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Utilization of Design Configurators in Order Engineering

Marko Mäkipää
Senior Researcher, School of Information Sciences, University of Tampere, FI-33014 University of Tampere , Finland, marko.makipaa@uta.fi

Pasi Paunu
Researcher, School of Information Sciences, University of Tampere, FI-33014 University of Tampere , Finland, pasi.paunu@uta.fi

Timo Ingalsuo
Researcher, School of Information Sciences, University of Tampere, FI-33014 University of Tampere , Finland, timo.ingalsuo@uta.fi

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Abstract

Configurators are essential tools in mass customization. While sales configurators and product configurators have received a fair amount of attention, this study explores a new type configurator for use in order engineering: design configurator. Design configurators can be used to automate order engineering and decrease lead-time for product quotations and customized designs. Thus, they can bring ETO companies closer to mass customization. By determining the requirements for and developing the concept of a design configurator, this paper paves the way for further research on design configurators. Through multiple case studies, the applicability and benefits of design configurators in different industrial contexts are illustrated.

Key words: *Configurator, mass customization, order engineering*

1. INTRODUCTION

Mass customization is seen as a promising approach to compete in the fragmented mass market [1,2]. By using flexible processes and organizational structures [1], mass customization enables companies to provide "tremendous variety and individual customization, at prices comparable to standard goods and services" [3]. In [4], where the term "mass customization" was coined, it was described as a solution for targeting a large number of customers as in the mass markets of the industrial economy and offering them individualized attention, as in the customized markets of pre-industrial economies. Most of the literature on mass customization defines it as a solution for consumers in mass markets desiring customized products.

In contrast to the consumer product industries, which have been dominated by standardization and mass production over the last century, in the capital goods sector, products continue to be designed to customer specifications and manufactured in job-shop facilities [5]. Thus, in the industrial B2B markets, the approach to mass customization is typically the exact opposite of that in the consumer business. While some mass customization theories and methods developed for mass producers can be applied in Engineering-to-Order (ETO) companies, not all are useful in ETO. The reason for this is a basic difference in the motivations for implementing mass customization between the two types of companies [6]. In ETO companies, mass customization is driven by the needs of shortening delivery time, variation management, and/or cost reduction [7,8,9]. Customers are accustomed to receiving individualized service and solutions that match their preferences, but in turn their sacrifice [1] is to accommodate the higher cost of individual designs and longer delivery times because of design process lead time.

A challenge for most ETO companies today is to continue delivering quality and high customer value while curtailing costs and shortening delivery time. Current definitions of mass customization focus on two factors: large variety or individualized solutions and cost efficiency. However, in the capital goods industries, a third factor is considered equally or slightly more important: delivery time. Thus, the prevailing definitions of mass customization are biased and defective from perspective of an ETO company. A more relevant definition of mass customization for ETO companies could be the following: Mass customization enables companies to provide a large variety comparable to purely customized of goods and services at significantly lower costs and/or shorter delivery times.

Yet, variation in the level of customization of products, processes, and transactions can also be seen in the capital goods industry. Researchers have described a number of approaches that lie between the two extremes: pure customization and pure standardization. When defining what mass customization is and what it is not, a continuum of possibilities is laid down from mass products to craft work involving various combinations of standardization/customization. Nonetheless, nearly all definitions imply that an approach in which the extent of customization extends from order-delivery processes to the design/engineering phase is a pure customization strategy or an ETO operation model [5,10]. This paper re-examines the accuracy of this view.

Industrial markets, like consumer businesses, seek solutions to fulfill individual customer needs in a cost efficient way by utilizing mass customization concepts. According to [11], the genius of mass customization is the customer co-design process. Customers are invited to participate in the value creation process by defining, configuring, matching, or modifying an individual solution. Successful customer involvement in the definition process can create a flow phenomenon which increases customers' satisfaction with the process and consequently with the end solution [11,12]. In industrial markets where somewhat more rational reasoning and buying behavior is assumed, a successful model for the product definition process can minimize customer sacrifice by saving the customers' time, money and effort.

