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Generalized single-vendor multi-buyer integrated inventory supply chain models with a better synchronization

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ABSTRACT

Researchers have synchronized both the single-vendor single-buyer and the single-vendor multi-buyer integrated inventory supply chains by transferring the lot either only with equal-sized or only with unequal-sized sub-lot (batches). However, synchronization by transferring the lot with unequal and/or equal-sized batches (combination of unequal and equal sized batches along with the previous two cases), though available in the former case, the latter one lacks it. Accumulating the inventory in each of the vendor and the buyers, here we develop a generalized single-vendor multi-buyer supply chain model individually by extending the idea of such synchronization, and present logical development of their minimal cost solution techniques. Thereafter, we highlight theoretically the uniqueness of the present techniques by showing the best available methods as their special cases. Special cases are validated with the solutions of some numerical problems. Then their comparative studies with recently developed techniques on two numerical problems are carried out to show significant cost reductions.

1. Introduction

Although researchers have given considerable attention to the production flow synchronization of the single-vendor single-buyer integrated inventory supply chain, they have paid little attention to the synchronization of the single-vendor multi-buyer case. Recently 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, 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 buyer's 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. Recently Zavanella and Zanoni (2009) also synchronized the single-vendor multi-buyer production flow by transferring the lot with equal sized batches (number of batches may be different for different buyers), and accumulating the inventory at the buyers. This model has been found to be inferior even in comparison with the models processed by Hoque (2008) in providing minimum cost solution for a numerical problem. Therefore, there remains a further research scope for a generalized procedure of controlling the vendor–buyers integrated inventory by a better synchronization of the system.

The integration of the vendor–buyers inventory in today's supply chain environment plays an important role in the successful implementation of JIT production. Researchers have considered integrated inventory both for the single-vendor single-buyer and the single-vendor multi-buyer cases. Close relationship among the vendor and buyers is essential for this integration. For the control of inventory, the single-vendor single-buyer integrated inventory supply chain has been synchronized by transferring the lot with equal and/or unequal sized partial shipments. An up-to-date review of the topic for a synchronized production flow has been provided by Hoque (2009). Ha (2010) reformulated a single-vendor single-buyer integrated production-inventory model with process unreliability consideration, and corrected necessary and sufficient conditions for optimality. Jaber et al. (2010) coordinated a three-level (supplier–manufacturer–retailer) supply chain with learning-based continuous improvement. They developed the models and their solution techniques

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to achieve chain-wide lot-sizing integration. Researchers have also given attention to the single-vendor multi-buyer case. Viswanathan and Piplani (2001) developed a model by offering a price discount to the buyers and analyzed the benefit of coordinating supply chain using common replenishment time periods. In this model the vendor does not keep any inventory and orders required quantity from an outside supplier whenever he/she receives an order from a buyer. Bernstein and Federgruen (2005) investigated the equilibrium behavior of decentralized supply chains where a single supplier servicing a network of retailers under demand uncertainty. A retailer's demand distribution may be dependent on its own retail price only or on its own price as well as those of the other retailers. Kim et al. (2006) proposed an analytical model to integrate and synchronize effectively the procurement of a raw material, production of multiple items utilizing the raw material and their delivery to multiple retailers. The objective was to find the production sequences of items, the common production cycle length and the delivery frequencies and quantities that minimized the average total cost. Abdul-Jalbar et al. (2006) also minimized the average total cost using single-cycle policies. Here the item is first stored in a warehouse and then known demands are met from there. Bernstein et al. (2006) dealt with supply chains where a single supplier servicing a network of retailers who compete with each other by selecting sales quantities. They coordinated the supply chains with simple pricing schemes: either retailer-specific constant unit wholesale prices or retailer-specific discount schemes. Gürbüz et al. (2007) presented a centralized ordering policy that orders for all retailers simultaneously from an outside supplier. They studied the impact of coordinated replenishment and shipment in inventory and distribution systems. Li and Zhang (2008) studied information-sharing on an uncertain demand under confidentiality in a decentralized supply chain, where one manufacturer supplies to multiple retailers competing in price. In this system the retailers deduce the shared information from the wholesale price to create a signaling effect that makes the manufacturer's demand more elastic, resulting in a lower equilibrium wholesale price and higher supply chain profit. Karabati and Sayin (2008) addressed the coordination problem for the single-supplier/multi-retailer integrated supply chain under offered quantity discounts from the supplier. They modeled each buyer's expectations based on limited view of the entire supply chain. Sarmah and Goyal (2008) investigated a coordination problem in a single-manufacturer and multiple heterogeneous buyers' situation. They developed a coordination mechanism to improve supply chain performance. Wu and Cheng (2008) attempted to quantify the impact of information sharing on inventory and expected cost in a multiple-echelon supply chain under a general end demand process. The authors showed that both the inventory level and the expected cost of the distributor and the manufacturer decrease with an increase in the level of information-sharing. Li et al. (2008) dealt with the replenishment routing problems of one supplier who can replenish only one of multiple retailers per period. They presented an algorithm to calculate a feasible routing so that the supplier can replenish the selected retailers on the selected periods without shortages. Nonetheless, synchronization of the single-vendor multi-buyer production flow for a balanced integrated inventory in attaining a minimum average total cost has received little attention of the researchers. Hoque (2008) synchronized the production flow by transferring the lot with equal or unequal-sized batches in developing three models, and presented optimal solution procedures to them. However, these models were found unable to provide the same minimum total cost of each of the two single-vendor single-buyer numerical problems, as obtained originally by Hill (1999) and Hill and Omar (2006) and recently by the modified solution procedure of Hoque (2009). Zavanella and Zanoni (2009) developed a single-vendor multi-buyer model by transferring the lot with equal sized batches and stocking them at the buyers. For a numerical problem this has been found to be inferior to the models of Hoque (2008). Thus, there is a lack of a properly synchronized generalized single vendor multi-buyer integrated inventory supply chain model that could lead to a minimum total cost solution considering all cases.

