21ST INTERNATIONAL CONFERENCE ON ENGINEERING DESIGN, ICED17
21-25 AUGUST 2017, THE UNIVERSITY OF BRITISH COLUMBIA, VANCOUVER, CANADA

IMPROVING PRODUCT CONFIGURABILITY IN ETO COMPANIES

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Abstract

For engineer-to-order (ETO) companies, it is from a strategic perspective crucial to be able to supply highly customized solutions to customers, while at the same time improving re-usability across projects to increase efficiency. To address the challenges this study aims to support ETO companies by improving their product configurability without compromising the flexibility, by focusing on product modularization. For this purpose, a 5 step framework is proposed with the aim of creating a product overview with a post perspective on requirements to improve the modularity of the product platforms. The framework was based on a literature review and tested in a case company, where it proved to be beneficial as it provided a structured approach to identify improvements to the products platforms modularity.

Keywords: Product modelling / models, Product families, Requirements, Platform strategies

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Please cite this paper as:
Surnames, Initials: *Title of paper*. In: Proceedings of the 21st International Conference on Engineering Design (ICED17), Vol. 3: Product, Services and Systems Design, Vancouver, Canada, 21.-25.08.2017.

1 INTRODUCTION

In today's market place, many companies are faced with increasing demand to provide customized solutions with delivery times, price and quality that are comparable to mass produced products. To overcome this challenge companies are working with principles of mass customization (Pine 1999).

Moving towards mass customization from a mass production perspective and an engineer-to-order (ETO) perspective are fundamentally different (Haug et al. 2009, Hendry 2010). By definition ETO companies make highly customized products that are designed to fit individual customers (Hvam et al. 2008). Therefore, for ETO companies to move towards mass customization requires them to limit their solution space (Petersen 2007) while for mass producing companies mass customization is about enabling greater product variety in an efficient way. It can be assumed that operating in an ETO setup is a strategic decision where customization is a necessity or competitive advantage in the industry. To support this, ETO companies' organizational setup, processes and product families must be highly flexible. Over the past years research has focused increasingly on mass customization in the ETO context i.e. product platform, modularization and configurations system (Petersen 2007, Hvam et al. 2008 and Haug et al. 2009). Applying the principles of mass customization has enabled ETO companies to operate in a span between configure-to-order (CTO) and ETO. It can be assumed beneficial to operate with a higher degree of CTO, but it is not always feasible for ETO companies to operate in a complete CTO setup (Haug et al. 2009), as it would compromise the required flexibility. Meaning that ETO companies would not be able to fulfil their customers' requirements, as it would require them to limit their solution space (Forza and Salvador 2008). To address the abovementioned challenges this study aims to support ETO companies by improving their product configurability without compromising the flexibility to make customized solutions i.e. finding the optimal balance between CTO and ETO solutions.

Product modularization is an acknowledged tool to achieve a higher degree of configurability (Pine 1999), and a method regularly used by ETO companies. In the process of designing products and modules, analysis of customer requirements is a common first step (Ulrich and Eppinger 2008 and Erixon et al. 1996). In many companies the designs of the product modules are based on an existing product family. This means that companies have conducted a number of projects that can be learned from in terms of understanding the requirements actually requested from customers. This post perspective to customization requirements has not received great attention, especially within ETO settings. This study therefore focuses on applying a post perspective to the customization requirements when designing product modules. The following research question will be answered in this study:

Can a post perspective on customization requirements be valuable when improving modularization of a product family and thereby balance product configurability in ETO settings without compromising the flexibility to make highly customized solutions?

To provide an answer to the research question this study propose an approach for redesign of product modules that consists of five steps, which are: (1) Modelling of the product family, (2) Mapping previous CTO Customizations, (3) Mapping previous ETO customizations, (4) Mapping predicted customizations, and finally (5) Identifying product module improvements potentials. To validate the suggested approach, it was tested and evaluated in an ETO company supplying printing presses for industrial use. The validation of the approach was carried out over three-month period in the context of a product platform project. Finally, a workshop with members from the development team was conducted where the approach was evaluated in terms of it contribution to the project goals and its usability.