In consumer business, sales configurators are seen as a valuable tool for collaborative product definition, which guide and educate the customer in the product definition. Sometimes the sales configurator is followed up with a product configurator that helps transform the product features defined in sales configurator to actual components for production. A similar approach is used in industrial markets, but usually the sales configurator is used by an expert sales person and rarely by the customer [8,13]. Also, many companies use a hybrid product strategy, offering customers standard products, mass customized products, and individually designed products.

In this paper, we present a new kind of configurator, a design configurator. The design configurator is a tool for automating the order engineering process. It is used for tendering and product designing purposes in the capital goods industry. We seek to extend the mass customization ideology to ETO products, which have, so far, not been considered within the scope of mass customization. The automation of the order engineering process with a design configurator can help extend the mass customization ideology to some level of ETO activities. We will define the concept and requirements for a design configurator and use multiple case studies method to evaluate its applicability and benefits in different industrial contexts.

The rest of paper is divided into the following sections. In Section 2, we discuss the special characteristics and objectives of mass customization of capital goods. In Section 3, existing literature on configurators is reviewed. In Section 4, the concept of a design configurator is defined. Section 5 presents some case studies that support the idea of design configurator. In Section 6, conclusions are drawn and further avenues for research are suggested.

2. MASS CUSTOMIZATION OF CAPITAL GOODS

An explicit mass customization strategy is unique to the company developing and implementing it [1]. In addition to company-specific differences, several other factors influence an optimal mass customization strategy. For instance, industry and product type affects the need for customization and the extent to which customization is economically viable with the prevailing technology. For example, mass customization of shoes has different requirements and utilizes different techniques than mass customization of digital content, e.g., personal radio or personal news portal. Also, consumer goods industries in general differ from capital goods industries. The rational decision-making process of the industrial buyer affects the development and selection of the applicable mass customization methods. The approach to mass customization is also a critical factor in implementing mass customization, whether based on mass or custom manufacturing [7]. Between these two extremes is a range of other industries that calls for a diversity of mass customization strategies [5].

The capital goods industry differs from consumer businesses in numerous of ways. Typically, suppliers' product offering may be used in the customer's production process or may be a component of the customer's end product. The industrial buyer is usually an expert of the customer domain and possesses a high level of requirements and product-related knowledge. Also, B2B customers are considered more rational buyers, seeking an optimal balance between product qualities, price, and delivery time/accuracy. Typical offerings of capital goods companies include a number of standard products, mass customized products, and products requiring order engineering or even new product development. In addition to this, life-cycle and value-added services are often offered separately or as a bundled product [14].

Customization strategy, or an ETO model, is widely used in capital goods industry to provide critical customer value. Customers typically have distinctive processes or product-related needs. Order engineering allows capital goods companies to tailor their offerings to specific customer requirements. A typical sales process involves two phases: external sales units are responsible for customer interaction, understanding customer requirements, managing customer relationship, and deciding on the price, whereas the internal sales support team is responsible for order engineering, cost calculations, and determining the delivery time. External sales teams are located near the customer, while the centralized internal sales support teams have a high level of product expertise. The unique customer requirements, complex products, and organization of sales in the capital goods sector pose many operational and sales-related challenges.

Efficient customization might be difficult to achieve in high-tech or knowledge-intensive industries, such as the capital goods industries. In [15], the qualities of an order quotation process are described on the basis of surveys conducted in the UK and USA. Only 4% of the respondents had never faced problems in meeting the proposal dates, whereas a half had lost contracts due to proposal delays. The average project value amounted to 2 million GBP of which 12% was spent in advance in preparing the offer. The average time spent in preparing the offer was 138 hours in sectors with normal product complexity, 772 in high complexity sectors, and 1030 hours in the electronics and telecom sectors. In effect, 62% of these hours never translated into a contract. Larger companies suffered the most in terms of both staff-hours and hit rates; up to 2881 hours were spent on offers for every realized contract. Yet, the lack of accuracy in estimates and offers expose companies to a significant commercial risk in the order fulfillment phase [15].

