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Impact of trade credit and inflation on retailer's ordering policies for non-instantaneous deteriorating items in a two-warehouse environment

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ABSTRACT

With the advent of better technologies in manufacturing and retail industry, consumer beliefs and needs have been altered. Supermarkets are expected to sell fresh products in good conditions which have a longer shelf life, or do not begin to deteriorate immediately (termed known as non-instantaneous deteriorating items); this characteristic is now usually observed in almost all food stuffs, fashionable items, electronic products, among others. In order to sustain in the retail sectors, the managers are moving forward to store these items in warehouses. Moreover, due to increasing competition in business world, supplier offers a permissible delay in payments to retailer in order to increase demand. This encourages the retailer to order a large quantity, which in turn entitles the organization to rent out an additional storage space. Considering the importance of such a scenario, the present research work develops a two warehouse inventory model for non-instantaneous deteriorating items with permissible delay in payments under inflationary conditions. Shortages are allowed and partially backlogged, since customers' willingness to wait decreases over time. The objective of this paper is to determine the retailer's optimal replenishment policies that maximize the present worth of total optimal profit per unit time. Finally, the proposed inventory model has been validated with the help of numerical example. Sensitivity analysis of the optimal solution with respect to key parameters of the inventory system has been also presented, which provides important managerial implications.

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1. Introduction

In recent years, inventory problems for deteriorating items have been widely studied under several assumptions. The phenomenon of deterioration is defined as damage, spoilage, decay, obsolescence, evaporation, pilferage, etc. Deterioration decreases the usefulness of the original item. It is always expected that goods must be ready available to the customers and that too in good conditions. Now, with the advent of technologies, it is expected that fresh products could have a longer shelf life and these can be made available in the shops or supermarkets more time. Furthermore, there are several items that do not begin deteriorating immediately. For example, items like dry fruits, potatoes, yams and even some fruits and vegetables have a shelf life and begin to deteriorate after a time lag. This phenomenon is termed as non-instantaneous deterioration. Thus, in a way it can be said that the current retail industry is thriving on the basis of non-instantaneous deteriorating items; the characteristic which is now usually observed in almost all food stuffs, fashionable items and electronic products. Perhaps, Wu et al. (2006) first introduced the phenomenon non-instantaneous deterioration and established the optimal replenishment policy for non-instantaneous deteriorating item with stock dependent demand and partial backlogged shortages. Subsequently, many researchers such as Ouyang et al. (2006, 2008), Wu et al. (2009), Jaggi and Verma (2010), Chang et al. (2010), Geetha and Uthayakumar (2010), Soni and Patel (2012), Maihami and Kamalabadi (2012a, 2012b), Shah et al. (2013), Dye (2013) and Tsao (2014) have studied inventory models for non-instantaneous deteriorating items under a variety of conditions.

Moreover, with changing market trends and increasing competition in business world, the trade credit policy is gaining popularity among many retail establishments. According to this policy, the supplier agrees to give retailer a certain fixed credit period to settle its account. During this credit period the retailer can start to accumulate revenues on the sales and earn interest on that revenue, but beyond this period the supplier charges interest.

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Notation[1]

Parameters

W	fixed storage capacity of OW (units)
D	demand rate known and constant (units/time unit)
Q	order quantity per cycle (units)
Z	maximum inventory level per cycle (units)
α	deterioration rate in OW, where $0 \le \alpha < 1$
β	deterioration rate in RW, where $0 \le \beta < 1$; $\beta < \alpha$.
r	the discount rate (%)
i	the inflation rate, which is varied by the social economical situations (%)
$R=(r\text{-}i)$	net inflation rate (%)
c	unit purchasing cost per item ($/unit)
p	unit selling price per item ($/unit)
s	the backlogging cost per unit per unit time, if shortage is backlogged ($/unit)
c_1	unit opportunity cost due to lost sale, if the shortage is lost ($/unit)
A	fixed cost of placing an order ($/order)
H	unit holding cost per unit item per unit time in OW ($/unit/time unit)
F	unit holding cost per unit item per unit time in RW ($/unit/time unit), where $F > H$.
M	the retailer's trade credit period provided by supplier (time unit)
I_e	Interest earned per rupees per unit time per year by the retailer (%)
I_p	Interest paid per rupees per unit in stock per year by the retailer (%)
t_d	time period during which no deterioration occurs (time unit)
t_w	time at which the inventory level reaches zero in OW (time unit)

