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MEASURING ABSORPTIVE CAPACITY: AN ANTECEDENT TO TIME-BASED MANUFACTURING PRACTICES

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ABSTRACT

This study defines absorptive capacity, develops valid and reliable instruments to measure it, describes a framework to examine its impact on time-based manufacturing practices, and tests the relationships between these variables.

INTRODUCTION

Champlin and Olson (1994) summarize three revolutionary change forces: global competition, technology advancement, and new managerial practices, which are changing the dimensions of competition. The Global Manufacturing Futures Survey indicates that U.S. manufacturers face unprecedented competition in world market, which is requiring them to move beyond the quality revolution to address global growth and competition. Global competitors with different product development strategies, management styles, labor relationships, labor costs, and suppliers are altering the competitive environment (Clark and Fujimoto, 1991; Vonderembse et al., 1997; Miller, De Meyer and Nakane, 1992). Second, advances in technology, presents new threats and opportunities (Huber, 1996). The increasing speed and power of computers and information technology and advances in manufacturing technology are changing the ways productivity is increased and customers are satisfied (Cooper and Zmud, 1990; Doll and Vonderembse, 1987). Third, new managerial practices are enabling firms to cope with rapid market and technological changes.

Evidences show that many firms are not gaining the full benefits offered by these new technologies and may withdraw them from use (Chen and Small, 1994). Huber (1996) claims that in highly unpredictable environments, the lack of organizational learning capacity can explain why organizations are less effective at assimilating new technologies. Mansfield (1988) asserts that a significant problem for U.S. firms is their inability to learn new technology quickly and effectively. A study by Mansfield (1993) involving 175 Japanese, Western European, and U.S. firms indicated that U.S. firms have been relatively slow in assimilating FMS technologies as evidenced by a low rate of return on these investments.

Managers are being challenged to reexamine their methods and to emphasize organizational learning capability in order to implement these new technologies and practices, successfully (Higgins, 1991; Sitkin, 1994). Markus and Robey (1988) identify three conceptions of causal agency on organizational change. The *technological imperative* views technology as an exogenous driving force which determines or strongly constrains the behavior of individuals and organizations, i.e., technology dictates itself. The *organizational imperative* assumes choices over technological options and control over the consequences, i.e., stability and authority in the implementation process. The *emergent perspective* holds that the use and consequences of information technology emerge unpredictably from complex social interactions. The emergent perspective indicates that the application of technology is the result of complex interactions among stochastic, continuous, and abstract events.

Initially, the technological imperative may be relevant as organizations adjust to new technologies. Firms can achieve some benefits by acquiring new and complex hardware and continuing to apply the same management concepts and methods. Investing in technology can serve as a temporary barrier to entrants. However, decreasing costs for computer technology and shortening technology life cycles brings hardware advantages to an end, quickly. Clemons and Row (1991) pointed out that, when the same equipment is available to all firms and most applications can be duplicated easily, sustaining technology advantage does not come from having the technology, but from using it effectively. The organizational imperative may be relevant when the external environment is somewhat stable. As customer's needs and competitor's actions change quickly and new technologies emerge rapidly, the context of the change destabilizes and the organization loses control of the change process.

In a knowledge intensive, highly uncertain post-industrial environment (Doll and Vonderembse, 1991; Huber, 1984), an emergent perspective may be appropriate (Clemons and Row, 1990). In this environment, firms study and experience the complex interactions among the technology, the organization's capabilities, and the customer's requests. The firms identify primary factors that shape their ability to absorb knowledge and implement technology, and they adjust implementation efforts as they learn more about the technology and how to use it to meet competitive threats and satisfy customer's needs.

