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A genetic algorithm-Taguchi based approach to inventory routing problem of a single perishable product with transshipment

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ABSTRACT

In this paper we present a model of inventory routing problem with transshipment in the presence of a single perishable product. In this problem, vehicle routing and inventory decisions are made simultaneously over the planning horizon to meet customer's demand under maximum level policy. Products are deteriorated at the exponential rate during the time they are stored in the depot or customer's warehouse. Due to the NP-hard nature of the model, we propose a genetic algorithm based approach to solve the problem. Moreover, the proposed algorithm parameters are determined using Taguchi design approach to achieve the best solution. Besides, a numerical example is used to illustrate the validity of the model. To the best of our knowledge, this is the first study that incorporates perishability of the products into inventory routing problem with transshipment, in which the products stocked in the depot or warehouses spoil due to their nature and also environmental issues.

1. Introduction

Inventory routing problem (IRP) deals with the issue of meeting the demands of customers, geographically spread over a given planning horizon. The IRP concerns the distribution of various products from a single or multiple type(s) of production depots (Campbell, Clarke, & Savelsbergh, 2002). Inventory routing problems (IRPs) are generally addressed when the inventory and routing decisions must be concurrently made and this will lead to a very hard optimization problem. In contrary, when a company allocates vehicles in order to meet the customers' requirements, no direct instruction from its customers exists in the IRP. The company allocates a fleet of ships in order to save the stock level by considering the customers' limitations at minimal cost through a given planning horizon (Siswanto, Essam, & Sarker, 2011). In general, the IRP has been applied for diverse time horizons and also different assumptions about the types of demands. The single-period IRP with deterministic demand is typically classified as the classical vehicle routing problem (VRP) (Yu, Chen, & Chu, 2008).

This paper deals with the case of vendor-managed inventory (VMI) systems, which is one of the most prevalent example of adding value through logistics (Coelho, Cordeau, & Laporte, 2012). Under this strategy, the supplier makes replacement choices according to its customers' demands and inventory levels. These decisions consist of the amount of each product, which should be delivered to each customer, and finding a way of combining them into vehicle routes in order to ensure the minimum costs of distribution, spoilage, and inventory at the location of the customers. The inventory policy applied to the product shipment is the maximum level (ML) policy, in which supplier should make the decision on the amount of product that needs to be transported to the customer. Order up-to-level policy, which fills up the customer warehouse, would be inapplicable in this regard, since extra inventories will negatively impact on the overall cost of the system owing to the short life of the products.

Transshipment is a concept applied within the IRP, under which, the external freight carriers are adopted to ship goods either directly from suppliers to end users, or between customers. This includes the advantage of transferring goods between the stores of the same chain for handling the demand fluctuations. Transshipments also occur when the capacity and storage constraints impose limits on the amounts, which can be delivered from clients, considering the fact that shortages are not permitted. It is worth to add that transshipment in the context of IRP was firstly introduced by Coelho et al. (2012).

Product perishability is a critical issue for certain industrial companies. Due to the limited shelf life of perishable products, an unsuccessful inventory management at each step of the supply

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chain from production to clients will incur high system costs, including the ordering costs, shortage costs, inventory handling costs, and outdating costs. In the previous work directly related to this research by Coelho and his co-workers, the inventory-routing problem with transshipment was thoroughly taken into account (Coelho et al., 2012).

In this paper, to the best of the our knowledge, perishability of the products is incorporated with the IRP, where the items stocked at the depots and warehouses, are spoiled exponentially due to the environmental issues and the fugitive nature of the products. In the presented vendor-managed inventory system, the supplier manages the system in a way to minimize the overall costs such that all demands are responded properly and no stock-out occurs. For this purpose, the items delivered to each customer should be those items that will be spoiled in its relative location according to the exponential rate and with considering the demand requirements of the ultimate users.

The remainder of this study is organized as follows: In Section 2, the literature on the concept of IRP is reviewed. The assumptions and formulation of the model are detailed in Section 3. Genetic algorithm approach adopted in this study is clarified in the fourth section. In Section 5, the numerical example is given in order to elucidate the model. Finally, Section 6 sums up the paper and briefly discusses the presented model.

2. Literature review

Most of the inventory routing literature consider the repetitive distribution of a single product from the depot of a single supplier to a set of customers with a fleet of homogeneous vehicles over a certain planning horizon (Abdelmaguid, Dessouky, & Ordóñez, 2009; Coelho et al., 2012; Yu et al., 2008). However, there are researches extending to the multi-product inventory routing problem. Coelho and Laporte (2013a, 2013b) presented a branch-and-cut method to solve the proposed model of inventory routing problem by taking into account the multiple products and multiple vehicles. Al-Khayyal and Hwang (2007) spread the problem to have multiple non-intermixable goods. The mixed ships transferring such goods have numerous partitions in order to disjointedly preserve these products. Siswanto et al. (2011) offered a ship inventory routing and scheduling problem with multi undedicated compartments (sIRPSP-UC). They solved the proposed model with the objective of minimizing costs, where a number of physical and technical restrictions are satisfied over an assumed planning horizon. They established four sub-problems to be decided altogether as follow: ship selection, route selection, and loading and unloading procedures. To solve the problem, a mixed integer linear programming (MILP) model was formulated and a multi-heuristics based approach was chosen to be appropriate for solving large problems.

