Transportation Research Part E 91 (2016) 112–128

Contents lists available at ScienceDirect

Transportation Research Part E

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

Effect of variable transportation and carbon emission in a three-echelon supply chain model

Biswajit Sarkar [a], Baishakhi Ganguly [b], Mitali Sarkar [a,*], Sarla Pareek [b]

[a] Department of Industrial & Management Engineering, Hanyang University, Ansan, Gyeonggi-do 426 791, South Korea
[b] Department of Mathematics & Statistics, Banasthali Vidyapith, Rajasthan 304 022, India

ARTICLE INFO

Article history:
Received 6 July 2015
Received in revised form 20 March 2016
Accepted 28 March 2016
Available online 19 April 2016

Keywords:
Supply chain
Single-setup-multi-delivery (SSMD) policy
Variable transportation
Variable carbon emission

ABSTRACT

Several industries controls carbon emission during transporting products due to increased transportation for obtaining the best transportation way with reduced cost. This study considers a three-echelon supply chain model where the supplier makes semi-finished products and transports to manufacturer for finished products. The manufacturer transports products by single-setup-multi-delivery policy to multi-retailer. The aim of the model is to reduce the supply chain cost by considering variable transportation and carbon emission costs are considered due to several shipments. An algebraic approach is employed to obtain the closed-form solution. Numerical example, sensitivity analysis, and graphical representations are given to illustrate the model.

1. Introduction

Because of global supply chain, the transportation during shipment of products becomes a major challenge among all players of supply chain. Due to this matter, transportation cost should be included in the total cost to calculate the whole supply chain cost. In the basic supply chain model, the transportation cost included within the ordering cost or setup cost, but now-a-days, global supply chain models use single-setup-multi-delivery (SSMD) policy of transportation instead of single-setup-single-delivery (SSSD). During SSSD policy, all products are produced in a single setup and transported to the retailer in a single delivery, but due to SSMD policy, all products are produced at a single setup, but it delivers to retailer in multiple deliveries. As a result, the number of transportation increases. Thus, a fixed transportation cost along with variable transportation cost are added into the model to make more realistic. The benefit of using SSMD policy is that it can save the holding cost of the retailer. The policy can be adopted only when the unit holding cost is more than unit transportation cost of the retailer. Thus, there is a trade off between the transportation cost and holding cost of the retailer. Therefore, the supply chain with variable and fixed transportation cost is more appropriate for the real scenario. In the literature, there are many authors considers transportation cost in the supply chain model. Among all, Cárdenas-Barrón (2007) wrote an excellent note on optimizing inventory decisions in a multi-stage supply chain. He used algebraical procedure to solve his model. He extended the model of Khouja (2003) by considering multi-stage and derivative-free method to obtain the optimal solution. Cárdenas-Barrón's (2007) and Khouja (2003) did not consider variable transportation cost. If the coordination is two or more, then the transportation cost plays very important role. Due to the SSMD policy, the number of transportation increases, it effects the weather by the matter of carbon emission. As similar with transportation cost, number of transportation increases which implies increasing percentage of carbon emission. Thus, the variable and fixed

* Corresponding author. Mobile: +82 10 7490 1981; fax: +82 314368146.
E-mail addresses: mitalisarkar.ms@gmail.com, mrs.mitalisarkar@gmail.com (M. Sarkar).

http://dx.doi.org/10.1016/j.tre.2016.03.018
1366-5545/

carbon emission cost are added in the total cost. Therefore, for this model, there is a trade off between the holding cost of the retailer with variable and fixed transportation as well as carbon emission cost of retailer. This idea is totally new which does not use by anyone of the researcher. Both the above mentioned models (2003, 2007) did not consider carbon emission cost.