When the environment changes significantly, the challenge for management may be implementing technologies in ways that promote organizational learning and enhance success (Boddy, McCalman and Buchanan, 1988). Cohen and Levinthal (1990) argue that the ability of an organization to exploit and assimilate knowledge and technology and generate organizational learning is absorptive capacity. Absorptive capacity results from the cumulative effect of continuous learning. Prior related-knowledge and effective organizational communication processes are major constituents of absorptive capacity. Boynton et al. (1994) claim that absorptive capacity appears to offer specific and promising avenues for future research about the success of innovation in information technology. Therefore, firms with higher absorptive capacity are more likely to succeed in implementing new technologies because they have related experiences and effective communications infrastructure. Levinson and Asahi (1995) argued that the introduction of any new knowledge or technology involves change, "when it comes to change, the absorptive capacity of an organization is perhaps the most critical factor in determining whether a planned change can be implemented successfully."

To facilitate understanding of absorptive capacity, this paper defines absorptive capacity based on the germinal work of Cohen and Levinthal (1990), and it develops valid and reliable measures of the factors that compose the absorptive capacity construct. The study develops a structural model that examines the relationships between absorptive capacity and time-based manufacturing practices as defined and measured by Koufteros et al., (1998). It applies structural equation modeling (LISREL) to a sample of 303 manufacturers in seven industry groups to test these relationships

RELATING ABSORPTIVE CAPACITY AND TIME-BASED MANUFACTURING

A firm's absorptive capacity (Cohen and Levinthal, 1990) has an affect on its ability to implement time-based manufacturing practices. The concept of absorptive capacity (AC) originated in macro-economics, where it refers to the ability of an economy to utilize and absorb external information and resources (Adler, 1965). Cohen and Levinthal (1990) adapted this macro-economic concept to organizations, and defined AC as "the ability of a firm to recognize the value of new, external information, assimilate it, and apply it to commercial ends." They argued that AC is largely an organizational learning concept and is the cumulative effect of continuous learning. Implicit in this definition is the notion that organizations are aware of information within the firm and have access to it. The current study defines AC as the ability to identify, communicate, and assimilate relevant external and *internal* knowledge and technology. AC is a function of the firm's existing knowledge base, the effectiveness of systems that scan the environment, and the efficacy of the firm's communication processes.

A study by Brown (1995) summarized the existing literature. She proposed that a firm's AC should have three major components: prior relevant knowledge, communications network, and communications climate. While these three dimensions might be adequate for absorbing readily available knowledge, it was deemed necessary to add a fourth dimension, i.e., the firm's knowledge scanning mechanism to explore knowledge unknown but useful to the firm. Knowledge scanning presents the firm with the opportunity to learn new concepts and ideas that were previously unknown. Table 1 contains definitions and literature for these four components of AC.

Koufteros et al. (1998) describe a research framework for time-based manufacturing and defined a set of practices, which include shop-floor employee involvement in problem solving, reengineering setup, cellular manufacturing, preventive maintenance, quality improvement efforts, dependable supplies, and pull production. Many of these practices are elements of just-in-time with a different emphasis. Time-based manufacturers focus externally on customers and implement these practices to shorten response time. According to Monden (1983), just-in-time is an internally focused production system that eliminates unnecessary steps in the production process; its primary purpose is cost reduction. Abbegglen and Stalk (1985) observe that just-in-time innovators became the first time-based competitors as their emphasis on cutting waste decreased manufacturing throughput time and ultimately propelled time reduction throughout the organization. This ability to compress manufacturing cycle time translated into faster asset turnover, increased output and flexibility, and more satisfied customers (Blackburn, 1991).

The success of Time-Based Manufacturing Practices are heavily dependent upon two essential activities: 1) the exploration and utilization of employee intelligence, such as employee involvement in setup reengineering and quality assurance programs; 2) the effective communication and coordination internally among functional departments and externally with suppliers and customers. These ensure smooth operation of the pull production system and helps to build a just-in-time value chain. In fact, improved learning and communications are exactly what AC is about. Empirical studies verify that AC factors, such as employee technical competence, learning from customers and suppliers, and open communication channels are crucial determinants of success for time-based manufacturers (Davy et al., 1992; Flynn et al., 1995; Sakakibara et al., 1997). Cooper and Kleinschmidt (1994) also identified several major determinants of product development timeliness, most of which are closely related to the conceptual domain of AC, including efficient cross-functional coordination, thorough analyses of market and technical trends, team's technical proficiency, and firm's prior experience in similar products. Consider the following hypothesis.