Mass customization and product configuration can help overcome these problems, enabling companies to offer a large product variety while decreasing the lead time and the costs in every phase of the order-fulfillment process. In fact, modularization of industrial products and standardization of modules can enhance the competitiveness of capital goods companies, instead of the ETO approach [8]. But for a large number of products, individual customization is still needed to cater to the unique measures, qualities, and preferences.

Technological development offers a possible solution to achieving cost-efficient customization in ETO companies. For example, in [16], an industrial company shifts from mass production to efficient and effective customization with aid of new technologies. The company Ross Controls, producer of pneumatic valves and air-control systems, focused on learning from the customers and expanded their capabilities to meet each customer's changing needs. They utilized CAD libraries to reuse old designs, quickly customized them to the specific needs of each individual customer, and used direct electronic linkages to production for achieving speed and cost efficiency.

Mass customization hinges on identifying a mechanism for interacting with the customer and obtaining specific information to define and translate the customer's needs and desires into a concrete product or service specification [17]. Thus, mass customization often requires a mechanism that facilitates elaboration of customer requirements, e.g., a configurator [18].

3. CONFIGURATORS

Increased pressure on manufacturing businesses to cost effectively deliver both quality and high customer value has led to new production processes that are faster, cheaper, and allow flexibility and variability in product design. The introduction of configurators in the field of mass customization has enabled businesses to realize smarter processes [19]. Configurators are focused on collecting information enough to define the product, service, or more recently a bundled offering [14].

In some studies, the term "mass customization" has been defined in a very pragmatic way to highlight the importance of technological development and the role of IT-systems: "the technologies and systems to deliver goods and services that meet individual customers' needs with near mass production efficiency" [19]. The role of different kinds of information systems is highlighted in mass customization since information can be regarded as the most important factor in the implementation of mass customization [20]. Unlike mass production, mass customization necessitates direct customer interaction for definition of the product and for gathering product-related information. Further, compared to pure customization, in mass customization this information needs to be gathered in a more structured and disciplined manner to support cost efficiency. Mass customization is successful only when it can address the need for information and communication both purposefully and efficiently [20]. If the customer interaction has been designed poorly, customers can be overwhelmed by the number of choices during product configuration [21,22].

An important factor in achieving an effective mass customization operation model is the definition of a fixed solution space beforehand. The process of customer interaction to configure the product inside this solution space should be made as convenient as possible. Automation of activities plays a vital part here. Configurators support the product definition process and also automatically restrict the choices available in the solution space. In [23], the configuration process is divided into three stages, each having their own type of configurability.

Existing literature typically discusses two types of configurators: (1) sales configurators and (2) product configurators. Sales configurators are used to collect customer requirements, preferences, and choices. They are used by the sales personnel, more typically in capital goods industries or by the customers directly. Product configurators are used to translate customer requirements into a product structure for production. Product configurators are typically used by internal sales staff. Sometimes, product configurators derive their input from sales configurators.

A third type of configurator has been identified: a design configurator. In this paper, we examine the design configurator as a possible solution to a more automated order engineering process for tendering and product designing. Through the automation of some previously manual tasks with a design configurator that is integrated with CAD and PLM systems, the transfer of an order from sales to manufacturing can be hastened.

The fundamental difference between the design configurator and the sales and product configurators is that the former extends the concept of the configuration process. It produces customer-specific products, by creating individual CAD designs within CAD, PLM, and ERP systems environment. This ability to automatically generate unique drawings for components and products differs from the sales and product configurators and justifies the introduction of this class of configurators.

Sales configurators are typically focused on collecting customer orders for a wide variety of mass customization models, including virtual ones. In addition to manufacture-to-order and assembly-to-order operational models, they can also be used for more light-weight customization. One of these models, used by automakers, utilizes a locate-to-order operational model, which is a virtual and more cost-efficient version of the build-to-order model [24]. In such cases, the sales configurator operates more like a selector for standard products [25]. The focus of sales configurators is to collect adequate customer information for the purpose of product definition.