Decision variables

t_r	time at which the inventory level reaches zero in RW (time unit)
T	the length of the replenishment cycle (time unit)

Functions

$I_o(t)$	inventory level of OW at time t (units)
$I_r(t)$	inventory level of RW at time t (units)
$B(t)$	backlogged level at any time t (units)
$L(t)$	number of lost sales at any time t (units)
$TP_i(t_r, T)$	present value of total relevant profit per unit time for case $i=1$, 2 and 3 ($/time unit)

Optimal values

$\boldsymbol{t_r^*}$	optimal time at which the inventory level reaches zero in RW (time unit)
$\boldsymbol{T^*}$	optimal length of inventory cycle (time unit)
$\boldsymbol{TP^*(t_r, T)}$	optimal total profit per unit time ($/time unit)

Hence, paying later indirectly reduces the cost of holding stock. Additionally, the trade credit policy offered by the supplier encourages the retailer to order a large quantity, which cannot be stored in his own warehouse. In this case, the company must rent a warehouse to store the excess items, since the order size is more than the company's own warehouse capacity. In the past few decades, inventory problems under these two areas have been extensively explored by the researchers.

Some of the remarkable research in the area of trade credit has been presented by Goyal (1985), Jaggi and Aggarwal (1994), Aggarwal and Jaggi (1995), Chung (1998), Sarker et al. (2000), Huang and Liao (2008), Chung and Liao (2004, 2006, 2009 and 2011), Teng et al. (2012), Cheng et al. (2012), Yang et al. (2013), Chen et al. (2014), Chung et al. (2014), Wu et al. (2014), Jaggi et al. (2015a), Jaggi et al. (2015b), among others. Recently, Ouyang et al. (2015) proposed an integrated inventory model with capacity constraint and a permissible delay payment period that is order-size dependent. Further research in this area is summarized by different survey papers: Chang et al. (2008), Soni et al. (2010), Seifert et al. (2013) and Molamohamadi et al. (2014).

Besides this, a good number of works have been published for two warehouse inventory system, viz., Das et al. (2007), Niu and Xie (2008), Rong et al. (2008), Dey et al. (2008), Hsieh et al. (2008), Maiti (2008), Lee and Hsu (2009), Yang and Chang (2013), Chung and Huang (2007) and Liang and Zhou (2011) are worth mentioning. Recently, Bhunia et al. (2014) developed trade credit two warehouse inventory model for deteriorating item considering uniform demand under inventory follows shortage (IFS) policy with partially backlogged shortages. In their work, they have proposed an alternative approach in the formulation of trade credit inventory model. In recent times, Jaggi et al. (2014) formulated inventory models for single deteriorating item for two warehouse system under permissible delay in payments. In their model formulation, demand is assumed as price dependent and shortages are allowed and are completely backlogged. Very recently, Jaggi et al. (2015c) explored the effect of deterioration on two warehouse inventory model in imperfect quality scenario. The major assumptions used in the above research articles are summarized in Table 1.

Considering the importance of above said facts, a two warehouse inventory model for non-instantaneous deteriorating items under trade credit and inflation has been proposed. Shortages are allowed and are partially backlogged. The inventory model considers non-instantaneous deteriorating items, since nowadays consumers' are more interested to buy the products which are unsullied and have a longer shelf life. In addition, the retailer has obtained a credit period from its supplier to settle the accounts; and the various costs are computed using the well-known discounted cash flow approach (DCF). The objective of this study is to determine the retailer's optimal replenishment policies that maximize the present worth of total optimal profit per unit time. Also, the interest earned on the revenue generated after selling the shortages at the beginning of the cycle has been considered in the inventory model, which is usually not paid attention by researchers and academicians. Finally, a numerical example is presented to illustrate the applicability of the proposed inventory model. Sensitivity analysis on key parameters has been provided to reveal some important managerial implications.

The rest of this paper is organized as follows. Section 2 defines the assumptions and notation used throughout the entire paper. Section 3 provides a description of the inventory model and then establishes the retailer's annual total profit in two-warehouse system. Section 4 discusses the optimality of the objective

[1] In addition, the following notations are used throughout this paper.

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