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Mediating effects of computer-aided design usage: From concurrent engineering to product development performance

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Abstract

As the rates of market change accelerate and customer expectations grow, product development becomes an increasingly important activity. In this environment, the performance of the product development process and the impact of product design on costs are critical factors for organizational success. To respond, firms are adding resources such as computer-aided design (CAD) to enhance product development efforts. The use of CAD technology is expected to enhance product development performance (development time, product quality, and design productivity) and to reduce product and manufacturing costs. To investigate these relationships, data were collected from 175 manufacturing firms regarding CAD usage, product development performance, and cost performance. From these data, valid and reliable instruments were developed to measure CAD usage. Structural model tests indicated that CAD usage has a positive impact on product development performance and cost performance.

Keywords: Computer-aided design; Product development; Empirical research

1. Introduction

Competition requires firms to procure and apply resources to create value by offering high quality products in a timely manner and with continuously improving efficiency (Gilmore and Pine, 1997; Roth, 1996). Firms pursuing these objectives must emphasize faster and more efficient product development processes, shorter and more cost effective manufacturing cycles, and quicker delivery times (Shilling and Hill, 1998; Stalk and Hout, 1990). These firms employ computer-based technologies to improve efficiency and minimize the detrimental effects of spatial and physical boundaries that divide key business processes.

Computer-aided design (CAD) is a widely used tool for product design (Burcher and Lee, 2000; Sun, 2000). Typically, CAD research focuses on adoption (Beatty and Gordon, 1988) and implementation (Adler, 1990; Beatty, 1992, 1993; Buxey, 1990; McDermott and Marucheck, 1995; Robertson and Allen, 1992; Symon and Clegg, 1991; Twigg et al., 1992). Prior research has used case studies that focus on prime users of CAD, such as manufacturers of printed circuit boards (Adler, 1990; Lee, 1989; McDermott and Marucheck, 1995) or field research involving a small number of firms (Beatty,

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1992, 1993; Buxey, 1990; Scarso and Bolisani, 1996; Symon and Clegg, 1991). Few studies have employed large-scale survey methods to assess CAD usage and to investigate its impact on product development.

Some research has found that CAD implementation is consistent with time reduction in product design (Fitzgerald, 1987), improvement in product quality (DeMatthew, 1989; Velocci and Childs, 1990), and cost reductions (Fitzgerald, 1987). Other CAD research indicates ‘‘gaps’’ between the expectation and realization of goals. The gaps appear as delays in achieving targeted goals, non-achievement of major goals, and unmeasurable achievement because goals are vague, obsolete, or unrealistic (Beatty, 1992; Symon and Clegg, 1991). Underutilization and the ineffective use of CAD contribute to these performance gaps (Buxey, 1990; Liker et al., 1995). Others attribute CAD's ineffectiveness to management's limited understanding of CAD's full potential, which leads to a failure to develop suitable organizational and technical support systems (Adler, 1989; Twigg et al., 1992).

This research defines CAD usage, differentiates between CAD use for engineering design and CAD use for cross-functional information sharing, and develops instruments to measure these variables. It considers the impact of CAD use on product development performance (product design time, quality, and productivity) and on reducing cost (product costs and manufacturing costs) and explicitly explores the link between utilization and performance. The instruments for CAD use are developed and the relationships among these variables are tested using data collected from 175 manufacturing firms.

2. CAD usage and product development

A summary of the important firm-level CAD research is provided in Table 1. Most of the literature focuses on adoption and implementation and does not address CAD usage or its impact on performance. Adoption studies usually assume that having CAD means that it will be used. According to Gross (1995), assimilating CAD takes time, often more than 10 years. Implementation studies usually assume that using CAD implies it will be used effectively.

Many CAD and CAD/CAM research efforts employ the process approach, which is essential to develop an understanding of CAD utilization. The process approach generates rich observations about the critical events that affect CAD usage (Adler, 1989, 1990; Robertson and Allen, 1992) as well as the impact of using CAD (Buxey, 1990; Robertson and Allen, 1993; Symon and Clegg, 1991). It often involves qualitative observations of the dynamics between organizational culture, strategy, structure, procedure, and skills (Adler, 1989) within the context of the firm's socio-political environment (Lee, 1989).

The adoption stage research suggests that the success/failure of CAD implementation is dependent on the resolution of adoption issues. Resolution of these issues (selecting the CAD system, specifying the target goals, choosing the implementation strategy, and planning for technical and non-technical change) promotes the development of specific contextual factors, which facilitates the implementation of CAD (Beatty and Gordon, 1988).

Much CAD/CAM research discusses the importance of contextual factors and relates the firm's context to its performance (Adler, 1990; Beatty and Gordon, 1988; Symon and Clegg, 1991; Twigg et al., 1992). Some researchers divide the organizational context into technical and non-technical factors and discuss the relative importance of these contextual factors on firm performance (Adler, 1990; Symon and Clegg, 1991; Twigg et al., 1992). A few suggest a relationship between contextual factors and utilization (Baba and Nobeoka, 1998; Kappel and Rubenstein, 1999; Liker et al., 1995; Robertson and Allen, 1992).

Typical performance measures are the achievement of pre-set goals for product development (Adler, 1990; Beatty, 1992, 1993; Symon and Clegg, 1991). Several studies evaluate the impact of CAD on workforce changes (Lee, 1989; Lefebvre and Lefebvre, 1988). Others focus on the performance of specific functions, e.g., the impact on manufacturing (Buxey, 1990) and engineering work (Robertson and Allen, 1992). Recent conceptual pieces recommend using process measures such as improved creativity, efficiency, and coordination (Baba and Nobeoka, 1998; Kappel and Rubenstein, 1999).

2.1. Framework for CAD usage

Initially, the impetus for CAD implementation was to drive cost from the clerical activities associated with product and process design by providing engineers with a tool that simplifies, shortens, and streamlines design drawing. The rapidly changing competitive environment and expanding customer expectations provided other important uses for CAD. Increasing demand for new and better product designs requires shorter product development time and better product quality while keeping costs low. This drives the opportunity to use CAD to integrate across functions by linking marketing, engineering, and manufacturing.