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Perishable inventory systems: A literature review since 2006

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Abstract
This paper presents up-to-date review of advances made in the field of Inventory control of perishable items since 2006. Contributions are highlighted by discussing main system characteristics including backordering, one or two warehouses and delay in payments.

Keywords: Perishable inventory, literature

Introduction
Inventories occur in all forms and for the most diverse purposes. We usually think of inventories as goods for sales, raw materials for production, work in progress held for later production stages, finished goods for supporting activities and customer service. But livestock in a farm, cash in a bank account, water in reservoirs, blood in blood banks, and personnel who need special training all have similar characteristics. They are all held to meet some future demands. They are all controllable within limits. For many organizations inventories are a major investment. Inventory management is an important function in many organizations even in the Internet age. The fundamental questions in inventory control are when to order and how much to order. This chapter presents the complete survey of published literature in mathematical modeling of deteriorating items and shortages.

Analysis
Dye *et al*. (2006) formulated a perishable inventory model. In this model demand was taken as a function of time and shortages were allowed with partial backlogging. Ghosh and Chaudhuri (2006) [55] discussed a perishable inventory model. In this model decay rate was taken as function of time and demand as a quadratic. Shortages were allowed in all cycles. Shah (2006) established a finite time horizon inventory model for decaying items with time value of money under the permissible delay in payments. Chen and Ouyang (2006) developed an inventory model for decaying items with permissible delay in payment. Chen *et al*. (2006) formulated a perishable inventory. In this model demand was taken as ramp type while decay rate as a function of time. Jaggi *et al*. (2006) [21] developed a perishable inventory model for decaying items. In which demand was induced by inflation. Lee (2006) formulated a perishable inventory with two-warehouse facilities. Manna and Chaudhuri (2006) [55] developed a perishable inventory model with shortages. In this model demand was ramp type and decay rate was taken as a function of time with unit production cost. Kanchanasuntorn and Techanitisawad (2006) [33] developed a perishable fixed life inventory model. Roy *et al* (2006) [65] formulated a perishable Inventory model. Pal *et al*. (2006) have formulated a perishable model for single decaying item by assuming the impact of marketing strategies such as pricing and advertising as well as the displayed stock level on the demand rate of the system. Shortages were allowed. A perishable production inventory model for decaying items in which demand was taken as a stock dependent was formulated by Jolai *et al*. (2006) under the effects of inflation. Shortages were allowed and partially backlogged. Huang and Liao (2006) [18] derived optimum order quantity of the EOQ

