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OBSERVED BENEFITS FROM PRODUCT CONFIGURATION SYSTEMS

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Abstract
This article presents a study of the benefits obtained from applying product configuration systems based on a case study in four industry companies. The impacts are described according to main objectives in literature for implementing product configuration systems: lead time in the specification processes, on-time delivery of the specifications, resource consumption for making specifications, quality of specifications, optimization of products and services, and other observations.

The purpose of the study is partly to identify specific impacts observed from implementing product configuration systems in industry companies and partly to assess if the objectives suggested are appropriate for describing the impact of product configuration systems and identifying other possible objectives. The empirical study of the companies also gives an indication of more overall performance indicators being affected by the use of product configuration systems e.g. increased sales, decrease in the number of SKU's, improved ability to introduce new products, and cost reductions.

Significance
Product configuration systems are increasingly used in industrial companies as a means for efficient design of customer tailored products. There are examples of companies who have gained significant benefits from applying product configuration systems. However companies considering use product configuration systems have a challenge in assessing the potential benefits to reach from applying product configuration systems. This article provides a list of potential benefits based on a case study of four industry companies.

Keywords
Mass Customization, product configuration, engineering processes, performance measurement, complexity management.

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1. INTRODUCTION

Customers worldwide require personalised products. One way of obtaining this is to customise the products by use of product configuration systems (Tseng and Piller, 2003), (Forza and Salvador, 2007),(Hvam et al 2008). Product configuration systems are increasingly used as a means for efficient design of customer tailored products, and this has led to significant benefits for industry companies. However, the specific benefits gained from product configuration are difficult to measure. This article discusses how to assess the benefits from the use of product configuration based on a suggested set of measurements and an empirical study of four industry companies.

Several companies have acknowledged the opportunity to apply product configuration systems to support the activities of the product configuration process (see for example www.configurator-database.com). Companies like Dell Computer and American Power Conversion (APC) rely heavily on the performance of their configuration systems, as a configuration of their complex product portfolio would not be feasible if the product configuration processes should be carried out manually (Tiihonen et al., 1996).

A product configuration system generates specifications as e.g. quotations, bills of materials, lists of operations, user manuals, drawings etc. (Hvam, 2001), (Hvam and Ladeby, 2007) A specification is a concept which we all know from everyday life. A specification can be defined as a description which can unambiguously transfer needs or intentions from one group of people to another. Examples of specifications include baking recipes, assembly instructions for an item of furniture from IKEA, or directions for driving somewhere.

In industrial companies where many people are involved in developing, marketing, selling, producing and servicing products, specifications make up an important part of daily life. Descriptions of customer requirements, product drawings, lists of parts, assembly instructions and service manuals are examples of specifications in industrial companies.

When making an offer or executing an order, there are a series of specifications which specify the product and how the product is to be produced, assembled, transported, used, serviced and recycled/scrapped. In the case of a mass-produced product, it is possible to work out all the specifications in connection with development of the product, and subsequently these specifications can be used every time a new product is produced.

If, on the other hand, customer tailored products are manufactured, it will be necessary to work out some of the specifications every time an offer has to be worked out or an order is received for a customized product. The term specification processes denotes the business processes which analyse the customer's needs, create a product which is adapted to the individual customer, and specify the activities which have to be performed in connection with, for example, purchasing, production, assembly, delivery and servicing of the product concerned (i.e. the product's life cycle properties).

A product configuration system is capable of supporting the activities of specifying products and their life cycle properties in the specification processes (Mortensen et al, 2010), (Mortensen et al, 2011), (Hvam et al 2012). The activities in the specification processes include an analysis of the customer's needs, design and specification of a product variant which full-fill the customer's needs and specification of e.g. the product's manufacturing, transportation, erection on site and service (specification of the product's life cycle properties). The activities in the specification processes are characterized by having a relatively well-defined space of (maybe complex) solutions as a contrast to product development, which is a more creative process (Schwarze, 1996), (Hvam & Have, 1998).

The concepts specification and specification processes are introduced as a consequence of the significance of having complete and error free specifications in the subsequent business processes in e.g. manufacturing, assembly, transportation, installation and after sales service (Guess 2002), (Nielsen, 2007), (Forza and Salvador, 2007). Furthermore operations management literature only has little focus on specifications and specification processes.

