Int. J. Production Economics 121 (2009) 266–273

Contents lists available at ScienceDirect

Int. J. Production Economics

journal homepage: www.elsevier.com/locate/ijpe

Logistics scheduling to minimize inventory and transport costs

Xiuli Wang [a,b,*], T.C.E. Cheng [b]

[a] School of Economics and Management, Nanjing University of Science and Technology, Nanjing, China
[b] Department of Logistics and Maritime Studies, The Hong Kong Polytechnic University, Hung Hom, Kowloon, Hong Kong

ARTICLE INFO

Article history:
Received 3 September 2008
Accepted 7 May 2009
Available online 28 May 2009

Keywords:
Logistics scheduling
Inventory and transportation
Algorithms

ABSTRACT

We study a logistics scheduling problem where a manufacturer receives raw materials from a supplier, manufactures products in a factory, and delivers the finished products to a customer. The supplier, factory and customer are located at three different sites. The objective is to minimize the sum of work-in-process inventory cost and transport cost, which includes both supply and delivery costs. For the special case of the problem where all the jobs have identical processing times, we show that the inventory cost function can be unified into a common expression for various batching schemes. Based on this characteristic and other optimal properties, we develop an $O(n)$ algorithm to solve this case. For the general problem, we examine several special cases, identify their optimal properties, and develop polynomial-time algorithms to solve them optimally.

1. Introduction

The production logistics activity of enterprises is typically composed of three stages, namely supply, production and distribution. In recent years, much of the literature has studied logistics scheduling that integrates production scheduling and job delivery to customers. For example, the reader is referred to Lee and Chen (2001), Chang and Lee (2004), Chen and Vairaktarakis (2005), Hall and Potts (2005), Pundoor and Chen (2005, 2009), Chen and Pundoor (2006), and Wang and Cheng (2007, 2009a). This line of research focuses on optimizing the total distribution cost and customer service level. On the other hand, for scheduling research that takes supply and production into consideration, Selvarajah and Steiner (2005) presented a polynomial-time algorithm to minimize the sum of total inventory holding cost and product batch delivery cost. Qi (2005) considered a logistics scheduling model that deals with material supply and job scheduling at the same time, where the objective is to minimize the sum of work-in-process (WIP) inventory cost and raw material supply cost.

There are research results on logistics scheduling that deals with all the three stages of supply, production and delivery. Hall and Potts (2003) considered multiple-production-stage scheduling with batch delivery in an arborescent supply chain. They analyzed the complexity of the problems and developed some dynamic programming algorithms. Wang and Cheng (2009b) considered a machine scheduling problem with supply and delivery of materials and products, where the warehouse, the factory and the customer are located at three different sites. The objective is to minimize the makespan. They did not take the WIP inventory cost into consideration.

In this paper we formulate a logistics scheduling model that considers production scheduling, raw material supply and product delivery at the same time. We assume that the supplier, manufacturer and customer are located at three different sites. Transportation service is provided by a third party, so transport vehicles are available at any time. The manufacturer needs to pay the third party for its service to transport materials to the factory, and deliver products to the customer. A job may be transported from

* Corresponding author at: School of Economics and Management, Nanjing University of Science and Technology, Nanjing, China.
E-mail address: wangdu0816@163.com (X. Wang).

0925-5273/$ - see front matter © 2009 Elsevier B.V. All rights reserved.
doi:10.1016/j.ijpe.2009.05.007

the supplier's warehouse to the manufacturer's factory at any time just before it starts processing, and a product is available for delivery to the customer as soon as it finishes processing in the factory. On the other hand, since the cost of processing all the jobs in a planning period is normally fixed and independent of the production schedule used, we only consider the cost of holding intermediate inventory, which is in terms of the WIP inventory level of the factory. The problem under study is to find an optimal joint schedule for material supply, production scheduling, and job delivery so that the sum of WIP inventory cost and transport cost is minimized. This logistics scheduling problem models the practical situation where a single dominant firm controls both upstream and downstream stages in a supply chain. So the firm could, in the short run, simply optimize its own operational decisions regardless of the impact of such decisions on the other stages of the chain (see, e.g., Erengüc et al., 1999).