Product configurators, on the other hand, focus on defining the product structure for production and on identifying items from the solution space that fulfill the customer requirements. They utilize readily designed component and module libraries as well as matching and selection rules to build a coherent product structure. Sometimes the collection of customer requirements is integrated with the product structure definition functionality. That is, sales and product configuration functionalities are implemented as one configurator solution, whereas in other cases the configuration models are detached to separate sales and product configurators.

Design configurators also need to collect customer requirements and may include the configuration of readily designed components, in addition to creating new drawings. Similarly, sales and product configuration functionalities can be integrated into the design functionality in one total configurator solution. These functionalities can also be realized in separate but interoperable configurators. However, a unique feature of the design configurator is its ability to create new components and modules.

Adjustments to meet the exact needs of customer and creation of CAD drawings for new components, modules, and whole products were previously considered as belonging solely to pure customization, completely removed from the mass customization concept [5]. However, advances in ICT, especially in CAD and PDM tools, have enabled companies to extend the mass customization concept to the order engineering process.

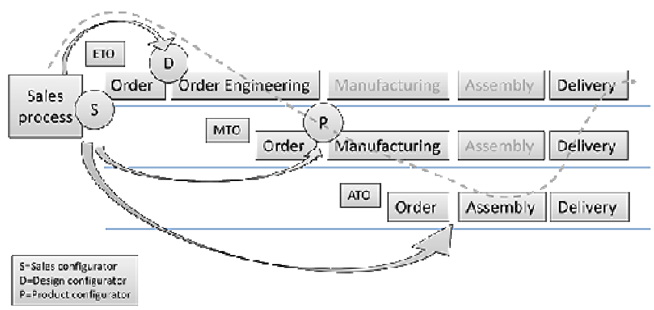

Figure 1. Different configurator positions in the order-delivery process

Figure 1 illustrates the typical uses of different types of configurators in different operational models. On the basis of its core functionality, each type of configurator can be located to a different phase of the order-delivery process. The sales configurator can be positioned between the customers and sales or between external sales and internal sales support. A product configurator can be placed between the sales and manufacturing/assembly, with no direct interaction with the customer.

A typical sales configurator used to link customers and sales is deployed either by the company sales personnel or as part of the custom software that customers use to record product preferences. A comparison of the configurator and the process control methods in [13] shows that the production and processes in this configurator are mostly ship-to-order (STO) and in some cases assembly-to-order (ATO), when the products have less customization but a high mass production rate.

A product configurator usually acts as a link between the PDM/PLM software and ERP systems environment where the configurator uses fixed product structures to construct product details. These details include the product variants with selection rules to generate the appropriate manufacturing structure and documentation for the product at hand. By comparing the product configurator to the process control methods in [13], we see that the production and processes in this configurator are usually make-to-order (MTO) and assembly-to-order (ATO). The customization with readymade components and the ability to mass produce them are both on the average scale on the chart. In order to achieve the desired efficiency, modulization of product is an essential requirement [3]. An essential aspect of a product configurator (like sales configurator) is that it acts as a user interface between the user and more complex PDM/ERP systems, thus simplifying the tasks and responsibilities of the user. As such, a product configurator aims to tackle the difficulties of information linking when combining, selecting, and mapping commercial and technical product data in the configuration process. In this way, it enhances the efficiency and responsiveness of companies. These are also the key components of mass customization and product variety management [26].

Apart from user-group focused division of configurators, they can be divided into four theoretical categories based on the knowledge modeling requirements and the support they provide to users:

1. Primary
2. Forced sequence
3. Interactive
4. Automatic

In the first category, the selection of product components/modules is done from a pre-defined list. Forced sequence configurators enable the selection of product components/modules from a list in certain order, narrowing the subsequent options available after each selection. An interactive configurator also narrows the available options after each selection but the order of selection is not restricted. In the case of automatic selection, heavy modeling is needed to transform the use environment characteristics and user requirements into product features and components as the automation-defined options are not pure product components/modules based on any list [8]. Another classification system suggests grouping configurators into fabricators, involvers, modularizers, and assemblers [27].