Typical goals for the specification processes are the ability to find an optimal solution according to the customer's needs, high quality of the specifications (complete and correct specifications), short lead time and a high productivity in the specification processes.

This article focuses on the possibilities offered by product configuration systems (Hvam, 1998), (Haug, 2010) as to the support of the specification processes and on how to assess the benefits to obtain from applying product configuration systems in the specification processes. In Section 3 suggested groups of targets for applying product configuration are listed. The targets focus specifically on benefits derived from the product configuration systems in the specification processes. Based on the empirical study, the targets will be evaluated and possible more overall targets observed covering other functions of the company or the total company will be discussed.

2 LITERATURE STUDY

Most configuration literature focuses on technical solutions, methods and techniques, while only a minor part of this literature focuses on empirical studies of the benefits from applying product configuration systems. In the following, some of the literature with an empirical perspective is presented.

(Barker and O'Conner 1989) describe the case of Digital Equipment Corporation (DEC). DEC uses configurators for validation of the technical correctness of customer orders and for guiding the actual assembly of these orders. They state "overall the net return to Digital is estimated to be in excess of $40 million per year", and that the configurators are "contributing to customer satisfaction, lower costs, and higher productivity"; "insures that complete, consistently configured systems are shipped to the customer"; "simplifies field and manufacturing training needs and avoids confusion about new products which can delay time-to-market significantly"; "increases manufacturing's flexibility"; "increased the technical accuracy of orders entering manufacturing"; "assures that when the components of the order come together for the first time at the customer site the system will work"; and "major positive impact on cycle times, inventory levels, and manufacturing costs".

(Ariano and Dagnino 1996) describe the case of a manufacturer of modular wooden office furniture who applies a configurator for the creation of bills of materials. They claim that the benefits achieved from the configurator are many: "a new and more organized way of structuring the company's product line"; "allows for a more consistent, faster, easier, and more comprehensive way to enter an order"; "while the order is entered, the system verifies that the configuration of the products is correct and compatible with the company's offerings"; "helps in quoting an accurate pricing to the company's products"; and "implies a reduction in the duplication of information, pricing deviations, and configuration inconsistencies".

(Fleischanderl et al. 1998) describe the use of a configurator for configuring large telecommunication systems. They claim that the configurator: has "improved the quality of the configuration results"; helps "avoiding error-prone manual editing of parameters"; has "revealed numerous errors, such as cables having wrong length codes"; and "makes the knowledge about the EWSD [telecommunication systems] configuration explicit".

(Forza and Salvador 2002a) describe the case of a small company producing voltage transformers. They mention the effects of the use of a configurator: a "reduction to almost zero of the errors in the configurations released by the sales office"; "reducing the total time necessary for generating the tender"; made it "possible to recover a notable volume of man-hours, which freed part of the sales personnel for tasks with greater additional value"; "made it possible to increase technical productivity, both as regards product documentation release and design activities"; an "increase in technical department productivity"; a "formalisation of the company knowledge"; and enabling "the transformation of individual competencies into organisational competencies".

(Forza and Salvador 2002b) describe a project of implementing product configuration software into a small manufacturing company producing mould-bases for plastics moulding and punching-bases for metal sheet punching. They claim that two main kinds of advantages have been achieved: (1) "reduction of manned activities in the tendering process (tendering lead-time from 5–6 to 1 day)"; and (2) "increase in the level of correctness of product information (almost 100%)". They argue that the case study shows that the company obtained: a rapid payback of the investment in configuration technology; a competitive advantage; and better inter-firm co-ordination.

Based on studies of twelve Danish firms that were using product configurators, (Pedersen and Edwards 2004) present the results of the twelve companies' answers to the question of which beneficial effects their configurator projects have realized. In the study, the firms were to estimate effects by giving scores from 1 to 5, where 1 equals "very small", and 5 equals "very large", while 0 equals "without influence". The three top scorers are: improved quality (avg. ~ 4.4); lower turnaround time (avg. ~ 3.6); and less use of resources (avg. ~ 3.3).

