Himanshu Saxena
001278141

Literature Review

Optimal policies and inventory models for retail inventory management of products with seasonal demand

Himanshu Saxena*
Department of Industrial Engineering, Northeastern University, Boston

---

ABSTRACT

In this review paper I focus on studies that provide a solution of optimization of inventory in retail stores during seasonal demand. Specifically, I focus on papers that provide an approach to model a solution to provide how much to stock, when to stock and where to stock to fulfill the seasonal requirements and minimize the inventory holding costs. I specifically focus on retail practices in high end marketplace with stiff competition for example a high-tech retail store. Inventory models with variable lead time and demand as a function of price and time have been discussed along with policies that enable optimal inventory management.

Review

The boom in technological advancements and customer centric market has led to ever increasing competition among the retailers. There are multiple brands offering the same product within the similar price range. The sales strategies could only improve the profits of the retail stores, but a solid supply chain and optimal inventory are the key to success. On numerous counts, the stores fail to provide the expected product because of unavailability. This creates a loss of sales and thus profits of the retail stores decline.

The scenario is worse during the seasonal demand. As the holidays approach, the number of potential customers in the market increases. There is a higher demand for most of the products and thus the holiday season is a golden opportunity for retail stores to meet their sales targets and maximize profits. Due to its popularity, the demand during holiday season or other festive seasons is known as seasonal demand. This seasonal demand is periodic in nature and is characterized by a general increase in demand. This high demand usually lasts for a few days and can be represented by a symmetrical curve.

As illustrated in Chen and Cheng (2006), for some companies, especially high-tech industries, demand usually has a seasonal variation with PLC [3]. To meet the customer demands during this period, every company tries its best to keep sufficient inventory of items. Overstocking and understocking can both lead to decrease in profits. If a certain type of product is overstocked and it fails to sell during its expected period, it can increase the handling cost and thus decrease profits of the store. In the same way, if an item is understocked, it may take away a potential customer which would result in increased stock-out cost.

The most efficient way to prevent this loss is through optimization of inventory. In every supply chain, inventory optimization is done by considering three factors: *(1) how much to order, (2) when to order, and (3) where to store* [1]. There is a high uncertainty in demand associated with timing, location, type and amount of demand throughout the year for retail stores, however, thanks to a periodic repetitive pattern of seasonal demand, a good forecast is possible by observing the historical data and new trends in demands. Also, as the occurrence of these seasons are defined well in advance, the retail chains have sufficient lead time for order fulfillment.

In some supply chains, the demand is a function of time and price with increasing, constant and declining phases [2]. Banerjee [5] modeled a solution to this problem and defined the optimal number of seasonal intervals before replenishment, the optimal order quantity, and the selling price to achieve highest profits. He inferred that it is beneficial for the distributor to shift to alternate market with higher demand, even at a lower selling price.

You (2005) has considered pricing for an inventory model with deterministic price dependent seasonal demand declining with time. He has considered seasons to be contiguous [4].

Park et all [6] developed and tested inventory model for seasonal demand for products of short sales seasons and without any replenishment. This is particularly useful in haute couture, i.e., high fashion industry. The objective of this study was to determine the time of switching primary sales effort from one season to the next along with the optimal order quantity for each season to maximize profits over the season. They develop a function for the total expected profit and used it to find the optimal demand and order quantity. They found out Q1 (order quantity 1) is independent of Q2 (order quantity 2) at any given demand d. They also develop a model for multiple season planning with a single product for each season. They proceed to develop a model for multiple items with a single resource constraint [6]

Mattos et all [7] tested out the inventory replenishment models on a practical situation. The primary objective was to improve retailer's supply chain processes by reducing the inventory. They made use of inventory review policy, picking piece implementation and minimum exposure definition. According to authors, for a fixed-cycle service level, a manager has three levers that affect the safety stock-demand: uncertainty, replenishment lead time, and lead time uncertainty. The safety stock evaluation must consider not only the probability of not

It was observed that retailers cannot only increase their profit but also decrease costs by properly managing products allocation and inventory policy review.

In modern day supply chains, the retail stores have an ERP tool for managing their inventory. The automated order system calls for stores replenishment for each product at each store with a pre-settled inventory reference level that generates a replenishment order once it hits 85% of its quantity or if the replenishment size order is at least half unit load.