Model with deteriorating items under supplier credit linked to order quantity. Chun Chen Lee (2006) has discussed a two warehouse inventory model with deteriorating under FIFO dispatching policy. In most of the existing literatures on two-warehouse inventory decision models, the last-in-first-out (LIFO) dispatching policy has always been assumed. This presumption, however, is not realistic with the actual practice of most business entities. In this paper, Pakkala and Acharya's two-warehouse LIFO model is generalized. Hou (2006) [17, 20] formulated a perishable inventory model for decaying items. In this model consumption rate was taken as stock dependent and shortages were allowed under inflationary condition. Hou and Lin (2006) [17, 20] discussed a perishable inventory model for decaying items. In this model selling rates were taken as stock dependent under inflationary condition. Wee *et al*. (2007) [10] established a perishable inventory model for decaying items with uncertain lead time. Maiti and Maiti (2007) [59] discussed a multi item inventory model with two-storage facilities.In this model demand was taken as stock dependent with fuzzy lead time. Rong *et al*. (2007) formulated a perishable inventory model for decaying item with two warehouse facilities. In this model shortages were allowed which were partially/fully backlogged with fuzzy lead time. Dye (2007) derive a perishable inventory model for a decaying items. In this model shortages were allowed and partially backlogged. Dye *et al*. (2007-a) developed a perishable inventory model for decaying items with a temporary sale price. Dye *et al*. (2007-b) determined a perishable inventory model. In which varying decay rate was taken. Shortages were allowed with exponential partial backlogging. Dye *et al*. (2007c) developed a perishable inventory model for decaying items with shortages. Chung and Huang (2007) developed a perishable inventory model with limited storage capacity for decaying items. Liao (2007-a) [40] formulated a perishable inventory model for decaying items under permissible delay in payments. Liao (2007-b) [40] stated a perishable inventory model for decaying items under supplier credit linked to ordering quantity. Lin and Lin (2007) discussed a perishable inventory model with decaying items for a two-echelon model. Mahata, and Goswami (2007) [63] formulated a perishable inventory model for decaying items with trade credit financing in the fuzzy sense. Maity *et al*. (2007) [59] discussed a multi item perishable inventory model for decaying items using chebyshev approximation. A perishable inventory model for decaying items was discussed by Chern *et al*. (2008). In this model shortages were allowed with partial backlogging**.** Liao (2008) [43] proposed a perishable inventory model for exponentially decaying items with two-level trade credit. Balkhi and Tadj (2008) formulated a perishable inventory model for decaying items. In this model demand, decay rate was taken as a function of time. Chung and Wee (2008) discussed a perishable production inventory model for decaying items with pricing policy under imperfect production. Banerjee and Agrawal (2008) formulated a perishable inventory model with two-warehouse facilities. In this model shortages were allowed and decay rate was taken as a three-parameter Weibull distribution. Huang and Liao (2008) [43] proposed a perishable inventory model for decaying items. In this model decay rate was defined as exponentially under trade credit financing. Hsieh *et al*. (2008) [13] determined a perishable inventory model for decaying items with two warehouse facilities. In this model shortages were allowed. Jung *et al*. (2008) [25] discussed perishable inventory model for decaying items. In this model decay rate was distributed as Weibull distribution and shortages were allowed with power demand pattern. Lodree and Uzochukwu (2008) [39] developed a production planning for a deteriorating item with stochastic demand and consumer choice. Roy *et al*. (2008) formulated a multi item perishable inventory model for decaying items with fuzzy costs using different defuzzification techniques. Niu and Xie (2008) stated a perishable inventory model for decaying items with two-warehouse facilities using 'FIFO' dispatch policy. Thangam and Uthaya kumar (2008) presented an inventory model. In this model shortages were allowed with partial backordering and demand was taken as a Poisson distribution. Singh *et al*. (2009) discussed an inventory model for perishable products by assuming power demand pattern and partial backlogging. Frank *et al*. (2009) discussed inventory policies for a make-to-order system with a perishable component and fixed ordering cost. Cheng and Wang (2009) discussed perishable inventory model for decaying items with trapezoidal type demand rate. Ouyang *et al*. (2009) formulated a perishable inventory model for decaying items with partially permissible delay in payments linked to order quantity. Maity and Maiti (2009) [57] discussed optimal inventory policies for deteriorating complementary and substitute items. Skouri and Konstantaras (2009) developed a model for decaying seasonable/fashionable products with shortages and demand as time dependent. Min and Zhou (2009) [58] developed an inventory model for decaying items. In this model shortages were allowed and partially backlogged and selling price was taken as stock dependent with capacity constraint. Mirzazadeh *et al*. (2009) [60] formulated a perishable inventory model for decaying items. In this model production rate was taken as finite with uncertain inflationary conditions. Shortages were allowed. Chung (2009) formulated a perishable inventory model for decaying items with permissible delay in payment. Bhunia *et al*. (2009) [36] discussed a perishable inventory model for decaying items. Lee and Hsu (2009) derived a perishable production inventory model for decaying items with two-warehouse facilities. In this model demand was taken as a function of time. Lin *et al*. (2009) [45] discussed an efficient replenishment model of deteriorating items for a supplier-buyer partnership in hi-tech industry. De and Goswami (2009) derived a probabilistic perishable inventory model for decaying items under trade credit financing. Skouri *et al*. (2009) developed a perishable inventory model for decaying items. In this model demand was taken as ramp type and decay rate as Weibull distribution.Shortages were allowed and partial backlogged. Ferguson and Koenigsberg (2009) developed a perishable inventory model for decaying items. Hsieh *et al*. (2009) [12] formulated a perishable inventory model for decaying items with trade credit financing. In this model demand and decay rate were fluctuating with time. Roy *et al*. (2009) derived a perishable inventory model for decaying items. Demand was taken as stock dependent with fuzzy inflation and time discounting over a random planning horizon. Roy and Chaudhuri (2009) proposed a production perishable inventory model for decaying items. Demand rate was taken as stock dependent and decay rate as a Weibull distribution. Shortages were allowed. Hsu *et al*. (2010) [8] discussed an inventory model for preservation technology investment with deteriorating inventory. Roy *et al*. (2010) derived a volume flexible production-policy for randomly

