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Manufacturing flexibility: defining and analyzing relationships among competence, capability, and customer satisfaction

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Abstract

Fast and dramatic changes in customer expectations, competition, and technology are creating an increasingly uncertain environment. To respond, manufacturers are seeking to enhance flexibility across the value chain. Manufacturing flexibility, a critical dimension of value chain flexibility, is the ability to produce a variety of products in the quantities that customers demand while maintaining high performance. It is strategically important for enhancing competitive position and winning customer orders.

This research organizes literature on manufacturing flexibility and classifies it according to competence and capability theory. It describes a framework to explore the relationships among flexible competence (machine, labor, material handling, and routing flexibilities), flexible capability (volume flexibility and mix flexibility), and customer satisfaction. It develops valid and reliable instruments to measure the sub-dimensions of manufacturing flexibility, and it applies structural equation modeling to a large-scale sample ($n = 273$). The results indicate strong, positive, and direct relationships between flexible manufacturing competence and volume flexibility and between flexible manufacturing competence and mix flexibility. Volume flexibility and mix flexibility have strong, positive, and direct relationships with customer satisfaction.

Keywords: Empirical research; Flexibility; Management of technology; Manufacturing; Operations strategy

1. Introduction

Manufacturers face an increasingly uncertain external environment as the rate of change in customer expectations, global competition, and technology accelerates (Huber, 1984; Skinner, 1985; Jaikumar, 1986; Doll and Vonderembse, 1991; Germain et al., 2001). Researchers and manufacturing managers contend that flexibility is a strategic imperative that enables firms to cope with uncertainty (Gerwin, 1987; Sethi and Sethi, 1990). Flexibility is the organization's ability to meet an increasing variety of customer expectations without excessive costs, time, organizational disruptions, or performance losses. Upton (1994, 1995) defines flexibility as increasing the range

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of products available, improving a firm's ability to respond quickly, and achieving good performance over this wide range of products.

To attain the type of flexibility that customers want (i.e. quick delivery of a variety of high-quality, low-cost products), organizations seek value chain flexibility (Zhang, 2001). Value chain flexibility is broadly defined to include product development, manufacturing, logistics, and spanning flexibilities (Zhang, 2001; Day, 1994). It focuses primarily on filling customer orders rather than on merely improving the efficiency and effectiveness of equipment and processes. Such a focus requires manufacturing firms to develop cross-functional and cross-company efforts that eliminate bottlenecks, increase responsiveness, and create a level of performance that enables firms to build competitive advantage (Blackburn, 1991; Hamel and Prahalad, 1989).

Manufacturing flexibility, the focus of this study, is the ability of the firm to manage production resources and uncertainty to meet customer requests (Behrbohm, 1985; Gerwin, 1993; Kathuria and Partovi, 1999; Hill, 1994; D'Souza and Williams, 2000; Koste and Malhotra, 1999). Sethi and Sethi (1990) contend that manufacturing flexibility is a hard-to-capture concept, and Upton (1995) believes that confusion and ambiguity about this concept inhibit its effective management.

Slack (1983, 1987) distinguishes resource flexibility (e.g., machine flexibility) from systems flexibility (e.g., mix flexibility). Correa and Slack (1996) define the attributes of systems flexibility (range and response) and types of systems flexibility (e.g. product mix and production volume). Different descriptors for manufacturing flexibility overlap; as an example, process flexibility intersects with operational flexibility. Some descriptors are aggregates of others; process flexibility includes routing flexibility, machine flexibility, and material handling flexibility. The concept of manufacturing flexibility is confounded because the attributes of flexibility (i.e. range, mobility, and uniformity) and the components of flexibility (e.g. machine flexibility and volume flexibility) are often mingled (Barad, 1992; Gupta, 1993; Benjaafar, 1994). This imprecise language makes it difficult to develop valid and reliable measures of manufacturing flexibility and to improve theory development.

Clear definitions and accurate measures are needed to construct and test theory related to manufacturing flexibility. The literature on this important subject is accumulating including case studies (Maffei and Meredith, 1995), industry specific studies (Suarez et al., 1996), and mathematical models (Kumar, 1987; Benjaafar and Ramakrishnan, 1996; Gupta, 1993; Jordan and Graves, 1995; Byrne and Chutima, 1997). Upton (1995, 1997) provides a measure of process range based on a small sample survey (54 plants). Suarez et al. (1995, 1996) offer a measure of flexibility on the printed circuit board industry. Gupta and Somers (1992) develop measures of manufacturing flexibility based on a large-scale survey, but they do not clearly describe the dimensions underlying each type of manufacturing flexibility.

Some researchers emphasize manufacturing flexibility as an internal resource, a competence (Carter, 1986; Das and Nagendra, 1993). They highlight task sequencing or dispatching disciplines, and they develop flexible machining systems with totally automated functions to cope with uncertainty. But flexible systems that focus on creating internal competencies (e.g. routing flexibility and machine flexibility) may not enhance customer satisfaction. Satisfaction increases as the firm builds capabilities (e.g. mix flexibility) that provide value to customers. To understand manufacturing flexibility, the internal competencies and external capabilities of flexibility should be clarified, and relationships between them should be examined.

This paper contributes to the manufacturing literature by: (1) delineating manufacturing flexibility into dimensions of flexible manufacturing competence (machine, labor, material handling, and routing flexibilities) and flexible manufacturing capability (volume flexibility and mix flexibility), (2) proposing a research framework, including hypotheses, that relates competence to capability and capability to customer satisfaction, (3) developing valid and reliable measures for the dimensions of competence and capability, and (4) testing the hypotheses described in the framework using structural equations modeling. The results and implications of our findings are also discussed.

2. Theory development

Kickert (1985) believes that "flexibility can be considered as a form of meta-control aimed at increasing