Int. J. Production Economics ∎ (∎∎∎∎) ∎∎∎–∎∎∎

Contents lists available at ScienceDirect

Int. J. Production Economics

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

An inventory model with non-instantaneous receipt and exponentially deteriorating items for an integrated three layer supply chain system under two levels of trade credit

Kun-Jen Chung [a,b,c], Leopoldo Eduardo Cárdenas-Barrón [d,*], Pin-Shou Ting [c]

[a] College of Business, Chung Yuan Christian University, Chung Li, Taiwan, ROC
[b] National Taiwan University of Science and Technology, Taipei, Taiwan, ROC
[c] Department of International Business Management, Shih Chien University, Taipei, Taiwan, ROC
[d] Department of Industrial and Systems Engineering, School of Engineering, Tecnológico de Monterrey, E. Garza Sada 2501 Sur, C.P. 64 849, Monterrey, N.L., Mexico

ARTICLE INFO

Article history:
Received 27 February 2013
Accepted 29 December 2013

Keywords:
Inventory
Deteriorating item
EPQ model
Replenishment policies
Trade credits
Permissible delay in payments

ABSTRACT

Recently, the enterprises, from a financial perspective, have been seeing that need of the integrating with others with trade credit policies as a promising issue for savings in the supply chain. In this direction, this paper establishes a new economic production quantity (EPQ) inventory model for deteriorating items under two levels of trade credit, in which the supplier offers to the retailer a permissible delay period and simultaneously the retailer in turn provides a maximal trade credit period to its customers in a supply chain system comprised of three stages. The purpose of this paper is to determine the optimal replenishment policy so that the total relevant cost is minimized. It is shown that this new EPQ inventory model forms a general framework that contains several inventory models that appear in some previous published articles.

1. Introduction

The managing of inventories is one of the most significant tasks that every manager must do efficiently and effectively in any organization. Nowadays, all organizations are involved in a global aggressive competitive market and then these organizations are taking seriously the activities related to manage their inventories. Thus, recently, the practitioners and researchers have been increasing their interest in optimizing the inventory decisions in a holistic way. With the optimizing inventory decisions taking account a holistic perspective, it is well known that all members of the supply chain obtain a better benefit that it cannot be obtained when one optimizes the inventory decisions in an isolated way.

It is well known that a supply chain involves several stages which directly or indirectly satisfy a customer request. Therefore a supply chain consists of the manufacturers, suppliers, transporters, warehouses, retailers and final consumers (Chopra and Meindl, 2004). On the other hand, the supply chain management is a set of approaches used in order to efficiently integrate all of the stages of the supply chain so that goods are manufactured and distributed at the right quantities, to right location and at the right time, in order to minimize total cost of the whole supply chain (Simchi-Levi et al., 2008).

According to that we mentioned before, nowadays researchers are interested in developing supply chain models which have real life applications. Recently, the business operations such as share marketing and trade credit financing have been a powerful tool to increase sales and profits. In practice, vendors allow a fixed period to settle the payment without penalty for their customers to increase sales and reduce on-hand inventory. In fact, a permissible delay in payment decreases the cost of inventory holding because this action decreases the amount of capital invested in inventory for the duration of the permissible period. Furthermore, for the period of the delay in payment, the retailer can accumulate revenue on sales and earn interest on that revenue via share marketing investment or banking business. In today's severely competitive business environment, businessmen are increasingly using trade credit to stimulate the demand of the products and attract more customers. As a result, the trade credit plays an important role in modern business operations.

The first works on optimizing inventory decisions were developed under isolated and reductionist perspective; and it can be traced to the originals economic order quantity (EOQ) and economic production quantity (EPQ) inventory models developed by Harris (1913) and Taft (1918), respectively. It is well known that the EOQ model is a

* Corresponding author. Tel.: +52 8183284235; fax: +52 8183284153.
E-mail addresses: kjchung@cycu.edu.tw (K.-J. Chung), lecarden@itesm.mx (L. Eduardo Cárdenas-Barrón).

0925-5273/$ - see front matter © 2014 Elsevier B.V. All rights reserved.
http://dx.doi.org/10.1016/j.ijpe.2013.12.033

special case of the EPQ model. Also, the EOQ and EPQ models are known as "instantaneous receipt" and "non-instantaneous receipt" inventory models, respectively. Today there are a huge of papers on inventory theory developed under both holistic and isolated perspectives.

In the classical EOQ inventory model, it is assumed that the retailer must pay to the supplier for the goods as soon as the goods are received. Perhaps, Goyal (1985) was the first researcher in dealing with the issue of delay in payments. Goyal (1985) basically establishes a single-item inventory model under permissible delay in payments. There are lots of papers that consider the EOQ inventory model with trade credit. Please refer to the review of trade credit in Seifert et al. (2013) and Chang et al. (2008). Seifert et al. (2013) present a complete review on literature about trade credit and analyze in detail the following issues trade credit motives, order quantity decisions, credit term decisions and settlement period decisions.

