Int. J. Production Economics 133 (2011) 172–181

Contents lists available at ScienceDirect

Int. J. Production Economics

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

# Inventory inaccuracies in the wholesale supply chain

Yacine Rekik *

*EMLYON Business School, 23 Avenue Guy de Collongue, 69134 Ecully, France*

ARTICLE INFO

Available online 22 April 2010

*Keywords:*
Inventory inaccuracy
General framework
Random yield problem
Wholesale context
RFID technology

ABSTRACT

The inventory level shown in the Information System contrary to popular belief and assumptions in most academic papers and in spite of the considerable amounts invested in information technology, is often inaccurate. The inventory inaccuracy occurs when the inventory shown in the Information System is not in agreement with the actually available inventory. In this paper, we first describe the major factors generating inventory inaccuracy. Then, we provide situations permitting to manage an inventory system subject to errors. We provide a general framework permitting to model the inventory inaccuracy issue. In particular, we link the inaccuracy issue with the well known random yield problem. The shown link permits us to derive the optimal ordering policy of an inventory framework where demand satisfaction is done based on the inventory records (which are subject to inaccuracies). We also propose an analysis permitting to show the added value of an advanced identification system such as the RFID technology.



## 1. Introduction

A general definition of the term accuracy includes obtaining the correct value for a measurement at the correct time (Schuster et al., 2004). According to DeHoratius and Raman (2004) and Iglehart and Morey (1972), inventory inaccuracy occurs when the inventory record, i.e., what, according to the information system, is available, does not match the physical inventory, i.e. what is actually available.

The literature on inventory models has rarely differentiated between the inventory record and the physical inventory. The two have always been considered to be the same and the main concern was on how, having observed demand and the resulting inventory levels, an inventory manager should determine when and how much to replenish. Based on recent empirical observations this implicit assumption has proven to be wrong. In fact, based on a study done with a leading retailer, Raman et al. (2001) reports that out of close to 370,000 SKUs investigated, more than 65% of the inventory records did not match the physical inventory at the store-SKU level. Moreover, 20% of the inventory records differed from the physical stock by six or more items. There is little research in the inventory management literature that deals with the impact of inventory inaccuracies. Most traditional inventory models do not take inventory inaccuracy into account (DeHoratius and Raman, 2004). The inventory inaccuracy issue became apparent due to the development of RFID technology (Kang and Gershwin, 2004). There has been a renewed interest in inventory inaccuracy and research so far has focused on one or a combination of the four following main issues:

(1) Issue 1: deriving appropriate inventory counting policies (how frequently to conduct inventory counts, how many products to count).
(2) Issue 2: determining safety stocks and replenishment policies in order to adjust for inventory inaccuracies.
(3) Issue 3: examining the parameters that influence the impact of inventory record inaccuracies on product availability and other performance measures.
(4) Issue 4: studying the root causes of inventory inaccuracies and their influence on the performance of inventory systems.

The majority of investigations dealing with the fourth issue are qualitative studies providing the factors generating errors in inventory systems (DeHoratius and Raman, 2004 and Raman et al., 2001 for example). Factors generating inventory inaccuracy can be classified under the following four error types:

- *Transaction errors*: transaction errors are unintentional errors occurring during inventory transactions. Some of these transactions happen when counting the inventory, receiving an order or checking out at the cash register.
- *Misplacement errors*: Misplacement errors occurs when a fraction of the inventory is misplaced, it is not available to meet a customer demand until it is found. According to Chappell et al. (2003), there are several sources generating misplacement errors such as: (i) consumers picking up products and then putting them down in another location,

* Tel.: +33 4 72 18 78 86.
*E-mail address:* rekik@em-lyon.com

0925-5273/$ - see front matter © 2010 Elsevier B.V. All rights reserved.
doi:10.1016/j.ijpe.2010.02.012

(ii) clerks not storing products on the correct shelf at the right time and (iii) clerks losing products in the backroom.

- *Shrinkage*: Shrinkage include inventory theft, spoilage and damage. Concerning damage and spoilage, customers can cause damages to products and as a consequence making them unavailable for sales. Some examples are tearing of a package to try on the contained cloth item, wearing down a shoes by trying it on and walking, erasing software on computers on demonstration, spilling food on clothes, and scratching a car during a test drive (Bensoussan et al., 2005).
- *Product quality, yield and supply process*: When the product quality is low or a production process has a low yield or a supply process is unreliable, the physical inventory is not known and as a consequence may be different from the inventory in the information system. According to Bensoussan et al. (2005), receipts are usually added to the inventory without a full inspection process. The consequence is that the information system may consist of both non defective products and defective products which are not available for sales.

