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Review

An integrated simulation–optimization study for consolidating production lines in a configure-to-order production environment

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ABSTRACT

This study investigates production lines consolidation in a configure-to-order production environment using simulation and optimization strategies. The current production environment has three separate production lines that will be consolidated into two production lines. Two production line configurations are analyzed: product and process layouts. Product layout has a continuous smooth flow, small work-in-process (WIP), short total production time per unit of product, and reduced material handling requirements. On the contrary, process layout offers more flexibility, allows for higher utilization of machines, and requires higher grades of operators' skills. A simulation-based comparison of the current and future systems is conducted considering lead time, throughput, utilization, and WIP. A mixed integer programming model that optimizes the transportation cost and waiting time is then formulated based on the selected process layout. Simulation results provide recommendations to improve the system level performance measures and support management decisions. The current transportation schedule is ineffective, and hence a real-time dashboard based on the optimization model is suggested. The dashboard will improve communication and transportation between the two production lines.

Contents

1. Introduction

Dynamic changes in market demands and companies' strategies require flexible introduction of new products and implementation of continuous improvements to internal processes in order to cope with the changes. One of the improvement changes is consolidating production lines, especially when demand decreases and companies' strategies change. Decision making on consolidation can be a difficult task due to the absence of data that supports the decisions and the uncertainty inherent in the decisions. Simulation modeling, widely used in manufacturing and service industries, network communications and military, can be effectively used in such cases.

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A configure-to-order (CTO) production environment consists of hybrid build-to-plan and make-to-order operations. This configuration is also known as the fabrication/fulfillment strategy, which allows for effective response to customer orders and lower inventory carrying costs. In the fabrication stage, components (subassemblies) are produced, tested, and assembled based on a forecasted plan. Components are then kept in stock until an order is received from a customer. In the fulfillment stage, tested commodities are assembled according to actual customer orders and no finished goods inventory is kept. According to Cao et al. (2003), the fabrication/fulfillment model provides the company with the flexibility of mass customization, and the speed and efficiency of mass production. However, the randomness inherent in this model makes the management of such environment a challenging task. Both product and process layouts are used in these environments. Product layout has a continuous smooth flow, small WIP, short total production time per unit of product, and reduced material handling requirements. On the contrary, process layout offers more flexibility, allows for higher utilization of machines, and requires higher grades of operators' skills. Process layout can also provide a strategic advantage over product layout. For instance, if the company decides to separate its processes or sell part of its operations to a third party, this will be easier to perform in a process layout than a product layout. One major disadvantage of the process layout is that it requires effective transportation between the production lines. To overcome this disadvantage, this study proposes a real-time dashboard that is based on optimization of the transportation between the production lines.

High-end server manufacturing is a typical CTO environment. In high-end server manufacturing environment, severs are built with components that incur high inventory carrying cost. The components are expensive, and extensive test processes are required to ensure quality and reliability requirements. Production lines are supported by multi-tier suppliers (both internal and external) with long supply lead time. The environment is characterized by the aggressive introduction cycles of new products (almost every two years), extreme demand skews (most orders arrive by the end of the planning period), and significant engineering changes. An overview of high-end server manufacturing is illustrated in Fig. 1. The current study discusses the consolidation of three separate production lines (product-based layouts) into two lines (process-based layouts) to improve utilization and throughput and provide space for strategic activities. Simulation modeling is used to predict and validate the operations in the consolidated environment. The simulation model is used to analyze throughput, cycle time, capacity, and utilization. Furthermore, it is used to conduct what-if predictive behaviors and ensure that future volumes can be satisfied in the consolidated environment. The simulation study shows that the current transportation schedule is ineffective for the new consolidation environment and, hence an optimization-based dashboard is developed to improve the transportation costs and communication between the production lines.

The rest of this paper is organized as follows: Section 2 presents a review of the literature related to the use of simulation and optimization in production environments. Section 3 discusses the architecture of the simulation framework, data collections, model building, and model verification and validation. Numerical results from simulation are discussed in Section 4. An optimization-based real-time dashboard that is developed to improve transportation and communication between the two production lines is presented in Section 5. Finally, conclusions and future work are summarized in Section 6.

2. Related literature

Consolidating production lines is a challenging task, especially in complex manufacturing environments. Several studies in the literature, mostly case studies, discussed production lines consolidation for different reasons. For instance, Haase (2006) discussed the configuration of high volume production lines of solar cells based on commercial issues and crystalline material technology. Zhou et al. (2009) conducted a study on reconfiguring a piston production line to reduce work-in-process and improve resource utilization. Their study used a simulation method to test different scenarios and drive recommendations based on the simulation results. Discrete-event simulation (DES) is one of the most widely used methods for studying production environments due to its flexibility.

DES can be effectively used to capture and analyze the complex behavior and interactions of complex systems with less effort when compared to analytical models. It can be effectively used to make accurate and sound decisions to identify the best alternative among several candidates (Song et al., 2005). DES has been used for many applications in manufacturing environments. Some examples include assessment of scheduling policies and work order release (Muller et al., 1990), performance evaluation of manufacturing systems based on cycle time, throughput, and WIP (Mönch, 2005), capacity analysis of assembly lines (Gujarathi et al., 2004), study of design changes (Zhiwei and Yongxian, 2008), and evaluation of design alternatives (Owens and Levary, 2002). A simulation model for a just-in-time (JIT) production system was developed in Baykoc and Erol (1998). Their study examined the performance of a multi-item, multi-line, multi-stage JIT production

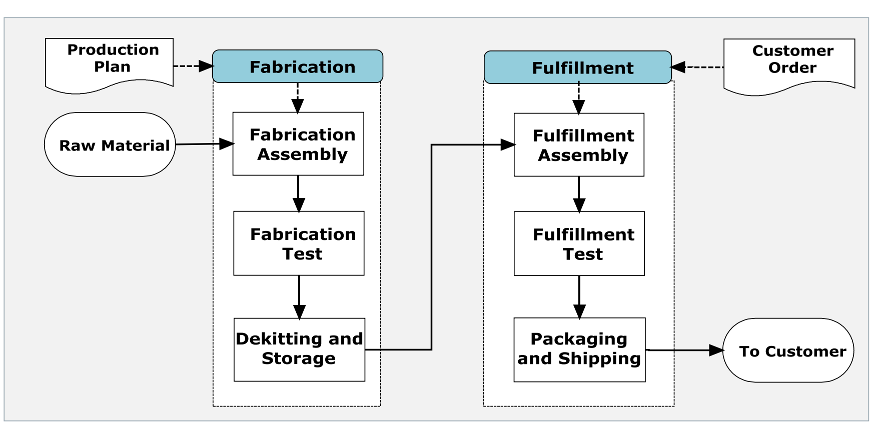

Fig. 1. An overview of a configure-to-order environment for high-end servers.