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IFAC-PapersOnLine 48-3 (2015) 1750–1755

A robust heuristic algorithm for multiple-customers coordinated scheduling of delivery and inventory problem

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Abstract: In this work, we tackle the problem of integrated delivery-inventory for the supply of multi-items to more than one customer, after its production by a manufacturer to minimize the total delivery and storage costs. A mathematical model incorporating the costs of both the delivery and the storage costs is developed as a Mixed Integer Programming model (MIP). The proposed approach is an heuristic algorithm where in the first phase, a heuristic search is deployed to construct a sequence of batches and in the second the batches are scheduled according to the due dates of the jobs. Extensive experiments are conducted to evaluate the efficiency of the algorithm in terms of time of resolution and solution quality. The evaluation is carried out against the solutions generated by the exact mathematical model of the problem. Experimental results demonstrate that the proposed heuristic algorithm is robust in term of time of resolution and generates feasible solutions for the instances where the MIP model cannot.

Keywords: Coordinated Scheduling, Production and Transportation, Multiple Customer, Mixed Integer Programming, Heuristic Algorithm,

1. INTRODUCTION

The coordination between vendor and buyer for improving the performance of inventory control has received a great deal of attention and the integrated approach has been studied for years. Typically, integrated approach focuses on the production-inventory decisions of supply chain partners while minimizing the total relevant cost of the system. During processing and supply of the product, inventory accumulates with the manufacturer and also with each of the buyers in this system. Delivery of the product in small lots reduces the inventory cost but increases set-up, ordering and transportation cost. On the other hand, delivery in larger lots increases inventory cost but reduces the other costs, and scheduling interference results because of scarce storage capacity at both the manufacturer and the buyers. Synchronization of the production flow is essential for the control of inventory and hence for minimizing the total cost of the system. The integration approach has been researched for years. Much research has focused on this area under various assumptions and objective measures that differ from the problem proposed in this paper.

One of the keys to successful implementation of juste in time (JIT) production in the modern supply chain environment is integration of the vendor-buyer inventory system. At the operational scheduling level, Chen (2010) reviewed the production and distribution scheduling models and classified these problems in five classes: (1) models with individual and immediate delivery; (2) models with batch delivery to a single customer by direct shipping method; (3) models with batch delivery to multiple customers by direct shipping method; (4) models with batch delivery to multiple customers by routing method (5) models with fixed delivery departure date. In the first model, jobs have delivery windows, and thus production windows can be incurred, however, due to the immediate and individual delivery requirement, the problems under this model can be reduced to fixed-interval scheduling problems (without the delivery). For all other models, no production windows have been specially considered in the survey. Problems addressing an objective function that combines machine scheduling with the delivery costs are rather complex. However, they are more practical than those involving just one of the two factors, since these combined-optimization problems are often encountered when real-world supply chain management is considered.

Recently, Grunder (2010) considered a single-product batch scheduling problem with the objective of minimizing the sum of production, transportation and holding cost. Particularly, he assumes that the delivery time depend on the batch sizes and proposes a dynamic programming approach based on a dominance relation property. Wang et al. (2013) extended this work to an integrated scheduling problem for single-item supply chain involving due date considerations with the objective of minimizing the total logistics cost.

Further, in order to streamline the single-vendor multi-buyer supply chain, the vendors production cycle should be synchronized with the ordering cycles of the buyers so that the total related cost for the entire chain can be reduced. Banerjee and Banerjee (1994) further developed an analytical model for coordinated inventory control between a vendor and multiple buyers dealing with a

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Peer review under responsibility of International Federation of Automatic Control.
10.1016/j.ifacol.2015.06.339

single product under stochastic demands and lead times through a common cycle approach. They focused their attention on the use of electronic data interchange (EDI). They argued that EDI makes the link between multiple buyers and the supplier feasible on a real-time basis and it is possible for the supplier to monitor the consumption pattern of the buyers. As a result, it is not necessary for the buyers to place an order, but the supplier can send the needed material according to a pre-arranged decision system. In their paper, the authors assume that the parties deal with a single product and they agree to ship the materials at fixed intervals (common to all buyers). At regular intervals, the quantity of material shipped by the vendor to each buyer depends on the quantity on hand, as a pre-determined replenish-up-to quantity is to be reached. Sarmah et al. (2008) investigated a coordination problem in a single-manufacturer and multiple heterogeneous buyers situation. They developed a coordination mechanism that allows improvement of supply chain performance.