### 1.1. Literature review

There exists an extensive literature on inventory management under supply uncertainty due to random production yield. To name a few examples, Karlin (1958), Shih (1980), Henig and Gerchak (1990), and Rekik et al. (2005) study a firm's optimal inventory decisions under random yield. Yano and Lee (1995) provide a comprehensive review of this literature. In the recent years, there has been a renewed interest in inventory inaccuracy and several papers study inventory models under inventory inaccuracy caused by others sources of errors. Among them, Sahin (2004) provides a comprehensive analysis of potential errors that may occur within an inventory system with a special focus on reasons why mismatches occur between the physical flow and the information flow representing it. Gaukler et al. (2003) investigates the effects of the RFID technology within a retail supply chain. They build a Newsvendor model that takes into account the non-efficiency of the replenishment process from the backroom to the shelf in the retail store. Atali et al. (2005) characterizes three demand streams that result in inventory discrepancy. Some demand streams result in permanent inventory shrinkage (such as theft and damage). Some demand streams are temporary and can be recovered by physical inventory audit and returned to inventory (such as misplacement). The final group of demand stream (such as scanning error) affects only the inventory record and leaves the physical inventory unchanged. The authors explicitly model how the different demands could lead to inventory discrepancies. In their framework, Kök and Shang (2004) represent inventory inaccuracy through random errors that change the physical inventory at the end of each period and errors are accumulating until a costly inspection is performed. they propose a near-optimal joint inventory inspection and replenishment heuristic. DeHoratius et al. (2005) model the inventory inaccuracy issue by an additional random variable called invisible demand and propose a simple Bayesian procedure to periodically update the inventory record.

Kang and Gershwin (2004) use simulation to analyze the consequence of inventory inaccuracy. they show that even small undetected losses can lead to important stock-outs. They also propose several way to tackle this problem including the deployment of RFID technology. The authors in Fleisch and Tellkamp (2004) use also simulation to show the consequences of inventory inaccuracy in a three stage supply chain. Considering misplaced type errors, the authors in Rekik et al. (2006b) show analytically the impact of errors on the inventory decision strategies and derive a threshold cost value, at which RFID deployment would become cost effective. Extending the model of Rekik et al. (2006a, b), consider the case of a decentralized supply chain with one manufacturer and one retailer whose inventory is subject to inaccuracies. They develop the optimal ordering strategies under the centralized and the decentralized scenarios and they study the impact of the RFID deployment on such supply chain. Heese (2007) studies a supply chain consisting of a Stackelberg leader manufacturer and a retailer with inventory inaccuracy and random demand. Using specific distribution functions, he derives the threshold value of tag cost in order for a firm to adopt RFID.

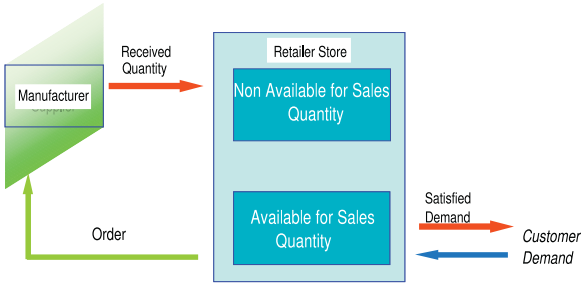


**Fig. 1.** The retail supply chain.

In Rekik (2006), the author proposes a classification of the existing investigations in inventory management that deal with inventory inaccuracies based on three levels:

(1) *Level* 1: The objective of the investigation in the sense that some investigations try to evaluate the impact of inventory inaccuracies through empirical studies while the others propose a quantitative framework to optimize the ordering policy used in the presence of inaccuracy problems.
(2) *Level* 2: The structure of the supply chain under study: among criteria characterizing this level, the author in Rekik (2006) considers the number of actors in the supply chain. In a centralized supply chain, a unique decision maker is concerned with maximizing the entire supply chain's profit. In a decentralized supply chain two or more actors act as different parties and each one tries to maximize his own profit. An other important point characterizing the structure is the context of the investigation. In fact, as it will be shown in the next section, managing inventory in the presence of errors is not the same in a retail or a wholesale context.
(3) *Level* 3: the nature of errors causing inventory inaccuracies where we can distinguish between additive and multiplicative error setting as it will be detailed later in the paper.

### 1.2. Retail versus wholesale supply chain

As described in the last session, the inventory inaccuracy issue makes the IS level non aligned with the Physical level. In the presence of inaccuracies, one should distinguish between two families of inventory framework depending on the way demand is satisfied.

(1) In the traditional retail supply chain, the end customers are physically present in the retail store and their demands are satisfied based on the physical on-shelf inventory. From demand satisfaction point of view, the information system does not play a major role in this type of supply chain structure. This structure of the supply chain can be modeled as illustrated in Fig. 1.
(2) In the wholesale supply chain, the customers are not physically present in the wholesale warehouse and the