2 BACKGROUND

2.1 Customizations in the ETO context

The customer order decoupling point (CODP) is a way to distinguish the ETO operation strategy in comparison to other strategies. Rudberg and Wikner (2004) define the traditional manufacturing concepts based on the CODP as ETO, make-to-order (MTO), assemble-to-order (ATO) and make-to-stock (MTS) where they also introduce the concept of a two-dimensional CODP space, with an engineering dimension and a production dimension. Hvam et al. (2008) focuses on the engineering dimension where he distinguishes between different entry points of the customer as selecting a variant, CTO, modify-to-order and ETO, where standard products, standard parts/ modules, a generic product structure or norms and standards respectively are defined at the time of customer entry (see Figure 1).

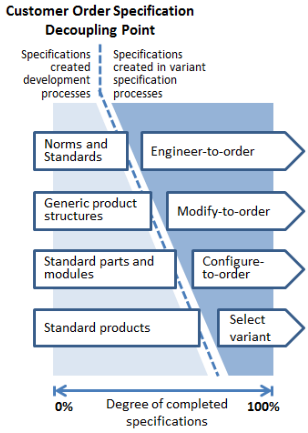

Figure 1. Types of engineering strategies, Adopted from (Hvam, N. . Mortensen, et al. 2008)

This implies that for ETO companies to improve configurability they have to move closer towards CTO setup where customizations can be made by combining a predefined set of parts and/or modules (Hvam et al. 2008). However, companies do not necessarily fall into one of the defined strategies, it is possible that some customized products are CTO, some ETO and some even a mix of both i.e. build-up of a mix of pre-defined modules and specially design parts.
The product solution space are by some considered to be limitless for ETO companies (Brunoe and Nielsen 2012), however Konijnendijk (1994) argues that even for ETO companies the solution space is limited by industry standards, legislation as well as internal recourse constraints. For ETO companies operating in the span between ETO and CTO, the solution space will by nature become more limited by the increased standardization of parts and modules. That is why it is important to balance the level of standardization - reuse as much as possible without compromising the flexibility to fulfil customization requirements.

2.2 Modularization in ETO companies

To understand the nature of product modularization the concepts of a product family and product platforms have to be defined. Meyer and Lehnerd (1997) define a product family as "a set of individual products that share common technology and address a related set of market applications" and a product platform as "a set of subsystems and interfaces that form a common structure form which as stream of derivative products can be efficiently developed and produced", this implies defining a common architecture for the product family. The product architecture can be defined as (1) the arrangement of functional elements; (2) the mapping from functional elements to physical components; (3) the specification of the interfaces among interacting physical components. (Ulrich 1995).
Modularity has been defined as one of the most important aspect of the product architecture (Eppinger and Ulrich 2000). The highest degree of modularity can be defined when each functional requirement can be directly connected to one module and where there are few interactions between the modules, making it possible to change specific modules without affecting other parts of the design (Eppinger and Ulrich 2000). This means that a well-defined product module has:

- a clearly defined relation to customer requirements or product functions, preferably a one-to-one relationship.
- clearly defined interfaces with connecting modules.
- a physical product structure that support the distinction between product functions.

