European Journal of Operational Research 205 (2010) 313–324

Contents lists available at ScienceDirect

European Journal of Operational Research

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

Production, Manufacturing and Logistics

Inventory management of multiple items with irregular demand: A case study

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ARTICLE INFO

Article history:
Received 28 November 2008
Accepted 27 December 2009
Available online 11 January 2010

Keywords:
Supply chain management
Inventory
Case study
Gamma distribution
Periodic review
Base stock

ABSTRACT

We present the case of a Greek commercial enterprise facing the problem of managing the inventories of thousands of different items, supplied by more than 20 European and Asian manufacturers and sold to a large number of different-type customers. A key feature of the problem is that the demand for the vast majority of items is intermittent and lumpy, thus not allowing the use of the usual normal or Poisson distributions. The paper describes the solutions given to several practical problems in the course of developing an easy-to-use yet effective and all-encompassing inventory control system. Emphasis is placed on the accurate modeling of demand by means of a gamma distribution with a probability mass at zero or a package Poisson distribution for very-slow-moving items. Using those models and simple quantitative tools we develop an efficient procedure for approximate but quite accurate determination of the base stock levels that achieve the desired fill rates in the proposed periodic review system. We briefly describe the computerized implementation of the new system and the very encouraging results.

1. Introduction

Inventory management has been recognized as one of the most important functions of industrial and commercial enterprises, which often has a great impact on their overall performance. The typical trade-off is between high holding and obsolescence costs of excessive stock on one hand and poor service and high shortage costs resulting from low inventory levels on the other. The desired solution is a suitable inventory control policy that will guarantee a satisfactory service level without keeping unnecessarily large inventories that are costly and difficult to handle.

Inventory theory is probably the most thoroughly researched area of production and operations management. However, although almost all large companies and many small and medium-sized enterprises increasingly try to apply scientific methods for better managing their inventories, the use of these methods is often limited to some basic tools like the computation of economic order quantities and rough approximations of reorder points or base stocks for achieving target service levels. The widespread application of more elaborate and appropriate methods for inventory control in practice is hindered by a number of factors including most notably the following:

- The standard textbook material on inventory control is based on the assumption that lead time demand follows a normal or Poisson distribution. This is often not the case in practice. Using the standard textbook models as approximations in cases where the departures from the assumed normal or Poisson distribution are serious leads to very unsatisfactory results.
- The standard textbook treatment of inventory management either completely ignores or provides very vague guidelines about the issues and complications that typically arise in practice due to the large number of suppliers and items that must be coordinated, incomplete or suspicious data, lead time variability, possibility of late order placement or emergency replenishment, etc.

The above reservations reflect precisely the skepticism at the top management of RODA s.a., the largest distributor of castors and wheels in Greece, when they asked us to assist them with the rationalization and computerization of their inventory control system. In a few words, the challenge that we faced and served as the main motivation for our work was to bridge the gap between theory and the practical peculiarities of a specific business environment so as to deliver a user-friendly and flexible computerized decision support system for the management of thousands of stock keeping units (SKUs), which the company orders and receives from more than 20 suppliers located in Europe and China. A key and distinguishing feature of the problem is that the demand for the vast majority of the SKUs is highly variable and irregular, thus defying the usual assumptions of normal or Poisson distribution.

In addition to addressing a specific company's problem, our work touched upon issues and technical problems of broader interest that, in our opinion, are worth communicating to the scientific community. The most interesting of these issues, problems, and

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doi:10.1016/j.ejor.2009.12.022

findings are summarized in the present paper, which we view as making a twofold contribution:

(i) At the managerial level, it provides a "complete" account (subject to journal space limitations) of the solutions given to several practical problems in the course of developing an easy-to-use yet effective and all-encompassing inventory control system. Some of these solutions may be directly or indirectly usable in similar situations.
(ii) At a more technical level, the paper describes the details of modeling intermittent and lumpy demand for a wide range of average volumes (both for slow-moving and fast-moving items), as well as an efficient procedure for approximate but quite accurate determination of appropriate base stocks and estimation of fill rates and other important operating characteristics in the proposed periodic review system.

The next section contains a brief literature review in two intersecting directions: (a) case studies of inventory control systems and (b) modeling of intermittent and lumpy demand for stock control purposes. Then, Section 3 describes the problem setting: the company, its products and suppliers, and the empirical inventory control and ordering policy that the company used to apply for the replenishment of its stock. Section 4 is devoted to the analysis and modeling of demand for the various types of SKUs. The section that follows describes the general features of the periodic review base stock system that was proposed with the aim of introducing more structure and streamlining the procurement operations. Section 6 presents, explains and validates the formulas for the computation of critical operating characteristics of the proposed system. Section 7 presents the determination of the appropriate base stocks for each class of SKUs and Section 8 describes briefly the decision support system that was developed for classifying the SKUs into different classes and then computing the respective recommended base stocks. The results of the new system development and implementation are discussed in the concluding section.