(Forza et al. 2006) describe the case of a company that produces electric motors. They state that the configurator: "enhances product assortment communication"; "makes it easier and faster to explore the solution space offered by the company"; "enables a faster, accurate generation of a feasible offer without consulting the technical office"; "enables a faster, accurate creation of product code, BOM, and production cycle"; "allows storage of a large amount of customer data collected during the exploration and configuration phases"; and "allows rapid retrieval of past configurations for maintenance or repair purposes".

(Petersen et al. 2007) describe the case of Aalborg Industries, who makes steam and heat generating equipment for maritime and industrial applications. (Petersen at al. 2007) state that because of the (sales) configurator the company is: "gaining significant benefits, and has learned much about the challenges of implementing product configuration in ETO".

(Hong et al. 2008) describe the case of Gienow Windows and Doors, where a configurator is used for: modelling the designs based on customer needs; creating requirements of materials, machines, and personnel; and identifying the optimal production schedule. They claim that "the lead time from a customer order to the product delivery has been reduced to 3 weeks compared to the average of 2 months in this industry".

(Ladeby 2009) and (Hvam and Ladeby, 2007) describes the configurator project at NNE Pharmaplan, who uses a configurator for 3D visualisation system of plant layouts. It is stated that a main benefit of the system is that "a customer does not have to wait for weeks before he sees drawings and illustrations of what has been agreed upon".

(Ladeby 2009) describes the configurator project of GEA Niro, who designs and supplies spray drying plants. The configurator of GEA Niro focuses on the quotation phase, and it is used in about 50 percent of the first quotations sent out to customers. He states that: "the process of making quotations has become more standardised end formalised"; "product knowledge has become more standardised"; the sales person "gets the whole quotation served on a plate and sends it to the customer"; and "preservation of knowledge has been a motivation for the configurator project".

3 HYPOTHESIS

The literature refers to numerous examples and a few surveys (Haug, 2011) on the impact of applying product configuration systems. However, the benefits are described in many different ways, and it is often uncertain whether the benefits claimed have been obtained from the product configuration system or from other initiatives in the company (Haug, 2012). In order to make a more specific assessment of benefits obtained a list of suggested benefits from applying product configuration in the specification processes has been made. The suggested measurements include:

- Lead time in the specification processes
- On-time delivery of the specifications
- Ressource consumption for making specifications
- Quality of specifications
- Optimization of products and services in the specification processes

Lead time refers to the interval of time from when a specification process is initiated until a finished specification is available. An example is the number of days from when a customer makes an enquiry until the customer receives an offer.

On-time delivery for specifications is defined as the number of specifications out of the total number of specifications which are completed within the agreed time span. On-time delivery is normally specified as the percentage of the total specifications which are completed at the agreed time. An example is when working out offers, where the company has promised the customers that they can always expect to receive an offer within at most 3 working days. A sample of 100 random offers shows that 45 of them are delivered within 3 working days, while 55 are delivered after 4 working days or later. In this case, the percentage of on-time delivery for offers is 45%.

Resource consumption for making specifications. The frequency of the individual specification activities, combined with the duration (use of man-hours) of the individual specification activities, reflects where the largest use of resources in the specification task lies, and where uniform tasks are executed with high frequency.
In order to be able to reveal the use of resources and find uniform tasks that are performed with high frequency, an analysis can be made of the activities performed in the specification process. The analysis can be carried out as a frequency study to find out how much of employees' time is spent on given tasks – defined in terms of the specification result or the specification method (activity).

Quality of specifications can be defined in several ways. One aspect is understandability/readability of the specifications, for example whether or not a customer understands the central elements in an offer he has received, or whether or not the production engineer understands the design drawings on which he is to base production. The basic question here is if the specification in question is able to pass on to the receiver an unambiguous and complete description, for example of the product's design. This aspect of a specification's quality is obviously difficult to measure, both because it can be a question of subjective evaluation on the part of the receiver, and because receivers of the specification can have different backgrounds for interpreting a specification.

