CONFIGURABLE PRODUCTS – LESSONS LEARNED FROM THE FINNISH INDUSTRY

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ABSTRACT

In this paper we present experiences on configurable products gathered in co-operation with Finnish companies. The reasons that made configurable products important include the ability to efficiently fulfil a wide range of customer requirements, shorter lead times in the sales-delivery process and increased control of production. We discuss the product development and sales-delivery processes of configurable products and their practical problems. These included partially configurable products, poor quality of configuration models and lack of clearly defined product policy. Companies had migrated to configurable products from one-of-a-kind products and fixed products (i.e. products manufactured repetitively according to a fixed specification). The direction of migration affects the benefits, problems and necessary changes. The requirements of the sales-delivery process and the product must be understood to gain full benefit from a product configurator. In addition, the process must usually be re-engineered and products designed for configurability. Companies often neglect these issues and the long-term management of configuration knowledge. This leads to major difficulties in configurator projects.

KEYWORDS

Product configuration; configurators; configuration experiences; survey

1. Introduction and definition of configurable products

Configurable products are important for industries that offer products adapted according to customer requirements. Information systems that support the customer specific adaptation, i.e. *product configurators*, are an interesting subject for research (see e.g.[1]). However, in our view product configuration is a much broader research area. The success of applying a configurator depends on the related business issues, products, processes, organizations and practices. Only through understanding these issues can configurators and configurable products be applied to their full potential. Such understanding is also valuable for developing configurators.

This paper reports experiences on configurable products gained in co-operation with Finnish companies. The results are largely based on an in-depth survey of ten companies[2]. Some experiences are derived from close co-operation with half a dozen other companies that use or plan to use product configurators. The companies were interested in developing their processes, products, information systems and knowledge management related to product configuration. They were neither a random sample nor a collection of state-of-the-art companies.

Our definition of the basic properties of configurable products is as follows:

- The product has been pre-designed to meet a given range of different customer requirements.
- Each delivered product individual is adapted to the needs of a customer.
- Each product individual is specified as an arrangement of pre-designed components. Thus, there is no need to design new components as a part of the sales-delivery process.
- The product has a pre-designed architecture.
- No creative or innovative design is needed as a part of the sales-delivery process. Rather, a product individual can be specified in a routine manner.

This definition coincided with how the companies perceived configurable products.

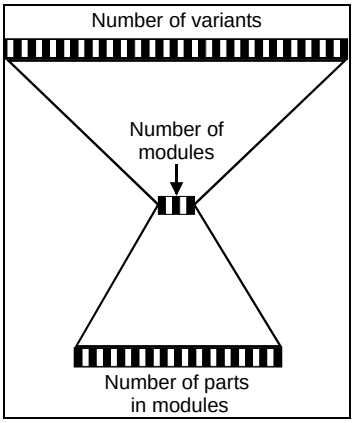

Figure 1. Controllability of configurable products

2. Reasons for operating with configurable products

We asked representatives of the companies in the survey to explain why they design and manufacture configurable products. We first list the reasons and then analyze them. The reasons mentioned most often were:

- ability to fulfil a wide range of customer requirements (7 companies),
- shorter lead times in the sales-delivery process (5),
- increased control of production (4),
- reduction in customer-specific design (4),
- efficient way to offer a broad product line (3), and
- improved quality (3).

Other reasons mentioned included easier selling, less capital tied up to work in progress and stock, and reduction of errors.

The ability to efficiently fulfil a wide range of customer requirements is the main reason for designing and manufacturing configurable products. This is vital in today's highly competitive global markets. Configurable products usually have a modular product architecture, where each module implements completely one or a few functions, and where interactions between modules are well defined[3]. This allows a broad product line as combinations of relatively few pre-designed modules.

Assemble-to-order production of configurable products is possible in many cases. This reduces lead times compared to one-of-a-kind products, which are engineered to order. In addition, the time and effort required for customer specific design can be practically eliminated. This allows companies to free engineering resources from customer specific design. Many companies wanted to use these resources for product development. This can be a significant factor, especially on markets with time-based competition.

