Advanced Engineering Informatics 38 (2018) 277–290

Contents lists available at ScienceDirect

Advanced Engineering Informatics

journal homepage: www.elsevier.com/locate/aei

Full length article

Modeling of transdisciplinary engineering assets using the design platform approach for improved customization ability

Samuel André*, Fredrik Elgh

Jönköping University, School of Engineering, Department of Product Development, Jönköping, Sweden

ARTICLE INFO

Keywords:
Product development
Engineering design
Quotation
Supplier
Engineer-to-order
Product platform

ABSTRACT

Original equipment suppliers (OES) that develop unique products are continuously faced with changing requirements during both the quotation and product development processes. This challenge is a different reality from companies that develop off-the-shelf products for the end consumer, which use fixed specifications and where product platforms have been a strong enabler for efficient mass customization. However, product platforms cannot adequately support companies working as OES. The reason is that a high level of customization is required which means that interfaces cannot be standardized, the performance is not negotiable, requirements are not initially fixed, and the specific system interacts with, is affected by, or affects other systems that are simultaneously developed in a transdisciplinary environment. The design platform (DP) approach provides a coherent environment for heterogeneous and transdisciplinary design resources to be used in product development by supporting both designing and off-the-shelf solutions. This research describes the introduction, application and further development of the DP approach at an automotive supplier to support the development of customized solutions when traditional modularity or platform scalability do not suffice. A computer tool called Design Platform Manager has been developed to support the creation and visualization of the DP. The support tool has a connection to a product data management database to link the platform model to the various kinds of engineering assets needed or intended to support variant creation. Finally, the support tool was evaluated by the case company representatives showing promising results.

1. Introduction

The engineer-to-order (ETO) industry differs from other sectors in that the customer is often involved in the quotation stages [1]. This situation contrasts with companies developing off-the-shelf products for the end consumer market and where the level of customization (i.e., variant selection) is low. Variant selection businesses often apply a practical approach to identifying and transferring customer needs into fixed specifications that guide product development (PD). The sales and distribution phase is in this case located after the product is developed and produced. However, original equipment suppliers (OES) commonly developing unique products to be integrated into the product of the customer, cannot work in that fashion, since requirements are often directly determined by the client, and hence the sale phase occurs before the products have been developed. It is not uncommon for products to be developed in cooperation with the customer, which is often an original equipment manufacturer (OEM) or another supplier which is part of a larger supply chain, and for projects to run for several years. During the cooperative development phase, requirements are often added, removed or changed. This has been investigated in the automotive industry by Almefelt et al. [2] and is said to be a natural process since knowledge is gained and prerequisites change throughout the project. These changes often stem from the complex interplay between the various disciplines and suppliers involved, who use the same interfaces as inputs for their development processes. When designs require changes to the interfaces, other suppliers and thus their designs are affected. The situation consequently requires changes in affected subsystems or changes to the requirements themselves. The increasing complexity of products where mechanics, electronics, and the embedding of code in the products; where products must be developed in cooperation between design, analysis and be evaluated regarding producibility, ultimately puts high demands on companies' abilities to work in a transdisciplinary fashion. As disciplines within companies, such as design, purchase, analysis, aftermarket etc. are centralized to specific departments it becomes more crucial and at the same time more complex to receive an overview of the company assets which have the possibility to be reused in ranges of products and to have a common object to be used for communication.

* Corresponding author.
E-mail addresses: samuel.andre@ju.se (S. André), fredrik.elgh@ju.se (F. Elgh).

https://doi.org/10.1016/j.aei.2018.07.006
Received 5 October 2017; Received in revised form 8 June 2018; Accepted 29 July 2018
1474-0346/

Product platform strategies, as enablers for customization, have been widely accepted in the industry to serve a wide variety of products while maintaining business efficiency. Early descriptions of product platforms focused on efficiently providing the market with a product variety while also keeping internal variation low and in that way reach a higher level of standardization of the production [3]. Platforms have also served to reach different customer segments efficiently and simultaneously by featuring commonality in product components and interfaces. Recent research has focused on platforms using a more abstract definition; these platforms aim to reuse more of the skills and knowledge (i.e., assets) created in a given company to reach higher efficiency during development. From that perspective, Johannesson [4] has asked whether businesses can afford not to adopt a platform approach. However, most of the existing research on product platforms is focusing on product developing firms with the end consumer as the customer in focus. These approaches tend to require a focused development of the platform and late customer involvement, which in turn requires a forecast regarding which future variants are to be derived from the product platform. There are limitations to developing such product platforms for OES since their business model forces them to develop unique solutions for each new project to satisfy the customer's specific requirements which essentially is their competitive edge. Changing requirements throughout the development process is also a factor that makes rigid product platform definitions hard or impossible to apply for the OES.

