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Comparing CONWIP, synchronized CONWIP, and Kanban in complex supply chains

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Abstract

Three types of JIT ordering systems used for supply chain management were quality tested, the Kanban, the original constant work-in-process (CONWIP), and a synchronized CONWIP. The synchronized CONWIP system is described for its ability to handle complicated supply chains, which consist of assembly stages with different lead times. In the system, orders for each process are released while adjusting the lead time of the subsequent process, and the released and processed orders are synchronized during the assembly stages. Practical questions, that is, which system is superior and which parameter affects superiority, were investigated for the three types of systems.

Keywords: Supply chain management; Just-in-time; Kanban; CONWIP; Synchronized CONWIP

1. Introduction

Deterministic models of integrated production and inventory, of production and distribution, and of production, inventory, and distribution systems have been developed as a step towards an integrated form of control between these systems. Published work on the models has been reviewed by Erengüç et al. (1999). A particular mathematical model was constructed in all of the published materials, and the objective function was then optimized in a particular way. Formulating the problems of supply chain management by using a particular deterministic model becomes difficult because a supply chain becomes more complicated and includes a lot of uncertain elements. Adapting a different approach to the problem is then necessary. Therefore, we constructed a stochastic model for the supply chain and formulated ordering systems for determining the timing of orders and quantities arranged at each stage of the supply chain system.

Not only deterministic models but also stochastic models of integrated production–distribution

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systems are reviewed by Sarmiento and Nagi (1999). In the published work on stochastic models for supply chain management, Chen (1999) applied an inventory control policy for a single station to a multi-station serial supply chain. Iyer (1999), Gavirneri and Tayur (1999), and Kerke et al. (1999) studied the effects of informing each inventory station of the demand. This is achieved by having the stations share the information by exchanging electronic data. Having the stages share information as soon as it is available is clearly valuable in improving the performance of the supply chain as a whole. Lee et al. (1997) showed that inaccurate information causes a bullwhip effect. Also, Chen et al. (1999) showed that such effects arise in demand forecasts.

The bullwhip effect is an amplification of fluctuations in processed quantities and inventory levels as one goes upstream along a supply chain process. Suppressing fluctuations in inventory levels leads to reducing inventories at each process. The same kind of amplification in multi-stage production systems has been pointed out by Kimura and Terada (1981) and Takahashi et al. (1994a, b). These publications show that an error in demand forecasts causes this kind of amplification in push-type ordering systems, such as material requirements planning (MRP) systems. However, in pull-type ordering systems or just-in-time (JIT) ordering systems, such as the Kanban system, an amplification is avoided because the actual demand is used instead of the demand forecasts.

In this paper, two types of JIT ordering systems, the Kanban and the constant work-in-process (CONWIP) were applied to supply chain management to determine the superior system. The Kanban system, a unique type of JIT ordering system, was developed by a Japanese automobile manufacturer, Toyota (see, for example, Kimura and Terada, 1981). The CONWIP system, an alternative to the Kanban, is another type that was developed by Spearman et al. (1990). The performance of the two systems was comparatively analyzed (Spearman et al., 1990; Muckstadt and Tayur, 1995a, b; Takahashi and Nakamura, 1998). Their work showed that both systems have advantages and disadvantages. While all of the aforementioned published works used serial production systems, no published works have tested a more complicated supply chain system to analyze the performance of these two systems. Takahashi and Nakamura (2004) used this complicated supply chain system to analyze the performance of push and pull systems. However, their research assumed the same lead times in all processes in the supply chain system for the sake of simplicity. Therefore, we used complicated supply chains that consisted of assembly stages with different lead times.

In the CONWIP system, the arrived and satisfied demand acts as the trigger for releasing orders to the production processes in the first stage. However, if lead times vary from each production process at each stage, production through each route of the processes varies in completion based on the difference in the lead time, and the inventories at the assemble stage increase. Synchronizing the production at each process is required to reduce the inventory at the assembly stage. For this purpose, we used a synchronized CONWIP system. Orders for each process in the system are released while adjusting the difference in the lead time, and the released and processed orders are synchronized at the assembly stage. For the Kanban, the original CONWIP, and the synchronized CONWIP systems, we investigated practical questions, that is, which system is superior and which parameter affects superiority.

This paper is organized as follows. A model of the supply chain system considered is described in the next section. Formulations concerning inventory level and the performance measures considered for the assumptions taken are also described in this section. A mathematical model of the JIT ordering systems, the Kanban, the original CONWIP, and the synchronized CONWIP systems for this supply chain system is in Section 3. Numerical studies based on the results of this analysis are presented, and the effect of the configuration of the supply chain is investigated in Section 4. Finally, the findings obtained are summarized in Section 5.

2. Modeling a supply chain system

In this section, the notations and assumptions that constitute the supply chain system under