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Achieving benefits with design reuse in manufacturing industry

Jarkko Pakkanen*, Petri Huhtala, Tero Juuti, Timo Lehtonen

Department of Mechanical Engineering and Industrial Systems, Tampere University of Technology, P.O. Box 589, FI-33101 Tampere, Finland

* Corresponding author. Tel.: +358-503433751. E-mail address: jarkko.pakkanen@tut.fi

Abstract

This paper is based on a research project for improving performance of companies in manufacturing industry in introducing new products. One section of the project relates to design reuse, and therefore this article presents a literature review to this theme. Goal of the paper is to present how design reuse can be defined and supported. Our results emphasize focusing on designing products so that reusable sections can be separated from varying sections because of customer specific needs. Five industrial cases discussed in the paper highlight also that operations, processes and IT support needs to be adapted with reusable designs.

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1. Introduction

Products are designed and produced to fulfil certain observed needs. These needs are changing because of several reasons such as different users, alternative ways to operate with products, limitations and social values. By taking these sources for difference into account, a variety of products is formed [1]. It has been summarized that product variety describes the range of products the company can offer within a certain period of time in response to market demand [2].

Variety is not a positive issue every time. Increase of product variety increases costs in product design, production, warehousing, sales and services. On the other hand, challenge of variety is wider than product variety only. Varying occurs during the life cycle of the product and it relates also to logistics and services before and after sales.

Product variants can be managed by designing new variants or by modifying existing variants according to new requirements and scaling existing products or their modules and components [1]. In the field of variety management, this paper focuses especially on design reuse in manufacturing industry. Reuse of existing elements in designing enables several benefits such as it can increase R&D efficiency and enable improving of operations because of increased repetitions and learning [3]. Design reuse is a broad term. The

aim of the paper is to present as an introduction what kind of principles and concepts exist in the context of design reuse and what kinds of practices support designing and using reusable product elements. Thus the paper includes two research questions (RQ's):

RQ1. How to define design reuse?

RQ2. How to support design reuse in manufacturing industry?

To answer these questions, we combine literature review with findings from industrial cases as the main research method in this qualitative study. First the literature is studied in Section 2. The goal is to clarify how design reuse is typically understood and categorized. The purpose is also to find out what kinds of issues are linked with design reuse. Therefore the literature review section contributes especially to RQ1. The review is made by using mainly Scopus (www.scopus.com) databases.

The paper aims also to contribute to research on design reuse by presenting good practices and challenges found from manufacturing industry and analyze these in regard to the findings from the literature review. In Section 3, five cases are briefly presented. In several cases, a company has found out that although the current way to operate is possible in its

business environment, the operations included in offering products to customer needs to be developed in order to stay competitive. The goal is to describe what kind of tactics have been applied and seen positive in enabling benefits with design reuse in cases. Finally, concluding remarks are given in Section 4.

2. Literature review on design reuse

This section includes review on design reuse. Benefits are studied first. After that, drawbacks and challenges are discussed. Categorizing design reuse to design by reuse and design for reuse is considered also. Then, product development tactics that contribute to design reuse are presented. Other views are presented after that. Finally, conclusions are presented about the studied literature including answer to RQ1.

2.1. Motivation and benefits with design reuse

In projecting manufacturing industry the whole engineering function can become a bottleneck in delivery projects of products [4]. Doing overtime work, hiring more personnel or negotiating longer delivery times to solve the effects of overload are not sustainable solutions and do not solve the cause of overload, but systematic design reuse is a better solution for improving productivity [4]. This means that increasing profitability can be challenging for manufacturing company if design reuse and commonality aspects in the product range of a company are not considered. Weak consideration of design reuse may cause challenges such as high cost of engineering and quality problems eventually in a final product because of delivery specific solutions.

Several benefits have been reported related to design reuse. Design reuse helps to reduce effort and risks, supports avoiding errors and uncertainties in development and in this way reduces developing costs and time, helps to familiarize production staff with the product design and helps customers to maintain familiar ways to use and maintain the product [5] [6]. These will lead to cost reductions, faster time to market, shortened testing and quality improvements.

It has been shown in modularization, product family and product platform context that it is possible to provide customer specific product variants while also getting benefits with design reuse [7][8][9]. Design reuse by utilising product families and product platforms enables offering variety without radical increase of costs [10]. These aspects related to design reuse are discussed more in Section 2.4.

2.2. Drawbacks and challenges with design reuse

Despite several benefits, also drawbacks have been discussed. Design reuse might prevent innovativeness and lead to design fixation [11]. Categorization of factors which are often preventing design reuse to five groups have been presented: engineering, cognitive, motivational, organizational and environmental factors [5]. Examples to these groups are summarised in the following based on [5]: Engineering aspects include for example obscure design rationale. Cognitive factors consider that there is a risk that

designers have bias towards identifying unfavorable aspects of another's design. Motivational factors highlighted that early phases of designing optimizes typically material costs in the cases which [5] studied. Organizational factors focus often on that the product elements include case specific sections instead of being standard designs. Another important organizational factor is also to understand differences in authorities between project managers and functional managers. From project schedule viewpoint, time is a major driver in preventing designing reusable elements. Environmental factors consist typically from aspects arising from clients and their values.

2.3. Design by reuse and design for reuse

Basically, the main prerequisite in design reuse is to make designs reusable and then store these reusable elements so that they can be found [12]. Design reuse can be categorized to design for reuse and design by reuse. Design for reuse includes identification and extraction of possible reusable knowledge fragments and enhancement of their knowledge content whereas design by reuse means using of existing concepts in new design situations [13]. Design for reuse enables reuse library that includes reusable knowledge and requires identification, rationalization, extraction and storing of reusable fragments of knowledge of a specific design domain based on knowledge concerning past designs or artefacts [13]. In other words, design for reuse is enabler of design by reuse.

From engineering perspective designing a reusable element requires more time than one of a kind element, because designer has to make sure that the element can be used also in other product variants and not in a single case only. This kind of designing and reuse is discussed more in the next section.

2.4. Design reuse highlighting different product development tactics

From design for reuse perspective, this paper emphasizes product designing that enables and supports designing a reusable structure for a technical system and its variants. According to literature review summarized in Table 1, modularization, product platform development and product family development are the main approaches that support this objective, but also parametrization, standardization, product configuration and ontologies are discussed. In the following, the main aspects of these are presented.

Parametric design is one way to support reuse by increasing commonality between variants [1][14]. CAD and CAE approaches are discussed from the viewpoint of component reuse and parametric design based on geometric models. Parameters embed design rules that are reused [12].

Standardization is enabler of reuse when the product or its elements do not need to consider variability [1][15][16]. Standardisation relates to product elements and interfaces between product elements [17].

Modularization is often presented product development strategy for increasing reuse in businesses in which different product variants are needed in order to fulfil customer needs. Modularization includes the defining of a modular

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