deteriorating item with trended demand and shortages. Olsson and Tydesjo (2010) discussed inventory problems with perishable items with fixed lifetimes and backlogging. Liao and Huang (2010) [44] formulated a deterministic inventory model for deteriorating items with trade credit financing and capacity constraints. Lin *et al*. (2010) [51] derived a two-echelon inventory model for deteriorating items. Chung (2010) developed a perishable inventory model for decaying items using the convexities of total annual relevant costs with permissible delay in payments. He *et al*. (2010) discussed a production perishable inventory model for decaying with multiple-market demand. Hsieh and Dye (2010) [11] formulated a perishable inventory model for decaying items with stock-dependent selling rate and capacity constraint. Chang *et al*. (2010-a) derived a perishable inventory model for decaying items using a discounted cash-flow analysis when a trade credit is linked to order quantity. Chang *et al*. (2010-b) formulated a perishable inventory model for decaying items in a supply chain with up-stream and downstream trade credits. Chang *et al*. (2010-c) developed a perishable inventory model for decaying items for non instantaneous decaying. In this model demand was taken as stock-dependent. Dye *et al*. (2011) developed a perishable inventory model for decaying items with effective investment in preservation technology. Roy and Samanta (2011) discussed an inventory model with two rates of production for deteriorating items with permissible delay in payments. Hung (2011) [19] formulated a perishable inventory model for decaying items. In this model demand was taken as generalized type and shortages were allowed. Jaggi *et al*. (2011) [22] derived a perishable inventory model for decaying items with two-warehouse facilities. In this model demand was taken as linear and shortages were allowed with partial backlogging. Konstantaras and Skouri (2011) [30] formulated a production perishable inventory model for decaying items. Demand in this model was taken as stock-dependent and shortages were allowed. Decay rate was taken as weibull distribution. Cheng *et al*. (2011) derived a perishable inventory model for decaying items. In this model demand was taken as trapezoidal type and shortages were allowed with partial backlogging. Pang (2011) calculated an optimal dynamic pricing inventory model with stock deterioration and partial backordering. Maihami and Kamalabadi (2011) calculated a joint pricing and inventory model for non-instantaneous deteriorating items with partial backlogging. The demand was taken as dependent on price and time. Musa and Sani (2011) formulated an inventory model for decaying items under permissible delay in payments. Alamri (2011) developed an optimal solution to a general reverse logistics inventory model for deteriorating items and time varying rates. Balkhi (2011) derived a perishable inventory model for decaying items with different supplier trade credits for finite horizon case. Singh and Singh (2012) formulated an integrated supply chain model for perishable items with trade credit policy. Kumar, and Goswami (2012) [27], proposed a fuzzy economic order quantity (EOQ) models by taking demand rate as a ramp type and decay rate as time dependent with partial backlogging. Sarkar (2012) formulated a perishable inventory model for decaying items. In this model decay rate was taken as a function of time. Sarkar *et al*. (2012) formulated a perishable inventory model for decaying items. In this model demand was take as quadratic function of time and shortages were allowed with partial backlogging. Tripathi (2013), developed an inventory model. This model was developed for different demand rate and different holding cost. Wu and Sarker (2013), developed a perishable inventory model for decaying items in a supply chain system. Yu *et al*. (2013), calculated a perishable inventory model for decaying items in a two-echelon supply chain with profit sharing. Singh *et al*. (2013) discussed the flexible manufacturing and stock out situation in their model with reverse logistics. A perishable inventory model for decaying items with decay rate as two parameter Weibull distribution in which demand was taken as a function of time and shortages were allowed was formulated by Agarwal and Singh (2013). Shukla *et al*. (2013) established an inventory model for decaying items. In this model demand was taken as exponential function and shortages were allowed. Bansal (2013), formulated a perishable inventory model for decaying items with the effect of inflation. Roy *et al*. (2013), formulated a production inventory model for defective items. In this model demand was taken as stochastic demand and shortages were allowed with backlogging and rework. Chiu *et al*. (2013), formulated a imperfect production inventory model with permissible delay in payments. Chung (2013), developed an inventory model for defective items. In this model delay in payments was allowed. Taleizadeh *et al*. (2013) developed an inventory model in which shortages were allowed with partial backordering. Ouyang and Chang (2013) developed a imperfect production inventory model. In this model payments were delayed and shortages were allowed with complete backlogging. Pahl and Vob (2014) formulated a perishable inventory model for decaying items with lifetime constraints. Moussawi-Haidar *et al*. (2014) [68] formulated a perishable inventory model for decaying items. In this model replenishment was instantaneous for imperfect quality items. Khanlarzade *et al*. (2014) [32] formulated a perishable inventory model for decaying items. Taleizadeh and Nematollahi (2014) formulated a perishable inventory model for decaying items. Shortages were allowed with backlogging. Hsu and Hsu (2014) [6], formulated an inventory model for imperfect items. Shortages were allowed with backordering. Lee and Kim (2014) [42] formulated a perishable inventory model for decaying items. In this model items were both decaying and defective as well. Taleizadeh and Pentico (2014) formulated a perishable inventory model for decaying items. Shortages were allowed with partial backordering. Tripathi (2014) formulated a perishable inventory model for decaying items.In this model shortages were allowed. Tripathi and Kumar (2014), formulated a perishable inventory model for decaying items. In this model inflation was taken under delay in payments. Singh and Sharma (2014) examined a perishable inventory model for non perfect production system. The demand in this model was taken as stock dependent. Tayal *et al*. (2014 a) proposed a single vender and single buyer two echelon supply chain inventory model by taking different conditions of space availability and lead time. Tayal *et al*. (2014 b) formulated a seasonal products inventory model by considering the option of a secondary market considering the lead time. Wu and Chan (2014) formulated a perishable inventory model for decaying items with expiration dates and partial trade credit to credit-risk customers. Bhaula and Kumar (2014) discussed a perishable inventory model for decaying items. In this model decay rate was taken as a weibull distribution and consumption rate was taken as stock dependent. Shortages were allowed. Roy *et al*. (2015) developed a two level inventory supply chain model to optimize the retailers

