INTERNATIONAL DESIGN CONFERENCE - DESIGN 2004
Dubrovnik, May 18 - 21, 2004.

DESIGN 2004

EXPECTED AND REALIZED COSTS AND BENEFITS WHEN IMPLEMENTING PRODUCT CONFIGURATION SYSTEMS

K. Edwards and J. Riis

Keywords: product configuration systems, costs, benefits and bconomics

1. Introduction

Mass customization has indeed become an important issue for many firms. Customers have become accustomed to the price of mass produced goods and are beginning to demand that products are customized to their personal needs while retaining the price associated with mass production. In Denmark firms are also being pressured to deliver mass customization, although Danish firms are characterised by an overweight of small to mid-sized companies, which traditionally have excelled in small batches and one of a kind production. However, like the rest of Europe Danish firms must follow suit, cut costs, and deliver the desired products, in which case mass customization becomes a critical issue.

A means for firms to achieve mass customization is product configuration systems. A product configuration system consists of a computer model of a product, which contains information about the relationship between the individual components of the product and any noteworthy restrictions, which one component imposes on another. For instance, a product model of a bicycle would have information regarding the frame, wheel, tube, tires, saddle, color, style of the different components etc. Restrictions in the model define what size of wheel fits with a given frame – no use in mounting a 26" wheel on a 12" frame.

The idea of mass customization is little over 25 years old, beginning with Davis (1987), and it has been researched extensively since, see Silveira et al. (2000) for a literature review.
However, it is only in recent years that off-the-shelf software becomes available, and many ERP systems now integrate configuration as a separate module in the system. So, apparently things should be dandy, and firms should just go ahead and achieve mass customization with the available technology. The reality of the matter is that there are significant costs associated with achieving the potential benefits of a fully integrated product configuration system, and this is the theme of this paper.

The objective of this paper is to report results from a study of twelve Danish firms, which have implemented or are currently in the process of implementing product configuration systems. This research project was initiated February 1st 2003 and will be terminated ultimo December 2004.
In the following paragraphs we shall, more detailed, explain what a product configuration system is and place it in a mass customization context. This is followed by a section briefly describing the project, study and methodology, which is again followed by a description of the involved firms and the results, and lastly we offer a discussion and conclusion.

2. Product Configuration Systems

In order to appreciate product configuration systems they must be placed within a context of mass customization. In this paper mass customization is defined by two dimensions: 1) The basic nature of customization, and 2) The means for achieving customization at or near mass production costs (Duray et al. 2000, p.607). The basic nature of customization refers to the observation (op. cit.) that variety in itself does not constitute customization. The customer must be involved in specification of the product. The means for achieving mass customization at or near mass production costs are essentially economics of scale as a consequence of modularity of the product. By modularizing a product and reusing as many modules as possible in all product variations it is possible for these modules to be produced at or near mass production prices.

A product configuration system is basically a model of a product describing the relationship between individual parts. This makes it possible to interactively design a product by specifying which parts should be used in the final product. A product configuration system can have varying levels of detail depending on how it is to be used, and two extremes can be identified: 1) Tender configuration systems and 2) Production configuration systems. A tender configuration system is a product configuration system designed with the purpose of generating a tender. This implies that the product configuration system only needs to possess knowledge regarding larger elements, which have a significant impact on the total price. Tender configuration systems are often used in heavy engineering, where the rough price of the elements is known, whereas precise information about price of material etc. is unknown. Generating a tender in heavy engineering projects, e.g. a large production plant, is in it self very costly, and a tender configuration system can significantly lower the cost of producing a tender. One of the interviewed firms documented a reduction from 2.650 man/hrs to 130 man/hrs for making a detailed proposition (Interview with firm B, 28th Oct 2003).

In the opposite end of the spectrum we find production configuration systems, which are product configuration systems capable of generating a complete production-ready product specification. Production configuration systems are most often linked to or integrated in an ERP system offering further advantages for automating production- and materials planning. Thus, when the desired configuration has been created, the system has complete knowledge of the product to be produced. The configuration is used by the EPR system to create routing, price of material, inventory etc. Production configuration systems find use in situations, where the product can be completely configured using the product configuration system. Standard cars, bicycles etc. would be examples of products, which lend themselves to this kind of configuration. It must be stressed that we make a distinction between product, production, and tender configuration systems, where the latter two are subsets of the first.

Returning to the mass customization issue, product configuration systems are a means of achieving customization. However, product configuration systems are not per se a means for achieving customization at or near mass production costs. As Pine (1999, p196) notes: "The best method for achieving mass customization – minimising costs while maximising individual customization - is to create modular components that can be configured into a wide variety of end products and services", which is also recognised by Duray et al. (2000, p608). While it is easy to design a product configuration system around a fully modular product, it is not a necessity, and it is possible to design a product configuration system for a non-modular product. The latter product will not see the cost advantages of modularisation, and the process of creating the configuration system will also be more complex due to idiosyncrasies in the individual product variants. Naturally this is recognised by other scholars, and Riis (2003) strongly encourages the use of strict product reviews before creating a product configuration system.

3. Project Description and Methodology

This research was conducted in the "The Product Models, Economy, Technology, and Organisation" project (PETO), which was formed with the intention of studying the process and effects of implementing product configuration systems. Most of the literature on product configuration systems deals with technical issues, and only a few recent papers have taken economic and organizational

issues (Forza and Salvador 2000 & 2001) into consideration. It is evident from several implementation projects (Riis 2003, Hansen 2003, Hvam 1999) that there are significant costs associated with the implementation, and realizing benefits is dependant on several factors other than mere technical issues. This research tries to measure costs and benefits associated with implementing product configuration systems in a number of Danish firms.

Given the fact that no other interdisciplinary studies of product configuration systems, to our knowledge, have been conducted, a qualitative and yet hypothetically deductive approach was selected.

