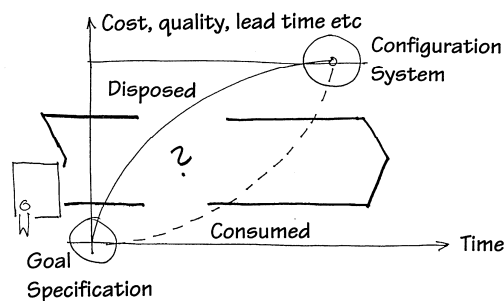


Figure 2. Sparse results from the conceptual phases

The main reason for developing a procedure handling conceptual modeling is to make the early phases explicit and visible. This is expected to improve conditions for bringing in relevant stakeholders early in the projects and improve conditions for ensuring that there exists a proper leitmotif from overall business goals to contents of the configuration model.

Another reason for developing the procedure is that it is sometimes difficult to maintain and update a configuration model when new products are introduced in the product assortment. It can be difficult to remember the meaning of attributes, constraints, resources and mode of action for the configuration system.

Last but not least it is the intention that the conceptual modeling procedure shall make it possible for a company to divide the modeling of production families between domain experts (purchase, production, quotation, sales, product

development) and IT specialists. To sum up there are four main reasons for developing a procedure for conceptual modeling of product families in a configuration system:

- Support business decisions in the early phases of a configuration project.
- Improve documentation thus conditions for updating and maintenance of the configuration system is improved.
- Allow a possible labor division of modeling product families between domain experts (e.g. sales, purchase, production, design, product development) and IT specialist.
- Allow the starting point for modeling to be the need of the company rather than modeling language and tools.

3. HOW TO MODEL A PRODUCT ASSORTMENT?

According to systems modeling Haberfellner (1994) and Hubka (1988), there are two types of attributes, which are relevant when a product or product assortment is being modeled. These attributes are named structural and behavioral attributes. Structure is answer to the question, what is it? And behavior is answer to the question, what is it able to do? Examples on structure attributes for a car are car type, size of the engine, number of doors and color. Examples of behavioral attributes for a car are speed, acceleration, noise-level and fuel consumption. The distinction between structural attributes and behavioral attributes is relevant because only the structural attributes can be determined directly during configuration. Formally speaking the behavioral attributes and the structural attributes are related to each other in a causal way. The identification of structure and behavioral attributes is fundamental when modeling products.

Another aspect that is relevant to modeling is deciding upon the overall structure of the configuration model. A product has several structures, see figure 3. A product has e.g. supply, purchase, production, assembly, shipping, transport, sales, maintenance and recycling structures.

Now one could ask which of the above structures should the configuration model be based on? Some of the factors that will influence the structure are application area of the configuration system, frequency of application, stability of the product assortment, domain complexity. Probably there does not exist a generic answer to determining the structure but often a functional structure is feasible. Seen from a front office point of view, customers are generally asking for solutions, which solve functions. Seen from a back office point of view production shall deliver parts which will become a product with certain functionality. A functional structure means that each element in the model solves functions. Identification of the functional structure is supported by the functions-means tree law. This tool is described further in section 4.2. It is relevant to work with more alternative product structures because one cannot look at a product structure and ask is this good or bad. Only by comparing alternatives it is possible to evaluate and find the most suitable one.

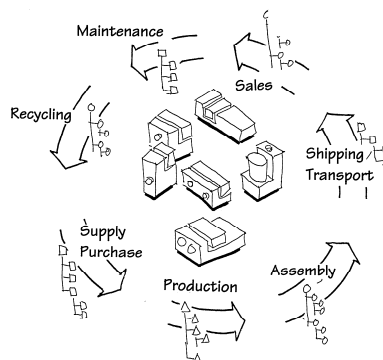


Figure 3. A product assortment has several structures, Andreasen et al (2004)

A formal way of describing the product assortment is a so-called Product Family Master Plan (PFMP). A PFMP consist of two main elements: a generic part-of structure and a generic kind-of structure, cf. figure 4.

The generic part-of structure describes the modules, assemblies and parts that exist in all the products within the assortment or the product family. Each element is described by attributes that are determined during configuration. The Generic kind-of structure describes the modules, assemblies and parts which are changeable in the product assortment. The Product Family Master Plan is thereby a complete description of the product assortment and the way variants are created.

