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Design for mass customization: Product variety vs. process variety

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ABSTRACT

Mass customization (MC) has become a reality and cannot be neglected as one of the leading strategies in satisfying customers and assuring companies survival in today's markets. MC can be offered either via product variability or process variability. How this is achieved using both approaches is the main core of this article. After an overview of related works, the influence of design variability on the overall generated value of the product is studied via a metric approach. A case study of the shoe industry is also presented, based on the experience of a European project called Dorothy.

1. Introduction

In order to survive in today's competitive economy, and to satisfy more demanding customers, companies are implementing mass customization (MC) which is defined as producing personalized products at a price similar to that of mass production (MP) [1]. MC can be offered via product and process variety. Product variety is defined as the diversity of products that a production system provides to the marketplace [2]. Process variety is the diversity and complexity in the processes due to product variety and process alternatives for each product variant [3]. Designing products for MC remains a main challenge for a company, thus we propose a metric based approach that is able to evaluate both product and process variety based on their impact on the perceived value for the customer, since in MC the whole value network focuses on the customer who is its main driver. Product variety and process variety are presented in Sections 2 and 3, respectively, and then we define value in Section 4. We study the influence of both product and process variety on customer perceived value in Section 5 and in Section 6, the whole method using the value metric is described. In Section 7 a case study in the shoemaking industry is set out and in Section 8, discussions are presented.

2. Product variety

The product is the centre of a value network. The goal of collaborating partners is to deliver to the customer a product generating value both for him/her and different partners in the network. The entire value network starts with a "good" design. But, in the case of MC, the design of the product embeds defining customization possibilities. And to keep the cost of product close to that of mass production, customization is assured via modularity, and commonality in product design. They both allow a differentiation of products while minimizing the internal complexity, cost, and time resulting from such differentiation by shortening the delivery lead times and enjoying economies of scope [2]. Moreover, approaches such as product family, product platform and product architecture have been recognized as effective means of accommodating increasing product variety while still achieving economies of scale [4,5]. Nevertheless, it remains a difficult task to design a product intended to be mass customized, therefore Tseng et al. [6] proposed a design approach for MC (DFMC). The core of their approach is to develop a MC oriented product family architecture (PFA) with a meta level design process integration as a unified product creation and delivery process model.

A constructional-theory-based method formed by six steps for mass customized products was proposed by Hernandez et al. [7]. The first step is to define the space of customization which is the set of all combinations of values of product specifications that an enterprise is willing to satisfy. The second one is to formulate an objective, which can often be the minimization of cost. The third step is to identify modes for managing product variety such as adjustable controls, modular combinations and dimensional customization that are used to customize the product. In the fourth step the number of hierarchy levels is determined and the modes for managing product variety are allocated to these levels. The fifth step consists of formulating a multi-stage optimization problem, while the sixth and final step is to solve this problem. Some of the advantages of this method are cost-effectiveness, its applicability to any distribution of demand, its suitability for small or large variety in product specifications, and adaptability of the product line. Its limitation is the need to formulate an objective function that includes all the various costs involved in a product design.

3. Process variety

Process platform planning is as necessary as product platform planning, since the customization of a product leads to exponen-

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tially increased variation in the production systems from machines, tools, labour, etc. [8]. In addition the major costs are endured during the production phase, and the quality and lead time of a product are determined at the production phase. Therefore it remains necessary to manage process variety as shown by Jiao et al. [9].

A detailed state-of-the-art regarding the many research works done on designing process platforms is presented by Jiao and Simpson [10]. Of the recent work done in this field is the work of Jiao et al. [8] who use the generic representation because of its capability of effectively describing a large amount of variants with minimal data redundancy [11]. They merge the Generic Product Structure (GPdS) and the Generic Process Structure (GPcS) into a Generic Product and Process Structure (GPPS). Qiao et al. [12] presented three approaches to deal with the challenges of implementing a mass customization manufacturing system. The first being a generalized production line platform to support reconfiguration. It includes movable and reconfigurable workbenches, and flexible transportation equipment. This production line saves time and cost since only a small amount of repositioning of the workbenches is needed to change the line. The second suggested approach is the Production line modularization which is grouping the production line into functional modules that can be aligned and combined to produce the customized product. XML based information integration for mass customization data driven and reconfiguration is their third suggested approach. Finally they present an integrated design and simulation system that is used to rapidly change and create system designs based on the varying manufacturing requirements, in order to satisfy the customized product order. It also verifies these designs through simulation. A system controller, a conceptual workshop and simulation, and a shop data information model are the three subsystems constituting the simulation system.