Based on earlier research and experience within the project group, a number of possible costs and benefits were deuced. A questionnaire was developed with the intention of capturing expectations and results from product configuration systems as well as the actual implementation process. The questionnaire was populated with questions directed at: 1) The specification process before and after implementing product configuration systems, this is the foundation for understanding the changes induced by implementing a product configuration system; 2) Technical issues of the implemented product configuration system; 3) Economic issues and 4) Organizational issues. It goes far beyond the limits of this paper to describe all questions and aspects of the questionnaire, and we shall limit ourselves to focus on the costs and benefits of product configuration systems. The questionnaire consists of 196 questions of which 47 were directed at economic issues, 33 at technical issues, 97 at organizational issues, and 19 regarded the specification process. The specification process before and after implanting product configuration systems was drawn in two different process diagrams allowing for easy comparison. The questions were designed to be both closed and open ended questions, in the latter case leading respondents to elaborate and explain certain positions (Jacobsen 1996:111-113). The open ended questions were used deliberately to allow some degree of exploration in the interview process, and respondents were allowed to pursue their line of thought before being interrupted and directed towards the question. Concluding questions were used to confirm and summarize the meaning of open ended questions.

A number of 20 firms were selected, and 14 firms agreed to participate in the study, 12 of which are represented in this paper. 2 firms are not represented, as one firm refused to participate and the other was selected because they had chosen not to implement product configuration systems.

The firms were selected from a larger pool of 43 firms with affiliation to the Association of Product Modelling[*], several of which have a yearly turnover of more than €250.000.000. The 20 firms were selected only because they had experience with product configuration systems. Some of the participating firms are just in the process of implementing and have only limited experience with systems in production use.

A number of employees from each of the selected firms were interviewed to ensure a broad understanding of the impact of the product configuration system in the respective organisations. Firms were asked to provide individuals of the following categories: 1) Sponsor, 2) Technician/programmer, 3) User, and 4) The project leader. These four roles were chosen, as they would theoretically represent all organizational levels of a product configuration project.

The interviews were intended to be conducted with a single respondent at a time, allowing for a detailed interview with personal opinion expressed. To gain a relation of trust, respondents were provided with a written and signed statement expressing that the information would remain anonymous and certainly not shared with their colleagues.

However, in some cases it was not possible to conduct individual interviews, and a group interview was the only option for having the particular firm participate in the study. It must be expected that these interviews to some degree fail to uncover problems with the product configuration system and the implementation process. Group interviews have a tendency of expressing consensus among the respondents. Measuring costs and benefits, which is the focus of this paper, was done using what we refer to as radar diagrams, which are explained in detail in the following section.

In all interviews multiple investigators (Eisenhardt 1989:538) were used to ensure complementary opinions and insights and to enhance confidence in the findings. During all interviews two

[*] A Danish association ”Foreningen for Produktmodellering”, www.produktmodeller.dk

investigators were present, and on some occasions even three and four investigators found their time to participate in the interviews. The combination of multiple investigators and open ended questions is very powerful, if investigators deliberately keep silent to pressure respondents into answering. On many occasions this was the deciding factor for getting a meaningful answer.
The interviews were taped and subsequently transcribed, which was followed by a condensing procedure for extracting the meaning of the interviews (Kvale 1994:189).

4. Radar Diagrams

Costs and benefits from implementing product configuration were uncovered in two stages: 1) The questionnaire and 2) Radar diagrams. A radar diagram is an intuitive graphical representation of a number of variables. Two Radar diagrams were used to explicitly gain information about costs and benefits from implementing a product configuration system, see Figure 1 for an example of the radar diagram for measuring benefits. The radar diagrams constitute a hypothesis regarding what could be considered costs and benefits from implementing product configuration systems (explained in the following section).
In the actual interview respondents were first shown the radar diagram for benefits, and upon completion the radar diagram for cost were shown.
For benefits, respondents were explained the meaning of the individual elements and how to rate them. Respondents were asked to give points for both expected and realized costs and benefits. Respondents were told to rate the most important realized or expected benefit with the highest score of five points, and the remaining expected and realized costs should be compared to this. By doing so we are able to compare expected and realized benefits to the highest scoring element. There are some problems to this approach: Benefits whether expected or realized are intangible, and respondents only have a qualitative impression of the expected benefits e.g. the time to produce a tender is too long and must be cut down. It is known what the time is now, but unclear how much the time should be reduced. Still, this approach allows us to gain insight as to what firms expect from product configuration systems, and what they gain.