As configurable products consist of relatively few pre-designed and independent modules, control of production is easier compared to one-of-a-kind products. There are fewer items to forecast and manage compared to an equivalent range of fixed products (Figure 1). Each module can have a fairly high volume making forecasting easier and manufacturing more economical. Fewer items are needed in the stock and less capital is tied up to work in progress and stock. Note that configurable products can be controlled effectively at module level. There is little justification for forecasting individual product variants, although some of the companies tried to do this with mediocre success.

Configurable products are easier to sell than one-of-a-kind products in the sense that the possibilities of the product have been decided in advance. This gives a more concrete point of reference in communicating what is possible to the customer. Pricing is usually much easier than for one-of-a-kind products. It is also easier to prepare supporting material for the different phases of the sales-delivery process.

Surprisingly, reduction of errors was explicitly mentioned only once by the companies surveyed. This reason may have been included as part of improved quality. In-depth discussions with some companies implied that reducing the number of errors is an important factor.

3. Processes related to configurable products

In this section we discuss the two main processes related to products: the product development process and the sales-delivery process. The product development process of a configurable product produces, among other deliverables, a *configuration model*. A configuration model contains all the information on the possibilities of adapting the product to customer needs. It consists of available components, rules on correct component combinations, and rules on how to achieve the desired functions for a customer. The configuration model is used repeatedly in the *configuration process* (Figure 2) that is a part of the sales-delivery process, to produce *configurations*, i.e. descriptions of the product individuals to be delivered. In the configuration process product individuals are *configured*, i.e. adapted to meet given customer requirements, on the basis of the configuration model and the customer requirements. These adaptation activities are referred to as *configuration tasks.* We call a person that configures a product a *configurer.*

The product development and sales-delivery processes of configurable products are separate. In this regard a configurable product resembles a fixed product and differs from a one-of-a-kind product. However, configurable products differ from fixed products since the latter are not adapted for each customer. The product development process of a one-of-a-kind product can be seen as a part of the sales-delivery process. It typically requires creative or innovative design that results in a specification of a single product individual. Creative or innovative design makes it possible to design new component types and to use an arbitrary product architecture. In principle, it becomes

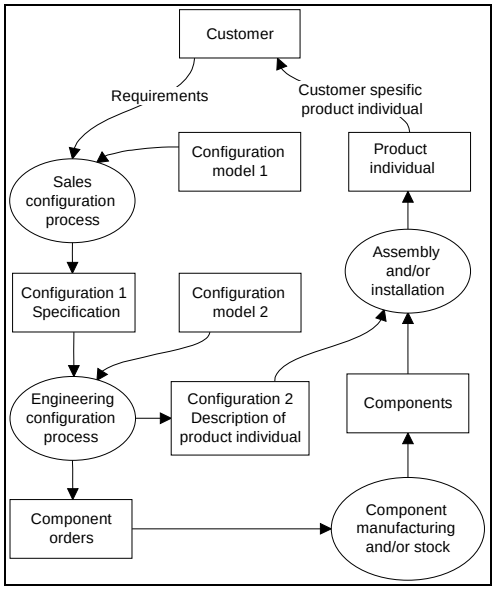

Figure 2. Sales-delivery process of configurable products

possible to satisfy any customer requirements. Some parts of the specification may be re-used in more or less ad-hoc manner in other products. A configurable product significantly enhances the re-use of design knowledge compared to a similar one-of-a-kind product.

Product development process

Identifying the market segments and their specific requirements are important in developing a configurable product. A company must choose the segments to which the product and each of its variation possibilities are targeted. It is critical to match the product architecture and variation possibilities to typical combinations of requirements. A mismatch makes the product hard to sell because suitable alternatives are not available by configuring the product.

A preliminary configuration model should be defined early in the product development process to define the variation possibilities of the product. This is an important part of the conceptual and system-level design of the product. It is vital for the configuration process to document the configuration model systematically. There may be different configuration models of the same product. These are typically meant to support different phases of the configuration process, for example sales and engineering configuration tasks.

A product expert with clear understanding of the product should enter the configuration model in a configurator. If a knowledge engineer enters the configuration model, he or she should not need to re-invent the configuration model or to gather the required information from multiple sources. Product policy and commercial and technical restrictions of the product are typically clearly beyond the expertise and authority of knowledge engineers.