Kulkarni et all [9] presented a model for determining the ordering policy, which minimized the total inventory cost. The paper took into consideration various models such as lot by lot size, economic order quantity, periodic order quantity, least unit cost, least total cost, least period cost, Wagner-Whitin algorithm etc. Total annual inventory costs for various items were calculated by each method. the Wagner-Whitin model gives the least total annual inventory cost in all the cases. The theory was applied to variety of items, i.e. items with highest and lowest annual usage value, highest and lowest unit cost, highest and lowest annual consumption. But in each case Wagner-Whitin model shows optimum results. The periodic order quantity model also proves to be competent as it shows very slight variations from the Wagner-Whitin model. The method saved 18% on the total cost.

References

[1] D.C. Whybark, Issues in managing disaster relief inventories, Int. J. Prod. Econ. 108 (1) (2007) 228–235.

[2] Inventory model for seasonal demand with option to change the market

[3] Chen, K. K., & Cheng, C. T. (2006). A seasonal demand inventory model with variable lead time and resource constraints. Applied Mathematical Modeling, 31, 2433–2445.

[4] You, P. S. (2005). Optimal replenishment policy for product with seasonal pattern demand. Operations Research Letters, 33, 90–96.

[5] Banerjee, Sharma (2010). Optimal procurement and pricing policies for inventory models with price and time dependent seasonal demand, 51, 700-714.

[6] Park, Chang, Ho (2004). Inventory Model with seasonal demand: A specific application to haute culture,

[7] Mattos, Pecora, Briso (2017). Improving sales through Inventory Reduction: A Retail Chain Case Study, Vol. 11, No. 10.

[8] Ehrenthal, Honhon, Woensel (2014). Demand seasonality in retail inventory management, 238, 527-539.

[9] Kulkarni, Rajhans (2012). Determination of optimal inventory model for minimizing total inventory cost, 803-809

Himanshu Saxena
001278141

Appendix

Research papers in reference

Available online at www.sciencedirect.com

SciVerse ScienceDirect

Procedia Engineering 51 (2013) 803 – 809

Procedia Engineering

www.elsevier.com/locate/procedia

Chemical, Civil and Mechanical Engineering Tracks of the 3rd Nirma University International Conference on Engineering (NUiCONE 2012)

Determination of Optimum Inventory Model for Minimizing Total Inventory Cost

Ms. S.M.Samak-Kulkarni[a]*, Dr.Mrs.N.R.Rajhans[b]

[a]*Asso. Prof. & Head of Mechanical Engg. Deaprtment, S.C.O.E.M, Limb., Satara, Maharashtra, India.*
[b]*Professor & Head of Production Engg Department, College of Engg, Pune, Maharashtra, India.*

Abstract

In most of the medium scale industries, demand is uncertain and difficult to forecast. Hence Ordering in right quantities at right time is always a crucial issue. In this paper; the authors present a model for determining the ordering policy which will minimize the total inventory cost. This paper takes into consideration various models such as lot by lot size, economic order quantity, periodic order quantity, least unit cost, least total cost, least period cost, Wagner-Whitin algorithm etc. Total annual inventory costs for various items are calculated by each method. The results obtained by applying each model for different items are summarized which shows that Wagner-Whitin algorithm gives optimum cost in each case.

Keywords: Wagner-Whitin Algorithm; Inventory Models; Inventory costs, LFL, POQ, EOQ, LTC, LUC, LPC.

1. Introduction

Inventory is the stock of any item or resource used in an organization. An inventory system is the set of policies that controls and maintains inventory levels [1]. It decides when stock should be replenished, and how large orders should be. The main concern of any manufacturing organization is to minimize the overall cost and thus increasing profit. The inventory cost comprises of four costs-purchase cost, ordering cost, inventory carrying cost and shortage costs. [2] Establishing the correct quantity to order from vendors or the size of the lots submitted to the firm's productive facilities involves a search for the minimum total cost resulting from the combined effect of the four individual costs. [1] Often the inventory managers have to take a crucial decision regarding the balance between ordering cost and carrying cost. If order quantity per unit time is small, the number of orders increases resulting in higher ordering cost, though carrying cost is very less. This sometimes may lead to stock outs, market loss.