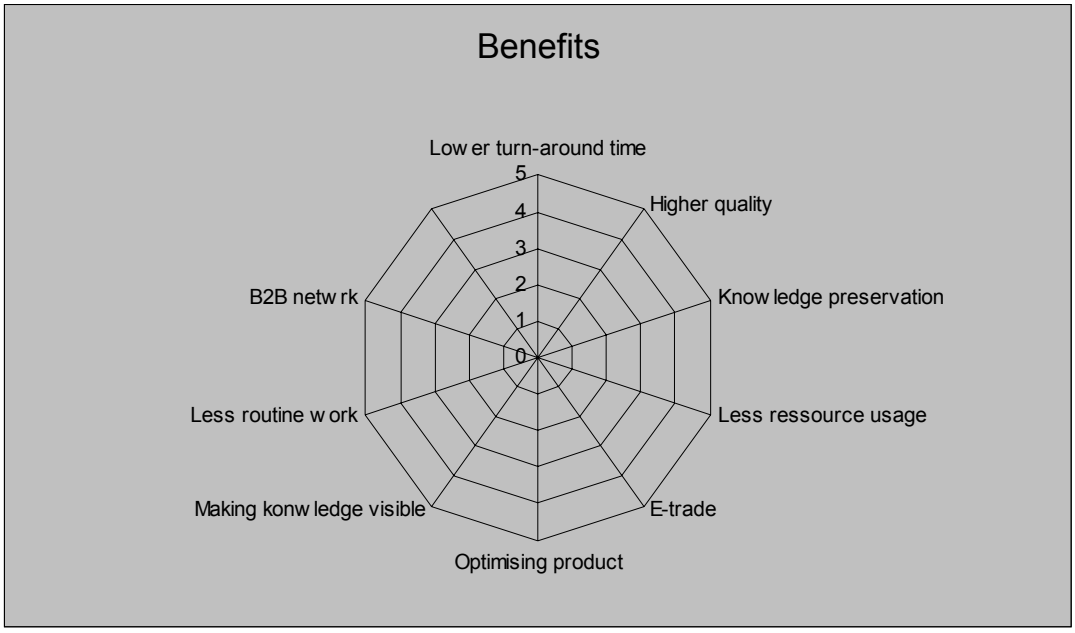

Figure 1. Radar diagram for rating benefits, one axis left open for respondents to add

Costs are more straight forward to measure, and respondents are also more aware of costs. The cost of a system is often estimated before proceeding with the project. Respondents were asked to pick the highest expected or realized cost and assign five points. Other expected or realized costs were compared to this. For instance, if a software package was the most expensive element costing 100.000 EURO, this would be given five points. Other elements would be compared to this, and if hardware

costs amounted to 60.000 EURO, it would be given three points. This approach was chosen because we did not expect companies to reveal the actual costs of their product configuration system. We did, however, expect firms to reveal the cost structure of the product configuration system using the rating system.
Investigating expected costs and benefits allowed us to gain an insight in the incentives for trying to implement a product configuration system and compare it to the realized benefits.
While the chosen companies are not easily compared, this method allows for some degree of comparability. Given the varying size and scope of the investigated product configuration systems, actual monetary costs and benefits are interesting but not comparable. We did, however, expect to observe a similar distribution of costs across companies.
When the first interviews were conducted, the list of costs and benefits were somewhat shorter and this highlights a known problem of explorative research: Is it legitimate to add items during a study? In this research we emphasize on the explorative element and find it indeed legitimate to do so. Adding items allows the investigators to explore new hypothesis and follow new lines of thinking during the study (Eisenhardt 1989:539).

4.1 Benefits

Benefits were deduced from literature (Forza and Salvador 2000 & 2001, Riis 2003, Hansen 2003, Hvam 1999) in the sense that the mentioned authors are not explicit about the benefits. However, they do describe results in more qualitative terms from implementing product configuration systems, which is what we used to deduct benefits. A list of distinct benefits were compiled of which the nine first were present in the first round of interviews: 1) Lower turn-around time, i.e. the time from order confirmation to delivery, 2) Improved quality, i.e. the quality of product specifications, 3) Preserved knowledge, i.e. knowledge is preserved in the configuration system, 4) Using less resources, i.e. fewer resources are used for specifying a product, 5) E-trade, i.e. e-trade is made possible by interfacing with the product configuration system, 6) Optimizing products, i.e. the product configuration system makes it possible to optimize with regard to price, performance, etc. , 7) Making knowledge visible, i.e. knowledge contained in the system is easily available and presented to users, 8) Less routine work, i.e. trivial tasks are performed by the system, 9) B2B networks i.e., the product configuration system allows other companies to interface directly with the product configuration system, 10) Improved certainty of delivery, i.e. detailed knowledge about specifications lead to detailed knowledge about what and when to produce, 11) Focus on standard goods, i.e. a product configuration system can only handle standard goods, in which case everything else is non-standard, and 12) Job training made easier, i.e. examples of different types of product configurations can be illustrated using the product configuration system. An unnamed variable was present in the diagram for the respondent to fill out if needed.

4.2 Costs

The literature is somewhat sparser on possible costs arising from using product configuration systems. However, Hvam (1999) and Riis (2003) present a procedure for implementing product configuration systems, which can be broken into a number of cost elements. To this list one significant cost was added: “Increased cost of innovation”, which is based on the hypothesis that some firms innovate based on interaction with customers, who sometimes require specific products not part of the standard products. Product configuration systems lock a firm into a system, where customers and employees focus much on standard goods, and there is a significant price penalty for ordering non-standard products. The consequence of this may be loss of input for further innovation. Often a firm uses non-standard orders as a basis for developing new standard products. By using a product configuration system non-standard requests are gently coerced into being standard by using limited choice and prohibitive pricing as instruments. With this cost we try to capture one long term potential negative effect of using product configuration systems. The compiled list of costs was not altered during the study and consists of the following elements: 1) Specifying the product model, i.e. the task of defining what should be part of a product model. 2) Choosing software, i.e. while off-the-shelf software is available, not all is equally suited for all tasks. 3) Coding, i.e. the task of programming the product

configuration system. 4) Integrating with existing systems, i.e. the task of integrating necessary elements of existing information systems in the product configuration system. 5) Implementation, i.e. the cost of teaching employees to use the system including related costs of bringing the system from completed development to production use. 6) Maintenance, i.e. the cost of maintaining the system. 7) Increased cost of innovation, i.e. costs associated with not getting information feedback from regular sales channels. 8) Project management, i.e. the cost of managing the project from start up to production. 9) Documentation, i.e. the cost of documenting the implemented system. 10) Consultants, i.e. the cost of using consultants. 11) Software, i.e. license costs related to a fully functioning system. 12) Hardware, i.e. costs related to server investments.

5. Data

12 firms have participated in the study with 30 interviews covering 39 individuals, resulting in more than 45 hours of taped interviews. What follows is a brief description of the participating firms, a description that is made anonymous by request of the participating firms. The firms are grouped after the company type, *before* they introduced product configuration, and the categories are: Heavy engineering, Mass producers, Batch producers, or One of a kind producers. This division is chosen, because it reflects on the production processes and the type of products produced. Heavy engineering firms have no continuous production and essentially make one of a kind, although based on proven concepts. Firms are anonymous and referred to as A, B, C… etc.