As discussed earlier, modular product architecture is almost a necessary characteristic of a configurable product. Note that some parametric products can be considered configurable although they are not necessarily modular. In our view, the main distinguishing characteristics between a non-configurable and a configurable modular product are that the latter has a systematically documented configuration model and a systematic configuration process.

Most companies offered *partially configurable products*, i.e. one-of-a-kind products that were tailored slightly beyond the possibilities defined in a configuration model. The modifications often affected only one or two components. In these cases most of the product individual could be configured and only the customer-specific modifications had to be designed. Most of the configuration and total cost of the product individual were determined by the configurable part of the product. Generally it seems more cost-effective to design rare or unpredictable variants case by case rather than to try to extend the configuration possibilities to cover all possible requirements. It is a strategic decision whether a company offers customer-specific design on top of configurable products. Note that a drawback of partially configurable products is that they are difficult to support with configurators.

Sales-delivery process

A request-for-proposal or an order from the customer initiates the configuration process (Figure 2). The customer requirements and the configuration may be incrementally defined and refined in the configuration process. Eventually, the configuration should contain all the information necessary for the next stage in the process, e.g. for manufacturing and installing the product individual. The configuration can be seen as an order to the next stage in the sales-delivery process.

The process may contain several stages, such as sales and engineering configuration. In the sales stage the product individual may be specified in terms of the abstract functions or modules that satisfy the customer requirements, which results in a sales specification or sales order (called *configuration 1*). However, in most companies the product individual was specified in technical terms even in the sales phase even though some customers defined their needs as functions. This means that the sales configurer had to map the functions to technical concepts, usually without systematic guidelines. In the engineering stage the output of the sales stage is used together with the configuration model for the engineering stage to produce a more detailed and concrete definition of the product individual (*configuration 2*) that can be used as a specification for assembly or manufacturing.

A configuration process in a company may not contain all these stages. For example, the whole configuration task may be carried out in the sales or engineering stage. When products are relatively simple and easy to configure, sales configuration can be the only configuration phase. The sales configuration task may sometimes even be carried out

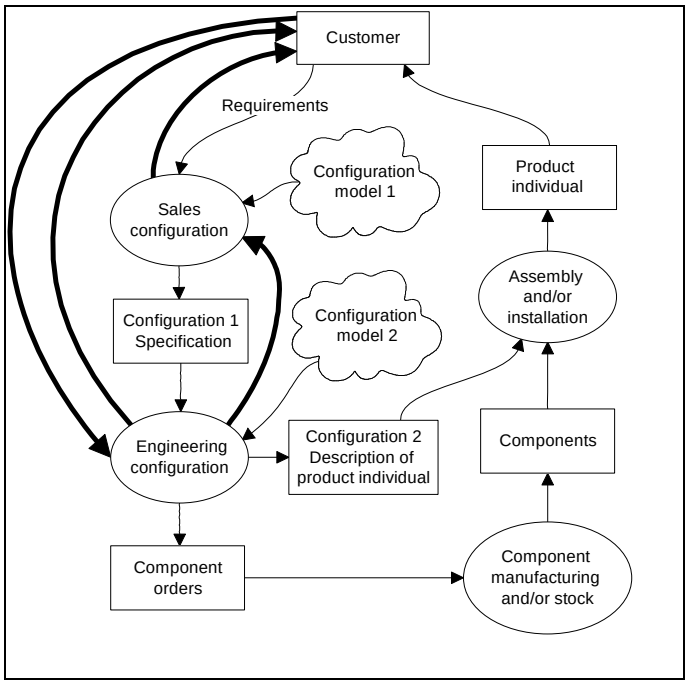

Figure 3. A typical sales-delivery process without configurator support

directly by the customer, for example via Internet when configuring PCs. However, some complex products require a product expert to configure them. In some companies, when sales persons did not have the required expertise, product experts were sent to support the local sales organization. This creates significant costs and is suitable only for expensive, high-margin products. A configurator enables a company to re-engineer the sales-delivery process of a fully configurable product and to transfer configuring even a complex product to the sales person or in some cases to the customer, without the help of a product expert.

