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Multi-item integrated supply chain model for deteriorating items with stock dependent demand under fuzzy random and bifuzzy environments ☆

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ABSTRACT

In this paper, we have investigated multi-item integrated production-inventory models of supplier and retailer with a constant rate of deterioration under stock dependent demand. Here we have considered supplier's production cost as nonlinear function depending on production rate, retailers procurement cost exponentially depends on the credit period and suppliers transportation cost as a non-linear function of the amount of quantity purchased by the retailer. The models are optimized to get the value of the credit periods and total time of the supply chain cycle under the space and budget constraints. The models are also formulated under fuzzy random and bifuzzy environments. The ordering cost, procurement cost, selling price of retailer's and holding costs, production cost, transportation cost, setup cost of the supplier's and the total storage area and budget are taken in imprecise environments. To show the validity of the proposed models, few sensitivity analyses are also presented under the different rate of deterioration. The models are also discussed in non deteriorating items as a special case of the deteriorating items. The deterministic optimization models are formulated for minimizing the entire monetary value of the supply chain and solved using genetic algorithm (GA). A case study has been performed to illustrate those models numerically.

1. Introduction

In the past few years, the research in deteriorating inventory is becoming important under various circumstances (Chung, Cárdenas-Barrón, & Ting, 2014; Guchhait, Maiti, & Maiti, 2014; Lee & Dye, 2012; Ouyang, Wu, & Yang, 2006; Widyadana, Cárdenas-Barrón, & Wee, 2011; Wu, Ouyang, Cárdenas-Barrón, & Goyal, 2014). This is because in the real life, decay and deterioration occur in almost all products, such as fruit, medicine and vegetables. Ghare and Schrader (1963) were the first to consider the effect of decaying inventory when the demand is constant. Heng, Labban, and Linn (1991) have presented an order-level lot-size inventory model for deteriorating items with finite replenishment rate. Chung (2000) researched on the inventory replacement policy for deteriorating items under permissible delay in payments. Benkherouf, Boumenir, and Aggoun (2003) worked on a diffusion inventory model for deteriorating items. Yang and Wee (2003) discussed integrated multi-lot-size production inventory model for deteriorating item. Sarkar, Ghosh, and Chaudhuri (2012) developed deteriorating inventory with time-quadratic demand and time-dependent partial backlogging with shortage. Ahmed, Al-Khamis, and Benkherouf (2013) proposed inventory models with ramp type demand rate, partial backlogging and general deterioration rate. Yang, Teng, and Chern (2001) discussed deterministic inventory lot-size models under inflation with shortages and deterioration for fluctuating demand. Saadany and Jaber (2010) introduces production/remanufacturing inventory model with price and quality dependant return rate. Taleizadeh, Stojkovska, and Penticoc (2015) developed economic order quantity model with partial backordering and incremental discount.

As the commercial market has become more competitive, supplier and retailer are comfortable to go with long term cycles with each other in order to reduce costs and improve efficiency. That is why supply chain coordination is essential. The basic model is based on the implicit assumption that the retailer must pay for the product as soon as he receives them from a supplier. However, in practical situation, the supplier will allow a certain

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fixed period (credit period) for reconciling the amount that the supplier be indebted to retailer for the items supplied. Many researchers have expressed their interest in optimizing the supply chain integrated systems in various environments. Goyal (1977) first introduce the idea of optimize the supplier and retailer total cost jointly. Das, Das, and Mondal (2013) developed integrated supply chain model for a deteriorating item with procurement cost dependent credit period. Wong proposed (Wong, 2010) supply chain with the distribution processing and replenishment policy under asymmetric information and deterioration. Sarkar (2013) presented a production-inventory model with probabilistic deterioration in two-echelon supply chain management. Sarker, Jamal, and Wang (2000) developed supply chain models for perishable products under inflation and permissible delay in payment. Uthayakumar and Parvathi (2011) worked on two-stage supply chain with order cost reduction and credit period incentives for deteriorating items. Teng and Lou (2012) discussed sellers optimal credit period and replenishment time in a supply chain with up-stream and down-stream trade credits. Huang (2001) worked on integrated supply chain model for supplier and retailer with defective items. Recently Wang, Teng, and Lou (2014) studied on supply chain for deteriorating items with maximum lifetime.