Firm A is engaged in heavy engineering producing large production plants, where orders typically ranged from 27 million to 100 million Euros. The main problem in these firms was the cost of producing a tender, which could in the worst case cost up to 4.500 engineering hours, thus putting a significant strain on the organisation. Firms A experienced total costs for developing and implementing their product configuration systems of approximately 1.6 million Euros, and the project lasted about three years. It should be noted that firm A at the time of interview was in the process of implementing a product configuration system. Firm B is also engaged in heavy engineering and experienced problems producing tenders at the rate required by the market. In year 2003 their product configuration system processed quotes for 4,4 billion Euros.

Firms C, D, E, F, G have traditionally been mass producing and have turnovers ranging from 12,5 million Euros to 600 million Euros and 166 to 3.765 employees. Quite a diverse bunch and all well positioned in their market and some market leaders.

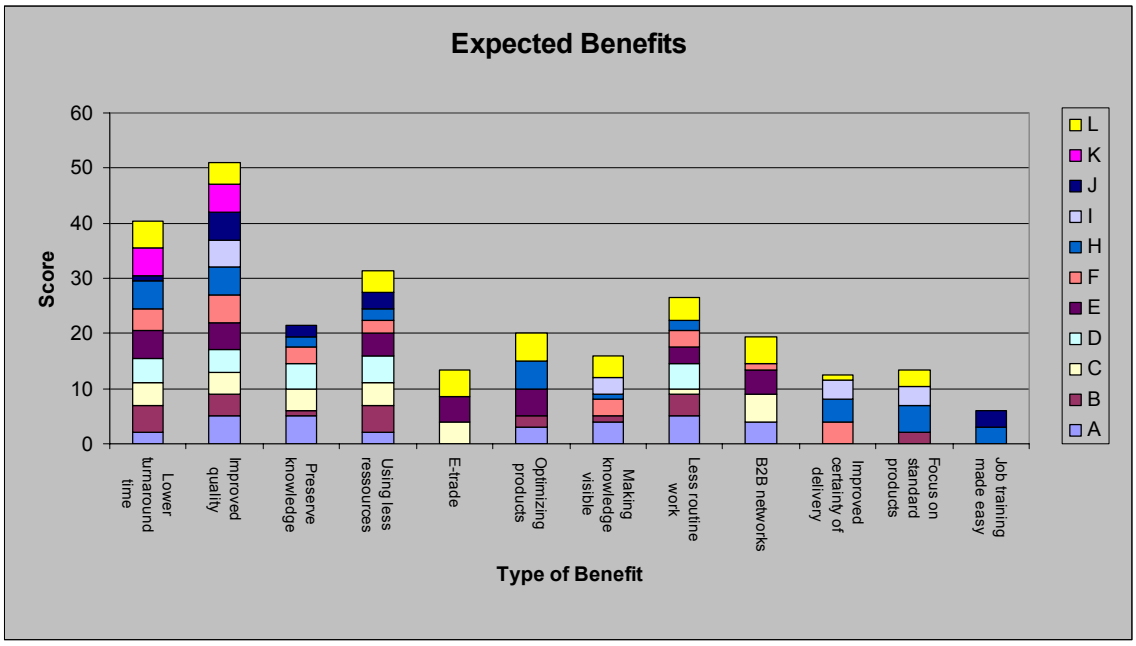

Figure 2. Expected benefits listed in aggregated stacks

Firms H, I, J are batch producing with one firm (I) sometimes modifying their product to such a degree that one of a kind production might also be a suitable description. Turnover in this group was from 550 million Euro and 801 employees to 22 million Euro and 166 employees.