Another aspect of quality is the number of errors. Errors in specifications can be defined as the proportion of the specifications containing errors. Here, errors are defined as those errors that, if they are not discovered, will lead for example to manufacture of a faulty product – so such errors as insignificant typos are not to be counted. An example is the number of lists of parts with errors, compared to the total number of lists of parts produced. Another example is the number of offers in which the pre-calculated cost price differs by more than 5% from the cost price arrived at by post-calculation.

Optimization of products and services in the specification processes. Using a configuration system makes it possible to optimize products in relation to the customer's requirements, or for example in relation to production costs or maintenance/service.

The suggested targets and how to exactly measure each of the targets are further elaborated in (Hvam et al 2008). The impact from product configuration has been studied in four different companies based on the suggested measurements. Besides these targets for the specifications processes other targets measuring the more overall impact from product configuration would be relevant to include (Hvam, 2006). Based on the literature and observations made from the case study, possible candidates for measuring the overall impact of product configuration systems will be identified and discussed.

4 INDUSTRY APPLICATIONS

4.1 Impacts from product configuration

In the following we shall give a brief introduction to the 4 industry companies of this case study, of their configuration projects and discuss the impacts observed.

4.1.1 Company A

Company A is an engineering and industrial company with an international market leading position within the area of development and manufacturing of cement plants. The company has a turnover around 1 billion USD.

A modern cement plant typically produces 2-10,000 tonnes of clinkers per day (TPD), and the sales price for a 4,000 TPD plant is approx. 100 million USD[1]. Every complete cement plant is customized to suit the local raw material and climatic conditions, and the lead-time from signing the contract to start-up is around 2½ years.

The company has implemented and used a configuration system since 2000 to support the quotation process. The first version of the configuration system was implemented on a budget at approx. 1 mio. USD. Today the company has a configuration team with 8-9 employees responsible for implementation and running of 10-12 configuration systems used in sales and engineering. The quotation process is carried out in two steps. The first step is a so-called budget quotation, including an overall dimensioning of the cement factory, a process diagram and a price estimate. The next step is a so-called detailed quotation, including a detailed description of the processes and machines in the cement factory. The configuration project focused on the budget quotation because the budget quote included fewer details, and because all significant decisions as to the cement factory's capacity, emissions, total project costs etc. are made during the budget quotation. The process analysis revealed that the process of making budget quotations was very resource consuming, with a long lead time and leading to quotations of varying quality. A gap analysis indicated that the lead time for making budget quotations could be reduced from 3-5 weeks to 1-2 days, the resources spent could be reduced from 15-25 man-days to 1-2 man-days and, finally, by using a product configuration system it would be possible to optimize the cement factory with respect to e.g. capacity, emissions, price and the use of previously designed machines. The impacts observed are outlined in the table below:

Lead time	Lead time for making quotations reduced from 3-5 weeks to 1-2 days.
On-time delivery	Now 95-100 % of quotations are delivered on time. Before, only 50 % of the requests were even responded to by a quotation, now 100 % gets a quotation.
Resource consumption	Resources for making quotations reduced with 50 %.
Quality of specifications	The quotations become more uniform and of better quality. More accurate calculation of sales prices.
Optimization of products/ and services	Possible to simulate different solutions to the customer. More structured negotiations with the customers. Possible to optimize the plant with respect to increased use of previously engineered and produced equipment.
Other observations	The configuration system ensures that the sales man obtains all necessary information before the quotation is made. This leads to an improved quality of the quotations and the subsequent engineering process. Application of the product configuration system has led to an increase in the sales of more standardized machines, which leads to significant savings in the engineering, production and erection on site

Table 1. Observed impacts from product configuration in company A

The suggested metrics give an unambiguous measurement of the benefits realized in the specification processes. Lead time, on-time delivery and resource consumption were possible to measure exactly. The quality issue was assessed by comparing the content of the quotations generated from the configuration systems with quotations made outside the configuration system.

