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The differential impact of product complexity, inventory level, and configuration capacity on unit and order fill rate performance

David J. Closs [a,*], Gilbert N. Nyaga [b,1], M. Douglas Voss [c,2]

[a] Department of Supply Chain Management, Michigan State University, N370 Eli Broad College of Business, East Lansing, MI 48912, United States
[b] Operations and Analysis Group, College of Business Administration, 214 Hayden Hall, Northeastern University, Boston, MA 02115, United States
[c] University of Central Arkansas, 210 Burdick Business Administration Building, Conway, AR 72035, United States

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ABSTRACT

This paper examines the simultaneous impact of configuration capacity, inventory level, and complexity on service performance as measured by unit and order fill rates in a configure-to-order environment. Demand skew is treated as a control variable. A simulation model based on data from a leading electronics manufacturer is used to test the hypotheses and identify the impact. Results suggest that there are differential direct and interactive effects of examined variables on unit and order fill rates.

1. Introduction

Manufacturers often face the need to produce increasingly complex products to meet more specific customer demands. Complexity is manifested as the variety of components in the finished product. In configure-to-order (CTO) production systems, final product configuration starts only after customer orders are received. Typically, the final product consists of multiple components, each having multiple subcomponents with stochastic attach rates and replenishment lead times. An attach rate is the percentage of base models that contain a specific product feature alternative. CTO systems are typical of computer, electronics and equipment manufacturers that await customer orders and then configure the customer specified unit using component inventory. Therefore, in a CTO environment, product complexity increases with increasing number of product components and subcomponents, and with increasing variation in component attach rates and replenishment lead times. Graman and Magazine (2002) posit that greater product complexity requires correspondingly higher inventory levels. This is problematic for CTO firms given increasing pressure to provide more product variety, reduce inventory, and minimize cost while simultaneously offering timely order fulfillment. CTO firms must also maintain enough configuration capacity to produce these increasingly complex products responsively particularly when demand is skewed or seasonal. Consequently, CTO firms face the challenge of configuring complex products to meet a broader range of customer requirements while simultaneously reducing inventory and configuration capacity. Examples of CTO firms experiencing these challenges of complexity include consumer and industrial manufacturers such as Dell, General Electric, Hewlett Packard, IBM, Motorola, and Sony.

Although prior research has examined inventory requirements related to product complexity (Graman and Magazine, 2002), limited attention is given to capacity as it relates to product complexity. Indeed, a review of the literature has not identified any work that has simultaneously examined the interactive effects of product complexity, inventory level, and configuration capacity on performance as measured by unit and order fill rates. Yet, these interactions and related strategies might significantly influence manufacturer performance. Generally, optimal performance is achieved when a firm adopts a holistic view where different processes and strategies are simultaneously evaluated and aligned.

The notion of strategic alignment or fit is well developed in the manufacturing strategy literature. Specifically, the competitive priorities framework stipulates that firms tend to emphasize

* Corresponding author. Tel.: +1 517 353 6381; fax: +1 517 432 1112.
E-mail addresses: closs@bus.msu.edu (D.J. Closs), g.nyaga@neu.edu (G.N. Nyaga), voss@uca.edu (M.D. Voss).
[1] Tel.: +1 617 373 2116.
[2] Tel.: +1 501 450 5320; fax: +1 501 450 5302.

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certain competitive dimensions and develop manufacturing capabilities to achieve the chosen dimensions to enhance their market position (Hayes and Wheelwright, 1984; Boyer and Lewis, 2002; Hallgreen and Olhager, 2006). The competitive dimensions are cost, quality, delivery, and flexibility. Hayes and Wheelwright (1984) posit that it is difficult, and potentially dangerous, for firms to try to compete by offering superior performance along all of the dimensions simultaneously. This strategy likely results in performance that is inferior on each dimension relative to other firms that devotes more resources to developing competitive advantages in key dimension as perceived by the customer (Hayes and Wheelwright, 1984, p. 41). Instead, a firm should prioritize limited dimensions to emphasize and appropriately fit its practices to the chosen dimensions (Anderson et al., 1989; Boyer and Lewis, 2002; Da Silveira, 2005). Manufacturing strategy encompasses a sequence of decisions that enable a firm to achieve desired manufacturing structure, infrastructure, and set of specific capabilities (Hayes and Wheelwright, 1984). These decisions relate to production process and control, technology, capacity, facilities, workforce, planning, etc. An effective strategy demonstrates consistency between competitive priorities with major focus and corresponding decisions regarding operational structure and infrastructure (Boyer and Lewis, 2002). According to the framework, firms must strive to achieve congruence between competitive priorities and firm processes and capabilities. We argue that manufacturers must also consider congruency in measuring performance of each dimension. This is because use of appropriate measures lead to correct identification of key capabilities requiring improvements and resulting in enhanced performance. However, alignment is not always achieved since many firms tend to focus on different strategic and structural variables independently. As a result, they miss opportunities to simultaneously identify effects of different processes and align processes to improve performance. Moreover, firms may adopt inappropriate performance measures leading to misalignment.