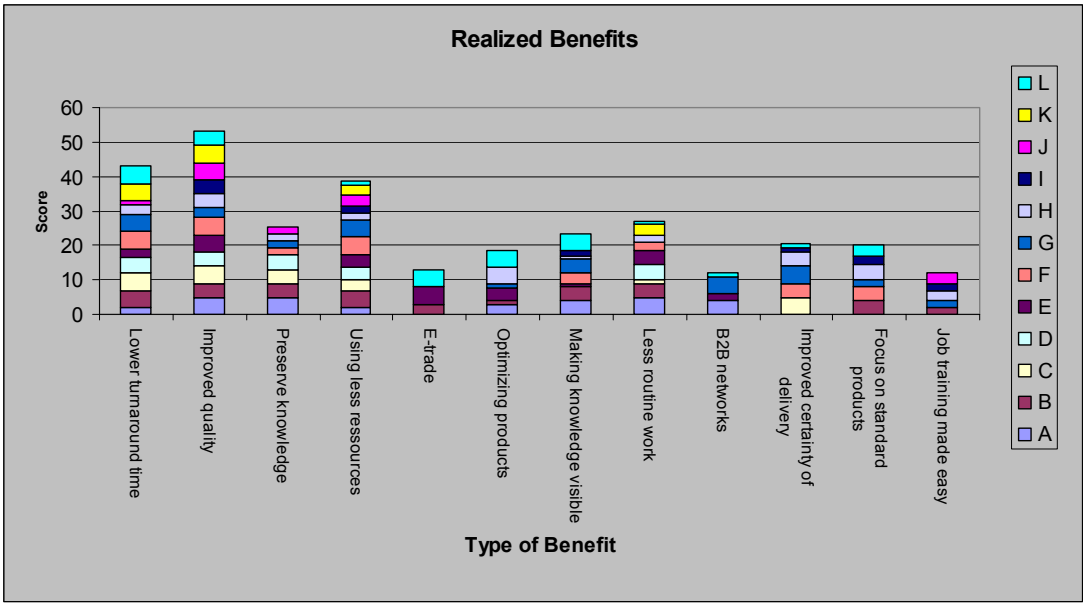

Figure 3. Realized benefits listed in aggregated stacks

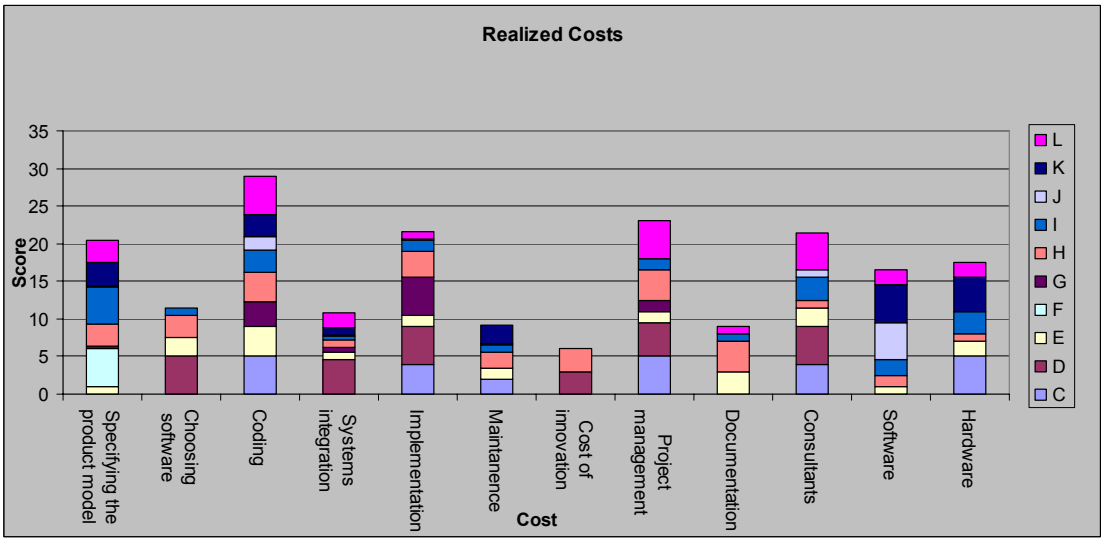

Figure 4. Realized costs listed in aggregared stacks

Firm G was the only firm where the listed expected benefits did not match at all. Firm G implemented product configuration with the sole intent of improving inter-company sale, and their second cited reason was to gain complete insight in their production plants across Europe. Firm G had observed that in some cases a customer demands a product which could not be produced in the local company, in which case a sister company in another country was approached by the local company. As the inter-firm profit is lower than regular sales, such requests were frequently delayed to the point, where the customer took his order and placed it elsewhere. The solution was a product configuration system to be use in all sister firms across Europe. The system provides a configuration system which is not tied to the local production system, and a sales person in Austria may configure and allocate production

resource in Denmark. This benefit was not observed in other firms and not added to the list of items in the belief that this is a special case.

6. Analysis and Results

In this section we analyse firstly the correlation between expected and realized benefits and secondly the correlation between expected and realized costs. Costs and benefits are listed in the same order as shown in Figure 2 and Figure 3. A ranking of benefits can not be made, as the total aggregated score of benefits provide little insight into the effect of a product configuration system, as one firm might have had expectations and another accidentally realized the benefit. As we are interested in the effects of product configuration systems, it is the correlation between expected and realized costs within the individual firms that will be analysed. The collected data was gathered using a qualitative approach as explained in section 3 and represent the respondents' interpretation of expected and realized costs and benefits in the interview situation. For this reason it makes little sense to use and present a rigid statistical analysis, which would only dilute the reader as to the confidence that one might place in the data. The raw data can be found in appendix.

6.1 Benefits

12 firms have participated all of which have answered the radar diagrams for both expected and realized benefits. The benefits are grouped in three categories: High importance representing four or five points, medium representing two and three points and low representing zero or one point. Firms that awarded high importance to a benefit had the feeling that this was an incentive for implementing PCS and important for the success. Medium importance was given to benefits that were reported to be interesting but not critical and not used as a core argument for implementing PCS. Benefits who received low importance were unimportant to the project and were never mentioned as an incentive but none the less nice, if realized.

Firm G holds a special position in this analysis, as driving incentive for implementing PCS was to improve inter-company coordination.

Lower turnaround time was an important expected benefit to 8 of 12 firms, medium important to two firms and unimportant to two firms. All of the firms, which found this benefit important, experienced that customers were lost because of the turnaround time for producing a tender. The two firms I and J that found this unimportant had particular reasons for this. Firm I had just implemented a new ERP system which also focused on reducing turnaround time. Firm J had a specific problem with the quality of their product specifications, but the time to produce the specifications was not a problem. Only two firms, E and H did have their expectations met.

Improved quality was an important expected benefit to all but one firm (firm G). The importance of improved quality is explained by the consequences of poor product specification quality. Product specifications that are not correct and require correction will be increasingly costly to fix, as the product passes through the production process. In for instance, firm F reported that incorrect product specifications could lead to a complete production halt on night shifts, when key staff (engineers) was off duty. Implementing a production configuration system, in this case, raised the rate of correct specifications from 60 % to 100 %, and no production stops had been reported since. All but two firms achieved their expectations, and the two was just marginally below (one point).

Preserve knowledge was an important expected benefit to three firms (A, C and D) and of medium importance to 3 firms and unimportant to 7 firms. Interestingly enough firms A, C, and D did so for different reasons. Firm A needed to preserve knowledge because of a generation gap in the organisation and foresaw the upcoming pension of a major part of their key engineers. This potential problem had to be countered by using an information system coupled to the configuration system. Firm C needed to allow sales staff to easily access knowledge of the different product variants. Firm D sells high quality, expensive durable goods, which are linked together to form a system, and customers over time may buy additional products and link into the system. Firm D uses the product configuration system to keep track of valid old configurations allowing sales staff to quickly answer questions about integrating a new product into an existing system of older products. As new products offer new and

improved features sales staff must precisely be able to identify what features integrate seamlessly and what not thus allowing customers to make an informed decision. All but one firm had their expectations met.