The suggested measurements focus on the quotation process. However, the company claims that other benefits, which are more significant than the improvements in the quotation process, have been obtained. These benefits include an increase in sales as all requests are now being responded to with a quotation and a reduction of costs in engineering, production and erection on site due to an increased sale of previously engineered and produced equipment. Even though

[1] A 4,000 tonnes per day (TPD), complete kiln line, semi turn-key, service, supervision, vehicles, training, steel plates to local manufacturer, and civil design.

these benefits have been measured, it is not possible to state how much the configuration system in itself has contributed to these benefits and how much come from other initiatives, such as product redesign, reengineering of business processes or improvement/ implementation of other IT-systems.

4.1.2 Company B

Company B is an international engineering company with a market leading position within the area of design and supply of spray drying plants. The company is creating approx. 340 mio. USD in turnover a year. The products are characterized as highly individualized for each project.

The configuration system was implemented in company B in 2004 and it is in many ways similar to the configuration system of company A. Today, the company has a configuration team with 10-12 employees running the configuration system and doing external configuration projects for other companies in the industry group. The configuration system is used in the quotation process. The aim of introducing a product configuration system is to reduce lead times and resources spent on making quotations, optimization of the spray drying plants and the formalisation of product knowledge, in order to make it accessible to relevant persons in the organisation. The impacts observed are outlined in table 2 below.

Lead time	Lead time for making quotations reduced from 3-5 days to 2 hours.
On-time delivery	Between 95 and 100 % after implementing the configuration system.
Resource consumption	Resources used for quotations reduced from 20 to 2 hours per quotation
Quality of specifications	The quotations become more uniform and of better quality. More accurate calculation of sales and cost prices.
Optimization of products/ and services	Mass flow diagrams and process simulation is integrated with the configuration system, which makes it possible to optimize the performance of the plant and single machines.
Other observations	The modelling of the products for the configuration system has led to an increased formalization of engineering knowledge. Increased sales due to a more efficient quotation process. Shorter total lead time. More standardized products in the projects leading to reduction of project costs.

Table 2. Observed impacts from product configuration in company B

Application of the product configuration system has lead to a reduction of lead times and resources spent in the quotation process. On-time delivery and quality of the quotations have been improved as well. It has been possible to measure those benefits, and it is clear that these benefits come from the application of the product configuration system. As with company A, other and more overall benefits have been observed like reduction of costs in engineering, production and installation due to sales of more standardized products. However, it is not possible to define how much the configuration system has contributed to these benefits.

4.1.3 Company C

Company C produces data centre infrastructure such as uninterruptible power supplies, battery racks, power distribution units, racks, cooling equipment, accessories etc. The total turnover is approx. 4 billion USD (2008). Company C has implemented and used product configuration systems since 2000. Today, Company C has 8-9 product configuration systems. The company has formed a configuration team with approx. 25 employees. The configuration team is responsible for development and maintenance of the product configuration systems, which are used worldwide.
The product configuration systems are an integrated part of the company's business setup. The products are sold through the product configuration systems, which makes it possible for the company to control a huge amount of sales personnel and agents around the world. The product configuration, which includes working out quotations and manufacturing specifications, is carried out by the configuration system, thereby saving considerably resources. The lead time for making quotations and manufacturing specifications is reduced significantly. And finally, the product configuration systems make it easier to introduce new versions of the products to the sales personnel and the customers.

Lead time	Lead time for making quotations and Bills of Material (BOM's) and routes reduced from 3-5 days to less than 1 hour.
On-time delivery	100 % for quotations and BOM's and routes generated by the configuration system.
Resource consumption	Resources used for making quotations and manufacturing (BOM's and routes) reduced to less than 10 % of previously used.
Quality of specifications	Specifications coming from the configuration system have significant fewer errors than "handmade" specifications, leading to fewer costs in production and installation.
Optimization of products/ and services	The use of the configuration system has made it possible to keep down the number of items maintained in the company's ERP-system. The company has estimated that the cost of an item number is approx. 10,000 USD in its life time
Other observations	The company is heavily focusing on keeping down complexity costs and sees the use of product configuration systems as part of an overall business strategy also including market focus and product modularization. Total lead time from sales to delivery and installation is reduced from 400 days to 16 days. Increased ability to introduce new products via the configuration systems.