For ETO companies the concepts of platforms and modularity should not only be considered in terms of a physical composition, a wider definition is required (Robertson and Ulrich 1998 and Jansson et al. 2014). Not all ETO companies are able to define and re-use physical components across projects and products, instead re-use of knowledge, processes, calculations etc. is more feasible. Therefore the

modular concept have to be defined in a broader extent in ETO companies e.g. a module could be defined based on a common process step or knowledge.
The different methods that have been proposed to design modules or modular architectures (Pimmler & Eppinger 1994, Browning 2001, Erixon 1998, Ericsson and Erixon 1999, Kashkoush & Elmaraghy 2017 and Ko 2013), commonly includes an analysis of customer requirements. In an ETO setup the individual customer requirements are "translated" into customized products, implying that customer requirements can be seen as requirements for customization. To understand the boundaries of the solution space and the level of flexibility needed for an ETO product platform and product modules, it is suggested to study realized customizations i.e. taking a post perspective on customizations requirements. This builds on the idea of minimizing non-value adding variety and allowing value-adding variety (Mortensen et al. 2010) Based on this, modules can be designed to improve configurability of the products, without compromising the required flexibility and the solution space.

3 APPROACH

This article introduces a five-step approach, which aims to identify potential for product module improvements in terms of improving the configurability of the products without compromising the flexibility to make customized solutions (Figure 2).

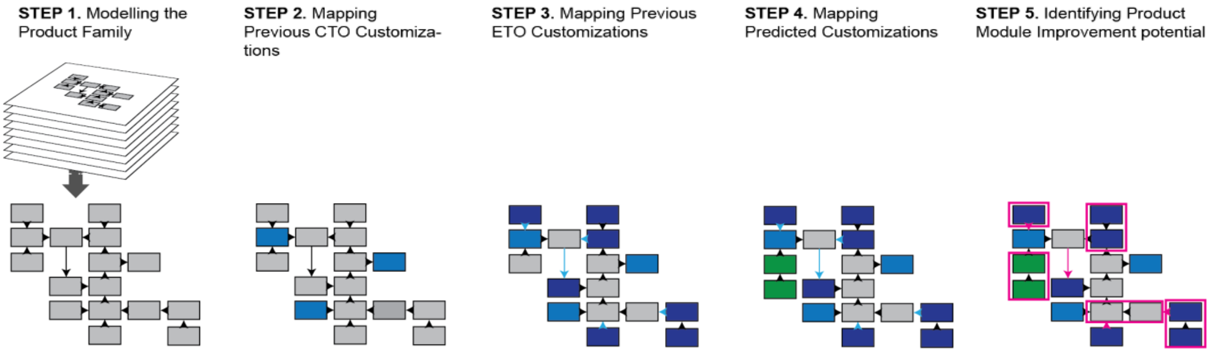

Figure 2. Five step approach to identify potential for product module improvements

3.1 Step 1. - Modelling the Product Family

The first step of the approach is creating a visual model of the product family in focus. Visualizing or modelling product functionality is a common first step in the process of defining product modules (Ulrich and Eppinger 2008 and Erixon 1998) in order to get an overview of the product. This is based on the assumption that visual models improve decision making when defining product modules (Harlou 2006). For this purpose, several methods for product modelling have been described in literature e.g (Hegge and Wortmann 1991, Eppinger and Ulrich 2000, Stone et al. 2000, Gonzalez-Zugasti et al. 2000, Dahmus et al. 2001, Du et al. 2001, Fixson 2005, Huang et al. 2005, Harlou 2006, Otto and Hölttä-Otto 2007 and Mortensen et al. 2008). When choosing a method it can be beneficial to choose a method that stakeholders are familiar with e.g. a product model that already exists and can be reused, or that logically speaks to the project group (Andreasen 1994). The importance is not the method itself, but the knowledge it represents. The product model of the product family must represent all individual customized products sold to customers in the past, within the product family.
The overall purpose of the product model is to get an overview of the product functionality where it is of great importance to consider the level of detail. The detail level must support the product level on which the product module must be defined. As a minimum the detail level should support *step 2. Mapping Previous CTO Customization*, meaning it must be possible to highlight all customizable functions.
The product model should represent both product functionality and the interactions between them e.g material flow, data flow and physical contact points (interfaces). However in consideration to readability and overview of the product model, it can, in case of complex products, be beneficial to separate the two into two visual models e.g. a *schematic model* (Ulrich and Eppinger 2008) for modelling product functionality and an *Interaction matrix* (Eppinger 1997) for interactions/interfaces.