Using less resources was an important expected benefit to 4 firms, of medium importance to 4 firms and unimportant to the last four firms. The firms, which found this important, were experiencing that producing a tender was a significant cost driver and had to be reduced. In particular firms B and L experienced that the tender/order ratio had been declining over that past 15 years, and this was becoming a problem. Using less resource was found to be linked to turnaround time in the sense that if less resource (different staff) were involved, the turnaround time would drop, simply because of the reduction in the number of times a tender would have to wait for staff.

E-trade was an important expected benefit to 3 firms (C, E and L) and unimportant to the remaining 9 firms. Firm C expected to make their configuration system available on the internet but decided later against it and thus did not achieve their expectations at all. Firm E achieved their goal and felt this was important due to their sales organisation. Firm E had an autonomous sales organisation dispersed with offices in many countries over the world which had their own IT systems for configuring and ordering. The configuration system was to bypass some of the local IT systems and allow for a common interface to configuration and also allowing the firm E to control the sales process. Firm L from the beginning envisioned their production configuration system to be available on the internet and hoped to reduce load on sales staff by allowing customers to configure and order the products without intervention by sales staff. All of the other firms did not want to allow customers to access their product configuration system and used it as an internal tool. Firm H based their business on e-trade but had already this capability and therefore rated it as unimportant in relation to their product configuration system.

Optimizing products was an important expected benefit to three firms (E, H and L), 2 firms found it to be of medium importance, and the remaining 7 said it was unimportant. Firms E and L have their configuration systems available on the internet, and therefore it is important that customers can use the configuration system as a means of optimizing their product choice. Firm H makes their product configuration system available to their sales offices, and it is important to use the product configuration system to guide the sales staff to the right product for the particular situation.

Making knowledge visible was an important expected benefit to 2 firms (A and L), 2 firms found this to be of medium importance, and the remaining 8 found it unimportant. Firm A was the heavy engineering firm focused on preserving knowledge. However, preservation was not enough and their knowledge should be easily available to all employees. To leverage this, their product structure was organised on Lotus notes allowing employees to view a particular product, identify parts and their relation to other parts as well as key staff with knowledge about the particular part. Firm L produces a complex product with many rules for its composition, and these rules has been integrated in the product model. Customers and staff should be able to access these rules when configuring a product who's' configuration conflicted with one or more rules and offer a reason and a possible solution. Both had their expectations met.

Less routine work was an important expected benefit to 4 firms (A, B, D, and L), 3 firms found this to be of medium importance, and the remaining 5 found it unimportant. The four firms which found this important experienced a large amount of repetitive work in the process of producing a tender. Firms A, B, and D achieved the expected benefit, but not firm L. While the product configuration system is functional in firm L and is used by customers, the sales staff has not experienced the hoped reduction in routine work. This is mainly because the sales staff does not use the product configuration system and remain working in their old ERP system. Two factors seem to be causing this: 1) A large part of the routine work is processing urgent tenders. A customer calls and asks to have a product delivered within three days, and since there is no spare production capacity, the sales person has to negotiate overtime work and further negotiate a suitable price with the customer.

B2B networks was an important expected benefit to 4 firms (A, C, E, and L), all the other firms found it unimportant. Firms A and E achieved it and allowed other companies to access their configuration system and order products. Firm C abandoned all access to their configuration system from outside agents. Firm L envisioned several companies with access to their configuration system but ended up

with a strategic alliance with only one firm. Other firms were in general weary of exposing too much information and knowledge to other firms, be it partners or competitors.

Improved certainty of delivery was an important expected benefit to 3 firms (F, H, and I). Firms F and H reached their goal, and firm I did not. Firm I implemented a new ERP system, which the configuration system was part of. However, the required organisational discipline was not strictly enforced, and staff did not always report status changes to the system, which lead to problems. Although the situation had improved compared to before the system was implemented, there was a clear awareness of the problem of data discipline. Interestingly enough, firm C and G realized this to full effect although not expected. When firm C upgraded their ERP system, the new system contained a new and improved materials planning algorithm, which is the sole reason for achieving this benefit.

Focus on standard products was an important expected benefit to 2 firms (H and I), 2 firms found it of medium importance, and the remaining 8 found it to be unimportant. Both firm H and I realized this, and it had special impact on firm I, which is manufacturing products in which a 40-60 m tower is a central component. It so happens that a tower, which is 2 meters higher that a standard tower may cost more than 100 % more to produce due to changes in the structural dynamics as well as the cost of additional engineering resources to make the required additional calculations. Before implementing the product configuration system this knowledge was not immediately visible to sales staff that accommodated customers to the highest tower. (A higher tower produces a higher benefit to the customer). With the new immediate access to real prices, sales staff can communicate this to customers, who find it difficult to justify a 100 % cost increase in the light of a 4 % increase in production capacity.

Job training made easy was a medium important expected benefit to just two firms (H and J), and the rest of the firms found this unimportant.

6.2 Costs

The task of analysing cost is somewhat hampered by the fact that some of the responding firms did not report expected costs.

Specifying the product revealed that firms are actually good at predicting the cost of specifying the product. In some cases (firm F and I) this can be time consuming and very expensive. Firm F estimated that 8 person years had gone into specifying their product. For firm I this was also a painful task, as the firm was used to a very fluid understanding of their product, thus documenting that the product and related processes turned out to be very consuming.

Choosing software is interesting, as some of the firms did not realize the importance hereof. Firm E in particular set out to use the Baan configurator but found after a few month of work that integration to their ERP system was difficult, and they decided to use the configuration system integrated in their ERP system.