The PFMP is described on a big piece of paper typically 2 meters times 3 meters. Very often companies have never been able to get an overview of the whole product assortment, see figure 5.

Experience has shown that the Product Family Master Plan is very good tool for discussing the product assortment, i.e. where to start modeling in the configuration system, which variants shall be included, which technologies are stable and which technologies will change? Where does the company make money on the variants and where does it loses money etc.

Having a complete and visual descriptions of the product assortment improves the possibilities for involving domain experts (sales, production, design) and company management in the crucial decisions during modeling in a configuration project.

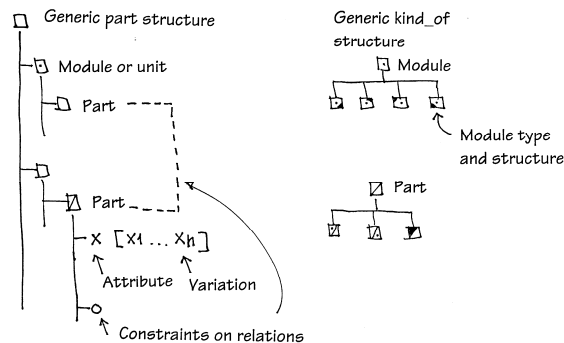


Figure 4. Contents of Product Family Master Plan, Mortensen (2000), Harlou (2006)



Figure 5. Discussing the product assortment in front of the Product Family Master Plan

The Product Family Master Plan constitutes the core of a modeling procedure that is the topic of the next section.

4. MODELING PROCEDURE

The modeling procedure consists of five phases supported by a number of tools. The content of each phase is further explained in the next sub sections.

- Identification of configuration task.
- Identification of Product Family Master Plan.
- Conceptual modeling of Product Family Master Plan.
- Detailed modeling of Product Family Master Plan.
- Modeling of product family in the configuration system.

The amount space in this paper does not allow all tools to be described in details and therefore focus is put on the tools that have been developed within the Technical University of Denmark.

4.1 Identification of configuration task

The purpose of this phase is to define what the configuration system must accomplish in accordance with stakeholders demands and overall business objectives. Important questions to be answered in this phase are: Who should benefit from application of the configuration system? Where to harvest the benefits? Which activities shall be supported by the configuration system?, What are the leitmotif from creation of business to contents of the configuration system?

The tools supporting this phase are:

- Stakeholder identification

- IDEF 0 – activity analysis
- Scenario techniques
- Use-cases
- Life cycle analysis

4.2 Identification of Product Family Master Plan

The objective of this phase is to get an overview and describe the product assortment. The means for describing the product assortment is the Product Family Master Plan. Important questions that this phase should contribute to answering: What are the variants that the company wants to offer to the market what are the variants that the company does not want to offer? What variants can be expected in the future?

Figure 6 shows examples on working with a Product Family Master Plan.



Figure 6. Working on different alternative Product Family Master Plans

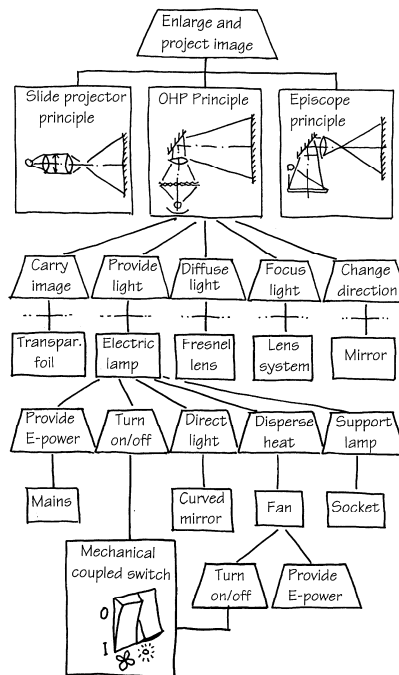


Figure 7. Function means tree, based on Andreasen (1980), Hubka (1988)

The identification of the function product structure is supported by the so-called function means tree, see figure 7. The starting point is identification of the overall function of the product. The overall function of an overhead projector (a means) is to enlarge and project an image. This function can be carried out by different means, e.g. slide projector principle, OHP principle and Episcopo principle. Each of these means requires the existence of lower level functions, e.g. carry

image, provide light, diffuse light, focus light, change direction, see figure 8. By this principle the function structure for a product assortment can be describe hierarchically.