3.2 Step 2. - Mapping Previous CTO Customizations

The next step is to highlight all the product functions that represent value adding options for the customer in the process of customizing the product. In this step we focus on the functionality options that are considered within the configurable product range i.e. can be customized without engineering development. Examples could be:

- Possible upgrades from the standard option
- Optional add-on functionality

Choosing a different colour scheme is an easy way to highlight the CTO Customizations on the visual product model (Figure 2.).

3.3 Step 3. Mapping Previous ETO Customizations

Given the purpose of the approach i.e. to improve product modularity and configurability without compromising the flexibility to make customized solutions, the next step aims to create an overview of the ETO customizations and analyse the impact from having those special designs. This means mapping all ETO customizations previously made for the product family in question, specifying the function, structural level of the function and interfaces affected by the customization. In doing so it might be relevant to add information about the ETO customizations, that could be relevant for the forth coming steps e.g for prioritization purposes, this could include:

- Frequency – in terms of how often this ETO customization has been applied
- Resource consumption - in terms of cost/ man hours/ production hours.

3.4 Step 4. - Mapping Predicted Customizations

Even though the historic perspective of what customizations (both CTO and ETO in step 2 & 3) the customers have requested in the past is important, the future perspective should not be forgotten. If product management or the sales organization has any input on functionalities predicted to be the focus for future customization (e.g. rising new technology, forewarned changes to legislation etc.), this can be mapped on the product model.

3.5 Step 5. - Identifying Product Module Improvement Potential

With the product overview in place including highlight of how ETO and CTO customizations affect the product family, the next step is to identify product module improvement potential. This could be done by defining new modules, re-defining current modules i.e. adding and/or removing functionality to/from a current module or improving interface. Erixon et al. (1996) define the concept of module drivers as criteria for defining product modules. Even though, all module drivers should be considered, this approach focuses on the ability to make customized solutions. Therefore, the following module drivers - with focus on commonality and variation - have been identified to be particularly important: *common unit, technical specification and style.*

What the analysis from the previous four steps has highlighted is a distinction between:

- The stable product core - functionality that are stable across all product configurations i.e. not affected by customizations (marked with gray in Figure 2.)
- Customizations/Optional functionality - Functionalities that represent the customers ETO or CTO customization requirements or functionality affected by these options. (Marked with light blue, dark blue and green in Figure 2.)

In order to improve the configurability and customizability of the product family, it is suitable to define modules of sub-functions that are stable across products and to define modules of sub-functions that vary across products (Erixon et al. 1996). By doing so, modules are defined in a way that a choice can be made on individual options without affecting other modules. The distinction between the stable product core and optional functionality is therefore important, as this implies that modules should be designed to contain purely optional functions or purely stable core functionality, we call these; Flex Modules and Basis Modules respectively. When defining modules the distinction between different functionalities must be ensured not only on the functional level, but also on the physical level (Eppinger & Ulrich 2000). It is therefore important to ensure that the physical product structure supports the module definition i.e. that all subsidiary parts and sub-assemblies required to build a module are grouped in a meaning full way and not mixed in with parts from other functionalities.

Therefore, a workshop with relevant stakeholders can be conducted and the following points could be discussed:

- Are the existing CTO customizations frequently sold? or are they optimized to support non-frequent or obsolete customization?
- Are modules designed to contain purely optional functions or purely stable core functionality? Or should they be re-defined to achieve clear distinction between Flex Modules and Basis Modules?
- Are there any frequently sold ETO customizations that should be prioritised for redesigned to become more configurable?
- Are there any interfaces that need to be extra flexible to support a high variety of changing ETO customizations?
- Does the physical product structure support the distinction between different functions?