Apart from the above, other types of configurators have also been described in the literature, some of which are similar to design configurator introduced next. In [25], a parametric component configurator is proposed for managing components whose parameters (such as length, width, height, diameter) change continuously, for example, the radius of a round table. However, in such cases, no new drawing of the component is necessary as delivering the revised parameter along with the product definition is sufficient for production. Also in [28], a parametric configuration is introduced that "enables the creation and selection of a product design without the necessity of pre-engineering and rule-based product documentation." Even in [28], no new components are automatically designed; rather a larger assembly of pre-designed components/modules and their geometric and physical relationships are configured. A parametric configuration is used to "customize product designs; generate lists of features and parts for the product design; to generate a price quotation; and to enhance other post-design processes."

In [25], a metaconfigurator is also introduced for enabling a designer to rapidly “come up with a general product design that, even if approximate, must be reliable.” A metaconfigurator might include complex rules such as technical regulations, safety standards, aesthetic features, and economic aspects that provide approximate solutions to the designer [25]. The design configurator introduced in this study can include similar rules, but our target is to achieve final and complete design of individually customized products. Similar models of design configurators have already been introduced in the literature. For example, in [29] a tool was introduced to design customized biomedical devices. The general dimensions of a tracheal stent were modified using a parameterization tool for a specific patient.

Although the ideology of a design configurator has been addressed in literature, precise and clear definitions and the applications of the concept need to be clarified.

4. A CONCEPT OF A DESIGN CONFIGURATOR

A design configurator extends the scope of mass customization and configurators into the realm of engineering processes. Primarily, a design configurator necessitates a shift in the product design approach: from modular-based to parametric. Utilization of parametric CAD models offers results comparable to pure customization as well as automation possibilities in model manipulation. Therefore, it provides a wider solution space than the manufacturing-to-order approach while requiring less lead time, and possibly engineering costs, than the engineering-to-order approach.

Thus, a design configurator affects the variety level, costs, and delivery time, depending on the approach direction, whether MTO or ETO (Figure 2).

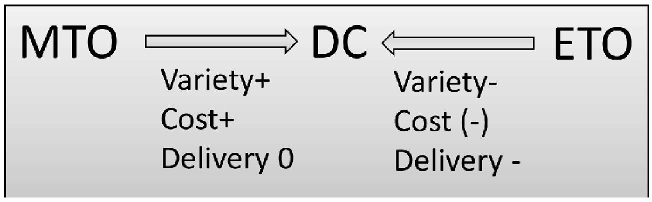

Figure 2. Effects of a design configurator on variety, costs and delivery time in the case of MTO and ETO

In this concept, the digitized product structures are stored, for example, in a PDM system and then reconstructed via different selective parameters through the configurator. The product skeleton is then manipulated parametrically with the help of CAD software. Each line and dot in the product design can be controlled by the design configurator and details updated via ERP or PLM systems, as needed. Figure 3 shows how the design configurator brings the ETO process closer to mass customization.

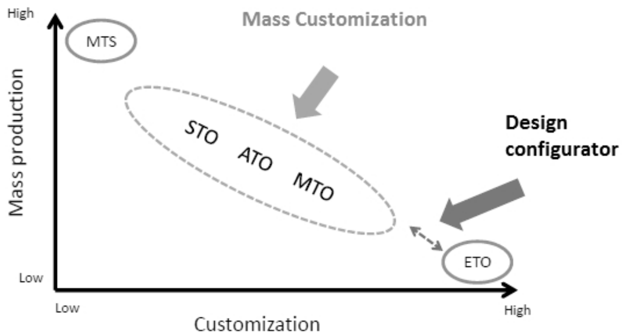

Figure 3. Design configurator in relation to mass customization (modified from [10]).

A design configurator thus enlarges the solution space from where all the product variations can be thought to originate. It enables almost infinite variations within the defined borders of the product specifications, which have been parameterized. Conceptually, the design configurator handles the entire order engineering process. It receives the input from sales, develops product design using pre-defined CAD models, and transfers the output to production. Its main contribution is automating the design stage in order engineering, which shortens the engineering lead time. Automation can also lead to fewer design mistakes caused by human error and reduce repetitive manual work.