The function means tree diagram provide an overview of alternative ways a function can be realized and is a good foundation for discussing the existing product assortment variants and identification of which part of the function structure that will be invariant and which parts is likely going to change.

Supporting tools in this phase are:

- Terminology charts
- Function means tree
- Product Family Master Plan chart
- Variance card
- Commonality card

4.3 Conceptual modeling

In this phase each of the elements of the Product Family Master Plan is described. For this phase a modeling tool has been developed Harlou (2006), which is inspired by the object oriented modeling paradigm, Coad & Yordon (1991), see figure 8. In this modeling tool each class in the Product Family Master Plan is described a Class Description (CD) card. Below the contents of a CD card is further explained.

- *List of aggregation classes* describes part-of relations to other classes. Aggregation classes for a car could be engine, transmission system and chassis.
- *List of inheritance classes* describes the kind-of relations to other classes. Inheritance classes of transportation equipment can be e.g. busses, planes and trains.
- *Function and picture contains* a short description of the functionality of the class within the product. As an example the main functions of a window is allow light to enter, allow venting and allow people to escape in case of fire etc. Picture contains a sketch/picture/diagram of the class. This is relevant for deciding on a consistent product terminology. When e.g. geometry is involved this can be utilized for determining coordinate system conventions, governing parameters etc.
- *Defining parameters* are the attributes that can be determined directly during configuration.
- *Components* are elements, which the class consists of. For a car components might be sunroof, stereo and air-condition which are typically boolean and not further defined.
- *Constraints within the class* are restrictions on how the components and defining parameters may be related. An example of a constraint within a car class could be that cars sold in South America should have an air conditioning system.
- *Constraints to other classes* are restrictions on how the classes can be related to other classes in the configuration system.
- *Mode of action* is description of the input and output parameters to the class. Input and output can be related to the user of the configuration system and other IT systems
- *Sources* describe the reason for the contents of the CD Card. The idea is that all defining parameters and constraints shall have a reason. The reason can e.g. be a stakeholder, documents within the company.

4.4 Detailed modeling

In this phase modeling is carried out in the same way as conceptual modeling but the configuration language used in the configuration system is utilized. The previous phases are independent from choice of configuration system. Main supporting tool in this phase is CR (Class Responsibility) cards, which has the same structure as class description cards.

4.5 Modeling by means of configuration language

In this phase the model is build up and tested within the configuration system. It is possible to divide the modeling between domain experts and IT experts. It means that identification of configuration task, identification of Product Family Master Plan, conceptual modeling are carried out by domain experts and detailed modeling and modeling in the configuration system could be carried out by IT specialists if desired based on the Class Description cards and Class Responsibility Cards.

Class Description Card		CD-Card
Class name:	Responsibility:	Status:
Class number:	Date:	<input type="checkbox"/> Working <input type="checkbox"/> Final
List of aggregation classes:		
List of inheritance classes:		
Function and picture:		
Defining parameters:	Components:	
Constraints within the class:		
Constraints to other classes:		
Mode of action:		
Sources:		

Figure 9: Class description card

To demonstrate how this proposed method works, the assumed QFD has only three customer requirements and five technical measures. However, the philosophy discussed in this research can be further exploited by considering more customer requirements and technical measures as well as a much larger group of people in a group decision-making process. In addition, the classification or the rank of linguistic values between WHATs and HOWs can become more complicated to meet practical needs. To sum up, with the use of improved fuzzy preference relation in a group decision-making process in QFD, the functionality in analyzing the relationship between WHATs and HOWs and prioritizing technical measures can be drastically improved that allows a group of decision makers to make decisions effectively with imprecise and vague information.