Alternately, if a bigger quantity is ordered, number of orders and hence ordering cost reduces considerably. But there is increase in carrying cost. Also more storage space, store staff is required. Storage for longer time may lead to defects in inventory items. Thus a proper balance between carrying costs and ordering cost is very necessary. This leads to development of an effective inventory model that will decide a lot size with minimum total inventory cost.

* Corresponding author. Tel.: 9822602102; fax: (02162)268778.
E-mail address: shilpa_samak@rediffmail.com

doi:10.1016/j.proeng.2013.01.115

World Academy of Science, Engineering and Technology
International Journal of Economics and Management Engineering
Vol:11, No:10, 2017

Improving Sales through Inventory Reduction: A Retail Chain Case Study

M. G. Mattos, J. E. Pécora Jr, T. A. Briso

***Abstract*—**Today's challenging business environment, with unpredictable demand and volatility, requires a supply chain strategy that handles uncertainty and risks in the right way. Even though inventory models have been previously explored, this paper seeks to apply these concepts on a practical situation. This study involves the inventory replenishment problem, applying techniques that are mainly based on mathematical assumptions and modeling. The primary goal is to improve the retailer's supply chain processes taking store differences when setting the various target stock levels. Through inventory review policy, picking piece implementation and minimum exposure definition, we were able not only to promote the inventory reduction as well as improve sales results. The inventory management theory from literature review was then tested on a single case study regarding a particular department in one of the largest Latam retail chains.

***Keywords*—**Inventory, distribution, retail, risk, safety stock, sales, uncertainty.

I. Introduction

In a globalized economy, the goal of multinational corporations is to find a more efficient flow of goods and services for corporate or individual consumers. The search for new sources and, the acquisition of increasingly competitive advantages, have been a constant challenge in today's highly competitive world in its marketing, finance, operations, logistics and sourcing. For supply chains, competitive advantage can be obtained through the development of logistics practices and procedures that can optimize order processing, shipping and inventory control.

The main challenge for retail managers is to provide items on the shelf, matching replenishment and demand, for several different products on various stores while overcoming out-of-stocks and excess at the same time [1]. As inventory must be allocated optimally across the stores, regarding the total available inventory, supply chain management is a complex task which requires careful planning and execution [2].

Retail inventory models, when exploited appropriately, lead to significant profits increase [3] once it reduces stock over at stores and ensures customer service level as well as improves the company's assets and capital expenses. Moreover, this inventory represents an important percentage of the fixed costs of a retail business, evidencing the necessity of a study directed toward the search for a model that optimizes these resources. Although this established approach to inventory control has proved to be very valuable in determining inventory parameters and planning resources [3], its value can be questioned in dealing with practical inventory control problems [5].

This work presents the analysis and results for one of the most traditional retail chains in Latam. In activity for 87 years, the company has more than 1,100 stores and also operates in electronic commerce. The chain sells more than 60,000 items from 2,000 different suppliers holding a major share of trade in toys, chocolates and candies, lingerie, CDs/DVDs, games, health/beauty and household utilities.

An automated inventory replenishment system recommends order quantities to the store manager every order cycle but, system inadequacy arises because inventory management in a retail store is a complex problem involving many constraints and varying product attributes. For the most part, management's understanding of the effect on safety stocks of uncertainty in lead time is based on an approximation of the demand during lead time using the normal distribution.

As having strong backend physical distribution process, inventory management is essential for fulfilling customer orders in a timely and accurate way which has been a recurring challenge for retailers, in order to support store-based operations. In that way, our paper yields some important insights for retail management leading to reduce inventory holding, handling and stock-out cost substantially.

High holding costs of inventory incur from excessive safety stock added by spoiled, expired, or broken during the warehousing process. On the other hand, little safety stock may cause sales lost and, thus, a higher rate of customer turnover. As a result, finding the right balance between high and low safety stock is essential.

The context of our research involves the inventory replenishment problem for products follows with demand rate fluctuation, seasonality, automated ordering system for stores replenishment, lead time variability, periodic delivery, monthly forecast and purchase with occasionally supplier product unavailability. Thus, this paper seeks out to identify inventory procedures and metrics that ensure stores replenishment towards stock reduction. The goal of this paper and it study case is to match demand with supply.