While research suggests that modularization is essential for effectively implementing mass customization through product configurators in the MTO process, the use of design configurators in the ETO process eliminates this need. The essential factors in the configuration of design are parametric models and the supporting manufacturing system. The automation and manipulation of engineering by the design configurator also have an organizational impact. Main design tasks are then focused on maintaining the parametric models, while the product variations are generated semi-automatically.

Considering the significant impacts of a design configurator on the engineering process of an MTO- or ETO-based company, it can be argued that the workflow and jobs in such companies should be designed in tandem, according to the socio-technical system view [30]. This is because the design configurator is an information system that involves complex interactions between people, machines, and the work environment. A design configurator can influence the designing principles in a variety of ways. Some of the factors associated with using a design configurator are listed below.

Non-technical factors:

- According to the socio-technical system view, the design configurator is designed to fulfill a certain task in a certain social context and a fit between two should be found.
- The complexity of the task affects the resources needed to complete the task. A design configurator should either decrease the amount of resources required for the completion of the task or provide other advantages, such as better quality or shortened delivery time.
- The chunks of the total effort to be automated with the design configurator and the chunks to be performed manually should be determined based on the evaluated impact on the business.
- The impact might be difficult to calculate (e.g., Will the shortened throughput time lead to increased amount of orders?). In some cases, the solution might provide tangible cost savings, which are easy to calculate and justify the investment. In other cases, justification may probably be based on expectations of increased competitiveness which can result in a greater number of orders. With the design configurator, the number of orders no longer has a linear impact on personnel resources needed. Thus, an increase in orders/quotations will lead to increased cost-efficiency in order engineering.

Technical factors:

- Ideally, the configurator should be centrally located in the order-production process, where it can both initiate and handle the design process as a whole.
- It must communicate with the CAD system to generate parametric models and optionally interact with ERP, PLM, and other software and push ready-made drawings to production once the order is finalized and accepted.
- Depending on the production environment, an optimal process that includes the design configurator must be developed as various implementations can lead to very different levels of model complexity and overall challenges in construction.

Mass customization strategies can be implemented in ETO businesses in various ways. As part of these strategies, the uses of design configurators also vary. For instance, instead of fully automated configurators, ETO businesses may use partial configurators [25]. Previous studies show that partial configurators typically assist the design process in the following ways:

- Offering component library, utilizing standard components in design
- Offering supplementary design tools for standard solutions
- Enabling reuse of designs
- Utilizing parametric CAD models

5. CASE STUDIES

Next, we present three short case studies to illustrate the current shift toward mass customization in ETO companies. These cases also demonstrate that a continuum of different strategies and methods exists, even with the use of a design configurator.

5.1 **Peikko Designer [31,32,33]**

The Peikko Group, founded in 1965, is family owned company specializing in composite beams and fastening products for concrete connections. They provide innovative solutions to help customers make their building processes faster, easier, and more reliable. They supply a large selection of concrete connections and composite beams both for precast and cast-in-situ (cast-in-place) requirements in wide variety of applications.

Peikko Group's vision is to be the leading company in the field of fastening technology, which includes concrete constructions (both precast and cast-in-situ) and composite beams. At Peikko, this leadership implies innovativeness of products, high recognition among designers and end users, and global presence.

To help different companies choose and use Peikko’s structural solutions, Peikko has developed a specific design and calculation software that assists structural architects in their jobs. This free and interactive 3-D design platform can be used to design and evaluate bolted column foundations and punching prevention reinforcement structures. The end result can be exported to AutoCad, and all the component details with calculation results can be printed. The main benefit of using the software is the ability to estimate the actual results with virtual structures, which can then be exported to other design environments. Peikko also offers design components in other design environments like AutoCad, where Peikko’s structures can be imported as product library into the existing software.