5. EXPERIENCE FROM APPLICATION

The modeling procedure has been tested in an American company and the PFMP itself is now utilized in more than 30 companies including LEGO, Danfoss, York refrigeration, Alfa Laval, APC and FLS. The case company is developing, manufacturing and selling building equipment. Approximately 5.000 people are employed in the company, which produces 4.500.000 products pr. year. In order to stay competitive the company has to be able to deliver customized products to the end users. The intention is to be able to deliver more than 300.000 variants seen from a customer point of view. Currently the products are not configurable, due to complex plastic components that are not changeable. Therefore, a so-called fulfillment project has been initiated in which 150 people are working. Approximately 25 people are working on the configuration part of the project.

The family master plan in this case was drawn on a big piece of paper approximately 4 meters times 2 meters. It was placed in the center of the project room where the 150 people were working, thus the majority of people working on the project had to pass the Product Family Master Plan on the way to their desks, to meetings etc.

During the project, this family master plan was important for creating dialogue with many kinds of stakeholders. Three alternative family master plans were developed during the projects. It seems important to carry out alternatives because there does not exist one correct Product Family Master Plan. The different alternatives will lead to configuration systems that possess different performance, maintainability and flexibility to bring in new products in the assortment. The most important consequence of utilization of the Product Family Master Plan is that it is bringing a concept phase into a configuration project, thus the family master plan is visible and it is possible for stakeholders to react on the contents before modeling in the configuration system starts.

Reactions from this company are:

- "I like the naming convention that you have used throughout your documentation"
- "It is crucial to have an unequivocal naming convention and way of describing things"
- "The way of visualizing the Product Family Master Plan was beneficial and provided an overview of the product assortment that we did not have before"
- "Your sketches in the Class Description cards together with the Product Family Master Plan are GOOD"
- "Your documentation does not tell how the configuration model is maintained, but it is the foundation for being able to maintain the model. If these documents does not exist we cannot maintain the configuration model"
- "If you had not introduced the Product Family Master Plan I doubt that we would have realized the commonalities between the product families"
- "It is difficult for us to forget the Bill Of Material. It is nice to see that the models are built up from function, functional units, assemblies and parts because we make decisions about these"
- "It sound like the Product Family Master Plan and the Class description cards is great for getting our thoughts down"
- "We consider using this procedure for the Back Office Configuration too"
- "We need to train people in the very important thinking pattern that is behind this procedure"
- "The people who fill out the CR cards must have detailed knowledge about the product, manufacturing, market and some basic understanding of object oriented modeling"
- "This is the only procedure that I have seen for documenting the configuration model"
- "I like the Product Family Master Plan, because we can bring in relevant stakeholder earlier on"

6. CONCLUSIONS

It is very clear that handling the conceptual phase of a configuration project is crucial for the success. It is often difficult to handle the conceptual phases because the knowledge by definition is vague. Application of the proposed procedure based on the Product Family Master Plan is formalizing the modeling activities in the early phases and proposes a visual way of working. The implication of this is that it is possible to involve stakeholders earlier on and have "facts" based dialogue concerning variance and commonality of the product assortment.

The Class Description Cards ensure documentation and traceability of a configuration model. Preliminary experiences shows that it is possible to divide the modeling task between domain experts and IT specialists, thus that modeling in the configuration system can be carried out based on the contents of the Class Description Cards.

Further work on the conceptual modeling procedure involves application in two configuration projects. The next step for the modeling procedure is development of a course on conceptual modeling that will be launched together with the new configuration language and tools. The goal of this course will be to train people in companies, thus they are able to model the product assortment by means of the modeling tools.

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BIOGRAPHICAL SKETCH



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Ulf Harlou holds a PhD and a M.Sc. in Mechanical Engineering and is employed as consultant at the Institute of Product Development (Technical University of Denmark). He has carried out industrial projects at Bang & Olufsen, Danfoss, Vestas Wind Systems, Alfa Laval, YORK Refrigeration and LEGO. These projects are all within the areas of platform based product development and product configuration.



Anders Haug is assistant professor at the Department of Entrepreneurship and Relationship Management at the University of Southern Denmark. His main research areas are information systems, knowledge management, knowledge representation, knowledge engineering and product configuration. Haug has a PhD in knowledge representation and management in the context of creating product configurators, and he has produced a number of international publications that deals with the development of product configurators, representation of complex industrial knowledge, sharing of product information, and more. Additionally, he has worked as a consultant on a number of configuration projects. Haug teaches in managing information systems, product configuration and product information management.