The configuration process typically included at least finding out the customer requirements, component selection, determination of the price of the product individual, preparing the configuration dependent parts of the proposal, and checking the completeness and consistency of the configuration. With some products it was necessary to determine parameter values for parametric components. The complexity of the configuration process increased when layout or component connection design was required. In some cases it was necessary to offer several alternative configurations for the customer to choose from. In addition to configuring new product individuals, some companies needed to modernize, i.e. *reconfigure* existing product individuals. This task may be very complex because it bridges the gap between temporally different versions of configuration models. A modular product architecture facilitates easier modernization of a product individual.

A few companies had good experiences on separate well-defined processes for configurable and partially configurable products. This allowed fluent delivery of configurable products while forcing participants of the process for partially configurable products to consider all the necessary issues. The processes for partially configurable products typically included a bid or sales review by a multidisciplinary team including designers, sales persons and production engineers to assess feasibility of the product and estimate the amount of work, time and cost incurred.

Problems in the configuration processes

In many cases 50-80%, sometimes even 100%, of sales specifications were *incomplete*, that is, some necessary information was missing. Many sales specifications were also *invalid*, i.e. they contained errors. According to one company, 20-25% of the effort of the unit responsible for engineering configuration went into completing incomplete specifications or correcting invalid ones. The cost of correcting errors in a configuration increases dramatically the further in the sales-delivery process they are noticed. However, rather few configuration errors reached production or later phases of the process.

Lead times in the configuration process were long. Plenty of time was used in the configuration process compared to the actual amount of work. The manufacturing and logistics processes have often been rationalized and automated, and function efficiently. There is usually more room for improvement in the configuration process than in the production process.

One of the most common problems of the sales-delivery process (Figure 3) was that incomplete and invalid configurations caused iteration in the sales-delivery process. It was quite typical that several contacts between the sales and engineering configurers, the sales configurers and the customers, and even between engineering configurers and the customers were required. Another form of iteration took place when the sales persons did not have the expertise to configure the product individual on basis of the available, possibly incomplete, configuration model. In these cases a product expert, typically in a different location, configured the product individual. It often took several iterations of the loop from the customer to the sales person and further to the engineering configurer and back. This was necessary to refine the initially vague customer requirements to accurate enough level to fix the final configuration. An iterative process is very error prone due to greater possibility of misunderstandings and frequent changes.

Some of these problems can be attributed to generally poorly documented configuration models. The models were incomplete, unsystematic, difficult to understand, and relatively often contained outdated information. Order forms

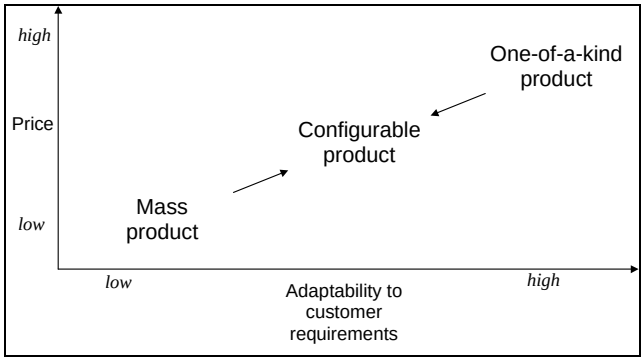

Figure 4. Configurable products compared to fixed products and one-of-a-kind products

either did not exist or were not systematically used. Therefore the configurers may not have known the possibilities of the product and the rules for a complete and valid configuration. In addition, product policy seemed to be either loosely defined or it was not followed. In these cases, the introduction of a product configurator faces challenges in systematizing both configuration models and processes.

Most of the products were only partially configurable. There was a strong tradition of one-of-a-kind production which led to excessive design. Sometimes changes thought to be minor modifications cost much more than anticipated. For example, a company estimated a cost of $11,000 for customer specific changes that actually cost $29,000. Of the design and management work, 18% was considered “normal”, 65% was needed for changes and 17% was spent correcting errors caused by the changes.

