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A branch and bound method for solving multi-factory supply chain scheduling with batch delivery

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ABSTRACT

This study addresses the scheduling of supply chain with interrelated factories containing suppliers and manufacturers. These elements of the chain are positioned in series and thus the efficient design of the link among them would insure good performance of the whole. In this paper, jobs transportation among factories and also delivery to the customer can be performed by batch of jobs. The capacity of each batch is limited and the cost per batch delivery is fixed and independent of the number of jobs in the batch. Thus decision should be made on the number of batches, assignment of each job to a batch and also production and delivery scheduling of batches in each factory. The problem scrutinization is on the tradeoff between minimizing transportation cost and tardiness cost. A branch and bound method for solving this problem is presented. A lower bound and a standalone heuristic which is used as an upper bound are also introduced. Computational tests are conducted to evaluate the performance of the proposed method.

1. Introduction

Globalization of nowadays markets and therefore increasing competitiveness, invoke manufacturer to consider activities from supplier to customer instead of their own plant's activities. In the other words, they tend to design and optimize the whole supply chain. Supply chain is an improved organization which contains suppliers, customers, a number of companies, products and services. The integration and coordination of these components of the chain would result in a reliable flow of goods, services and information. Thus, sharing information, coordination in planning and scheduling of manufacturing facilities in the same supply chain, may leads to performance enhancement, higher reliability, lower inventory and, etc.

The significance of distributed scheduling problem in a multi-factory production network has been one of the hottest topics in recent years (Chung, Chan, & Chan, 2009). As there are number of factories along the supply chain, the scheduling activities are more complex than the traditional single-factory scheduling problems (Moon & Seo, 2005).

Different positioning of the factories along the supply chain may leads to different structure and characteristics of the system. Factories can be positioned in parallel, serial or network structure. In parallel structure, multiple factories which are considered to be able to produce various types of product are positioned in a parallel structure. Sauer (1998), Karatza (2001), Guinet (2001), Moon, Kim, and Hur (2002), Jia, Nee, Fuh, and Zhang (2003), Archimède, Charbonnaud, and Mercier (2003), Chan, Chung, and Chan (2005, 2006), Jia, Fuh, Nee, and Zhang (2007), Naderi and Ruiz (2010), De Giovanni and Pezzella (2010), Shah and Ierapetritou (2012) and Behnamian and Ghomi (2012) investigated the parallel multi-factory scheduling problem.

But if factories are positioned in the series, the system would have the serial structure. While the material enters the system, the first plant starts processing. After finishing the process on this plant the semi-finished product would transfer to the downstream plant and the production process would start there. If these two plants are positioned in two different geographical places, transportation constraints should be considered too (see Fig1).

Interrelation among factories in the serial multi-factory supply chain causes the high value of complexity. This means that the effect of material shortage in the upstream factories would be extended through the supply chain and cause delay in production in the downstream factories. On the other hand, stopping the production in the downstream factories because of inventory accumulation would cause decrease or stop in production of upstream factories. Thus, Production and transportation between upstream and downstream factories should be synchronized in order to decrease inventory cost and also to avoid risk of stock out for a factory (Simchi-levi, Kaminsky, & Simchi-levi, 2000). H'Mida and Lopez (2012) applied the constraint satisfaction approach for the

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Nomenclature

Indices

f	factory
m	factory
i	job
j	job

Parameters

F	number of factories
n	number of jobs to be processed
d_j	due date of job j
B	capacity of each vehicle (maximum number of jobs in a batch)
p_{jf}	processing time of job j in the factory f
M	big number
τ^f	the transportation time between factory f and $f+1$
η	the cost of tardiness
β	the cost of delivery

Decision variables

σ_{jh}	equal to 1 if job j is positioned in batch h, and 0 otherwise
Δ_h	equal to 1 if there is at least a job in batch h, and 0 otherwise
A_h	The arrival time of batch h to the customer
T_j	tardiness of job j

integrated production and transportation scheduling case study in the serial multi-site manufacturing environment. Huang and Yao (2013) investigated a problem which considers sequencing, lot-sizing and scheduling of several products which are being manufactured through several firms in a serial-type supply chain. They implemented a time-varying lot-sizing policy for problem formulation and also solved it by a three-phase heuristic.