Grounded on inventory literature proceedings the development of this work took four stages: planning the replenishment policy; reviewing stock reference levels; checking the performance indicators and acting to improve the replenishment process. The remainder of this paper is organized as follows. In Section II we provide a summary of

M. G. Mattos is with the Universidade Federal de Minas Gerais, Brazil (phone: +55 21 99956-1302; e-mail: guimaraes.mattos@gmail.com).
J. E. Pécora Jr. and T. A. Briso are with the Universidade Federal de Minas Gerais, Brazil (e-mail: pecora@ufpr.br, thais_briso@hotmail.com).

Computers & Industrial Engineering 59 (2010) 807–818

Contents lists available at ScienceDirect

Computers & Industrial Engineering

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

Inventory model for seasonal demand with option to change the market ☆

Snigdha Banerjee [a,*], Ashish Sharma [b]

[a] School of Statistics, Devi Ahilya University, Vigyan Bhawan, Khandwa Road, Indore 452 017, India
[b] Department of Mathematics, G.L.A. Institute of Technology and Management, NH-2, Mathura 281 406, India

ARTICLE INFO

Article history:
Received 13 March 2009
Received in revised form 7 August 2010
Accepted 19 August 2010
Available online 22 August 2010

Keywords:
Inventory
Product life cycle
Partial backlogging
Seasonal demand
Primary market
Alternate market

ABSTRACT

In real life, when bulk purchase becomes convenient or even mandatory, it is a common practice for distributors to explore an alternative market in order to maximize the revenue earned. In this paper, we consider an inventory model for a product having seasonal demand with two potential markets, say, primary and alternate. The distributor has a single opportunity of procurement prior to multiple demand seasons in the primary and the alternate market. Both the markets have similar demand patterns, with time lag between their demand seasons. The demand is a price and time dependent function with increasing, constant and declining phases within each demand season. The scale parameter of demand rate depends upon the market. In each market, successive seasons are separated by random time. In one replenishment cycle, the distributor has a single option to exit the primary market by transferring the inventory, with or without change in selling price. This option can be exercised at the end of any complete season at the primary market. Our investigations indicate that it will be beneficial for the distributor to shift to the alternate market even at a slightly lower selling price if demand rate in the alternate market is higher. Optimal number of seasons at the primary market before change of price or market is obtained. Optimal policy is obtained for jointly determining the order quantity and price. Concavity of the profit function is discussed. Solution procedure, numerical examples and sensitivity analysis are presented.

1. Introduction

The boom in the recent past and the current recession worldwide has witnessed multinational companies seeking, inducing and promoting globalization of demand for products, which has developed the scope for alternate markets in a big way. Some situations allow a single product to be sold in two alternate markets at different times with same or different price. Some other situations involve time gap between demand seasons in the same market. It is a commonly observed phenomenon that many products have three phase product life cycle (PLC) type demand, that is, demand increases, stabilizes and then decreases (Panda, Senapati, & Basu, 2008). While PLC times vary, the basic shape is consistent over a wide range of products.

As illustrated in Chen and Cheng (2006), for some companies, especially high-tech industries, demand usually has a seasonal variation with PLC. This is also true for many other products as observed from Fig. 1, which shows the monthly sales data (in quintals) of pulses collected for the year 2007–2008 from a distributor located in Mathura (UP).

The distributor sells his product in many cities of UP and in the month of February, that is, at the end of the first demand season of the year, shifts a major part of the goods to densely populated metropolitan cities in Maharashtra where the season begins in March, demand is high and higher price can be charged for the same product. This is also true for many climate based products like woolen clothes, rain coats, annual crops. For example, in India, winter season starts around September in the northern regions and then moves southwards till January. Hence, demand for woolens experiences a boom at one place and slump at another place at the same time. These sales also depend upon many other factors like festivals, fluctuating climatic conditions, which may induce a random time interval between two successive demand seasons at the same place. Thus the distributor may stay back in the same market to save the transportation cost, wait for a random time till the next season and try to increase the revenue by changing the selling price or he may move the remaining goods to an alternative market to take advantage of the higher demand with or without change in the selling price.

