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Integration of inventory and transportation decisions in a logistics system

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ABSTRACT

This paper addresses some of the challenges faced by a company which is responsible for delivering coal to its four subsidiaries situated along a river, through river hired or self-owned vessels. We propose to adopt a vendor managed inventory concept that involves establishment of a central warehouse at the port, and apply the Markov Decision Process (MDP) to formulate both ordering and delivery problems, considering different transportation modes, costs, and inventory issues. An efficient algorithm is developed for solving the MDP models. Our computational tests show that the proposed strategy can significantly reduce the overall system costs while maintaining smooth Just-in-Time supplies of coal to the subsidiaries.

1. Introduction

Vendor managed inventory (VMI) is an important coordination mechanism in supply chain management where the supplier is given the responsibility of managing inventory in accordance with agreed-upon number of units at specified retail locations (Aviv and Federguen, 1998). The VMI system can reduce inventories and shortages by using advanced online messages and data-retrieval systems (Angulo et al., 2004; Zhao and Cheng, 2009). In addition, as the vendor is guided by mutual agreements on inventory levels, fill rates and transaction costs, both suppliers and customers can maximize their benefits (Andel, 1996; Wang, 2009). However, as most such systems are complicated, the vendor is usually faced with challenges of designing an integrated replenishment strategy (Silver et al., 1998; Nachiappan and Jawahar, 2007). In this paper, a VMI model is applied to a two-echelon logistics system comprising of a parent company (which is called SPC in this paper) and its subsidiaries located along the Yangtze River, China. The parent company is responsible for delivery of coal, the raw material for production, to its subsidiaries. Coal is first supplied from Huainan Mining Group Corporation (HMGC) to the Wu Hu port (WHP) by train, and is then shipped to the subsidiaries using river vessels.

In this paper, we propose establishment of a central warehouse at WHP, which should own a fleet of vessels, and administer the VMI system at the central warehouse for both ordering and delivery decisions. The objective is to integrate ordering and delivery decisions in the system such that the overall costs, including holding, shortage and transportation costs, can be minimized. We thus build a stochastic planning model based on the Markov Decision Process (MDP). An algorithm based on Modified Policy Iteration (MPI), with the action elimination procedure, is designed for the MDP model, such that an approximate optimal solution can be found within reasonable time.

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It is suggested by theoretical and computational analysis that the VMI mode of operations provides significant competitive advantages. In contrast to the existing VMI literature, where the suppliers and their downstream enterprises belong to different business entities, in this paper, the warehouse (acting as a supplier) and the subsidiaries (acting as customers) are all controlled by SPC, such that they have more incentives for information sharing. Moreover, the proposed model can still be considered as VMI for the following two reasons: (1) the warehouse and the subsidiaries are independent of each other in financial terms; and (2) the warehouse is responsible for inventory decisions of the subsidiaries in a VMI-like fashion.

In terms of supply and demand, the model and approach provided in this paper match the situations where a supply lead time may exist, and demands of customers are stochastic, but can be approximated to some discrete distributions. In addition, different from most literature about VMI, our study focuses on complicated logistics systems where different transportation modes are involved along the supply chain, and their capacities, fixed and variable costs, and other issues like penalty costs, lead time, are fully considered. The proposed method for the integration of inventory and transportation decisions is more comprehensive and realistic. We introduce some advanced supply chain notions such as VMI and Just-in-Time to a traditional industry in China, and also successfully apply a stochastic process MDP model for solving practical problems. Therefore, this work can provide insights to companies facing similarly complicated operations in reality.

The rest of this paper is organized as follows. In Section 2, the background of the problem is given. Some general strategies, including VMI, are proposed for overcoming problems in the existing logistics system. A review of relevant literature is provided in Section 3. Section 4 addresses notations and provides a detailed analysis for developing the MDP model, involving both delivery and ordering decisions at the warehouse. In Section 5, a MPI-based algorithm for solving the MDP models is presented. Comparative analysis of the proposed system with the current system is conducted in Section 6. Finally, conclusion is given in Section 7.

2. The background of the problem

SPC, which includes more than 80 subsidiaries, either wholly- or partially-owned, is one of the largest producers and suppliers of petrochemical products in China. Coal is one of the important raw materials for petrochemical products such as synthetic resins, synthetic fibers and chemical fertilizers. In 2007, SPC purchased more than 20 million tons of coal, of which nearly 0.25 million tons were consumed by its subsidiaries in the Yangtze River region. One of the coal suppliers to this region is HMGC. Each year, approximately 0.6 million tons of coal are transported through the midway Wu Hu port (WHP) to SPC's subsidiaries, by the supplier. WHP is the largest port for coal transshipment along the Yangtze River and plays a crucial role in coal distribution. In our case study, we focus on ordering and delivery decisions for subsidiaries along the Yangtze River, since the current logistics system has some special properties and potential for improvement.

2.1. Current system and its problems

YA, YI, JI and AN are the four main subsidiaries along the Yangtze River. According to their past ordering data, we find that monthly demand of each subsidiary closely follows a Poisson distribution. In the current delivery system, each subsidiary submits its monthly order to the parent company and then the SPC transfers these orders to the supplier (HMGC), without making any modifications. The ordered quantity of coal is delivered from the supplier to the WHP port by train, and is then transshipped to individual subsidiaries by vessels. See Fig. 1 for reference.

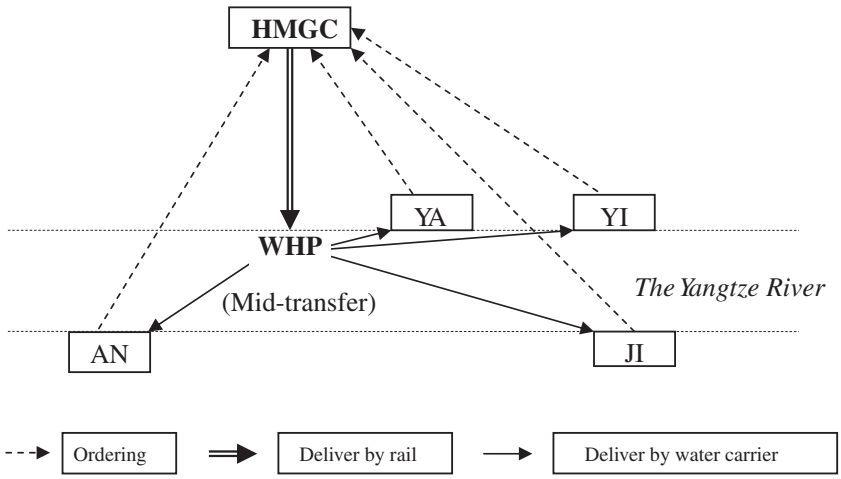

Fig. 1. The current logistics system.