Hypothesis 1: There is an overall positive relationship between a firm's *Absorptive Capacity* and its level of *Time-Based Manufacturing Practices*.

RESEARCH METHOD

Instruments are developed to measure the four dimensions of AC. The methods include four phases: (1) item generation, (2) pre-pilot study, (3) pilot study, and (4) large-scale data analysis. Results for instrument development can be obtained from the authors. Instruments for the seven dimensions of time-based manufacturing practices are taken from Koufteros et al. (1998).

The final version of the questionnaire was administered through large-scale mailing to 2831 manufacturing managers who were randomly selected from the Society of Manufacturing Engineers' U.S. membership database.

There were 303 usable responses which were submitted to rigorous reliability and validity assessment. The statistical package SPSS 8.0 for Windows was used to conduct all the statistical analysis. The items were purified by examining the CITC of each item with respect to its specific dimension in the AC construct. To further ensure the unidimensionality and convergent validity of measurement instrument, the purified items under each construct dimension were submitted as a group to dimension-level exploratory factor analysis. The entire group of items under each construct was then put into a construct-level exploratory factor analysis to check for their discriminant validity among different dimensions. Cronbach's (1951) alpha was calculated to assess reliability.

RESULTS OF THE STRUCTURAL MODEL

There appears to be an overall positive relationship between a firm's AC and its level of time-based manufacturing practices based on a Pearson correlation of 0.65. This is significant at $p<0.001$, and it is considered to be very high for empirical research studies.

Time has become a decisive factor of manufacturing performance in today's increasingly turbulent business environment. But many of the time-based manufacturing practices, such as pull production, reengineering setup, and dependable suppliers, requires a highly cooperative and well informed manufacturing operations system. The model was also examined using structural equation modeling (LISREL). The LISREL coefficient was 0.81 ($t = 8.95$), which indicates strong support for the hypothesis. For the model, the Non-Normal Fit Index was 0.93, and the Comparative Fit Index was 0.94. The Root Mean Square Error of Approximation was 0.072. The result indicates that improving AC, such as fostering an open communications climate and knowledge scanning, are valid measures of facilitating time-based manufacturing practices in a firm.

CONCLUSIONS

This study is possibly the first large-scale empirical efforts to investigate systematically the concept of a firm's AC. Measures for AC were developed through very carefully designed large-scale data collection and rigorous statistical instrument validation process. The concept of AC is getting even more important as organizations seek ways to streamline operations. The results of this study seem to indicate that AC is an antecedent to successfully implement time-based manufacturing practices. For a complete paper and references, contact the author at Mark.Vonderembse@utoledo.edu.

Table 1. Variables, Definitions, And Literature For Absorptive Capacity

Variable	Definition	Literature
Absorptive capacity	Ability to identify, communicate, and assimilate relevant external and internal knowledge and technology.	Adler, 1965; Brown, 1995; Cohen and Levinthal, 1990
1. Prior relevant knowledge	Understanding of job skills, technology, and management practices possessed by the workers and management in the organization.	Boer et al., 1990; Boynton et al., 1994; Cohen and Levinthal, 1990, 1994; Kedia and Bhagat, 1988; Nicolini and Meznar, 1995
2. Communication network	Scope and strength of structural connections which bring flows of information and knowledge to different organizational units.	Aletan, 1991; Beatty, 1990; Bessant, 1994; Chen and Small, 1994; Cohen and Levinthal, 1990; Goldhar and Lei, 1994; Voss (1988)
3. Communication climate	Atmosphere within the organization that defines accepted communication behavior.	Levinson and Asahi, 1995; Nevis et al., 1995; Roth et al., 1994
4. Knowledge scanning	Mechanism that enables firms to identify and capture relevant external and internal knowledge and technology.	Boynton's et al., 1994; Cohen & Levinthal, 1990, 1994; Levinson & Asahi, 1995; Roth et al., 1994