Applied Mathematical Modelling 49 (2017) 375–393

Contents lists available at ScienceDirect

Applied Mathematical Modelling

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

Inventory control policy for a periodic review system with expediting

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ARTICLE INFO

Article history:
Received 9 April 2015
Revised 7 February 2017
Accepted 20 April 2017
Available online 10 May 2017

Keywords:
Inventory
Inventory control policy
Expediting
Simulation-based optimization
Infinitesimal perturbation analysis

ABSTRACT

In this work, we examine a single stage, periodic review inventory system where two modes, namely regular mode and expediting mode are available for a firm to obtain its replenishment. The firm can choose expediting mode with shorter lead time at a higher cost when necessary. A two-replenishment-mode model, with random expediting points is established and an innovative ordering policy (*S, e*) which replenishes the inventory level to *S* in every cycle and expedites a part of the order using fast mode when the inventory level drops to or below a certain level *e*, is proposed. A simulation-based optimization approach is employed to solve the problem. To be specific, an infinitesimal perturbation analysis (IPA) method is applied to estimate the gradients of the objective function and a gradient search algorithm is then used to find the best (*S, e*). Numerical experiments have validated the IPA estimate of (*S, e*) and shown that our new (*S, e*) policy outperforms the pure order-up-to policy and two single review moment policies. Sensitivity analysis has been conducted to evaluate the impact of system parameters of interest and managerial insights have been drawn.

1. Introduction

In today's global market, a fast-growing trend of outsourcing while establishing supply chains has been witnessed over the last several decades. To maintain competitive advantage, firms face the challenge of reducing costs while maintaining customer service; thus, high level of flexibility in ordering policy and fast response to demands have become vital to a firm's success. Outsourcing materials, production or services to low-cost third party suppliers would no doubt have economical benefits. However, doing so would also lengthen the response time because of the increased lead time. The introduction of expediting mode, a commonly observed practice, has been proven to be an effective way of increasing a firm's responsiveness without incurring unaffordable costs.

Generally speaking, compared to regular mode, expediting mode allows a firm to satisfy its needs for shorter lead time of shipping, manufacturing or processing, albeit at higher cost. Hence, in practice, a firm can obtain the bulk of its order through regular mode and resort to expediting mode if necessary. By allowing expediting mode to be triggered at any time, firms can enjoy the flexibility of placing an expedite order whenever needed and thus still maintain customer service levels

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http://dx.doi.org/10.1016/j.apm.2017.04.036
0307-904X/

without having to face the unnecessary penalty costs or potential risks of emergency demands or supply delays. Therefore, expediting mode might be applied in various situations. Firms that have implemented a manufacturing information system usually reorder materials on a cyclic basis and will receive messages from the information system if the inventory level of a part drops below a certain level. Upon receiving the message, the inventory manager analyzes current situation and can decide to request the part supplier to expedite a portion of the order through expediting mode. Another example is retailers. They must pay attention to the warehouse inventory and customer demand. If the retailer realizes at any time that the inventory level of an item falls below a dangerous level, she may consider contacting the supplier to expedite delivery. Project management is another area where expediting is commonly applied. Supervisors usually keep an eye on the milestones of projects. At the time when the supervisor believes the progress is slower than expected, she can decide to expedite tasks in order to be able to meet the deadline.

In this paper, we focus on a periodically reviewed inventory system with an expediting option which was originally introduced in [1]. The system is characterized in several aspects. Firstly, there exist two freight modes, namely regular mode and expediting mode to deliver an order to a firm. The firm can choose expediting mode with shorter shipping lead time at a higher cost when there is a necessity. Secondly, according to the demand information, the firm needs to decide whether the current order needs to be expedited and an expediting level is introduced in the system to help decide the expediting time point. Thirdly and most importantly, our system allows to expedite a part of the outstanding order rather than have to expedite the entire order in case of possible shortage of inventory. In other words, the order is split into two parts at the decision point, one part continues under the regular freight mode while the other part switches to fast freight mode. Therefore, the decision to be made at the expediting time point is how large the fast freight part and regular freight part should be.

We consider a periodic review model of the system with a certain cycle time. The demand process is stochastically increasing and has independent stationary increments. The order-up-to level S needs to be decided at the beginning of each cycle. In the model of [1], the decision of expediting is always made at the end of production and the time point is fixed and known. While in a more general case, we may only want to make the expediting decision when the inventory level drops below an expediting level $e(e < S)$. Özsen and Thonemann [2] introduced an inventory control approach that has been used by one of Germany's leading equipment manufacturers. In their approach, a message is sent by its ERP system when the inventory level drops below an expediting level and the planner analyzes future demand and outstanding orders. Then, he/she decides if expediting order is necessary and how much to expedite. The expedited part is received after a fixed period which is less than the regular lead time. In this case, the time point at which the expediting decision is made becomes random because of the stochastic demand process. Hence, in this work, we propose a new periodic review, random expediting point model with the aim of deriving the inventory control policy (S, e) and minimizing the average cost of holding, shortage penalty and extra unit cost of expediting.

Inventory control plays a significant role for cost saving of a firm [3,4]. There have been extensive studies in the field of inventory management for a system where inventory can be replenished from two sources with different lead times and cost structures. The literature on this subject generally appears under various names such as expediting, emergency orders, dual supply modes, dual sourcing, etc. Among these studies, the most notable papers are [1,5–7]. This work contributes to the area of order expediting or emergency orders for inventory system and is closely related to those of [1,2,7]. All these papers consider inventory control policy in a periodic review setting and propose to expedite part of the current order to reduce the risk of backorders.

The continuous review system was first introduced in [8] which proposed a model with order expediting and introduced a parameter called expediting level. Moinzadeh and Nahmias [9] investigated an inventory control system with two options for resupply and consider an extension of the standard (Q, r) policy to allow for two different lot sizes and two different reorder levels. Chiang [10] proposed two continuous review ordering policies, giving the option that companies might expedite before a threshold time point during the lead time. The threshold time point is an operational parameter which specifies the last time point when an expediting decision can be made. Jain et al. [5] sought to extend Groenevelt and Rudi's [1] model by introducing a continuous review policy and allow partly expedited orders. Quite a similar problem was also discussed in [11] which aimed to find optimal (Q, r, r_e) levels. Chiang [12] also proposed to partly expedite orders when inventory falls below a certain level at the end of the manufacturing lead time. This work can also been seen as an extension of the (Q, r) model. Kouvelis and Tang [13] considered a retailer that sources from a supplier with uncertain lead time to meet its deterministic demand and the retailer has the option to expedite a portion of the replenishment order. They characterize the optimal expediting policy and study how the expediting option affects the retailer's decisions on the replenishment order.

The use of order expediting or two supply modes has been extensively built upon (s, S) policy. Huggins and Olsen [14] considered a two-stage supply chain management problem where shortages are not allowed. It is shown that the optimal regular ordering policy is an (s, S) type policy, but the expediting is not a base stock policy. Huggins and Olsen [6] modeled an inventory control problem in which stochastic demand must be met and shortages can be filled by expediting. They characterized the structure of the optimal expediting policy and showed the optimal regular production policy is (s, S) for the model with one mode of expediting. For the model with two forms of expediting, they explored the structure of the optimal expediting policy and showed the optimal regular production policy is (s, S). Jain et al. [7] studied an inventory model of a firm that periodically orders a product from a make-to-order manufacturer. Placing an order as well as use of each freight mode has a fixed and a quantity proportional cost. They derived the optimal freight mode allocation policy,