2. Literature review

The scientific literature in the area of inventory *theory* is so huge that any attempt to provide a comprehensive coverage of even a small part of it in a few journal pages would be doomed to failure. However, reports of inventory control *practice* in the form of case studies published in academic journals are much more limited. In the following paragraphs we first refer to a few selected papers, which present case studies having common general features with the problem that we had to address. Then, we present publications that deal specifically with the issue of modeling intermittent and lumpy demand, placing emphasis on articles motivated by practical applications and focusing on specific variations of the Poisson and gamma distributions, which have been employed in the past and are also used in the analysis of our case in later sections.

2.1. Case studies of inventory control systems

During the last decades, a number of inventory control case studies have appear in the academic literature, reporting applications mostly in the electronics, chemical, and automotive industries. One of the earliest such publications is by Gelders and van Looy (1978), who present various inventory policies both for slow-moving and fast-moving items in a petrochemical plant with around 22,500 SKUs.

Vereecke and Verstraeten (1994) describe an algorithm for the implementation of a computerized inventory management system for spare parts in a large chemical plant, located in Belgium. The spare parts inventory contains about 34,000 different types of items, 90% of which have demand frequency lower than 4 times a year.

More recently, Aronis et al. (2004) develop a Bayesian methodology to obtain more accurate forecasts for the demand of spare parts of electronic equipment and then apply it to obtain the appropriate values of the parameter S of an $(S-1, S)$ inventory system for these parts. Kukreja and Schmidt (2005) present the case of a large utility company having 29 power generating plants in five American south-eastern states. The inventory under study consists of low-usage but expensive items with a lumpy demand pattern. They develop and propose a continuous review inventory system with transhipments in case of stockouts. Syntetos and Boylan (2006) use simulation to measure the effectiveness of a periodic review order-up-to inventory system for controlling the stock of items with intermittent demand. They use real data from the automotive industry and evaluate the system with both statistical and economic criteria. Porras and Dekker (2008) compare different reorder point methods for effective spare parts inventory control at a large oil refinery in the Netherlands. They note that it is difficult to devise good strategies for the management of spare parts because they are typically slow-moving with highly stochastic and erratic demands.

2.2. Modeling of irregular demand

A common finding in most inventory control case studies is that the demand of specific SKUs cannot always be modelled accurately by means of the normal or Poisson distribution, as is usually assumed in standard textbooks, because it is often erratic, intermittent and/or lumpy. In addition to the references in the preceding sub-section, see also the papers of Williams (1984) and Willemain et al. (2004). Dolgui and Pashkevich (2008) report that 37.3% of the approximately 145 million SKUs that the UK Royal Air Force (RAF) kept in stock at the beginning of year 2000 had fewer than 10 demand transactions over an observation period of 6 years.

Before proceeding further it is useful to clarify the terms *erratic*, *intermittent*, *sporadic*, *lumpy*, *slow-moving*, *irregular*, because they are not always used unequivocally. According to the classification proposed by Ghobbar and Friend (2002), the demand is characterized as intermittent when it appears randomly with many time periods having no demand; an erratic demand pattern is characterized by highly variable demand size; lumpy demand is both intermittent and erratic; slow-moving items have intermittent demand with each demand size equal to one item or very few items. However, the terms *sporadic* and *intermittent* are frequently used interchangeably (Dunsmuir and Snyder, 1989) and the same can be said for the terms *lumpy* and *irregular* (Regattieri et al., 2005), as well as for the terms *intermittent* and *irregular* (Willemain et al., 2004). In general, *irregular* demand has a broader interpretation, encompassing essentially all demand types that cannot be expressed by means of the usual normal and Poisson distributions; the title of the present paper reflects this broader definition.

The difficulties arising from the sporadic and erratic nature of the demand, especially of spare parts, are often addressed in the inventory literature with a focus on suitable forecasting methods. Examples of such publications include Croston (1972), Rao (1973), Willemain et al. (1994), Johnston and Boylan (1996), Bartezzaghi et al. (1999), Ghobbar and Friend (2003), Regattieri et al. (2005), and Syntetos and Boylan (2005). These works do not explicitly connect the forecasting methods to any specific inventory model. There are only a few papers that link forecasting methods directly to inventory control models. Specifically, Watson (1987) studies the lumpy demand case and examines the interactions between demand forecasting and continuous review reordering subsystems, while Syntetos and Boylan (2006) and Teunter and