4. Transition to configurable products

Several companies that had previously delivered one-of-a-kind products had migrated to configurable products to reduce the lead-times in the sales-delivery process and to re-use the product knowledge (Figure 4). In making this transition the main effort goes to pre-designing and systemizing the products from design-for-configuration point of view. The transition may require considerable investments in product development, modularizing the products and systemizing the product knowledge that often only exists in the designers’ minds. In addition, the sales force must learn not to offer unnecessary changes to the product that would result in customer-specific design. This cultural change in the process may be difficult to accept.

The investment in systemizing one-of-a-kind products to be configurable is profitable only if the number of delivered product individuals is high enough and there is enough similarity between them to allow significant re-use of the product knowledge in the configuration models. In addition, the product should not be very complex, such as a plant, nor can the pace of changes to the configuration model be too high. Otherwise managing the configuration model may become too difficult.

Some companies that had previously offered fixed products had also moved to configurable products (Figure 4). This has usually addressed the need for a broader product line than can be efficiently managed as fixed products. However, it is generally not feasible to change very low-priced, really high-volume commodity products to configurable products. When migrating from fixed products to configurable products, the types of functions that the customers require may be better known than in case of one-of-a-kind products. Designing a configurable product may still require considerable effort. Introducing a configuration process to a sales-delivery process that has previously operated with fixed products can cause problems. More specification work than previously must be done by the sales persons and in the engineering configuration. All the processes in the company and the supporting systems must be altered to handle customer-specific variants of products. Changes in processes, information systems, flexibility of manufacturing and culture may be difficult and expensive.

5. Configurators

Product configurators have become important support tools for configuration tasks. If used successfully, the benefits in lead times and quality can be significant. However, there are problems related to their use. The main problem is related to the long-term management of product knowledge. Many configurator projects have failed due to difficulties of maintaining configuration models up-to-date. To avoid these problems, a relatively high degree of maturity in the change processes of the company is necessary. In addition, there is no generally accepted way of representing a configuration model. Matching a configurator to the products and processes of a company is difficult but important for a successful application.

A configurator should make it possible to model the configuration model directly with minimal programming effort. This is a pre-requisite for successful long-term management of product configurators, but it may not be enough. In addition, a configurator should have the following properties:

- an intuitive, understandable, visual modeling environment;

- a structured, probably object-oriented modeling method; and
- means for modeling the evolution of products, components and their interdependencies.

The first property aims to ensure that the configuration models can be managed by the product developers, product managers and other people in the company who understand the products best. The second property increases the understandability of the models and consequently helps managing the model by dividing it into relatively independent packages of knowledge whose interactions are well-defined. The third property adds to the modeling method some aspects of configuration management[4] and product data management[5]. These may include versions of products, components and rules on components, as well as effectivity intervals and rules on the different versions. In our view, there is a clear need for better support for long-term management of configuration models as the pace of changes to products is increasing.

A considerable problem related to the management of configuration models has also been the effective distribution of the configurator to the entire sales force. It may be necessary to support both automated and manual configuration tasks if all retailers (for example, those with low sales volumes) are not willing to acquire or use a configurator. This problem is worse if a retailer sells products from several manufacturers and should operate several configurators. A solution to this problem seems to be to centralize the support for configuration tasks and to implement a web-browser-interface to the centralized configurator. This approach may have problems with security in the Internet but these can probably be solved with appropriate security technology. More importantly, integration to the information systems of the retailer can be difficult.

6. Conclusions

Product configuration is an important research issue and not limited to research on product configurators. A broader view is very important for companies utilizing configurators. The developers of configurators can also benefit from such research.

Successful utilization of product configurators necessitates understanding and often re-engineering the sales-delivery process as well as designing products for configurability. Neglecting these issues in a configurator project often leads to major difficulties. Long-term management of configuration models should be a major concern. A good match between the needs of a company and configurator functionality also makes long-term management easier. Some aspects of practical processes are difficult to support with configurators. These include partially configurable products, reconfiguration and several stages of the configuration process.

Further research is needed to analyze in-depth the conditions under which a company can benefit from migration to configurable products and using a configurator. The main factors seem to be the degree to which product knowledge in configuration models can be re-used, the complexity of the resulting configuration model and the pace of changes to the configuration models. This issue is being addressed in one of our current research projects.

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