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# Heuristic algorithms for production and transportation planning through synchronization of a serial supply chain

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ABSTRACT

This study suggests an approach that synchronizes timing points found between a supplier and a buyer in a serial supply chain with one in two timing points to allow for more efficient and agile material flow. This approach is applied to the problem of finding an optimal solution for the production quantity in each production lot and the job sequence with minimum supply chain total cost and lead time. Five heuristic algorithms were developed based on simulated annealing (SA) and a genetic algorithm (GA). Of the developed heuristic algorithms, GA2 exhibited the most robustness.



## 1. Introduction

Synchronization is defined as an adjustment that causes a given event to occur or recur in unison (Webster's Online Dictionary, 2005). This concept has been considered important in the pursuit to efficiently satisfy customers' demand through control of material or information flow in the supply chain. Fraser (1997) noted that close coordination and timing among different partners in a supply chain are very important for supply chain synchronization. Likewise, Hahn et al. (2000) noted that the competitive strength of products in the marketplace is determined by the combined capabilities of all partners in the supply chain rather than by the partner's capabilities alone; also pointed out that synchronization of various activities is important to achieve the maximum benefits. Ashcroft (2005) explained supply chain synchronization as the most important goal for developing the higher level of supply chain competitive.

Although synchronization in the material of the supply chain has been studied, it has been dealt with in most studies on a conceptual basis, and only a few analytical studies have been undertaken better understand how material flow can reduce supply chain total cost. Several approaches exist to synchronize the production lead time of suppliers to reduce inventories for their buyer (Takahashi et al., 2005), the timing point for a supplier to deliver products that a buyer wants to consume (Garcia et al., 2004; Wang et al., 2004; Boeck and Vandaele, 2008), or the cycle time of manufacturers or transporters to affect the economy of scale (Vergara et al., 2002; Khouja, 2003).

Just-in-time (JIT) is used primarily by approaches that aim to synchronize either the production lead time of suppliers to reduce inventories for their buyers or the timing point for a supplier to deliver products that a buyer wants to consume; however a drawback was noticed that there exist inventories in every partner of the supply chain when JIT is applied (Takahashi et al., 2005). Although various approaches have been developed to reduce the inventory level in the supply chain, the inventory holding cost imposed on suppliers is generally ignored. In Deloitte and Touche's (2005) approach, which aims to synchronize the timing for a supplier to deliver products to be consumed by buyers, the inventory holding cost is imposed on the retail price. Given the approaches and findings of previous studies, it is clear that it is necessary to utilize a synchronizing approach for effective inventory management in whole supply chains.

Implementation of an effective transportation plan is one in the most important factors to improve the performance of supply chain synchronizing. Although there are good synchronized production plans among partners, many companies cannot obtain the advantage of supply chain synchronizing without an effective transportation plan. Thus, some approaches have been suggested to synchronize the cycle time of manufacturers or transporters in order to better control the economy of scale; these approaches permit delivery of products made by suppliers through infrequent delivery of large amounts. However, because of the constraints to meet a fixed cycle time that is often longer than the maximum lead time among suppliers, these approaches require more lead time to complete all processes. Conversely, frequent delivery of small amounts for an order can be considered a good approach to reduce the supply chain total cost (Deloitte and Touche, 2005; Aderohunmu et al., 1995; Banerjee and Kim, 1995; Lu, 1995; Hill, 1997). Indeed, this approach has been implemented in a variety of

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transportation processes, although not yet to the supply chain synchronizing approach. As various types of production methods, such as CKD/SKD (complete knockdown/semi-complete knockdown), are implemented, more complex and varying types of transportation must be considered in order to develop an effective plan. Thus, it is necessary to consider various types of transportation in order to suggest a synchronizing approach for supply chains. In this study, the suggested synchronizing approach takes into account situations involving frequent delivery of small amounts of goods and infrequent delivery of large amounts of goods.

In this study, a new approach that synchronizes each timing point found between a supplier and a buyer in the serial supply chain with one in two timing points is suggested as means to make material flow more efficient and agile. First, two timing points that are the timing point for a supplier to complete its production and to begin its transportation of products to its buyer are synchronized with a single timing point (points 'A' in Fig. 1). Next, two additional timing points, namely, the timing point for a buyer to receive products from its supplier and for the buyer to start consuming the products are synchronized with another timing point (points 'B' in Fig. 1). Then, it is expected that all products from suppliers can be delivered to its buyer without any delay, meaning that our synchronizing approach is capable of reducing the inventory holding cost imposed on each partner and the lead time to complete production.