pricing. In this model the demand was not certain. Chung and Ting (2015), formulated an inventory model using partial trade credit policy in a supply chain system. Ghoreishi *et al*. (2015), formulated a perishable inventory model for decaying items. In this model shortages were allowed with partial backlogging and demand was taken as price dependent. Chen and Teng (2015), formulated a perishable inventory model for decaying items. In this model decay rate was taken as function of time. Das *et al*. (2015) formulated a perishable production inventory model for decaying items. Ghiami and Williams (2015) [5] formulated a perishable inventory model for decaying items. In this model buyers were multiple. Taleizadeh *et al*. (2015) formulated a perishable inventory model for decaying items with deteriorating items. Singhal and Singh (2015) formulated an inventory model with multivariate demand under volume flexibility and learning. Credit financing in policies of orders for non-instantaneous decaying items and the demand was taken as price dependent under the environment of permissible delay in payments was developed by Jaggi *et al***.** (2015) [23]. Tayal *et al*. (2015) formulated an perishable inventory model, for trade credit period with investment in preservation technology.

Conclusion

In this paper we have provided an up to date review of deteriorating inventory literature up to 2005. In this paper it is important to notice that most of the models assumed deterministic setting. Future research should emphasize on these complex and very poorly covered aspect of deteriorating inventory control.

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