While considering practical aspects, one must realize that bulk purchase becomes convenient or even mandatory for some products. For instance, in case of annual crops like wheat, cereals, oilseeds, pulses, when the new crop arrives, a distributor has to buy the product in bulk so that he can sell it over many demand seasons, since later the product will either not be available for bulk

☆ This manuscript was processed by Area Editor Mohamad Y. Jaber.
* Corresponding author. Tel.: +91 731 2562434; fax: +91 731 2462003.
E-mail addresses: bans_1@rediffmail.com (S. Banerjee), ashish_sharma34@rediffmail.com (A. Sharma).

0360-8352/$ - see front matter
doi:10.1016/j.cie.2010.08.008

2-2004

Inventory Model with Seasonal Demand: A Specific Application to Haute Couture

Byung Joon Park
Singapore Management University, jpark@smu.edu.sg

Yih-Long Chang
Georgia Institute of Technology

Johnny C. Ho
Columbus State University

Inventory Model with Seasonal Demand: A Specific Application to Haute Couture

February 23, 2004

B. Joon Park
Singapore Management University
School of Business
469 Bukit Timah Road
Singapore 259756
Singapore
Tel: 65 6822 0733
Fax: 65 6822 0777
Email: jpark@smu.edu.sg

Yih-Long Chang
DuPree College of Management
Georgia Institute of Technology
800 West Peachtree Street, NW
Atlanta, GA 30332-0520
U.S.A.
Tel: (404) 894 4334
Fax: (404) 894 6030
Email: yihlong.chang@mgt.gatech.edu

Johnny C. Ho
Abbott Turner College of Business
Columbus State University
Columbus, GA 31907-5645
U.S.A.
Tel: (706) 562 1668
Fax: (706) 568 2184
Email: ho_johnny@colstate.edu

Inventory Model with Seasonal Demand: A Specific Application to Haute Couture

Abstract

In the stochastic multiperiod inventory problem, a vast majority of the literature deals with demand volume uncertainty. Other dimensions of uncertainty have generally been overlooked. In this paper, we develop a newsboy formulation for the aggregate multiperiod inventory problem intended for products of short sales season and without replenishments. A distinguishing characteristic of our formulation is that it takes a time dimension of demand uncertainty into account. The proposed model is particularly suitable for applications in haute couture, i.e., high fashion industry. The model determines the time of switching primary sales effort from one season to the next as well as optimal order quantity for each season with the objective of maximizing expected profit over the planning horizon. We also derive the optimality conditions for the time of switching primary sales effort and order quantity. Furthermore, we show that if time uncertainty and volume uncertainty are independent, order quantity becomes the main decision over the interval of the primary selling season. Finally, we demonstrate that the results from the two-season case can be directly extended to the multi-season case and the limited resource multiple-item case.

Key Words: Inventory Model; Newsboy Formulation; Optimal Policies

Mathematical and Computer Modelling 51 (2010) 700–714

Contents lists available at ScienceDirect

Mathematical and Computer Modelling

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

Optimal procurement and pricing policies for inventory models with price and time dependent seasonal demand

Snigdha Banerjee [a,*], Ashish Sharma [b]

[a] School of Statistics, Devi Ahilya University, Vigyan Bhawan, Khandwa Road, Indore 452017, India
[b] Department of Mathematics, G.L.A. Institute of Technology and Management, NH-2, Mathura 281406, India

A R T I C L E I N F O

Article history:
Received 28 June 2008
Received in revised form 20 September 2009
Accepted 22 September 2009

Keywords:
Inventory
Time and price dependent demand
Seasonal demand
Time dependent partial backlogging
Pricing

A B S T R A C T

In day to day life, one observes that many commodities have a seasonal demand pattern, where demand rate depends upon both price and time. A common observation is that in the event of shortage, the proportion of customers who will wait to purchase the item decreases as the waiting time increases. In this paper, we consider a deterministic inventory model that incorporates these aspects when the product under consideration has general price and time dependent seasonal demand rate. Inventory once ordered can be used for more than one season. Order for replenishment is placed at the end of the season in which inventory depletes completely. The period of shortage cannot exceed one season. Backlog of shortages is time dependent. Conditions for optimality of the net profit function for pricing and procurement decisions are discussed. The solution procedure, numerical examples and sensitivity analysis are presented.