4 CASE

4.1 Background Information of the Case Company

Nilpeter A/S is a family owned Danish manufacturing company producing customized printing presses for labelling and packaging material (see Figure 3). The company has global presence with production in Denmark, USA and India, Sales offices in Denmark, Thailand, and a network of sales-agents across the globe.

The company currently has a number of different product lines, to support different markets, different printing technologies and different end-customer industries i.e. Health & Beauty, Wine & Spirits and Food & Beverage. Nilpeter's customers need flexibility in their printing presses to support multiple customers with a variety of printing needs. Nilpeter is aware that catering to specific customer needs is adding complexity cost to their organization, product assortment and supply chain. However, the highly custom solutions are one of their key competitive advantages in the market and therefore a strategic decision. While the flexibility in their solution space is not something they are willing to compromise, they still aim at being more efficient in providing customized solutions.

The product families are very modular on a high level, with one print technology or processing step per module. It is a sectional modularity, meaning that the customer can configure their printing press, with different print technologies. However, many customizations are made on a lower product level - customizations of the individual printing modules. At the lower product levels, there is less modularity, and customizations are more dependent on engineering development.

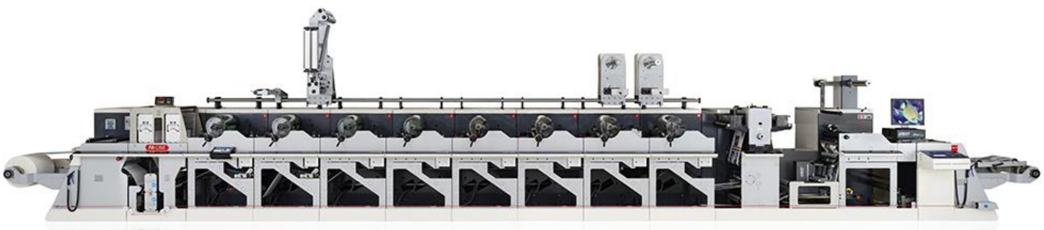

Figure 3. Nilpeter label press

Nilpeter have a sales catalogue, with what would be considered their preferred solution space. Most of the customizations available within this solution space are CTO, however some solutions are ETO. Customizations not available in the sales catalogue, receives a special item number and are handled as ETO solutions.

Currently Nilpeter is working on developing a new product platform based on an existing product platform, and wish to improve the configurability of the new platform compared to the old. For this purpose the proposed approach in this article will be tested and evaluated in terms of how well it supports the company.

4.2 Step 1. - Modelling the Product family

A functional model as proposed by Ulrich and Eppinger (2008) was chosen to for modelling the product family. This was chosen in consideration of the complexity of the product family and required detail level for the purpose of improving modularity.

Functions and sub-functions were placed on the product model in a way that represented the printing process and to some extent reflected the physical location of corresponding part(s) on the physical product. Some sub-functions were difficult to place, as from a functional perspective they were related to one sub-function, but from a physical perspective were part of a different structure e.g. ventilation pipes have a drying function, but on the physical product they are not placed in the drying system. In these cases the functional perspective was prioritized. Furthermore, it was chosen only to map interfaces on a sub-functional level in consideration to the readability of the product model.

4.3 Step 2. - Mapping Previous CTO Customizations

Here the configurable product range was defined as all customization options available in the sales catalogue, all though some of these actually require engineering activities (ETO customizations). Customer options were highlighted on the product model by using a different colour schemes for the functions where different types of options were highlighted with different colours. The customers' options that were highlighted included:

- *Functional add on* - were the customer choose to add a function to the standard configuration
- *Functional upgrades* - were the core functionality itself is part of the standard configuration, but it is possible for the customer to upgrade to a more advanced version e.g. the press comes with an antistatic functions, but is possible for the customer to upgrade the functionality to a more active solution if he wants work with certain web-materials.
- *Functional add on/upgrades that affect the layout of the product* - Where a functional upgrade or option changes the general layout of the product/module, requires altering of the standard configuration, by adding or removing functionalities. E.g. if the customer chooses to upgrade the unwind function from a standard to a OEM version this requires altering of the standard Unwind/Infeed module by removing all unwind related functionalities, and moving certain functionalities from the Unwind base to the Infeed base.