Network structure is a combination of serial and parallel structure. The same as parallel structure, there are a number of identical plants in each stage and the allocation of orders (jobs) to factories should be considered too. Chung, Lau, Choy, Ho, and Tse (2010) studied the multi-factory scheduling problem. In this study factories are structured as network. They considered a capacity constraint, precedence relationship and production lines with parallel machines. They presented a modified genetic algorithm to minimize the completion time.

As mentioned above, since products of a factory would be delivered to the next factory as a raw material, the system's cost significantly depends on the transportation cost of products. Thus the coordination of production and transportation is a challenging problem for this collaborative environment. Cheng and Kahlbacher (1993) introduced an approach that allots number of jobs to several batches each of which would be delivered to downstream factory as a single shipment. This problem would be considered as a batch delivery problem. Designing a batch of products to be delivered is a reasonable approach in reducing the transportation cost. As it may increase the number of tardy jobs or the total tardiness, the goal of the problem is to determine simultaneously the optimal number of batches, the assignment of jobs to the batches and the scheduling of batch in order to minimize the problem's objective function. The simple example of this procedure is shown in Fig2. The objective of this paper is the summation of total transportation cost and total tardiness cost. The total transportation cost is an increasing function of the number of batches.

As the coordination of the production and delivery scheduling can improve the overall operational performance of the supply chains, it has being recently considered by researchers.

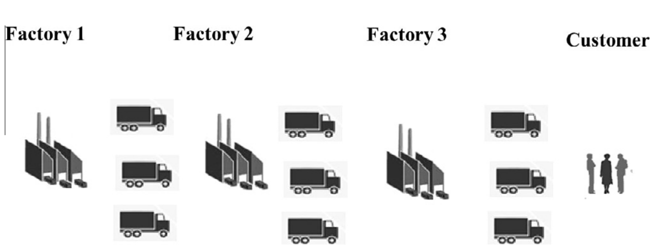

Fig. 1. Serial multi-factory supply chain.

Single machine scheduling problems with non-identical job release times and delivery times has been studied by Potts (1980) and Hall and Shmoys (1992). A sufficient number of vehicles are considered to be available to deliver jobs. Herrmann and Lee (1993) considered a single machine scheduling problem when the due dates of jobs are common. They minimized the summation of earliness–tardiness and batch delivery costs where the cost per tardy delivery is fixed. Cheng, Gordon, and Kovalyov (1996) considered a problem of the delivery costs and the summation of earliness of the orders for single machine. They also established a relation between this problem and parallel machine scheduling. They extended the complexity results and algorithms of the parallel machine scheduling problem to their problem. Hall and Potts (2003) considered number of scheduling, batching and delivery problems in the context of a two-stage supply chain where a supplier makes deliveries to several manufacturers, who also make deliveries to customers. They minimized the summation of scheduling and delivery cost. Capacity restrictions on delivery batches are considered on the studies of Lee and Chen (2001), Chang and Lee (2004), Potts (1980), Hall and Shmoys (1992) and Li, Vairaktarakis, and Lee (2005). In these studies only some scheduling objectives like maximum completion time (makespan), summation of completion times, maximum lateness, number of tardy jobs and total tardiness, are considered without taking into account any delivery costs. A comprehensive literature review on production and distribution scheduling models' was presented by Chen (2010). The problem of scheduling and batch delivery to a customer with the aim of minimizing the summation of the total weighted flow time and delivery cost on a single machine is considered by Mahdavi-Mazdeh, Shashaani, Ashouri, and Hindi (2011). Mahdavi-Mazdeh, Sarhadi, and Hindi (2007) and Mahdavi-Mazdeh, Sarhadi, and Hindi (2008) have also minimized the summation of the total flow time and delivery cost considering multiple customers with zero and non-zero ready time. An integrated due date assignment and single machine production and batch delivery scheduling problem for make-to-order production system is addressed by Rasti-barzoki and Hejazi (2013). In their research, manufacturer received number of orders from customer and this orders need to be processed on one or two machines and finally to be sent to the customer in batches. Their goal was minimizing the summation of the total weighted number of tardy jobs and the delivery costs.

Thus, the objective of this paper is to design the multi-factory supply chain to simultaneous assessment of both prementioned costs. One of the manifest differences of this problem with flowshop is transportation among factories and considering its cost as an objective function; because in the flowshop system the transportation among machines is usually negligible. Another