Chapter 13
Modeling of Hybrid Production Systems with Constant WIP and Unreliable Equipment

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ABSTRACT
Material flow in production systems can be controlled by a purely push-pull (just-in-time), or by a hybrid push-pull control mechanism. One type of push-pull production control can be implemented by controlling only the last stage during part withdrawals to trigger the production at the first stage. While the final stage is operated according to a pull mechanism, intermediate stages are operated according to a push system of control in order to keep the work-in-process (WIP) at a constant level. Since the WIP levels are limited in hybrid systems, production output rate is very susceptible to equipment failures. In order to establish suitable WIP capacities between the stages of production, it is essential to analyze the production line using appropriate models and tools. This paper develops a discrete iterative model to study and analyze behavior of a push-pull system with unreliable equipment at any stage. The model is utilized to optimize WIP capacities at intermediate stages and number of kanbans at the last stage. Furthermore, an experimental design is set up to analyze effects of various maintenance policies, line design parameters, and operational factors on line performance measures by using simulation results from the model.

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INTRODUCTION

Just in time (JIT) production control or “pull” systems are used to produce what is needed at the right time and in the right quantity. While in a JIT system kanban-based control is implemented at each stage of production, in a push-pull system, production at the first stage is scheduled according to the demand for the products in the last stage. Withdrawal of finished products from the last stage triggers the production at the first stage by an information signaling kanban. Rest of the operations is performed by a push system. Push-pull system of production is commonly used in electronics assembly and other production lines.

Several studies have been carried out on the implementation and efficiency of JIT systems. Fallow and Browne (1988) present a simulation study for a JIT system. Sarker and Fitzsimmons (1989) compare the performance of pull systems with that of push systems under different operational conditions. Yamashita et al. (1989) present a theoretical model for a production line driven by demand. They determine line efficiency, which is measured in terms of average shortages and average in-process inventory levels. Olhager and Osthund (1990) present the integration of push and pull systems and its benefits in a manufacturing environment. Wang and Wang (1990) present a Markov model to approximate the optimum number of kanbans for reducing in-process inventory. One of the most comprehensive literature reviews on JIT systems is presented by Golhar and Stamm (1991) who identify and classify 860 articles in the area.

Bard and Golany (1991) developed a planning model to assist managers in determining optimal kanban policies at each station of a JIT line. Hodgson and Wang (1991) present Markov decision process models for hybrid push/pull control strategies in multistage systems. Golhar and Sarker (1992) develop a model for economic manufacturing quantity in a JIT delivery system. Chu and Shih (1992) summarize and classify the simulation studies performed on JIT systems. Berkley (1993) presents a simulation model and its results for determining minimum performance levels for two-card kanban controlled lines. Fukukawa and Hong (1993) present a mixed integer goal programming model to determine the optimal number of kanbans in a JIT production system and Zhuang (1994) studied the optimum levels of price and delivery frequency between a supplier and a JIT buyer firm. Wang and Xu (1997) presented a simulation analysis of a hybrid pull/push production control strategy and indicated the efficiency of such systems. Savsar (1996, 1997, 2000, 2006a, 2006b) analyzed JIT systems from different perspectives using simulation as well as other meta-modeling approaches, including neural network. Beamon and Bermund (2000) studied a hybrid push-pull system and presented a control algorithm for multi-stage, multi-line production systems. Duri et al. (2000) compared three pull control policies, namely the kanban, base stock, and generalized kanban. The effects of kanbans and other factors on JIT system performance have been investigated mostly for pull types of production control strategy. Countless number of other JIT applications and related models can be seen in the literature. Most of the literature deals with the efficiency of JIT systems under different operational conditions. Either mathematical models are developed based on restrictive assumptions or simulation models are utilized in the analysis of JIT systems. Some companies also use trial and error procedures such as reducing the number of kanbans until the system comes to a halt or gets into trouble. In relation to the effects of intermediate buffer capacities on a push type of serial production line, several papers, including Hillier and So (1991), Hillier et al. (1993), Papadopoulos and Vouros (1996), and Savsar and Youssef (2004), have been published.

In this paper, a discrete mathematical model is presented to analyze a push-pull system of production as illustrated in Figure 1. When a final product is withdrawn from the finished products
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