Tian et al. [13] argue that in the case of MC, the parameterised method may be used to plan the processes of the products, subassemblies and parts since there are great similarities between the products for MC and their components. In the parameterised process planning, a set of parametric variables is linked to a process based on the resemblance of products or components, and then a process is automatically generated by inputting the values of the corresponding variables.

Thus much work exists on designing for MC and controlling process variety. Nevertheless, most of these concentrated on cost and delays, while few considered customer satisfaction as a main factor for deciding on product/process variety. The customer remains the driver of the whole network and the purpose of this network is to generate value. Thus any decision should be made based on its influence on the generated value. In the following section we describe customer perceived value.

4. Value

A product generates Value. Value, as defined by the standard AFNOR FNX50-151 [14], is the judgment carried by the user on the basis of his/her expectations and motivation. Specifically it is a measure that increases when the satisfaction of the user increases or when the needed spending for the product decreases. It has three criteria which are cost, quality, and delay.

As shown in Fig. 1, value has different beneficiary parties [16]. Those are all partners in the value network such as the customer, suppliers, enterprise, stakeholders, etc. To simplify the problem, we consider only the value for the enterprise and the customer.

We consider that there are two types of value for the enterprise, the financial value and the company's image, whereas for the customer, it is divided into financial value and value of service. These four values are based on the previously defined criteria, cost, delay and quality. Only the enterprise financial value is objective while the others are subjective.

Customer value is context dependent [17] and is highly subjective and is influenced by several factors, such as the

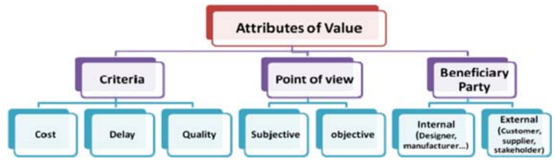

Fig. 1. Attributes of value [15].

quality of the product, its price, the services provided, the customization offer, and the delivery lead time. Nevertheless defining what level of customization really satisfies the customer is hard to achieve. Providing a high product variety and large customization options might receive an unfavourable response from the customer. Lehman [18] calls high product variety levels, "too much of a good thing". Therefore the impact of product variety on customer satisfaction should be taken into consideration.

Moreover, the price of a product and its delivery lead time highly impact customer value as well, therefore process variety achieved via process platform is also an important factor for successfully implementing MC.

More the customer is satisfied thus higher is its perceived value, then more is his/her will to buy, leading to increased sales and then to increased generated financial value for the partners of the network.

In the case of MC, value for the customer is affected by the price of the product, its quality, and the customization experience. And since value is difficult to measure, we use six main performance indicators to evaluate it. These are:

1. Quality/Price (Q/P). The quality is different from one product type to another. In the case of a shoe, it is impacted by three main factors, aesthetics, fit and functionality [19].
2. Customization process indicator (CPI) = total time for customization process/max allowed time for customization process. A customer might tolerate spending one week for customizing his/her house but not his/her shoe. The max allowed time for customization process should be derived from a market analysis.
3. Abortion rate (AR) = number of aborted interaction processes/number of log-ins [20]. This indicator allows us to detect if the customer does not like the interface of an online product customisation system. A customer aborts the customization process before payment for three main reasons, he/she did not really want to buy in the first place but was just checking, he/she was not satisfied with the final customized product or its price, or he/she finds the interface unfriendly.
4. Used variety indicator

   $$(\mathrm{UVI}) = \sum_{i-1}^{n} W_i \times V_i/\mathrm{NV}$$

   where W_i is the average weight of importance of variant i for customers; V_i is a proposed variant $1 \leq i \leq n$; $i \in Z$; NV is the total number of all possible variants.

Piller [21] identified the used variety metric UVM = (number of perceived variants)/(number of all possible variants), we add to this indicator the average weight of importance of a variant for the customers. For example, for a sport shoe variants for fitting and comfort are of greater importance than those of aesthetics. While for a woman's evening shoe the variants of aesthetic are more important than those of the fitting. Also a weight can be negative if the variant reduces customer satisfaction.

5. Quality of order reception (QOR) = (number of orders delivered on time ∩ Number of orders with zero defected products)/(total number of orders).
6. Order delay time (ODT) = the time elapsed between order placement time and order received time.