1. Introduction

Numerous factors depending upon natural or business conditions affect various determinants of market demand. Sometimes such conditions recur at regular intervals. As a result, demand for some commodities depicts recurrent patterns called seasonal variation. For example, as mentioned by Shugan et al. [1] hourly seasonality is observed in health clubs where demand peaks during morning and evening, that is, before and after the normal working hours. Hence, morning and evening can be considered to be seasons, and the demand has hourly seasonality. Similarly, demand rate at departmental stores generally peaks during weekends and can be considered to have the same demand pattern every week. Hence, every week is a season. The price during each season may be considered to be constant. Bradley and Arntzen [2] have developed a model that simultaneously plans capacity, inventory investment and production schedule. They applied the model to two multinational manufacturing companies that experienced seasonal demand. One of the companies produced electronic goods and the other produced consumable office stationery. They observed that demand for some types of consumable stationery peaked when students get back to school and also during Christmas. This reflects the naturally occurring seasonality in demand. On the other hand, the electronics company experienced severe end-of-quarter demand spikes, which the authors describe as "self-induced pattern driven by business practices".

The present market scenario has witnessed a rapid proliferation of stock keeping units in retail of goods having seasonal demand. This has brought to the forefront, various problems concerning the profitability of retailers dealing with such commodities. Price is a major determinant of demand and hence affects the optimality aspects of many inventory models directly as well as indirectly. Inventory models that incorporate realistic situations often consider demand to be price

* Corresponding author. Tel.: +91 731 2462003; fax: +91 731 2462003.
E-mail addresses: bans_1@rediffmail.com (S. Banerjee), ashish_sharma34@rediffmail.com (A. Sharma).

0895-7177/$ – see front matter © 2009 Elsevier Ltd. All rights reserved.
doi:10.1016/j.mcm.2009.10.022

Available online at www.sciencedirect.com
ScienceDirect
Applied Mathematical Modelling 31 (2007) 2433–2445
www.elsevier.com/locate/apm

A seasonal demand inventory model with variable lead time and resource constraints

Kee Kuo Chen [a], Ching-Ter Chang [b,*]

[a] National Taiwan Ocean University, Department of Shipping and Transportation Management, Keelong, Taiwan, ROC
[b] National Changhua University of Education, Department of Information Management, Changhua, Taiwan, ROC

Received 1 June 2005; received in revised form 1 June 2006; accepted 6 September 2006
Available online 7 November 2006

Abstract

In this paper, two new methods are proposed for solving a seasonal demand problem with variable lead-time and resource constraints. Despite its significance, no study has been done on such problem to obtain the best policy. First, in order to solve the variable lead time, a linear programming relaxation using piecewise linearization techniques is derived. Then, a mixed integer program with linearization techniques is constructed for the seasonal demand problem. Finally, some illustrative examples are included to demonstrate the applicability of the proposed models.

Keywords: Lead time; Seasonal demand; Linearization; Mixed integer

1. Introduction

In recent years, many companies have realized that inventory cost savings can be achieved using Just-In-Time (JIT) techniques in their supply chain system [3,22,12]. Variable lead time is the key to successful implementation of JIT because the lead time can be shortened by adding extra crashing costs to reduce the total cost of safety stocks in JIT [1,13,15,14,10,7,16]. The model of Ben-daya and Raouf [1] is one of the fundamental works in the variable lead-time problems. Later, many studies have been made on the variable lead time with constant demand [21,1,13,10,11]. Snyder et al. [18] derived exponential smoothing models to forecast lead-time demand. Chang and Chang [8] have proposed an inventory model with variable lead time and price-quantity discount. Chang [7] has recently proposed an approximate global optimization approach for solving inventory models with variable lead time in which the demand following a normal distribution and lead-time crash cost structure are considered. Compared with previous ones, the model of Chang [7] is more promising in solving practical constant demand inventory problem with variable lead-time. However, this may not be true in some practical situations. In practice, most firms had variable demand and the demand rate remained flat only in the

* Corresponding author.
E-mail address: chingter@cc.ncue.edu.tw (C.-T. Chang).