Furthermore, it was chosen to highlight the functions that are dependent on options for other functionalities e.g. the placement of idler rollers depends on the print technology chosen on the flex-print module. Finally, it was chosen to highlight all OEM functionalities, as it was found that it is relevant to know the functional dependency on suppliers.

Step 1 and 2 was conducted in iterations - with a first draft and then updated with input from different subject matter experts.

4.4 Step 3. - Mapping Previous ETO Customizations

ETO customizations were in this case defined as the customizations not available in the sales catalogue. The customization was identified and then mapped to the implicated functionality with input from the engineering department.

- What functionality was affected and on what level e.g. high level modules, lower level modules or specific components?
- What interfaces were affected?
- How many times was each customization sold?

The mapping was done by listing up the customizations and drawing lines pointing to the affected functionalities.

4.5 Step 4. - Mapping Predicted Customizations

A few predicted customizations were mapped on the implicated functionality in a similar way as for the ETO customizations.

4.6 Step 5. - Identifying Product Module Improvement Potential

To identify the product modules improvement potential a workshop was conducted with members from the new product platform development project. The product model (Figure 4), developed based on the previous steps, was printed in large scale version and used as a foundation to discuss module improvement potential for the entire product family.

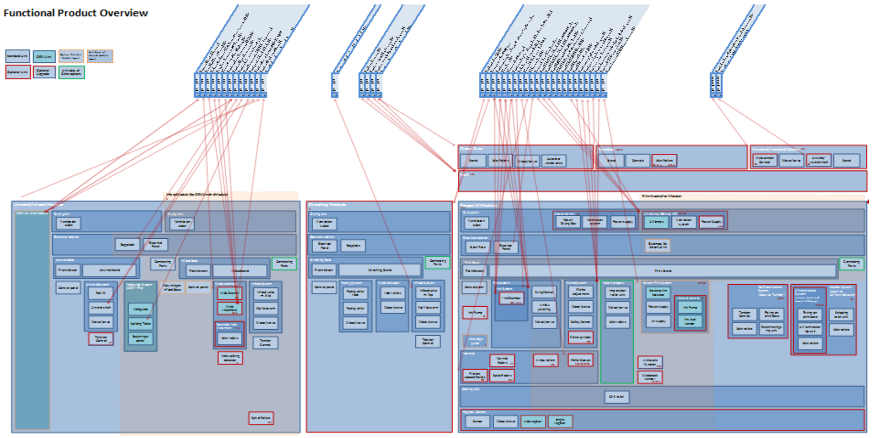

Figure 4. A part of Nilpeters Functional Model with mapped CTO and ETO customizations (figure included for illustrative purpose only)

As the project is in progress, some module improvements have already been identified and considered in the new design of the product family. Nevertheless, during the product module walkthrough it was possible to identify both new improvements potential as well as confirming already identified improvement potential, by highlighting specific types of sub-functions on the product model, as mentioned below. The different types of modules improvements potential that was identified on the product model included:

- Identified sub-functions that has been considered as basic functionality, but have been affected by ETO customization. Here it was discussed that these sub-functions should be separated from the rest of the basis functionality i.e. product modules should be re-defined with a clear distinction between Flex Modules and Basis Modules e.g. on the Unwind module where different types of unwind shafts have been integrated as ETO customizations, by separating the unwind shaft from the Unwind module, these customizations could be handled as CTO customizations.
- Identified sub-functions where the same ETO customizations was applied many times. Here it was discussed that the customization should be included in the configurable product range. One example of this was on the Foil Unwind/Rewind module, were a customization on the unwind shaft was applied in 40% of sold modules.
- Identified sub-functions where a high variety of different original equipment manufacturers (OEM) solutions have been integrated. Here it was discussed that interfaces can be improved to accommodate a high number of OEM variants. An example of this is the Web-inspection solution, where a high number of specialised OEM solutions are available dependent on the specific customers' requirements and the interface therefore have to be flexible.