The rest of the paper is organized as follows. In Section 2 we formally describe our model and present the notation. In Section 3 we develop an optimal algorithm for the special case of the problem where all the jobs have identical processing times. In Section 4 we examine several special cases of the general problem, identify their optimal properties, and develop polynomial-time algorithms to solve these cases optimally. In the last section we conclude the paper and suggest topics for future research.

2. Description and notation

Suppose that the manufacturer receives n orders (jobs), $N = \{J_1, J_2, \ldots, J_n\}$, from a customer. Here, the customer may represent a distribution center that serves some customers that are close to one another in a geographical area. The n jobs are processed by a single machine (facility) in the factory. Each job J_i has a processing time p_i. The jobs as raw materials before processing in the factory have to be transported from the supplier's warehouse. We suppose that a vehicle can load at most K_s jobs on a supply trip from the warehouse to the factory, and the transport cost of a supply trip is $\mu_s + x_s\gamma_s$, where μ_s is a fixed cost for each supply trip, γ_s is the cost per loaded job and x_s is the number of the loaded jobs in the supply trip. All the jobs on a supply trip constitute a supply batch. The jobs as products after processing in the factory need to be delivered to the customer. We suppose that a vehicle can load at most K_d jobs on a delivery trip from the factory to the customer, and the transport cost of a delivery trip is $\mu_d + y_d\gamma_d$, where μ_d is a fixed cost for each delivery trip, γ_d is the cost per loaded job and y_d is the number of the loaded jobs in the delivery trip. All the jobs on a delivery trip constitute a delivery batch.

By controlling the sizes of supply and delivery batches, the arrival times of supply batches, the departure times of delivery batches, and selecting a suitable sequence to process the jobs in the factory, we seek to minimize the sum of WIP inventory cost and transport cost.

The following notation will be used throughout the paper:

B_k^s: the kth supply batch;
t_k^s: the arrival time at the factory of supply batch B_k^s;
B_h^d: the hth delivery batch;
t_h^d: the departure time from the factory of delivery batch B_h^d;
$\varphi = [B_1^s, B_2^s, \ldots, B_u^s]$: a supply scheme that transports all the jobs from the warehouse to the factory, where u is the number of supply batches in a supply scheme;
$x_k = |B_k^s|$: the number of jobs in B_k^s for $k = 1, 2, \ldots, u$;
$X = (x_1, x_2, \ldots, x_u)$: a vector denoting the numbers of jobs in the supply batches;
$\psi = [B_1^d, B_2^d, \ldots, B_v^d]$: a delivery scheme that transports all the jobs from the factory to the customer, where v is the number of delivery batches in a delivery scheme;
$y_h = |B_h^d|$: the number of jobs in B_h^d for $h = 1, 2, \ldots, v$;
$Y = (y_1, y_2, \ldots, y_v)$: a vector denoting the numbers of jobs in the delivery batches;
$\lceil x \rceil$: the smallest integer that is no less than x;
$\lfloor x \rfloor$: the largest integer that is no larger than x.

The WIP inventory cost in the factory should in theory be a function of the sum of the time that each job spends in the factory. We assume that the WIP inventory cost associated with a job J_i is $c_i(k,h) = \alpha(t_h^d - t_k^s)$, if $J_i \in B_k^s$ and $J_i \in B_h^d$, where $\alpha(>0)$ is the inventory cost of each job per time unit. So the objective function is given by

$$F(\varphi, \psi) = (u\mu_s + n\gamma_s) + (v\mu_d + n\gamma_d) + \sum_{J_i \in B_k^s, B_h^d} c_i(k,h) \tag{1}$$

where the three terms on the RHS represent the supply cost, the delivery cost, and the total WIP inventory cost, respectively.

For the problem under study, there exists an optimal solution in which the following properties hold obviously.

Observation 1: Once a supply batch arrives at the factory, a job in the batch begins processing.

Observation 2: Once all the jobs of a delivery batch have finished processing, the delivery batch should depart from the factory.

Observation 3: There should be no idle time between the first and the last processed jobs in the factory.

Observation 4: The jobs belonging to the same supply batch should be processed consecutively, and a delivery batch should consist of consecutively processed jobs.

In the following discussion, we only consider solutions that possess the properties stated in Observations 1–4.

3. Identical job processing times

In this section we first give a unified expression of the objective function for the case where the jobs have identical job processing times. We then prove some optimal properties, and develop an $O(n)$ algorithm for this case. This case models the practical situation of a monopolistic manufacturer that specializes in making a