0307-904X/$ - see front matter
doi:10.1016/j.apm.2006.09.009

European Journal of Operational Research 238 (2014) 527–539

Contents lists available at ScienceDirect

European Journal of Operational Research

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

Decision Support

Demand seasonality in retail inventory management

J.C.F. Ehrenthal [a], D. Honhon [b,*], T. Van Woensel [c]

[a] LOG CONNECT AG, Embrach, Switzerland
[b] Jindal School of Management, University of Texas at Dallas, 800 W. Campbell Road, Richardson, TX 75080, USA
[c] School of Industrial Engineering, Eindhoven University of Technology, P.O. Box 513, 5600 MB Eindhoven, The Netherlands

ARTICLE INFO

Article history:
Received 15 February 2013
Accepted 20 March 2014
Available online 13 April 2014

Keywords:
Retailing
Inventory control
Lost sales
Non-stationary demand
Seasonality

ABSTRACT

We investigate the value of accounting for demand seasonality in inventory control. Our problem is motivated by discussions with retailers who admitted to not taking perceived seasonality patterns into account in their replenishment systems. We consider a single-location, single-item periodic review lost sales inventory problem with seasonal demand in a retail environment. Customer demand has seasonality with a known season length, the lead time is shorter than the review period and orders are placed as multiples of a fixed batch size. The cost structure comprises of a fixed cost per order, a cost per batch, and a unit variable cost to model retail handling costs. We consider four different settings which differ in the degree of demand seasonality that is incorporated in the model: with or without within-review period variations and with or without across-review periods variations. In each case, we calculate the policy which minimizes the long-run average cost and compute the optimality gaps of the policies which ignore part or all demand seasonality. We find that not accounting for demand seasonality can lead to substantial optimality gaps, yet incorporating only some form of demand seasonality does not always lead to cost savings. We apply the problem to a real life setting, using Point-of-Sales data from a European retailer. We show that a simple distinction between weekday and weekend sales can lead to major cost reductions without greatly increasing the complexity of the retailer's automatic store ordering system. Our analysis provides valuable insights on the tradeoff between the complexity of the automatic store ordering system and the benefits of incorporating demand seasonality.

1. Introduction

The main challenge in managing retail inventory is to match replenishment and demand, that is providing items on the shelf justified by an upcoming shopper demand. Economies of scale in supply, inadequate store execution and demand variation often lead to out-of-stocks and excess inventory. While store execution and retail out-of-stocks have received considerable attention in academia and business practice (see Aastrup & Kotzab, 2010), the impact of demand variation has largely been overlooked (Bijvanc & Vis, 2011).

Demand in retailing is known to vary depending on the day of the week and time of year, around important holidays such as Christmas, and the seasons. For example, ice cream is in higher demand in the summer months. Demand is also generally not evenly distributed within the day. For instance, in business districts more customers shop just after working hours on weekdays. Retailers can, to some degree, reduce demand variation, for instance by reducing promotions or offering "everyday low prices". However, customer buying habits, like shopping on weekends, limit a retailer's ability to completely smooth demand variations. This creates the need for retailers to account for seasonality in their inventory control and shelf inventories, in (partial) synchronization with the demand pattern (Aviv & Federgruen, 1997).

Not accounting for demand seasonality leads to systematic mismatches in demand and supply at the item-store level, resulting in higher than needed costs. For example, Gruen and Corsten (2008) show that out-of-sync replenishment and demand lead to recurring out-of-stocks in retail stores on specific days of the week. Yet, from our conversation with retailers, it appears that many of them lack the capabilities or skills to incorporate demand seasonality into their store ordering and shelf replenishment systems. Six medium-sized European retailers reported to us that their automated store ordering (ASO) systems do not have the technical capabilities to account for demand seasonality within the week. Similarly, two of Europe's largest retailers told us that even though their ASO system allows for different yearly seasonality patterns for each item, they currently refrain from using refined seasonality pattern analysis because of the added level of complexity. We also

* Corresponding author. Tel.: +1 972 883 5947.
E-mail address: dorothee.honhon@utdallas.edu (D. Honhon).

http://dx.doi.org/10.1016/j.ejor.2014.03.030
0377-2217/