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A system level product configurator for engineer-to-order supply chains

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ABSTRACT

Supply chains in construction, infrastructure building, ship building, factory design and conveyor systems are operating in an engineer-to-order type of environment. Companies in these project-based businesses have special requirements for product configuration. Products have configuration dependencies with each other and there are system level configuration dependencies between several products. Incomplete product configuration items that are subject to change or require engineering work prior to production can occur. This paper introduces the requirements for system level configuration and proposes a prototype solution for ship projects and engine-room related supply chains.

1. Introduction

The need for reconfigurable products and processes originates from increasing customer demand for variety. One widely used strategy has been developing a product platform from common components, modules, or from parts forming a core technology. Product configurators are computer tools to manage the validity of offered product structures and support the translating of customer requirements into physical building blocks.

The need for configuration management in engineer-to-order type of businesses is similar. In engineering related products, the focus is more on the methods of analysing or designing new products in such a way that it would be possible to reuse the product components and apply modifications with low cost and reduced time. Therefore, a typical objective of an engineering process is about reusing components and existing design structures as much as possible. One of the key challenges of engineer-to-order (ETO) type of production is that designs and bills of materials are not complete and evolve over time. This feature may be referred to as “white spots”, which are incomplete product configuration items that are subject to change or require engineering work prior to production. These types of incomplete product configurations are typical of project-based businesses and engineer-to-order types of companies. The application domain area is quite generic. The challenge can be seen in many areas, such as construction, civil engineering, factory design, conveyor systems, and airplane interior design. The research problem of this paper is to study how “white spots” and engineer-to-order can be approached in system-level configuration.

The use of product platforms is very wide for managing configuration uncertainty [1,2]. A product platform is a set of common components, modules or parts, from which a stream of derivative products can be created. Product platform design requires the selection of shared parts and assessment of potential sacrifices in individual product performance that result from parts sharing. Examples of platform application are in developing automotives, consumer electronics, computers, aircraft, and many other products, ranging from very simple to complex ones, where there are different ways to create a product family [3].

One case is in the use of an integral platform. This is a single, major part of the product family that will be shared by all the products in the family. Given that platform, a development design team then adds an individually designed portion to the product to create a finished variant design. Platform-based designs can result in economies of scale from producing mass production of the same modules, as well as lower design costs from not having to redesign similar subsystems, and many other advantages arise from the sharing of modules, which will be listed later on in the following paragraphs.

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In supporting platform strategy, research from the management and design literature shows the various advantages as well as disadvantages of designing products based on platforms. Gupta and Souder [4] suggest that thinking in terms of platforms is one of the key drivers behind the success of short cycle times. Ulrich and Eppinger [5] point out that a platform can cost 2–10 times more than the development of a single product due to increased development complexity.

Since the product platform is mostly applied to mass customized products to meet efficiency and responsiveness by offering standard parts to increase reusability, then its effectiveness with more highly customized products is questionable, because whenever the customization degree is increased, then platform benefit is decreased [6,7]. A platform should be selected for use in product families through the use of conjoint analysis [8]. Krishnan et al. [9] demonstrate a way to obtain an optimal platform-based family based on a network model for products that can be measured along a single performance index that may increase with time. Simpson et al. [10] also illustrate a model to design a product family based on a scalable platform, one that can be sized to provide the necessary variants. Nelson et al. [11] have also revealed a formulation for the problem of designing an optimal set of platform-based products, and an approach to select one of those designs from the Pareto optimal set. Fujita et al. [1] also present another optimization approach to designing modular product families from catalogs of existing modules using an integer-programing formulation and simulated annealing as a solving method. Platform design poses many challenges, including coordinating design efforts to increase commonality, while retaining optimal distinctiveness and minimizing the potential over-design of variants [12].