Straight off a days multi-item economic order quantity (EOQ) and economic production quantity (EPQ) models in supply chain is also getting attention by various researchers. Chen and Chen (2005) discussed multi-item replenishment problem in a two-echelon supply chain. Wu and Golbasi (2004) discussed multi-item, multi-facility supply chain models and its complexities. Tsao and Sheen (2012) developed multi-item supply chain under credit periods and weight freight cost discounts. Taleizadeh, Niaki, and Barzinpour (2011) developed multiple-buyer multiple-vendor multi-product multi-constraint supply chain problem with stochastic demand and variable lead-time. Hoque and Kingsman (2006) worked on synchronization in common cycle lot size scheduling for a multi-product serial supply chain. Kumar and Kropp (2006) studying the operational efficiencies of a multi-product supply chain using excel spreadsheet model. Table 1 represent the summary of some related literature for multi-item supply chain models.

In many real-life cases, several factors in the decision making procedure, such as incomplete data, additional qualitative criteria and imprecision preferences. Such determination can be reached using the parameter under fuzzy, fuzzy random, etc. environments. Several researchers has worked on those imprecise environments to solve EOQ or EPQ model. Maiti and Maiti (2006) discussed fuzzy inventory model with two warehouses under possibility constraints. Peidro, Mula, Poler, and Verdegay (2009) developed fuzzy supply chain planning under supply, demand and process uncertainties. Chen, Lin, and Huang (2006) introduced fuzzy approach for supplier evaluation and selection in supply chain management. Xu and Zhai (2010) discussed two-stage supply chain under fuzzy demand. Jana, Das, and Maiti (2014) developed multi-item inventory models over random planning horizon in random fuzzy environment. In spite of the above mentioned developments, coming after, following additions can also be made in the formulation and solution of supply chain models for deteriorating items.

- Till now, none has formulated multi-item integrated supply chain models (MISCM) allowing credit period, procurement cost and stock dependent demand for deteriorating items. This vacuum has been removed by this investigation.
- In a real-life supply chain system, limitations on available budget and storage space are very often faced by the suppliers and retailers. These resources are sometimes fuzzy, random fuzzy or bifuzzy in nature. The MISCM under fuzzy, random fuzzy or bifuzzy environments has been introduced first time.
- The objective and constraints under fuzzy random and bifuzzy environments has been successively introduced for the first time in MISCM and transformed to a corresponding deterministic model using probability-possibility and possibility-possibility chance constraint techniques.
- A practical real life example has been provided to validate the proposed model and some sensitivity analysis has been done and changes are depicted via graphs.
- MISCM has been solved by using contractive mapping genetic algorithm.

The rest of this paper is organized as follows. In Section 2, we recall some preliminary knowledge about fuzzy, fuzzy random and bifuzzy. Section 3 provides the notations and assumption used throughout in this paper. In Sections 4 and 5, multi-item supply chain models are proposed for deteriorating and non-deteriorating items respectively. In Sections 6 and 7, deterministic models have been formulated and also the models under imprecise environments has been consider. In those section we have also discussed the solution procedure to those models. Section 8 provides the general information about contracting mapping genetic algorithm and how it is used to solve the proposed models. A real life example is solved, results are compared and explained graphically in Section 9. Section 10 summarizes the paper and also discusses about the scope of future work.

2. Preliminaries

Definition 2.1 (*LR fuzzy variable* *Dubois and Prade, 1980*). Let $L(\cdot)$ and $R(\cdot)$ be two reference functions. If the membership function of fuzzy variable ξ has the following form

$$\mu_{\xi}(x) = \begin{cases} L\left(\frac{m-x}{\alpha}\right), & x \leqslant m, \alpha > 0; \\ R\left(\frac{x-m}{\beta}\right), & x \geqslant m, \beta > 0. \end{cases}$$

then ξ is called *LR* fuzzy variable, L, R are called left and right branch of ξ respectively, the reference function $L, R : [0, 1] \to [0, 1]$

Table 1
Summary of related literature for multi-item supply chain models.

Author(s) and year	Constraints	Demand rate	Credit period	Imprecise environment	Multi-item
Wu and Golbasi (2004)	Yes	Uniform	No	No	Yes
Chen and Chen (2005)	No	Uniform	No	No	Yes
Chen et al. (2006)	No	Uniform	No	Only Fuzzy	No
Peidro et al. (2009)	Yes	Uniform	No	Only Fuzzy	Yes
Wong (2010)	No	Uniform	No	Only Fuzzy	No
Xu and Zhai (2010)	No	Uniform	No	Only Fuzzy	No
Taleizadeh et al. (2011)	No	Uniform	No	No	Yes
Das et al. (2013)	No	Uniform	Yes	No	No
Sarkar (2013)	No	Uniform	No	No	No
Wang et al. (2014)	No	Credit Period Dependent	Yes	No	No
Present paper	Yes	Stock-dependent	Yes	Fuzzy, Random and Bifuzzy	Yes