Coding is high ranking in both realized and expected costs. What is interesting is the systematic misjudgement of the required resources to code. Firm C expected this to be fairly cheap but found that the bulk of costs were in fact related to coding. The lesson here is to be aware of the cost of coding, like software projects' complexity is high, and attention to detail is paramount, which makes it difficult to predict.

Integration to existing systems, on the other hand, is much more straight forward, in particular when using a configuration system, which is part of the company ERP system. Because the interfaces are often specified, it is possible to predict the amount of coding necessary to integrate with existing systems.

Implementation, i.e. the cost of training can also be a surprise to some firms. In particular firms with users in different countries (Firms C, D, G, H) realize high costs. This is related to different organisational setups, different computer systems and to some extent different cultures.

Maintenance costs are in general low. Some firms rated maintenance costs to zero, which is disturbing, as a product configuration system must be maintained to be useful. Follow up questions revealed that the true cost of maintenance was present but too low to be significant compared to other costs.

Cost of innovation was only given a rating by two firms. The remaining firms gave this rating zero points. The two firms recognised that they had to use resources to obtain information about the market, because of the changed specification process. However, most of the responding firms are new to configuration, and this may impact the answer.
Three out of four firms underestimated the cost of **project management**.
The highest expected costs were **Documentation**, which interestingly enough is one of the lowest realized costs. All but one firm expected this to be fairly costly but decided to not document because of pressing schedule and lack of resources. It is expected that firms not documenting their system will have a potential maintenance problem, if key employees leave the firm.
Consultants are, not surprisingly, expensive. Two firms (C and D) miscalculated the need for consultants, although the two situations are very different. Firm C needed to meet a target deadline and did not have the required in-house resources, which lead to use of expensive consultants. Firm D did not specify clearly what jobs the consultants should do and more importantly not do, in which case the consultants kept working on the system.
Software costs are also very low, which was not expected. This is related to the fact that many of the interviewed firms use the configuration system present in their ERP system. This provides the firms with a configuration system at no additional cost.
The cost of **hardware** was only rated high in one case, and others rated it low compared to other costs. Four firms found the hardware costs to be negligent.

7. Conclusions

This paper has reported findings on costs and benefits when implementing product configuration systems. Product configuration systems have been characterised, and their relationship to mass customization explained. No less than 12 firms have been interviewed, which provided the data for expected costs and benefits. The data gathered and used is predominantly qualitative and a combination of interviews and radar diagrams was employed. The radar diagrams is a pseudo quantitative approach to gathering data on costs and benefits when implementing product configuration systems. The weakness is that 'real' factual data are not collected. However, it was the not possible to actually gain access to these numbers and in most instances firms have not have a quantitative measurement of turnaround time, amount of resources used etc. What firms do have is an understanding of the market in which they sell their products and the firms have a clear understanding of, for instance, if their turnaround time is to high compared to what is acceptable in this particular market. Radar diagrams are well suited for gathering and making a pseudo quantifiable measurement of the costs and benefits from implementing product configuration systems.
It has proven particularly difficult to gather information on the exact or even rough estimates on the expected costs. There are two reasons for this: 1) Some firms have used product configuration systems for more than 15 years and the knowledge is no longer present in the firm, and 2) Exact calculations were not made before initiating the project and the project was based on a rough estimate.
All the firms provided data on the expected and realzed benefits from implementing product configuration systems. And from these it is possible to draw come conclusions regarding the primary incentives for implementing product configuration systems. The three highest aggregated scoring expected benefits with more that 30 points from implementing product configuration systems are: 1) Improved quality in specifications, 2) Lower turnaround time, and 3) Using less resources.
It is obvious that the interviewed firms have a problem with the quality of their product specifications and a product configuration system solved this. The product configuration system affects the quality of specifications in two ways: 1) Validate configurations against a set of rules and 2) Ensure all relevant information from the customer is collected. The latter could be achieved with a simple list, however experience has shown this is not enough. Using a configuration system it is impossible to complete a product configuration without all the required information and this forces employees to do so.
Lower turnaround time is a direct consequence of automating the process of configuration a product. Allowing a computer system (product model) to validate a configuration instead of a fellow employee is much more efficient and also does away with a potential queuing problem.

In the same vein using less resources is a consequence of automating the process of configuration a product. It is, however, interesting that this benefit was not the primary motivating factor and this is perhaps to be found in the fact all of the interviewed projects engaged the projects from a technical standpoint.

Acknowledgement

This research has been funded by The Danish Technical Research Council, STVF (Statens Teknisk Videnskabelige Forskningsråd) http://www.forsk.dk/eng/stvf/index.htm.
We would also like to acknowledge the help from our fellow researchers participating in the project (listed alphabetically): Assistant professor Benjamin Loer Hansen, associate professor Ph.d. Lars Hvam, a, Ph.d. student Martin Mails, research assistant Morten Møldrup, associate professor Niels Møller, and associate professor Jørgen Lindgaard Pedersen. Without the help of these fine individuals this paper would not have been the same, however, we are responsible for any remaining vulnerabilities.

References

Davis, Stanley, 1987, "Future Perfect"

Duray, Rebecca, Peter T. Ward, Glen W. Milligan, William L. Berry, "Approaches to mass customization: configurations and empirical validation", Journal of Operations Management 18 (2000) 605-625.

Empirical evidence from the PETO project (Product Models – Economics, Technology and Organisation). More than 30 interviews are planned and in the process of being conducted in Danish companies. Currently 9 interviews have been completed.

Edwards, K, Jespe Riis, Morten Møldrup, Jørgen Lindgaard Petersen, Lars Hvam, Niels Mølle. 2003 "Teoretisk Foranalyse", The PETO project, Department of Manufacturing Engineering and Management, Technical University of Denmark.