Table 3. Observed impacts from product configuration in company C

Company C has realized significant improvements of the sales and ordering processes from applying the product configuration system. As with Company A and B, it has been possible to measure or at least assess those benefits, and it is clear that those benefits come from the product configuration system, as the configuration systems now generate the specifications. In company C, the use of product configuration systems is a part of an overall business model also including a modularized product assortment, a focused market strategy and a supply chain based on mass production of standard modules and assembly of customer tailored products. The total business set-up has led to significant improvements of productivity, quality and delivery times. In this context the configuration system is a necessary part in order to achieve the total benefits.

4.1.4 Company D

Company D is making electronic switchboards. It has more than 100 employees and a turnover of approx. 15 million Euros. The analysis of the current specification process for making quotations and BOM's revealed that the lead-time for generating quotations and BOM's was 3 to 5 days, and the company uses 2 to 4 man-hours for each quotation. The process leads to frequent errors, and often the time necessary for the optimization of the boards cannot be found.

Lead time	Lead time for making quotations and BOM's reduced from 3-5 days to 10 minutes.
On-time delivery	On-time delivery for quotations and BOM's generated from the configuration system 100 %.
Resource consumption	Resources used for making quotations and manufacturing BOM's reduced from 2-4 hours to 10 minutes. The resources are reduced to zero in the cases, where the customers use the configuration system directly.
Quality of specifications	Significant reduction of errors in quotations and BOM's by using the configuration system.
Optimization of products/ and services	The configuration system makes it possible to optimize the products with respect to heat loss, component fabricates and vacant space.
Other observationsre	The modelling of the switch boards for the configuration system gave rise to an evaluation of the components used when designing the switch boards to the customers. This has led to an optimization of components used with respect to number of items, costs and performance. More error-free specifications in manufacturing led to improved productivity.

Table 4. Observed impacts from product configuration in company D

By implementing a product configuration system the company gets a much more structured flow in the specification process, where the company's knowledge regarding construction of an electronic switch board is made available to the customers, and complex calculations can be made very quickly. The desired effects for the company of the application of a product configuration system are identified as:

A significant reduction of lead time for making quotations and BOM's from 3-5 days to 10 minutes.

A total elimination of resources spent for making quotations and BOM's, as the customers can now configure an electronic switchboard on their own by using the product configuration software available on the company's homepage.

The opportunity of optimizing the electronic switch boards with respect to e.g. heat loss and price.

In company D the effects on the sales and ordering processes of applying product configuration could be measured unambiguously, except from the quality and optimization, where the improvements were assessed based on a study of the specifications generated before and after using the configuration system. Being a small company, those effects have a significant impact on the company's total performance. Modelling the products for the configuration system gave rise to improvements of the products. More error-free specifications have contributed to improved productivity in manufacturing.

5 CONCLUSION

The study of the four cases has shown that the application of product configuration systems may lead to significant benefits. The suggested measurements focusing on the specification processes have been tested. The case study shows that it is possible to measure some of those indicators and also that those improvements can be linked to the application of product configuration systems. In the four cases studied the lead time has been reduced significantly (94-99 % reduction). On-time delivery for the specifications has been improved, and is now between 95-100 %. Resources used for making the specifications have been reduced with 50 to 95 %.

The companies in the case study claim that the quality of the specifications have improved significantly and the product configuration systems have made it possible to optimize the products with respect to cost and performance. However, further work is needed in order to clarify in more detail how quality and optimization of products and services can be measured.

Besides the specific measurements on the specification processes, the study of the four companies has made it clear that other and even more significant benefits have been achieved from applying product configuration systems. These benefits include:

- Increased sales
- Reduced total lead time for delivery of products, partly due to more correct and timely specifications.
- Improved total on time delivery, partly due to more correct and timely specifications.
- Reduction of costs in e.g. production due to sales of more standardized products and more error free specifications
- Reduction of e.g. engineering costs caused by a collection of all needed information via the configuration system
- Formalization of engineering knowledge
- Reduction of item numbers

Further work is needed in order to clarify how these benefits can be measured in more detail, and how the relative contribution from the configuration system to those overall benefits may be documented. This also includes an investigation of how the product configuration system is seen as a part of an overall business strategy, thus being a needed brick in the puzzle in order for the company to realise its business strategy.

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