A Refinement of the Classical Order Point Model

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ABSTRACT

Factors such as demand volume and replenishment lead time that influence production and inventory control systems are random variables. Existing inventory models incorporate the parameters (e.g., mean and standard deviation) of these statistical quantities to formulate inventory policies. In practice, only sample estimates of these parameters are available. The estimates are subject to sampling variation and hence are random variables. Whereas the effect of sampling variability on estimates of parameters are in general well known in statistics literature, literature on inventory control policies has largely ignored the potential effect of sampling variation on the validity of the inventory models. This paper investigates the theoretical effect of sampling variability and develops theoretically sound inventory models that can be effectively used in different inventory policies.

Keywords: Inventory Control, Inventory Management, Inventory Models, Order Point, Safety Stock

INTRODUCTION

The main objectives of this paper are to: (1) critically review the basic traditional inventory model (S, Q), and (2) propose improved and relatively simple formulations for the (s, Q) model that can be used by practitioners. The improved formulation produces service levels that are on average equal to the desired or intended service levels. In addition, the methodology may be extended to other common inventory models (e.g., R, S model) with relative ease.

Graves (1988) and Silver, Pyke, and Peterson (1998) recognized that stock are generated because of different circumstances or are kept for a variety of purposes without ear-marking them. A component of inventory, cycle stock, is generated to achieve economies of scale through batch production, batch material handling or transportation (Tsou, 2009). Technical issues are another reason for batch production, especially in process industries. Pipeline stock or work-in-process inventory, is generated because of processing or transfer lead time (Pettersen & Segerstedt, 2009). Another component of inventory, Anticipation stock, is accumulated...
in industries that face demand seasonality (Toelle & Tersine, 1989). Such inventories are accumulated prior to periods of peak demand.

Safety stock, on the other hand, is a portion of inventory kept to deal with the variation and uncertainty of supply and demand sources (Tomlin, 2006). The level of safety stock is a function of the degree of uncertainty in those sources, the desired level of customer service specified by the management and the associated costs. The importance of safety stock and its accurate calculation have become more important over time for at least two reasons. (1) With the lean manufacturing movement, small lot production and delivery, cycle stocks and pipeline stocks have decreased, thereby, increasing the chance of stock out (Domingo & Alvarez, 2007; Balakrishnan, Bowne, & Eckstein, 2008); (2) concern for bottom line and managers’ awareness of the underestimation of inventory carrying cost have urged them to reduce inventories to the bare minimum. Under such circumstances, accurate calculation of safety stock naturally becomes more important (Louly & Dolgui, 2009; Hou, Zeng, & Zhao, 2009).

Silver et al. (1998) mentions five classes of criteria for determining the level of safety stock: through the use of a common factor, by considering shortage costs, based on service considerations, based on the effects of disservice on future demand, and based on aggregate considerations. In retailing, wholesaling and in some manufacturing settings, the level of safety stock for individual items is incorporated in different inventory control policies to formulate a decision rule for order timing and order quantity for the item. There are basically four common inventory control systems (and several variations of them): order-point, order-quantity \((s, Q)\), which is the subject of this article; order-point, order-up-to-level \((s, S)\); periodic-review, order-up-to-level \((R, S)\); and periodic-review, order-point, order-up-to-Level \((R, s, S)\) (Buxey, 2006). The explanation of notation is presented in Appendix A.

Most inventory control systems assume that the demand volume can reasonably be modeled by a normal distribution. Other theoretical probability functions such as Geometric (Carlson, 1982), Negative Binomial (Deemer, Kaplan, & Kruse, 1974; Ehhardt, 1979), Poisson (Archibald, 1976; Archibald & Silver, 1978), or density functions such as Gamma (Burgin, 1975; Das, 1976), Lognormal (Presuti & Trepp, 1970), Exponential (Brown, 1977), Logistic (Fortuin, 1980), Weibull (Shah, Shah, & Wee, 2009), and many more, have also been suggested by researchers in order to model demand or forecast error. However, due to model complexity associated with employing distributions other than the normal distribution, practitioners have largely preferred the latter one. For example, studies show that the effect of using demand distributions, other than normal, on inventory decision rules is usually small (e.g., Fortuin, 1980).

In formulating inventory decision rules, it has commonly been assumed that the true mean and standard deviation of demand volume are known. However, these parameters are seldom known and usually are estimated from sample historical data. These estimates are subject to sampling variation and hence are random variables. Inaccurate estimates of demand and supply parameters will increase costs such as stock-out and carrying costs. Therefore, robust demand and supply estimates may reduce inventory costs (Jacob & Wagner, 1989). The effects of sampling variability on the estimates of parameters are well established in the field of statistics (Kutner, Neter, Nachtsheim, & Williams, 2004; Stapleton, 2009; McCloskey, 2009). However, the authors have not yet encountered any publication that theoretically addressed this issue in the context of inventory control policies and the computation of safety stock. The existing literature has largely employed ad hoc simulation studies to address the sampling variation of these estimates as described.

A simulation study performed by Ehrhardt (1979) concluded that in a \((R, s, S)\) system with setup, shortage, and holding costs, sample estimates of parameters did not seriously affect the optimal policy. Vaughn (1995) through simulation analysis, showed that in \((s, Q)\) systems
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