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Product concept and prototype flexibility in manufacturing: Implications for customer satisfaction

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Abstract

A rapidly changing competitive landscape and dynamic customer expectations require manufacturing firms to seek flexibility in product development. Product concept flexibility (i.e., developing design options) and product prototype flexibility (i.e., creating working models) emerge as effective ways to quickly develop new products that meet competitive challenges and satisfy customer demands. Product concept flexibility enables firms to fully explore various product definitions and ideas. Product prototype flexibility allows firms to gather customers' feedback and investigate design feasibility. Using data from 273 manufacturing firms, this research tests mediating, moderating, and additive models that relate product concept flexibility, product prototype flexibility, and customer satisfaction. The results indicate that firms with high product concept flexibility are more likely to benefit from prototype flexibility than firms with low product concept flexibility, and that product concept flexibility and product prototype flexibility act independently and additively to predict customer satisfaction.

Keywords: (P) Manufacturing; Product development flexibility; Empirical research

1. Introduction

Firms face an increasingly uncertain environment as changes in global competition, customer expectations, and technology accelerate (Sethi et al., 2003; Wang, 2004; Buganza and Verganti, 2006; Huang et al., 2007). Researchers and managers contend that flexibility is a strategic imperative that enables firms to cope with uncertainty (Iansiti and MacCormack, 1997; Sethi and Sethi, 1990). Flexibility is the firm's ability to meet an increasing variety of customer demands without excessive costs, time, organizational disruptions, or performance losses (Thomke, 1997; Upton, 1995).

Many firms focus on manufacturing and strategic flexibilities, but there is a compelling need for flexibility in product development. During product development, customer requirements and technologies can change radically (Bhattacharya et al., 1998; Thomke and Reinertsen, 1998; MacCormack et al., 2001; Molokken-Ostyold and Jorgensen, 2005). Thus, managing a flexible product development process to achieve good performance is challenging for managers, especially the front-end of a product development process where uncertainty and equivocality are the greatest (Zhang and Doll, 2001). During this initial phase, product concepts are developed, product architecture and specifications are defined, and development plans are prepared. These are fuzzy tasks because decisions made in the front-end should attempt to account for ambiguities

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and uncertainties that may emerge in the downstream implementation phase. Inadequacy in early identification of constraints and opportunities may result in late engineering changes, delays in product launch, and poor product quality (Verganti, 1999; Dixon, 1992; Suarez et al., 1995; Molokken-Ostyold and Jorgensen, 2005).

Product development flexibility is the ability to design and launch a variety of new products quickly with minimal disruptions and losses (Thomke, 1997; Upton, 1995). It enables firms to respond quickly to changing customer needs with innovative products. It increases the manufacturability of products by simplifying their structure and facilitating process improvements (Clark and Fujimoto, 1991). Literature on this important subject is accumulating including case studies (Iansiti and MacCormack, 1997), industry specific studies (MacCormack et al., 2001; Thomke, 1997), and mathematical models (Bhattacharya et al., 1998). Iansiti and MacCormack (1997) define flexible product development as delaying commitment as late as possible and developing products on internet time. Thomke and Reinertsen (1998) propose a flexibility index, a ratio between the percent change in a particular product attribute and the percent change in profits. In most cases, this index is difficult to quantify. MacCormack et al. (2001) provide a measure of flexible product development based on a small-sample survey (29 projects). Bhattacharya et al. (1998) present a mathematical model of real-time definition where a firm adapted and tuned its product definition process to the prevailing level of market uncertainty.

Recent literature raises at least two important issues for managing product development efforts: set-based product conceptualization and rapid prototyping. They are labeled in this paper as "product concept flexibility (CF)" and "product prototype flexibility (PF)", respectively, corresponding to Verganti's (1999) concept of anticipation and reaction capabilities. Verganti (1999) claims that firms should combine and balance anticipation capability (i.e., the ability to predict information needs and secure the information in the early phase of product development) and reaction capability (i.e., the ability to introduce changes late in the process with minimal or no penalties in cost or time) to achieve planned flexibility. Verganti (1999) argues that anticipation and reaction are not mutually exclusive; they should be integrated for successful product development. His study on the mechanisms for combining anticipation and reaction is based on a small-sample case study, thus some insights might have limited significance from a statistical perspective and would benefit from further investigation with a larger sample.

For this study, the research objectives are to define and discuss CF and PF and to investigate how they interact with each other to achieve customer satisfaction. CF enables firms to fully explore various product ideas. PF builds working models to help firms solicit customers' feedback, check engineering designs, and increase learning experiences. To investigate the relationships among CF, PF, and customer satisfaction, three alternative models are explored: (1) a mediation model where the effect of CF on customer satisfaction occurs through PF (an indirect effect), (2) a moderating model where PF influences the strength of the relationship between CF and customer satisfaction but does not impact customer satisfaction, and (3) an additive model where CF and PF impact customer satisfaction directly and independently. These models are examined and compared based on a large-sample survey of 273 manufacturing firms.

2. Theory development: The dimensions of product development flexibility

Product development flexibility enables an organization to quickly develop products that meet tightly specified customer needs (Dixon, 1992; Suarez et al., 1995). CF and PF are critical sub-dimensions of product development flexibility that may enhance product development outcomes and customer satisfaction (Dahan and Srinivasan, 2000; Gayretli and Abdalla, 1999). CF allows firms to generate and evaluate a variety of different product concepts. PF enables a firm to create multiple working models of a product.

In the following section, CF and PF are defined and discussed along with the general attributes of flexibility: range, mobility, and uniformity (Leeuw and Volberda, 1996; Sethi and Sethi, 1990; Thomke, 1997; Upton, 1995). Range is the ability to create a large or small number of alternatives with a large or small degree of difference among the alternatives. Mobility is the speed with which a firm can change from one alternative to another. Uniformity is the ability to maintain performance standards as switches are made among alternatives.

2.1. Product concept flexibility (CF)

CF refers to the ability to develop quickly and recall accurately set-based product concepts and definitions. It is the ability to anticipate the needs of markets and customers, generate multiple concepts for those needs, and move the concepts along with the parallel development of the design alternatives. Sometimes, firms may use a modular, mix-and-match approach where sets of components are assembled late in the process. The primary inputs to the process for developing the product concepts are customer needs, ideas from R&D, and market analysis; the outputs are the product concepts that meet customer expectations.

Traditional design practices, whether concurrent or not, often converge on a solution quickly and later modify it repeatedly until objectives are met. This is called point-based product development where an effective solution depends on making the right initial choice. If a bad starting point is chosen, refining the solution at a later stage can be both time- and money-consuming. In contrast, CF is a set-based approach to product development. Sobek et al. (1999) describe the principles of set-based concurrent engineering using Toyota's product development practices. Set-based concept begins with a large set of possible solutions