The IRP models proposed in the literature comprise many assumptions with different time horizons owing to the demand variation of products. The single-period IRP with deterministic demand, which is classified as the classical vehicle routing problem (VRP), was addressed by Dror and Trudeau (1989). They presented the split delivery VRP (SDVRP), in which each customer is served by a single vehicle through relaxing a constraint of the VRP. Cost saving can be significantly achieved by considering both the total distance and the required number of vehicles. Despite relaxation of the constraint, the problem remained NP-hard. This led to further studies extending the approximate approaches for the problem (Belenguer, Martinez, & Mota, 2000; Ho & Haugland, 2004; Lee, Epelman, White, & Bozer, 2006). The increasing importance of reverse logistics made Tasan and Gen (2012) to develop a capacitated VRP with simultaneous pick-up and deliveries tackling the distribution of goods to/from customers at the same time by a GA due to the NP-hard nature of capacitated VRP. Lu and Vincent (2012) adopted data envelopment analysis (DEA) for evaluating the parameters of GA on solving the pick-up and delivery VRP with soft time windows and considered each combination of the parameters as a decision making unit. Simplification of the dynamic vehicle routing problem with multi-depot by means of a distance-based clustering method was introduced by Yu et al. (2013) in which, the posed problem was solved by the improved ant colony optimization approach. It should be mentioned that there are other studies that have focused on the vehicle routing problem (Boudia, Louly, & Prins, 2008; Chiu, Lee, & Chang, 2006; Ozsoydan & Sipahioglu, 2013; Rhee, 1993). In addition, Abdelmaguid et al. (2009) investigated the inventory routing problem (IRP) with split delivery and vehicle fleet size constraint. Because of the complication of the IRP, they formulated an approximate method, which is able to quickly find a near-optimal solution based on an approximate model of the problem and Lagrangian relaxation. Dror, Laporte, and Trudeau (1994) presented a relaxation of the vehicle routing problem by considering split delivery. Archetti, Bertazzi, Laporte, and Speranza (2007) introduced a mixed-integer linear programing model for single-period IRP with deterministic demand and applied a branch-and-cut method to solve the mathematical model. Among the other studies that have been carried out on the inventory routing problem with deterministic demand, the study conducted by Anily and Bramel (2004) can be pointed out. Seifbarghy and Samadi (2014) investigated a cyclic inventory routing problem with a special case for a single product under economic order quantity policy in which, a tabu search algorithm is developed to solve the posed problem.

For the multiple-period IRP with deterministic demand, Campbell et al. (2002) and Campbell and Savelsbergh (2004) proposed a two-phase approach based on a set of decisions, where a delivery schedule is initially created by utilizing the integer programming. Then, the second phase is surveyed by the structure of a set of delivery routes by using heuristics. Gen and Syarif (2005) proposed a model to determine an efficient integration of production, distribution and inventory system for multi-products and multi-time periods planning and solved it by developing a new spanning tree-based (hst GA) to solve the proposed problem. Moreover, Toriello, Nemhauser, and Savelsbergh (2010) provided a time decomposition for the inventory routing problem. They showed that the solution of a sequence of single-period subproblems rather than solving a multi-period problem reduces the computation time. Haughton (2014) offered a tractable approximation method to find the optimal solutions of the cyclic inventory routing problem under conditions of limited modeling and calculating capacity. Chen and Lin (2009) studied the inventory routing problem with stochastic demand involving the repeated delivery of goods from the depot to a set of customers over the planning horizon. To incorporate risk aversion, a hedge-based stochastic inventory-routing system (HSIRS) combined with the Generalized Autoregressive Conditional Heteroskedasticity (GARCH) model and Forward Option Pricing (FOP) model based on the Black-Scholes model, from the hedge point of view, was developed to deal with the multi-product multi-period inventory routing problem with stochastic demand. The significance of the proposed method was confirmed by the computational results. In addition, there are other researches, which have focused on the stochastic demand in the IRP context (Adelman, 2004; Dror & Ball, 1987; Huang & Lin, 2010; Kleywegt, Nori, & Savelsbergh, 2002; Shukla, Tiwari, & Ceglarek, 2013; Yang, Mathur, & Ballou, 2000).

Transshipment has been expressed as a novel concept in the context of inventory routing problem in the last decade. Coelho