To realize this idea, the no-wait approach was applied to our synchronizing approach. The no-wait approach has been widely used to make products without any interruption among machines, especially among plastic or steel goods, as quality can suffer significantly if there is some delay among processes. This approach has also been applied to make plans for a computer system (Reddi and Ramamoorthy, 1973), to treat foods (Hall and Sriskandarajah, 1996), and to develop semiconductor inspection facilities (Ovacik and Uzsoy, 1997). Hence, the no-wait approach can be useful for various processes that must be completed rapidly. Indeed, Garcia et al. (2004) recently dealt with problems in synchronizing a concrete production and transportation plan using the no-wait approach.

Fig. 2 shows an example of inventories in the serial supply chain that is made up of 4 manufacturers and a retailer with various synchronizing approaches. The gray zone in Fig. 2 signifies the reduced inventory obtained from the synchronizing cycle time for partners. In this case, if the no-wait approach with infrequent delivery of large amounts is implemented, inventory of the raw material during the delay for a manufacturer that is not consumed can be removed. Moreover, reduced inventory of products made by a buyer is readily apparent in the no-wait approach with frequent delivery of small amounts in the case of three production lots for each partner. Thus, the no-wait approach is expected to remove inventories in the serial supply chain. An example of lead time for three manufacturers with various synchronizing approaches is shown in Fig. 3, where the length of setup time, lead time for production, and lead time for transportation is assumed to be constant during the synchronizing approach. If the no-wait approach is implemented, all jobs can be concluded in a shorter time; a comparison of previous studies with our study is summarized in Table 1.

We next treat the problem of finding an optimal solution for the production quantity for each production lot and the job

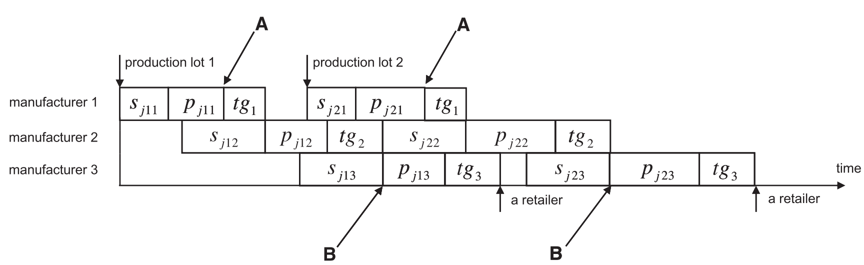


**Fig. 1.** Synchronized timing points in the suggested synchronizing approach.

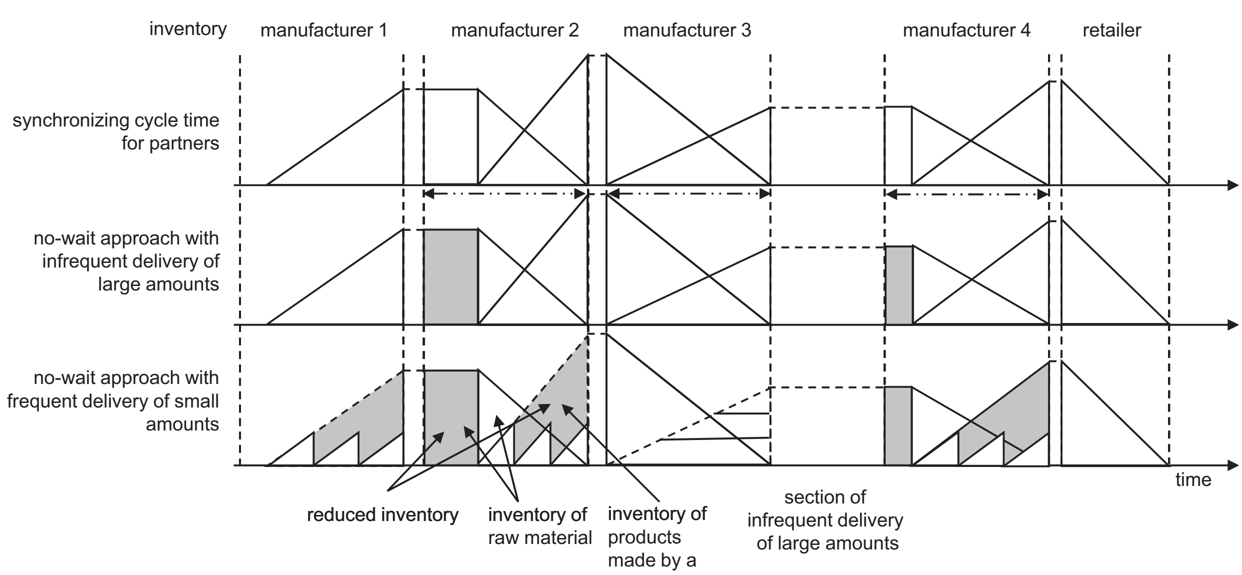


**Fig. 2.** Inventories in the serial supply chain with various synchronizing approaches.