First, this research examines the simultaneous effects of product complexity, inventory level, and configuration capacity on unit and order fill rates in a CTO production system where the final product consists of components and subcomponents that have stochastic attach rates and replenishment lead times. Demand skew, as represented by seasonal spikes in customer demand, is considered a control variable.

Second, this research assesses the relative impact of product complexity, capacity, and inventory on unit and order fill rates. Bourne et al. (2002) indicate that it is difficult to identify the true drivers of individual performance measures. Perhaps this is due to the relative impact of different factors on performance measures such as unit and order fill rate. Mirchandani and Mishra (2002) support this notion and found that unit and order fill rates are influenced by different factors. Theoretically, unit and order fill rates should be highly correlated if a customer's order is composed of both many SKU's and large quantities of each unit, with common drivers influencing both. However, given the work of Mirchandani and Mishra (2002) the potential exists for one of the above independent variables to affect unit and/or order fill rate differently. Previous work has not examined this possibility using empirically derived data.

The next section reviews past literature involving the variables under investigation and defines the research hypotheses. The third section discusses the simulation design. Fourth, simulation results are presented and discussed. Fifth, the managerial implications of these results are presented. Finally, study limitations and future research opportunities are provided followed by concluding remarks.

2. Literature review

The following literature review focuses on performance measurement and then on the specific drivers of performance measures.

2.1. Performance measurement

To be competitive, manufacturers must efficiently and effectively manage inventory and capacity in an environment with increasing product complexity. Performance measurement is also necessary for firms to identify and guide efforts to enhance competitiveness (Van Hoek, 1998). The use of incorrect measures may result in an inability to meet customer expectations, suboptimization of firm performance, and intra-firm conflict (Lambert and Pohlen, 2001). A commonly used availability service performance measure is fill rate (Johnson and Scudder, 1999). Fill rates take several forms. Unit fill rate is defined as the number of units (e.g., cases) filled as a fraction of units ordered (Bowersox et al., 2006) and is a disaggregate availability measure in that it considers a single stock-keeping unit (SKU). Unit fill rate may also represent the percentage of components available to completely assemble a configured product. Order fill rate is defined as "orders filled complete as a fraction of [the] total number of orders" (Zinn et al., 2002, p. 22) and is an aggregate measure of availability in that it encompasses other types of fill rates, such as unit fill rate.

Griffis et al. (2004) suggest performance measures (e.g., unit or order fill rate) should be selected to properly align with firm strategy. Focusing on an incorrect measure may lead to a mismatch between firm strategy and service capabilities, which may ultimately undermine competitiveness. At least three disconnects potentially exist between firm performance measurement needs and their performance measure choice (Griffis et al., 2004). *First*, however, unlikely it may be, a firm might not measure performance. In this case there exists a lack of information relating system output to any existing performance goals. *Second*, incorrect information might be measured. This occurs when a firm utilizes unreliable or invalid measures. In this case, a firm has performance measures in place but for some reason – perhaps manipulation of fill rates by employees for personal gain – the information obtained through these measures is incorrect. *Third*, a firm might utilize the wrong measures. When the wrong measures are utilized, and the problem goes unrecognized, the firm is more likely to take incorrect actions due to a lack of knowledge regarding the true state of organizational performance.

This research focuses on the third of these disconnects. If firm profitability depends substantially on availability of a particular SKU, then unit fill rate is an appropriate performance measure. In this situation, if a firm focuses on order fill rate, this important product may not be afforded the attention it deserves. On the other hand, if firm profitability depends substantially on a limited customer base, then it is important to provide each customer with high product availability. Order fill rate is the appropriate performance measure in this case because it measures the service level provided to key customers with respect to the combination of SKUs found in each order. In this situation, a focus on unit fill rate would only capture a small portion of each customer's order. For example, consider the case of a full-line computer manufacturer, which sells equipment ranging from PCs to servers through two different channels utilizing a combination of strategies based upon their CTO manufacturing structure.

First, the manufacturer sells equipment direct to customers. No one customer in this channel represents a significant contribution to the manufacturer's overall profitability. However, certain product configurations are more profitable than others with most per unit profit derived from a very small number of SKU's sold at