Eisenhardt, Kathleen M., 1989, "Building Theories from Case Study Research", Academy of management Review, Vol 14, No.4, pp.532-550.

Faltings, B. and Rainer Weigel, 1994, "Constraint-based knowledge representation for configuration systems" Technical report No. TR-94/59, Department D'Informatique.

Forza, Ciprane and Fabrizio Salvadore,2002, "Product configuration and inter-firm co-ordination: an innovative solution from a small manufacturing enterprise", Computers In Industry 49 pp. 37-46.

Forza, Ciprane and Fabrizio Salvadore, 2001, "Manageging for variety in the order acquition and fulfilment process: The contribution of product configuration systems", Int. J. of production economics 76, pp. 87-98.

Hansen, Benjamin Loer, 2003, "Development of Industrial Variant Specification Systems, Ph.D. thesis, Department of Manufacturing Engineering and Management, Technical University of Denmark.

Hvam, Lars, 1994, "Anvendelse af Produktmodelering – set ud fra en arbejdsforberedelsessynsvinel", Ph.D. Dissertation, Driftteknisk Inistitut, Technical University of Denmark.

Hvam, Lars, 1999, "A Procedure for building Product models", Robotics and Integrated Manufacturing.

Jacobsen, Jan K. ???, "Interview – Kunsten at lytte og spørge", Hans Reitzels Forlag (in Danish)

Kvale, Steinar, 1997, "InterView", Hans Reitzels Forlag (in Danish) translated from English: Nake, Bjørn, 1994, "InterView"

Pine,B. Joseph II, 1999, "Mass customization – The New Frontier in Business Competition", paperback, Harward Business School Press.

Riis, J. 2003,(In Danish) "Fremgangsmåde for Opbygning, implementering og vedligeholdelse af produktmodeller", Ph.D. Thesis, Department of Manufacturing Engineering and Management, Technical University of Denmark.

Silveira, Giovani Da, Dennis Borenstein and Flávio S. Foglitto, 2000, "Mass customization: Litterature review and research directions", Int. J. of production economics.

Schwartze,. S, 1996, "Configuration of Multiple-variant products", BWI, Zürich.

Kasper Edwards, Assistant Professor
Technical University of Denmark, Manufacturing Engineering and Management
2800 Lyngby, Byg 423, Produktionstorvet, Denmark
Telephone: +45 45256010, Telefax: +45 4593 4467
E-mail: ke@ipl.dtu.dk

Appendix

Expected Benefits	A	B	C	D	E	F	G	H	I	J	K	L
Lower turnaround time	2	5	4	5	5	4	0	5	0	1	5	5
Improved quality	5	4	4	4	5	5	0	5	5	5	5	4
Preserve knowledge	5	1	4	5	0	3	0	2	0	2	0	0
Using less resources	2	5	4	5	4	3	0	2	0	3	0	4
E-trade	0	0	4	0	5	0	0	0	0	0	0	5
Optimizing products	3	2	0	0	5	0	0	5	0	0	0	5
Making knowledge visible	4	1	0	0	0	3	0	1	3	0	0	4
Less routine work	5	4	1	5	3	3	0	2	0	0	0	4
B2B networks	4	0	5	0	5	1	0	0	0	0	0	5
Improved certainty of delivery	0	0	0	0	0	4	0	4	4	0	0	1
Focus on standard products	0	2	0	0	0	0	0	5	4	0	0	3
Job training made easy	0	0	0	0	0	0	0	3	0	3	0	0

Realized Benefits	A	B	C	D	E	F	G	H	I	J	K	L
Lower turnaround time	2	5	5	5	3	5	5	3	0	1	5	5
Improved quality	5	4	5	4	5	5	3	4	4	5	5	4
Preserve knowledge	5	4	4	5	0	2	2	2	0	2	0	0
Using less resources	2	5	3	4	4	5	5	2	2	3	3	1
E-trade	0	3	0	0	5	0	0	0	0	0	0	5
Optimizing products	3	1	0	0	4	0	2	4,5	0	0	0	5
Making knowledge visible	4	4	0	0	1	3	4	1	2	0	0	5
Less routine work	5	4	1	5	4	3	0	2	0	0	3	1
B2B networks	4	0	0	0	2	0	5	0	0	0	0	1
Improved certainty of delivery	0	0	5	0	0	4	5	4	2	0	0	1
Focus on standard products	0	4	0	0	0	4	2	4,5	3	0	0	3
Job training made easy	0	2	0	0	0	0	2	3	2	3	0	0

	Expected						Realized										
Costs	**A**	**C**	**D**	**E**	**H**	**L**	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**	**J**	**K**	**L**
Specifying product model	5	0	0	1	3	3	5	0	0	1	5	0,3	3	5	0	3	3
Choosing software	2	0	3	1	3	2	0	0	5	3	0	0	3	1	0	0	0
Coding	3	2	0	3	3	4	5	5	0	4	0	3,2	4	3	2	3	5
Systems integration	3	0	5	1	2	2	0	0	5	1	0	0,7	1	1	0	1	2
Implementation	0	2	2	1	3	3	0	4	5	2	0	5	4	2	0	0	1
Maintenance	0	1	0	0	3	0	0	2	0	2	0	0	2	1	0	3	0
Cost of innovation	0	0	3	0	3	0	0	0	3	0	0	0	3	0	0	0	0
Project management	0	3	2	2	3	2	0	5	5	2	0	1,5	4	2	0	0	5
Documentation	2	4	3	0	3	3	0	0	0	3	0	0	4	1	0	0	1
Consultants	1	2	3	3	1	4	0,5	4	5	3	0	0	1	3	1	0	5
Software	0	0	0	1	2	2	3	0	0	1	0	0	2	2	5	5	2
Hardware	0	3	0	2	1	2	0	5	0	2	0	0	1	3	0	5	2