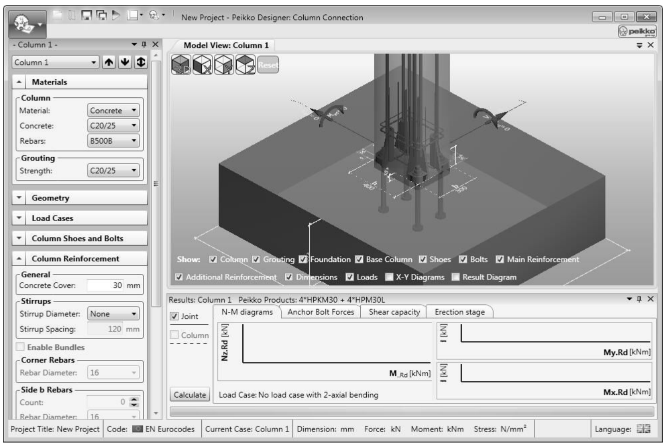

Figure 4. Peikko Designer.

One of the advantages of using Peikko's product library is that it contains the most up-to-date details on the structural components that Peikko regularly produces. This way the designer can be assured that he or she is using the right kind of structures and can view the result of the selection on the overall product.

5.2 Cargotec MacGregor [34,35,36]

Cargotec MacGregor, part of Cargotec Corporation, offers integrated cargo flow solutions for maritime transportation and offshore industries. One of their products is hatch covers.

Each merchant ship is a complex puzzle of thousands of components and materials with varying requirements. Hatch covers are a vital part of this puzzle. Cargotec and its partners have developed a systematic and fast computerized configuration model for side-rolling hatch covers, which reduces design throughput time, improves productivity, and ensures consistent quality.

Hundreds of customer requirements are compressed into a few dozen engineering parameters. Computer modeling finds an optimal customized solution by analyzing input data systematically and quickly. Shortening the design process enables faster purchase of critical parts. This yields the company a competitive advantage, increasing productivity and savings on costs.

As a result of the configuration model, the design leadtime was reduced from an average of 8 weeks to one or two days.

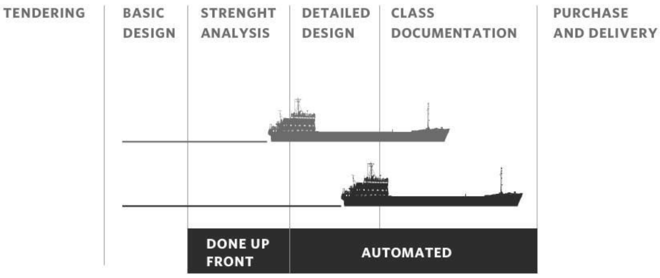

Figure 5. Change in engineering activities [36].

A typical project needs four separate model configurations and about 30 drawings are automatically produced from each hatch model, which fully describe the design for the shipyard, manufacturing, and the ship classification society.

5.3 Asoma Studio [37,38,39,40]

Asoma PLC, founded in 1942, is a contract manufacturer of technically advanced precision components created using a vacuum forming method. Their production method uses heat and negative pressure to shape plastic sheets. The advantages of vacuum forming over other manufacturing methods include inexpensive, lightweight, shock-resistant and readily shaped products, fast-paced R&D, and a 100 percent material recycling rate. Their customers are typically leading enterprises in the automotive, electronics, engineering, appliance, hospital, and sanitary sectors. Asoma offers services ranging from product development to full production of readymade products according to customer requirements. Minimal start-up costs and fast-paced R&D of vacuum forming enable short series production and ETO operations.

Asoma's vision is to generate added value for its customers at all stages of the R&D process from design to manufacturing. For Asoma, the most important concern in sales is determining whether their manufacturing technology suits the customer's product. In order to speed up the sales process, Asoma launched a service portal called Asoma Studio in the beginning of 2012.

Asoma Studio offers tools that enable customers to evaluate their own designs against Asoma's production technology, calculate costs, manage the order process, and view, comment and modify 3D-models. It saves time in new product development (NPD) and offers 3-D visualization for customers who do not have access to design tools. It also educates customers about the possibilities and limitations of different technologies, uses of materials, and costs of production, fostering customers' own NPD-processes. It also stores and manages documents and comments related to the order process, ensuring up-to-date design documentation during the entire order-delivery process.

