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An inventory model under inflation for deteriorating items with stock-dependent consumption rate and partial backlogging shortages

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ABSTRACT

In this paper, we extend Teng, J.T., Chang, H.J., Dye, C.Y., Hung, C.H. [2002. An optimal replenishment policy for deteriorating items with time-varying demand and partial backlogging. Operations Research Letters 30(6), 387–393.] and Hou, K.L. [2006. An inventory model for deteriorating items with stock-dependent consumption rate and shortages under inflation and time discounting. European Journal of Operational Research 168(2), 463–474.] by considering an inventory lot-size model under inflation for deteriorating items with stock-dependent consumption rate when shortages are partial backlogging. The proposed model allows for (1) partial backlogging, (2) time-varying replenishment cycles, and (3) time-varying shortage intervals. Consequently, the proposed model is in a general framework that includes numerous previous models as special cases. We then prove that the optimal replenishment schedule exists uniquely, and provide a good estimate for finding the optimal replenishment number. Furthermore, we briefly discuss some special cases of the proposed model related to previous models. Finally, numerical examples to illustrate the solution process and some managerial implications are provided.

1. Introduction

In many real-life situations, for certain types of consumer goods (e.g., fruits, vegetables, donuts, and others), the consumption rate is sometimes influenced by the stock-level. It is usually observed that a large pile of goods on shelf in a supermarket will lead the customer to buy more and then generate higher demand. The consumption rate may go up or down with the on-hand stock level. These phenomena attract many marketing researchers to investigate inventory models related to stock-level. The related analysis on such inventory system with stock-dependent consumption rate was studied by Levin et al. (1972), Baker and Urban (1988), Mandal and Maiti (1997, 1999), Balkhi and Benkherouf (2004), etc. Recently, Alfares (2007) proposed the inventory model with stock-level dependent demand rate and variable holding cost.

As a matter of fact, some products (e.g., fruits, vegetables, pharmaceuticals, volatile liquids, and others) deteriorate continuously due to evaporation, obsolescence, spoilage, etc. Ghare and Schrader (1963) first derived an economic order quantity (EOQ) model by assuming exponential decay. Next, Covert and Philip (1973) extended Ghare and Schrader's constant deterioration rate to a two-parameter Weibull distribution. Shah

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and Jaiswal (1977) and Aggarwal (1978) then discussed the EOQ model with a constant rate of deterioration. Thereafter, Dave and Patel (1981) considered an inventory model for deteriorating items with time-proportional demand when shortages were prohibited. Sachan (1984) further extended the model to allow for shortages. Later, Hariga (1996) generalized the demand pattern to any log-concave function. Teng et al. (1999) and Yang et al. (2001) further generalized the demand function to include any non-negative, continuous function that fluctuates with time. Recently, Goyal and Giri (2001) wrote an excellent survey on the recent trends in modeling of deteriorating inventory since early 1990s.

The characteristic of all of the above articles is that the unsatisfied demand (due to shortages) is completely backlogged. However, in reality, demands for foods, medicines, etc. are usually lost during the shortage period. Montgomery et al. (1973) studied both deterministic and stochastic demand inventory models with a mixture of backorder and lost sales. Later, Rosenberg (1979) provided a new analysis of partial backorders. Park (1982) reformulated the cost function and established the solution. Mak (1987) modified the model by incorporating a uniform replenishment rate to determine the optimal production-inventory control policies. For fashionable commodities and high-tech products with short product life cycle, the willingness for a customer to wait for backlogging during a shortage period is diminishing with the length of the waiting time. Hence, the longer the waiting time, the smaller the backlogging rate. To reflect this phenomenon, Chang and Dye (1999) developed an inventory model in which the proportion of customers who would like to accept backlogging is the reciprocal of a linear function of the waiting time. Concurrently, Papachristos and Skouri (2000) established a partially backlogged inventory model in which the backlogging rate decreases exponentially as the waiting time increases. Teng et al. (2002, 2003) then extended the fraction of unsatisfied demand backordered to any decreasing function of the waiting time up to the next replenishment. Teng and Yang (2004) further generalized the partial backlogging EOQ model to allow for time-varying purchase cost. Yang (2005) made a comparison among various partial backlogging inventory lot-size models for deteriorating items on the basis of maximum profit. Lately, Hou (2006) developed an inflation model for deteriorating items with stock-dependent consumption rate and completely backordered shortages by assuming a constant length of replenishment cycles and a constant fraction of the shortage length with respect to the cycle

Table 1
Major characteristics of inventory models on selected articles.

Author(s) and published (year)	Demand rate	Deterioration rate	Allow for shortages	With partial backlogging	Under inflation
Aggarwal (1978)	Order level	Constant	No	No	No
Alfares (2007)	Stock-dependent	No	No	No	No
Baker and Urban (1988)	Stock-dependent	No	No	No	No
Balkhi and Benkherouf (2004)	Stock-dependent	Constant	No	No	No
Bierman and Thomas (1977)	Constant	No	No	No	Yes
Buzacott (1975)	Constant	No	No	No	Yes
Chang and Dye (1999)	Time varying (logconcave)	Constant	Yes	Yes	No
Chern et al. (2005)	Time varying	Constant	Yes	Yes	No
Chern et al. (2008)	Time varying	Time varying	Yes	Yes	Yes
Covert and Philip (1973)	Constant	Weibull distribution	No	No	No
Dave and Patel (1981)	Time proportional	Constant	No	No	No
Ghare and Schrader (1963)	Constant	Constant	No	No	No
Hariga (1996)	Time varying (logconcave)	Constant	Yes	No	No
Hou (2006)	Stock-dependent	Constant	Yes	No	Yes
Mak (1987)	Constant	No	Yes	Yes	No
Mandal and Maiti (1997)	Stock-dependent	Stock-dependent	Yes	No	No
Mandal and Maiti (1999)	Stock-dependent	Stock-dependent	No	No	No
Misra (1975)	Constant	No	No	No	Yes
Misra (1979)	Constant	No	Yes	No	Yes
Montgomery et al. (1973)	Constant	No	Yes	Yes	No
Papachristos and Skouri (2000)	Time varying (logconcave)	Constant	Yes	Yes	No
Park (1982)	Constant	No	Yes	Yes	No
Rosenberg (1979)	Constant	No	Yes	Yes	No
Sachan (1984)	Time proportional	Constant	Yes	No	No
San Jose et al. (2006)	Constant	No	Yes	Yes	No
Shah and Jaiswal (1977)	Order level	Constant	No	No	No
Teng et al. (2002)	Time varying (logconcave)	Constant	Yes	Yes	No
Teng et al. (1999)	Time varying	Constant	Yes	No	No
Teng et al. (2007)	Price dependent	No	Yes	Yes	No
Teng et al. (2003)	Time varying	Constant	Yes	Yes	No
Teng and Yang (2004)	Time varying	Constant	Yes	Yes	No
Yang (2005)	Time varying	Constant	Yes	Yes	No
Yang et al. (2001)	Time varying	Constant	Yes	No	Yes
Present paper	Stock-dependent	Constant	Yes	Yes	Yes