To overcome this shortcoming this paper deals with the development of two generalized single-vendor multi-buyer models with a better synchronization of the production flow, and also accommodating well known single-vendor single-buyer as well as recently developed single-vendor multi-buyer models. First, we deal with the development of a generalized single-vendor multi-buyer integrated inventory supply chain model by accumulating the inventory at the vendor, and assuming a batch transfer when the previous one finishes at the buyers. The production flow is synchronized by combining the ideas of synchronization of Hill (1997, 1999) for the single-vendor single-buyer problem. In the model of Hill (1997), either all batches are of equal sized or all of them are of unequal sized. In Hill (1999) either all the batches are unequal or they are a combination of unequal and equal sized batches. In the case of unequal-sized shipments, the next shipment increases by the ratio of the production rate and the sum of demand rates of all buyers. In the case of combination, 1st follows unequal sized shipments and at a certain stage the remaining ones are kept to be equal sized. To control the single-vendor multi-buyer integrated inventory in transferring the lot for a minimum total cost we combine all these options together in developing the model, that is, the lot is transferred with unequal and/or equal sized batches. It has also been extended to include the case of transferring a batch just after finishing its processing, as proposed by Hill and Omar (2006) for the single-vendor single-buyer case. Since both the models are found to be of the same format, we present a common minimal cost solution technique to the models. Then we carry out a comparative study of the 1st model with the models given by Hoque (2008) on the result of a numerical problem to show a reasonable cost reduction. Then by a comparative study of the 2nd model with that of Zavanella and Zanoni (2009) on the result of a numerical problem provided by them, a significant cost reduction is shown. In addition, we show theoretically that Hill (1997, 1999), Hill and Omar (2006) and Hoque (2008, 2009) are special cases of the present techniques. These special cases are also highlighted with the solutions of some numerical problems. Thus, this paper presents a superior minimal cost solution technique to the single-vendor multi-buyer integrated inventory supply chain problem with a better synchronization of the production flow, which includes the well known single-vendor single-buyer problem as their special cases.

The outline of the remainder of the paper is as follows: Section 2 deals with assumptions, notations, presentation of the models and development of their optimal solution techniques. In Section 3 we show the special cases theoretically. Section 4 deals with the solutions of several numerical problems and their comparative studies. The conclusion is drawn in Section 5.

2. Models formulation and their solution techniques

2.1. Assumptions and notations

In developing the models we assume the following:

(i) deterministic constant demand and production rates;
(ii) each of the buyers estimates his/her demand, holding and ordering costs considering various cost factors and informs the manufacturer;