This article's goal is to investigate the possibility of applying, supporting and take advantage of a platform approach at an OES where traditional product platform definitions have been shown to be hard or impossible to implement. Therefore, this article, in detail, applies and realizes the design platform (DP) approach, described in [5]. The academic contribution consists of adding to the feasibility and validity of the DP for a type of company that traditionally has been unable to fully take advantage of product platforms. The study also builds upon existing research which has emphasized similar challenges for OES [6] and proposed methods to support their situation [7]. The industrial contribution consists of the application and support of the proposed approach to enable OES to engage in platform development to a greater degree, which has been pointed out as a crucial factor to stay competitive [4].

2. Related work and state of the art

Requirements management is a research field which deals with how requirements are elicited, analyzed and specified [8]. Since customization concerns the fulfilling of individual customer requirements, these two research fields are highly linked. There is a vast body of knowledge in the area of managing requirements and there exist many studies in the areas of consumer products [8] and configuration systems [9]. However, the prerequisites of customizing for an end consumer differ from those for an OEM, and past research has proposed different methods. OES are often required to stretch the boundary with each new PD project, which forces them to explore new ground regarding design and the way they carry out design. The dynamic and transdisciplinary nature of this environment often results in changes to or the addition of new requirements and the elimination of others [2]. Other reasons for changing requirements include incomplete capture, traceability issues, customer-driven changes, incorrect or ambiguous language, missing requirements and redundancy [10].

2.1. Customization in the OES industry

Research has previously focused largely on company and customer integration and collaboration [11], often involving a single business interface [12], which in many cases is an over-simplification of reality. OES are often part of a supply chain where other suppliers and an OEM act in between them and the end customer. This complexity introduces several interfaces and stakeholder interests that the company must manage. Holistic research in this area, taking all or several of these perspectives into consideration, remains scarce. Tuli and Shankar [11] describe lean in collaborative product development and review the existing literature on the supplier, OEM, and customer integration. One interface with the customer that is central to customization is the customer order decoupling point (CODP). The CODP is defined as the point in the flow of goods at which forecast-driven production and customer order-driven production are separated [13]. The CODP is often viewed as a point on a one-dimensional line that can be coupled to the level of customization [14]. Wikner and Rudberg [15], however, propose a two-dimensional categorization for companies in the product realization process, including both the engineering and production dimensions.

To gain efficiency when offering customized products, Vollmar and Gepp [16] study the introduction of standardization in the ETO oriented business. Standardization is however not a possible approach for all companies developing customized products due to the inability to standardize interfaces, that the performance is not negotiable, requirements are not fixed at the outset, and the specific system interacts with, is affected by, or affects other adjacent subsystems that are simultaneously developed by other actors. Design reuse has been coined an enabler for ETO companies to succeed in the process of designing customised products. Brière-Côté et al. [17] propose a support method to incorporate emerging solutions in a generic product structure as a way of increasing design reuse in ETO companies. They used functional, technological and physical levels of abstraction. Baxter [18] considered knowledge to be actionable information and problematized the fact that many previous design knowledge reuse systems exclusively focused on geometrical data, which is often not applicable in the early stages of development. Future reuse models need to contain problem-solving methods, solution generation strategies, design intent and project knowledge. Knowledge-based engineering (KBE) has been pointed out as an enabler for mass customisation to manage large ranges of variant designs as well as respond quickly to customer requirements. KBE, however, needs to be further researched to, for example, develop methodological support, improve transparency and efficiently source and reuse knowledge [19]. Stokes [20] presented a complete framework and a detailed methodology, called MOKA – methodology and software tools oriented to knowledge-based engineering applications, that aim to collect and formalize knowledge to create knowledge-based systems.

2.2. Enabling customization by platform models and methods

A product platform approach can be defined as the development and implementation of technology, components or subsystems that are shared across multiple products [21]. Product platforms have also been shown to prolong the average product life cycle, because of shared components and the flexibility of introducing newer components over time within that same architecture. The authors also state that product variants derived from a product platform, according to this definition, have both higher aggregate sales and aggregate gross profit margins over the product lifecycle compared to products which are not derived from a platform. A more abstract definition is given by Robertson and Ulrich [22]: "The collection of assets [i.e., components, processes, knowledge, people, and relationships] that are shared by a set of products". Other definitions found in research papers usually fit in between these two. Halman et al. [23] state that companies in the industry have not been keeping pace with research on platforms due to a lack of tools. The authors have also identified a disjointed view of platforms in the industry, which could be at least partly explained by the wide range of definitions that literature has proposed. One risk of using a product platform approach is the tradeoff between commonality and distinctiveness [22]. This trade-off has been subjected to optimization, as summarized by [24]. Another trade-off involves development efforts for the initial platform and the uncertainty regarding whether the right