Robers and Cooper (1976) discussed about a fixed charge transportation problem. Burns and Sivazlian (1987) discussed a dynamic analysis of three layer supply chain. Gupta (1992) extended Robers and Cooper's (1976) model with discrete transportation costs, whereas Stenger (1996) extended Burns and Sivazlian's (1987) model by reducing inventories in a multi-echelon manufacturing firm. Vroblefski et al. (2000) surveyed a lot size model with different transportation cost structures for serially distributed warehouses. Rau et al. (2003) discussed an integrated inventory model for deteriorating items under a multi-echelon supply chain environment. Wang and Sarker (2005) derived one aspect of the supply chain management with their short-term control and SSMD policy. A simple kanban coordination mechanism demonstrates that it is practical in the flow coordination of materials among the different nodes (companies) in a supply chain. Seo (2006) developed a three-stage supply chain by improving reorder decision policy with real-time shared stock information. Park et al. (2010) developed a three-level supply chain network design model with risk-pooling and lead times. Roy et al. (2011) proposed an optimal shipment strategy for imperfect items in a stock-out situation. Sana (2011) formulated a three-layer supply chain model with single-supplier, manufacturer, and single-retailer with both perfect and imperfect quality of products. Roy et al. (2012) discussed a three-echelon supply chain model based on theoretical analysis as (i) when demand per unit time of each member of the chain is uncertain (ii) when uncertain demand is distributed uniformly over finite time horizon. Yang et al. (2013) proposed a closed-loop logistics system in which manufacturing and remanufacturing cycle is formed by utilizing three optimization methods as sequential optimization, centralized optimization without benefit sharing, and centralized optimization with benefit sharing. Sarkar (2013) developed a two-echelon supply chain model with variable transportation cost with SSMD policy. He did not consider any carbon emission cost. He solved the model with algebraical approach. Recently, Cárdenas-Barrón and Porter (2013) considered a supply chain model for an assembly system with pre-processing of raw materials. Many researchers like Ben-Daya et al. (2013) and Sana et al. (2014) addressed several three-layer supply chain models with multiple suppliers, manufacturers, and retailers for multiple items. Cárdenas-Barrón and Treviño-Garza (2014) made an optimal solution to a three-echelon supply chain network with multi-product and multi-period. Cárdenas-Barrón and Sana (2014) developed a production-inventory model for a two-echelon supply chain when demand is dependent on sales teams' initiatives. Yang et al. (2015) discussed about two-stage optimization method for multi-objective supply chain network design problem with uncertain transportation costs and uncertain customer demands. Sarkar et al. (2015) extended the concept of Sarkar (2013) with the effect of carbon emission during transporting items from vendor to buyer. Modak et al. (in press) derived a three-echelon supply chain coordination by considering duopolistic retailers with perfect quality products.

At the time of delivery of finished goods from the manufacturer to multi-retailer, similar type of fixed or some variable transportation costs are involved. Earlier, transportation cost is measured together with the production cost and ordering cost. Now-a-days, transportation cost of a vehicle involves fixed cost as well as variable cost. The fixed transportation cost is assumed to be a constant sum in each time interval, usually indicates some essential expenses such as parking fare and rewards to the driver. On the other hand, variable transportation cost depends mainly on the oil consumed which is related directly to the distance traveled. Mongia et al. (1991) presented an inventory model to reduce the carbon emissions cost. Ahn et al. (1994) presented a mathematical model to minimize the inventory and transportation costs in the logistics systems. Edmonds et al. (1995) proposed an inventory model with cost and effectiveness of energy agreements to alter trajectories of atmospheric carbon dioxide emissions energy policy. Zhao et al. (2004) addressed a problem of deciding the optimal ordering quantity and frequency for a supplier-retailer logistic system in which transportation cost as well as the multiple uses of the vehicles are considered. It is based on the traditional economic order quantity (EOQ) formula. Ertogral et al. (2007) proposed a production and shipment lot size model in a vendor–buyer supply chain with transportation cost. Wang and Su (2007) improved the evaluation of a multi-echelon production, transportation, and distribution system. Chou (2009) discussed the estimation of transportation cost in a generalized linear model-based expert system. Madadi et al. (2010) considered a multi-level inventory management decisions with transportation cost. Grahn et al. (2009) explained the role of biofuels for transportation in carbon emission reduction scenarios with global versus regional carbon caps. Jun et al. (2011) established an economic analysis and some policy suggestions on gas power generation projects by assuming carbon emission reduction. Elhedhli and Merrick (2012) derived a green supply chain network design to reduce carbon emission costs. Tsao and Lu (2012) formed a supply chain network design by considering transportation cost discounts. Various investigators such as Thanarak (2012) and Zhao et al. (2012) developed different supply chain models by assuming social costs of carbon dioxide emissions. Haas et al. (2013) developed the influence of spatial and household characteristics on household transportation costs. Tseng and Hung (2014) discussed a strategic decision-making model by including social costs of carbon dioxide emissions for sustainable supply chain management.

Many organizations have raised their efforts to control and reduce the cost of carbon emission. By utilizing of information and improving communications with suppliers, industries can reduce carbon emission cost for themselves and their suppliers. Carbon emission cost may be fixed or variable or both.

This research presents a three-echelon supply chain model with variable transportation and carbon emission costs. In this study, the single-setup-multi-delivery (SSMD) policy is utilized as a transportation policy within the players of SCM. This system reduces the whole supply chain cost by reducing the holding cost when the transportation cost and carbon emission cost are not high compared to the holding cost. Supplier delivers unfinished products to manufacturer who transfers them