A recent study Hoque (2008) dealt with the development of three models for supplying an item to more than one buyer after its production by a manufacturer. In the first two models, all batches are of exactly the same size but the timing of shipment is different. In the first one, the manufacturer transfers a batch to a buyer as soon as its processing is finished, whereas in the second, a batch is transferred to a buyer as soon as the previous batch is finished there. In the 3rd model, the next shipment size increases by the ratio of the production rate and the sum of demand rates of the buyers. In this case, the time of meeting a buyers demand by a batch equals the time of processing the next batch at the manufacturer, and the next batch is transferred as soon as the previous one finishes at buyers. In developing the models, the production flows have been synchronized by transferring the lot in such ways for the control of inventory and hence for minimizing the total average cost. However, these models have been found to be inferior to some single-vendor single-buyer models, obtained by transferring the lot with equal and/or unequal sized batches, in providing minimum cost solutions to some numerical problems. Then Hoque (2011) proposed two single-vendor multi-buyer integrated models with synchronization and claimed to yield a lower cost comparing to existing models in the literature. Most recently, models are actually based on different treatments of the total ordering costs. As the result,Hoque (2011) conclusion may be questionable. Hariga et al. (2014) compared the cost between the results of the models in Hoque (2011) and Zavanella and Zanoni (2009), then they concluded that both models are not appropriate as they are using different functional forms of the total setup and ordering costs.

This paper considers integrated delivery-inventory for the supply of multi-items to more than one customer, after its production by a manufacturer. The manufacturer transfers the jobs to a customer by an available transporter allotted to each customer. The aim of this paper is to develop an algorithmic approach capable of establishing solution feasibility for integrated scheduling problem instances of various types and difficulty levels. The study is based on a real-world problem originating from an automotive manufacturers. We focus on single plant production (supplier) scheduling with multi-product, multi-customer delivery-storage problem. The plan consists of production and delivery stages. The jobs are operated in batch mode. Sequence and machine dependent setup and cost time are not considered in this study, in the objective to study the delivery stage (Figure 1). The objective is to determine an optimal scheduling for the delivery of customer orders, specifiying the arrival time of each product. The general objective of the problem is to find the minimal cost of the delivery and the storage cost. A comparative study of the solutions of several numerical problems is also carried out, to validate the analytical findings and to examine the limitations of the methods used.

The organization of the remainder of the paper is structured as follows. In Section 2, we present the problem definition and formulation in detail. In Section 3 we describe the optimization method for solving the problem. Then, In Section 4, we describe the proposed heuristic of the problem. In Section 5 and 6, we perform an experimental analysis of the proposal and draw some conclusions and suggest the future research directions.

2. PROBLEM DEFINITION AND FORMULATION

In the supplier side, a facility of multi-machines available to produce a finite number of heterogeneous jobs (products), which prevents the suppliers' storage cost assumption. Each job needs a constant processing time, however we assume that the total production time of any batch is less than the minimum round-trip delivery time for the transporters. Each round trip between the factory and each customers h requires a delivery cost η_h as well as a delivery time τ_h. The batches delivered from the vendor to the customers can be of equal or unequal-sized batches. It is assumed that directing delivery method is used for sending the batches to the customers. The number of transporter considered to deliver the product from the supplier to the customers equals to the number of customers. The considered transporters have the same capacity c, where the total number of job belonging to the same batch cannot exceed the capacity of the vehicle used. If job j of customer h, is delivered before its due date d_j, it is known as a early job and a cost equal to β_h is incurred, where β_h equal to the earliness penalty of the job j belongs to the customer h. Batching and sending several jobs in the batches will reduce the transportation costs. The cost of the system includes delivery and holding costs. The objective is to determine the sequence of batches that has to be processed and scheduled of the distributions that have to be used by customers, such that the expected total cost of both vendor and customers be minimized.

In Figure 1 a multi-customer multi-transporter model has been depicted as an example.

2.1 Assumptions and notations

The mathematical models are developed based on the following assumptions:

(1) The system consists of m customers who are supplied by a single-vendor one transporter allocated to each customer h.