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Customizability analysis in design for mass customization

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Abstract

Product customization has been recognized as an effective means to implement mass customization. This paper focuses on the customizability issue of design, that is, to evaluate the cost effectiveness of a design to be customized in order to meet individual customer needs. Three aspects of customizability are identified, namely, (1) design customizability: the intrinsic nature of product by design, which renders customization to be easy or deficient for either customers or the manufacturer, (2) process customizability: the economic latitude of (production) process variations due to product customization, and (3) the value of customization as perceived by the customers. While design customizability is measured based on the information content metric, the evaluation of process customizability follows the general gist of process capability indices. Conjoint analysis is employed to explore customer preference for multiple product features in terms of utility. Customizability analysis thus exhibits a maximization of customer-perceived value while exploiting the potential of design to be customized by achieving optimal design and process customizability indices.

Keywords: Mass customization; Product design; Customizability; Product and process platforms; Performance measure; Information content; Process capability

1. Introduction

Mass customization [1] aims at best satisfying individual customer needs with near mass product efficiency [2]. The rationality of developing product and process platforms as a means to achieve product variety while maintaining economy of scale has been well recognized in both academia and industry alike [3–6]. The fundamental concern regarding product and process platforms manifests itself through the fact that the company must optimize external variety versus internal complexity resulting from product differentiation [7]. It thus becomes imperative to assess the added value of customization with respect to the impact of customization on the loss of scale economy in design and production. This paper focuses on such a customizability issue. Specifically dealt with is the issue of measuring customizability inherent in the product and process platforms with economic consideration. The goal is to present design and process engineers with insights into product customization and its produceability.

Some researchers have strived to develop design metrics for tradeoff analysis in customization. Martin and Ishii [8,9] develop quantitative tools to determine customer preference for variety and to estimate manufacturing costs of providing variety. Gonzalez-Zugasti et al. [10] propose a quantitative measure of the value of product families to the company and apply it to select the best design from a set of possible alternatives. Simpson et al. [11] employ a market segmentation grid to identify suitable scaling factors based on which a common product platform can be customized to satisfy a range of performance requirements. They characterize the amount of variety within the product family based on the variation of scaling factors. Conner et al. [12] apply robust design principles to address product family tradeoffs using the commonality and performance indices developed by Simpson [13]. Blackenfelt [14] introduces the quality loss function to facilitate the optimization of the degree of variety within a product platform.

Collier establishes the basis of commonality indices for measuring the degree of commonality underlying a product structure in the form of a bill-of-materials (BOM) [15]. Siddique [16] proposes measures of

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component commonality and connection commonality based on the analysis of the modular structures of automotive underbodies. Jiao and Tseng extend Wacker and Trelevan's [18] individual indices of component commonality and process commonality to coherent single indices and map out managerial implications regarding tradeoffs between component commonality and process commonality [17]. Kota et al. introduce a product line commonality index to assist product family design [19]. McAdams et al. [20,21] study the issue of similarity measure from a functional design perspective. Jiao and Tseng [22] investigate the fundamental concerns of modularity and commonality as well as the relationships in between. Martin and Ishii [23] propose the generational variety and coupling indices to characterize the impact of market requirements on changes of product platforms over time. Ulrich [24] studies the modularity issue in the context of product architectures.

On the empirical side, existing research on examining the cost consequence of customization and how it affects operational performance has been limited and inconclusive. Ho and Tang [25] discuss the modeling and analysis of value and cost tradeoffs from marketing and economics perspectives. Kekre and Srinivasan [26] investigate the market benefits and cost disadvantages of broader product lines. Banker et al. [27] observe that product complexity has a significant impact on the cost of supervision, control and tool maintenance as well as congestion and quality. MacDuffy et al. [28] suggest that the impact of product variety on performance varies, and is generally much less than the conventional manufacturing wisdom predicts. Herrmann and Chincholkar [29] propose a design-for-production method for designers to evaluate product designs by comparing their manufacturing requirements with an available production capacity and an estimated cycle time. Kusiak and He suggest design-for-agility rules to make product designs robust against the changes in production schedules [30].

While decision making about customizability often involves tradeoffs among the marketing, design and production departments, existing approaches seldom tackle all these aspects within a coherent and integrated framework [31]. Given the multidimensional nature of product and process platforms in build/configure-to-order production, it rises in importance to achieve a synergy of customer needs, products and processes throughout customizability analysis [32].

Towards this end, this paper identifies two sources of customizability, namely, design changes and process variations. Accordingly, two indices are developed for measuring design customizability and process customizability, respectively. The rationale behind a customizability index is to measure the cost-effectiveness of a customization feature in terms of the customer-perceived value and the associated flexibility in product and process platforms. The utility theory is applied to model the customer-perceived value of each individual product feature. Conjoint analysis is employed to develop a joint utility of multiple features of a specific customer order. Therefore, customizability analysis can be formulated as either a design evaluation or design optimization problem. The objective is to maximize customer-perceived value of customization while achieving optimal design and process customizability indices.

2. Fundamental issues of customization

Considering the market benefits of customization and the costs of providing variety, it is reasonable to fulfill customization within a company's capabilities in design and production. In practice, this is often achieved by developing product and process platforms [3]. A product platform performs as a base product from which product families can variegate designs to satisfy individual customer requirements. Corresponding to a product platform, production processes can be organized as a process platform in the form of a bill-of-operations (BOO) (e.g. standard routings), thus facilitating build/configure-to-order production for given customer orders [7].

As shown in Fig. 1, the customization process can be illustrated along the entire spectrum of product realization according to the domain framework [33]. A product platform is characterized by a set of design parameters (noted as D), which suppose to meet certain customer needs characterized by a set of functional requirements (noted as F). The corresponding process platform can be characterized by a set of process variables (noted as P). Assume Δ implies certain changes from the platforms in terms of F, D

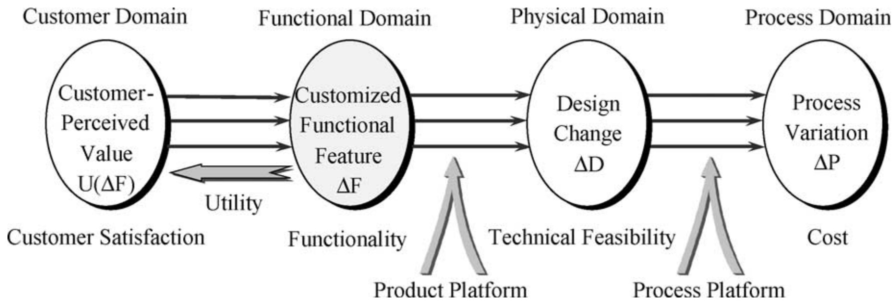

Fig. 1. Multiple views of customization.