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Simulating an agile, synchronized manufacturing system

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Abstract

Retail customers are demanding more variety, more features and quicker order response times from manufacturers. Furniture production systems have had to become more flexible to respond to the variety of styles, fabrics and patterns offered by retailers. In this make-to-order environment, the orders received must be grouped into specific, logical *batches* whose short-cycle operations require close coordination and monitoring throughout the facility. For upholstered furniture, each batch may be unique because it consolidates orders having fabrics of different colors, texture or style. In recliner chair and similar production systems, the parallel component subassembly lines must maintain synchronization within each line and between the lines for components to *simultaneously* reach final assembly. The simulation developed represents an existing production system. It generates expected outputs under conditions of *operation variability*, *queue lengths* (*buffers*) and *batch changeover* (*set-up*) *times* over a range of 3 uniform and feasible batch sizes. Thus, the real-time *status and location* of components and subassemblies consigned to a specific production batch is essential for maintaining and improving quality and utilization of personnel, space, material and other resources.

Keywords: Just-in-time; Synchronized/parallel assembly; Agile production; Quick response; Uniform batch size; Simulation

1. Introduction

Simulation is the most robust and realistic way of evaluating the performance of a system of multiple queues. Its primary use is to test changes in a system *before* they are implemented. Combined serial and parallel queue disciplines are difficult if not impossible to be treated by analytical methods. According to Hall (1999), testing of different probability distributions and various parameter changes found in many production systems cannot be accommodated except by simulation.

Discrete object-oriented computer simulation has been used to identify and help solve problems in an ever increasing number of applications. The ongoing research on hundreds of assembly lines at General Motors by Alden et al. (2006) has led to many simulation models and observations that have saved millions of dollars. Simulation saves considerable time and money by viewing the dynamics of a system and providing insight into and a better understanding of those dynamics. Kline et al. cites the use of simulation as an operations research tool in analyzing a hardwood processing system that produced cabinets and similar products. The simulation helped illustrate the feasibility of alternative solutions by observing the *animated* flow of

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products through the processes. Simulation can also offer genuine excitement by pre-testing ideas and introducing realistic "what-if" changes in the parameters. As Keller et al. (1991) and Spedding and Sun (1999) concluded, simulation can also be useful in enhancing a cost accounting system by evaluating *manpower*, *space* and *equipment* requirements.

Enormous amounts of money continue to be spent by companies and industries to improve **small-lot** production. McRainey (1977) observed, as have others, that manufacturers are constantly being challenged by the demands of the distribution systems for quick response and just-in-time (JIT) requirements of customers. Manufacturers and certainly their marketing personnel, seek small-lot production with processes changed over quickly from one product to another to better serve customers. However, as Katayama and Bennett (1999) conclude per the classical economic models, i.e. EOQ/EMQ, an emphasis on agility must simultaneously focus on changeover costs when producing in smaller lots. Whitehead (2000) restates an underlying principle from the JIT concept that *agile*, small-lot systems can exist in concert with *lean* manufacturing systems. Both focus on reducing waste through lower inventory investment, space savings, better material handling, and reduced changeover and processing times. Thus small-lot sizes are fundamental to flexible JIT systems and enhance superior customer service.

The simulation study from Baykoc and Erol (1998) examined the performance of a multi-item, multi-line, multi-stage JIT system and demonstrated how the systems react under different circumstances. The variability of processing time and arrival demands of subsequent operations were studied. Sianesi (1998) demonstrated that the flexibility inherent in JIT production applied to "mixed-model" systems reduces WIP inventories in make-to-order environments.

The system described in this study is more complex in that the subassemblies are produced on separate but *parallel* lines and linked to a specific mixed-product *batch*. Also the operations must be synchronized within a relatively narrow time interval. Delays of any component batches may cause all production to slow or stop. The time for a unit or batch in the system will depend on the *maximum* of the various operation and waiting times and not just on their sum. This leads to more complicated queue disciplines. It is a requirement to finish each of the dependent operations at the same time. There is little value by completing an operation or a batch early only to wait for other parallel operations to be completed. In fact, it may be disruptive and wasteful of costly resources of space, personnel and equipment.

Simulation models do require empirical data, yet reasonable estimates or sample data are helpful in identifying the empirical data needed. In the system studied, estimates were used to help develop the simulation model and generate results approximating an existing production system. Stopwatch studies or video tape gathering of real-time data may discover other variables for which the simulation model does not accommodate. On the other hand, the model verifies the fundamental logic employed in managing the system and points towards areas where constant improvement, the company credo, can enhance profitability. Large lots may appear more economical but smaller lots or batch sizes leads to less waste of space, inventory investment and better customer service. Statistical analysis of empirical data may add refinement to the results but being able to manipulate the model and ask "what-ifs" appears to offer more of a contribution to understanding a complex system.

To represent an actual, interactively constrained production system by a discrete event, animated model is a challenge. The ability of a simulation to visually represent the flow, delays and projected throughput helps understand some of the requirements for maintaining, controlling, improving and managing a fairly complex JIT system. The simulation model designed makes a number of realistic assumptions in order for production to respond to the need for small-batch production. The simulation objective:

- To discover the effect on throughputs for selected standard batch quantities as a function of operation time variability, batch changeover times and WIP buffers.

2. Upholstered furniture manufacturing

Furniture manufacturing is an industry where the lead time and retail inventory are critical to sales. The Grubb Furniture Mfg. case study Keller et al. (1991) reminds us that if customers want a particular item that is not in stock at the retailer, they still want it *now* or as soon as possible. If the