Considering the mentioned platform challenges and requirements, it is not surprising to find that platform applications of engineering-to-order are not easy to implement. Design, tendering and contract management are three core capabilities in ETO companies [14]. Many failures to implement ETO are caused by demand uncertainty, high level of customer involvement during product design, and product customization such that production control becomes more difficult [15]. Enterprise level information systems do not support engineer-to-order processes and project based businesses very well. One of the problems is that many systems need material demand information in advance for production and purchase planning. It is difficult to support the using of product features instead of material numbers or incomplete configurations in master production scheduling. Despite the problems, there are still many opportunities to apply standardization or system level configuration strategies in the ETO context. A good motivation is that engineering projects face strict deadlines and many contractors are working on several projects simultaneously.

This article discusses system level configuration strategies by firstly reviewing literature related to the problem. Then the requirements for system level configurator software are presented in the context of ship building projects and more specifically in engine room related configurations. Prototype software is presented and some key differences with traditional product configurators are highlighted. Finally, in the conclusions section the system level configurator approach is discussed from a general point of view.

2. Literature

The requirements for information system targeted for engineer-to-order are different compared to make-to-order operations [16]. The need for engineer-to-order configurators has been identified in several industries. Duchi et al. [17] see in their case study analysis a trend for ETO companies to apply mass customization principles. Willner et al. [18] analyze the requirements for successful ETO configurator adaptation. According to this study, product and process configurators need to be tailored and adjusted to suit the ETO requirements. Quotation and pricing process in the ETO environment have been developed by Brunoe and Nielsen [19]. Mass customization principles to reduce the cost of variety can be applied to ETO as well. Jensen et al. [20] examined three cases of engineering-related construction products. They propose a products-in-products concept by introducing higher architectural level modular structures. Parameterized products may be then used in the next product level [21]. One possibility, proposed by Haug et al. [22], is to reduce the variability. However, this may require large changes in the offering. In this section we analyze some approaches to ETO features: (1) the transition from customer requirements to technical parameters, (2) changes in parameters of configuration, (3) functional modularization, and (4) the system level issue of dependencies between configurable products.

2.1. Customer requirements to technical parameters

For product configuration in an engineer-to-order environment an important part is to translate customer requirements into technical parameters and further to physical building blocks. This approach is also used in the design process, where product family can be presented from the functional, physical, and technical perspectives [23,24]. The functional 'view' deals with customer grouping, the technical view with the design of modules through the coupling of design parameters regardless of their physical realization, and finally the physical view deals with the physical realization of the modules based on past design and process capability trade-offs. The three views are independent and issues relating to different business functions are dealt with in different views, and mapping between the viewpoints is utilized to maintain the product family when initiating new product design [25].

Fig. 1 shows the two-way relationship between functional requirements (FR) and technical requirements (TR). For instance, if the functional requirement is providing the room temperature, then the technical requirement could be how much steam pressure and mass are required. However, it is possible, for instance, that steam pressure and mass are inter-related with each other. Indeed, in meeting customer satisfaction and efficiency, it is also possible to adjust FR according to optimal TR by still meeting the customer requirement. The same case is also applied to physical requirements (PR). In considering space limitation, the next section models the linking of TR and PR in such a way that they show the interdependency among these requirements. In some cases, they might overlap with each other so that they represent concurrent engineering meeting efficiency and customer expectation.

The process of translating requirements into actual products is time-consuming and the actual project execution is taking place

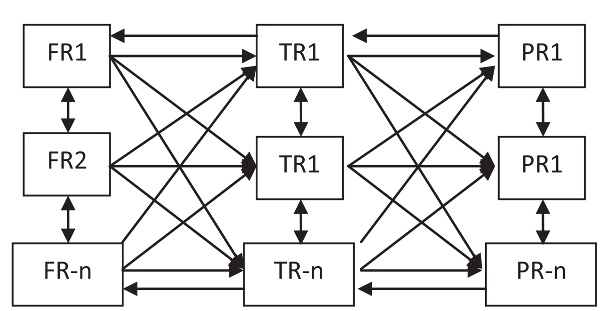

Fig. 1. Functional to technical requirement mapping.