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Impact of inventory inaccuracy on service-level quality in (Q,R) continuous-review lost-sales inventory models

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ABSTRACT

This article focus on the behavior of a (*Q*,*R*) continuous-review lost-sales inventory model exposed to an inventory record inaccuracy (IRI). An unusual phenomenon has been observed which runs counter to certain empirical practices in the SMEs based on the principle that safety stock is only necessary for certain intervals in the data inaccuracy rate. Both analytical results and simulation modeling are proposed to investigate the relationship between the quality of service, safety stock and inventory inaccuracy under demand variations. It is shown that the service-level quality is a non-monotone function of the inaccuracy rate, i.e., the service-level quality increases up to an IRI level and subsequently decreases. Other inaccuracy distribution functions have produced the same phenomena with constant demand as well as with demand fluctuations. Finally, another noteworthy result also shows the same phenomenon between the function involving a level of safety stock defined by simulation and the function between the service-level quality and IRI. These different observed results are discussed in terms of both their contribution to the (*Q*,*R*) inventory management policies in SMEs and of the limitations to this study.

1. Introduction

Inventory record inaccuracy[1] (IRI) is a recurring problem for the decision-makers and empirical observations have recorded the IRI rates amounting to more than 50%.[2] In fact, Iglehart and Morey (1972) already supposed that such divergences may be introduced due to time lags between flows of information and material, pilferage, incorrect units of issue, inaccurate physical inventory counts, etc. According to numerous authors, the existence of IRI is also due to replenishment errors, shoplifting, and improper handling of damaged merchandise, imperfect inventory audits, transaction errors, misplaced products and incorrect recording of sales.

The effects of this dysfunction are numerous and can very much jeopardize the financial performance for the firm through lost sales, delay penalties, re-scheduling, and suboptimal planning and by the resulting increase in use of small transport vehicles. For example, DeHoratius and

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[1] This notion was introduced by Schrady (1970) as the discrepancy between the recorded inventory quantity and the actual inventory quantity physically present on the shelf.

[2] DeHoratius and Raman (2008) examined nearly 370,000 inventory records from 37 stores of one retailer in the USA and find 65% to be inaccurate. Kök and Shang (2004) showed that the percentage of inventory records that were inaccurate totalled 1.6% of the total inventory value (#dollar;10 million worth of inventory) of the *Beta* enterprise in 2004.

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Raman (2008) estimated that inaccuracies can cost retailers as much as 10% of their profit.

Organizational and/or technical improvements have thus been proposed to address this recurring problem. Nowadays, the experts suggest an improvement in data quality for inventory management technologies based on advanced information technologies such as *enterprise resource planning* (ERP) and *radio frequency identification* (RFID). In the SMEs, certain business process improvements might be achieved with these technologies such as cutting inventory costs, labor costs and stock losses. Additionally, even with the advanced information systems of regular inventory, the intensity of computerization in various SMEs is still insufficient. Moreover, these SMEs have neither the availability of a sufficient workforce and budget to enhance performance nor the capacity to invest in such kind of equipment. In case of IRI in measuring inventory levels, stock management is carried out on the basis of incorrect data resulting in a shortage issue. One typical short-term reaction of the decision-maker will be to increase the level of safety stock to achieve the objective of his/her service level target. This mechanism can be observed above all in SMEs. Hence, simultaneously facing this IRI problem and a plethora of uncertainties, SMEs usually react by estimating an empirical level of safety stock.

From a theoretical point of view, many papers consider such problems with inventory policy approaches and/or management of information in various and numerous assumptions. Some researchers lay emphasis on optimizing the counting or information systems, or on the required buffer size to minimize shortage risk and costs. To our knowledge, works on optimizing safety stock (e.g. Shin, 1999; Ross, 2002; Atali et al., 2005) never take into consideration the risk induced by inventory inaccuracy. Most researchers do indeed introduce the fluctuation of demand and shipment delay, but few of them take IRI into account. Their research usually focuses on (Q,R) system optimization models under uncertainties in lead-times, demand, supply, machine breakdown, etc., but rarely emphasize the effect of inventory inaccuracy upon service-level quality. For example, Sahin et al. (2008) and Sahin and Dallery (2009) propose a newsvendor type model which analytically derives the optimal policy in the presence of records errors of evenly distributed inventory and demand in the supply chain. Rekik et al. (2008) have also developed an analytical model of a single-period store inventory model subject to misplacement errors and compare it to a RFID implemented inventory system. Another analysis focuses on the IRI reduction aspect of RFID technology and on the problem of finding the optimal investment levels that maximize profit by decreasing inventory inaccuracy (Uçkun et al., 2008).

Therefore, the main goal of this paper is to analyze the impact of IRI on service level independently of an optimization consideration. A simulation model based on a (Q,R) continuous-review lost-sales inventory model with constant demand has been completed by an analytical approach that aims to appraise the relationship between IRI and the volume of products which remain out of stock over a long period of time. These models have been extended by changing the IRI distribution functions (symmetric vs. non-symmetric) to match the reality of the SME as much as possible. In the same way, inventory counting has been added to the model in order to narrow inventory uncertainty. Different demand variations (distribution functions) have also been considered as well as the hypothesis that demand decreases when the service level decreases (dynamic effect).

This paper is organized as follows. Firstly, a literature review shows that little research has dealt with the impact of IRI on service-level quality subjected to demand fluctuations. Secondly, a simulation model is described and based on a (Q,R) policy taking into account inaccuracies in inventory records. Thirdly, using several simulations, non-monotone function is shown to exist between the quality of service and the inventory inaccuracy rate. These simulation results are then explained by an analytical analysis. Fourthly, these results are also illustrated by the influence of inventory counting as well as demand degradation in the case of poor quality of service. Other results confirm the same relationship between IRI and service-level quality in (Q,R) continuous-review, lost-sales inventory models in the case of different inaccuracy distribution functions. Finally, discussion and outlooks are proposed by focusing on both service-level quality and safety stock calculation in the event of inventory inaccuracy.

2. Literature review

Research on IRI has been taking place since the 1960s with the report by Rinehart (1960) on a case study of a Federal government supply facility. The author stated that this inaccuracy produces a ''deleterious effect'' on operational performance. Following this, Iglehart and Morey (1972) reported that this divergence between stock record and physical stock results in ''warehouse denials''. Their research took into consideration the frequency and depth of inventory counts and stocking policy to minimize total cost per time unit. Studying a similar problem, Kök and Shang (2004) have suggested implementing a cycle count program and carefully adjusting base-stock levels across periods to minimize total inventory and inspection costs. Moreover, focusing on the significance of measuring IRI, DeHoratius and Raman (2008) show that inventory counts may not impact record inaccuracy and additional buffer stock may not be equally necessary across all items in all stores. They also suggest that inventory density and product variety have substantial implications for identifying and eliminating the source of inventory record inaccuracy. However, their study is only based on the retail stores of one firm and does not include all factors that might impact variation in IRI from one store to the next.

In fact, safety stock in the continuous-review lost-sales inventory models is one of the effective inventory management policies for mitigating long run total cost. Ritchken