5 DISCUSSION

From the Nilpeter case it becomes clear that including a post perspective to customization needs, by creating an overview of actually conducted customizations can be useful when improving configurability. The stakeholders in the study were able to identify both new improvement potential and to confirm already considered improvements with the created overview. In an evaluation workshop, it was discussed if the model actually contributes to the redesign and improvement process, as the project team had already identified many of the improvement areas, however it was stated that the complete overview and a more consistent approach is valuable both in terms of making sure all improvement areas are identified and considered, as well for argumentation towards management.

In the use of the approach however the distinction between ETO and CTO customizations turned out to be less useful than a distinction between customizations the company have defined on their sales catalogue and completely new customizations. It might therefore be more suitable for companies to use an individually defined distinction between customizations for step 2 and 3 in the approach e.g. new- vs. reused customizations, standard- vs. non-standard customization, fast track- vs. slow track customizations. That been said, to support the aim of improving product configurability, it would be valuable to highlight ETO vs. CTO customizations in parallel.

The Nilpeter stakeholders discussed the fact that the same ETO customizations were reused between customers, but also that same ETO customizations had been handled individually. This indicates lacking overview of previously conducted customizations why an improved overview of the customizations could have a purpose outside the redesign process - in an operational setting to support increased reuse across customization projects.

With the aim of *supporting ETO companies by improving their product configurability without compromising the flexibility to make customized solutions* in mind, the proposed approach helps to highlight functional commonality - the stable core - and optional functionality across product customizations. With this overview in place it is possible to optimize and standardize in a way that supports choices between option functionality and standardize what is stable. In doing so, product configurability can be improved without limiting the part the solution space that creates value to the customer in terms of customization requirements, and therefore with compromising the flexibility to make customized solutions.

6 CONCLUSION

ETO companies increasingly have to become more efficient when delivering highly customized products. One way to achieve this goal is for these kinds of companies to adapt some of the main concepts of mass customization, which usually involves increasing modularity in their product range. However, for many ETO companies limiting their solution space in a way that affect the customers' customization requirements is not feasible.

This study tries to address this challenge by identifying improvements in the products family modular structure without compromising the required flexibility to make customized solutions, by taking post perspective view on the customization requirements. To identify these improvement areas a five-step approach is proposed. The first step is concerned with making a product model for the product family in focus. The second and the third steps are where the both previous CTO and ETO customization that are mapped to the product model. The fourth step is where future customization requirements are identified. Finally, the fifth step is concerned with identifying product module improvement potential. By going through the individual steps of the proposed approach ETO companies are able to get a visual overview of the product family and the customizations both in terms of CTO and ETO. In addition, information regarding how often the customization have been sold and how ETO solutions impact specific interfaces, modules and product structures. This gives ETO companies a foundation to evaluate whether the right modular setup is being used in the company or what improvements should be done to identify the optimal balance between CTO and ETO solutions. As shown in this study, taking the post perspective on the customization requirements in ETO companies can give very valuable information regarding the how to improve the modular setup of a product family. The approach proposed in this research was tested in a development project in an ETO company, where it gave valuable input for the overall project success where both already identified improvement areas where confirmed along with identification of new improvement areas.

The approach presented in the study has only been tested in one ETO company. Therefore, further testing in different environmental settings is needed to improve the generalizability. Further studies will also include more investigation of the impact when ETO solutions are generated – that is what changes are required on the actual module and interfaces. Finally, it will be analysed in more details what is the overall impact from changing functions on different levels of the product family in focus.

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ACKNOWLEDGEMENTS

The authors would like to express their gratitude to Nilpeter A/S for their contribution to this research.