It is important to remark that the trade credit policy discussed in Goyal (1985) assumes that the supplier offers the trade credit but the retailer does not offer the trade credit to his/her customer. This action is well known as one level of trade credit policy and integrates only two stages of the chain with a member in each stage. Obviously, it would be interesting to study when the retailer also offers the trade credit to his/her customer and this is well known as two levels of trade credit policy for the integrating of the chain with three stages and one member in each stage. In this direction and perhaps, Huang (2003) first explores the EOQ model under two levels of trade credit policy when the supplier offers to the retailer a permissible delay of M periods, and then the retailer also provides to its customer a permissible delay of N periods, respectively. That is the two levels of trade credit policy previously mentioned and also it was treated in Teng (2009). It is worth to point that there are some key points of differences between Teng (2009) and Huang (2003) which are explained as follows:

(A) From the viewpoint of Huang (2003): In Huang (2003)′s work, if the customer purchases one item from the retailer at time t belonging to $[0, N]$, then the customer has a trade credit period $N-t$ and must make the payment at time N. Thus, the retailer allows a maximal trade credit period N for the customer to settle the account. In fact, the trade credit periods offered by the retailer to the customer are different. The customer′s trade credit period N offered by the retailer in Huang (2003) should mean as the due day customer makes its payment to the retailer. Essentially, the viewpoint of Huang (2003) can be used only in the well known market of credit cards. The inventory models under two levels of trade credit policy using the viewpoint of Huang (2003) can be found in several papers such as Huang and Hsu (2008), Chung (2008, 2011, 2013), Huang (2006, 2007), Teng et al. (2007), Soni and Shah (2008), Liao and Chung (2009), Kreng and Tan (2010), Feng et al. (2013) and Zhou et al. (2013); just to name a few.

(B) From the viewpoint of Teng (2009): In Teng (2009), if the customer purchases one item from the retailer at time t belonging to $[0, T]$, then the customer has a trade credit period N and must make the payment at time $N+t$. So, the retailer allows each customer with the same trade period N. The viewpoint of Teng (2009) can be used in any general business transactions and this is not restricted to business cards as it was happen in Huang (2003)′ works. The inventory models under two levels of trade credit policy from the viewpoint of Teng (2009) have been found in many articles such as Teng and Chang (2009), Jaggi et al. (2008), Teng and Goyal (2007), Teng et al. (2009, 2013), Chen and Kang (2010), Ho (2011), Chung (2012) and Soni and Patel (2012); just to name a few recent works.

Chung and Huang (2003) are the first researchers that generalize the EOQ model of Goyal (1985) to the EPQ model under one level of trade credit policy. Additionally, Huang (2007) incorporates both Chung and Huang (2003) and Huang (2003) to further discuss the EPQ model under two levels of trade credit policy.

Commonly, there are many items that deteriorate over time and generally the rate of deterioration is small. Therefore, the effect of deterioration of the items in the determination of the lot size must be taken into account. In this direction, Ghare and Schrader (1963) are pioneers to develop an EOQ model by negative exponential distribution. Their research assumes that the instantaneous deterioration rate is constant and known. Combining Ghare and Schrader (1963) and Goyal (1985), numerous researches dealing with the inventory models for deteriorating items under the trade credit policy can be found in Jaggi and Aggarwal (1994), Arcelus et al. (2003), Chu et al. (1998), Chung and Liao (2004, 2006), Chung and Huang (2007), Liao (2007a,b, 2008), Huang and Liao (2008), Tsao and Shreen (2008), Liao and Chung (2009), Thangam and Uthayakumar (2009), Chang et al. (2010a, 2010b), Min et al. (2010), Mataha and Mataha (2011), Dye (2012), Liao et al. (2012), Mataha (2012), Thangam (2012), Chung and Cardenas-Barron (2013) and Soni (2013) and their references.

Recently, Liao (2008) proposes an EPQ model with exponentially deteriorating items under two-level trade credit policy following the viewpoint of Huang (2003). Actually, the inventory model discussed by Liao (2008) is an EPQ model and it is rather meaningful. However, the process of her modeling has shortcomings such that the annual total relevant cost is wrong. Consequently, the main purpose of this paper not only removes those shortcomings of Liao (2008) to establish a new EPQ inventory model but also presents the complete solution procedure for this new EPQ inventory model.

Furthermore, Chang et al. (2010b) present an EPQ model with exponentially deteriorating items under two-level trade credit policy following the viewpoint of Teng (2009). Regarding that the two different two-level trade credit effect on decision of cycle time, total cost of the system and the collaboration between vendor and purchaser, please refer to this paper and Chang et al. (2010b).

The rest of this paper is organized as follows. Section 2 describes the notation and assumptions that are used throughout this paper and also presents the mathematical model and analysis. Section 3 identifies the shortcomings of Liao (2008). Section 4 shows the unimodality of total cost of the inventory model. Section 5 derives the necessary and sufficient conditions, and an important theorem to determine the optimal cycle time. In order to illustrate that our proposed inventory model contains several previous inventory models then in Section 6 special cases are identified. Finally, some conclusions and future researches are given in Section 7.

2. Mathematical model and analysis

All notation and assumptions are similar as those in Liao (2008) and they are adopted throughout the whole paper.Notation

D	annual demand rate known and constant (units/time unit)
P	annual production or replenishment rate known and constant (units/time unit)
$P>D$	annual production or replenishment rate must be greater than annual demand rate
A	cost of placing an order ($/order)
ρ	a constant and greater than zero, $\rho=1-(D/P)>0$
c	unit purchasing price per item ($/unit)

Please cite this article as: Chung, K.-J., et al., An inventory model with non-instantaneous receipt and exponentially deteriorating items for an.... International Journal of Production Economics (2014), http://dx.doi.org/10.1016/j.ijpe.2013.12.033