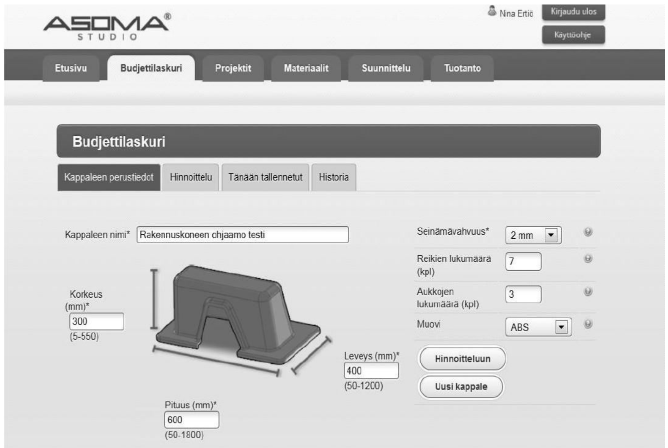

Figure 6. Asoma Studio's budget calculation tool based on different measures, material selection, material strength and number of holes [40].

Asoma Studio is built on cloud-based technology and is based on Microsoft technologies and CadFaster 3D collaboration tool. It provides tools for collaboration, streamlining the sales and order engineering process, cost calculations, and project management.

6. CONCLUSION

As the case studies demonstrate, many companies are already offering different kinds of engineering tools to assist customers in the product definition process. Increased global competition has led to automation and digitalization not only in production but also in product development activities, especially in the case of order engineering products. Current developments and the discussed examples suggest that eventually full-fledged design configurators for order engineering will be constructed to enhance competitiveness in industrial markets. Design configurators promise faster response times for product quotations and order engineering processes, thus securing critical orders in a turbulent business environment.

Design configurators can dramatically shorten the response times and the order engineering lead time. They also require modeling capabilities for complex products, sophisticated design systems and maintenance of product models. While they may not necessarily reduce costs, they definitely change how the work is organized. With design configurators, most of the order engineering effort is completed in advance, which includes modeling the product architecture and examining scalability, quality, options, and their available variants. The process of order engineering becomes more stable. For instance, fluctuations in demand do not significantly affect workforce requirements; they merely result in computing effort. Design configurators may replace some of the old job positions (e.g., order engineer) with newer ones (e.g., product architecture designer, product variation manager, product modeling expert). They can enhance competitiveness by facilitating faster response to customer quotations and orders.

However, there are certain limitations in design configurators, such as handling FEM calculations and adjusting the design accordingly. Future research is needed to improve our understanding of CAD configuration processes, the required IT infrastructure, the impact of design configurators on the order engineering process, and their limitations.

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Korišćenje konfiguratora za dizajniranje pri projektovanju prema porudžbini

Marko Mäkipää, Pasi Paunu, Timo Ingalsuo

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Rezime

Konfiguratori su suštinski alati u kastomizovanoj industrijskoj proizvodnji (Mass Customization). Dok konfiguratori prodaje i konfiguratori proizvoda dobijaju dovoljno pažnje, ova studija proširuje istraživanje na projektovanje prema porudžbini sa konceptom konfiguratora za dizajniranje pri projektovanju. Konfiguratori za dizajniranje pri projektovanju mogu da se koriste za automatizaciju projektovanja prema porudžbini, pomažući da se skrati vreme potrebno za navođenje proizvoda i prilagođavanje dizajna, i dovodeći kompanije koje se bave projektovanjem prema porudžbini (ETO companies) bliže kastomizovanoj industrijskoj proizvodnji. Uspostavljanjem zahteva i kreiranjem opisa konfiguratora, ovaj rad uspostavlja bazu za dalje istraživanje konfiguratora za dizajniranje pri projektovanju. Korišćenjem metode višestruke studije slučaja, ilustrovani su primenljivost i koristi u različitim industrijskim kontekstima.

Ključne reči: *Konfigurator, kastomizovana industrijska proizvodnja, projektovanje prema porudžbini*