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# Inventory inaccuracy in retail stores due to theft: An analysis of the benefits of RFID

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## ABSTRACT

We consider a finite-horizon, single-stage, single-product periodic review store inventory in which inventory records are inaccurate. We assume that inventory inaccuracies are introduced by theft type errors that arise within the store. We propose a comparison between three approaches based on which the inventory system can be managed in presence of theft errors: in the first approach, we assume that the inventory manager ignores errors occurring in the store. In the second approach, we focus on the benefit that can be achieved through a better knowledge of errors, i.e. by taking into account this information in designing the inventory policy. In the third approach, we focus on the contribution of a perfect RFID technology that enables to improve the system. We analyze the problem of having theft in store by optimizing the holding cost under a service level constraint. The comparison between the three approaches permits us to analyze the impact of theft errors and the value of the RFID technology on the inventory system. We also propose an analytical critical tag cost which makes the deployment of the RFID technology cost effective.

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## 1. Introduction

One of the underlying assumptions in the formulation of classical inventory problems is that there are no anomalies in the expected physical and information flows and as a consequence, the inventory manager operates with accurate inventory records. In real practice, due to failures arising in operational processes, this assumption may not be verified, resulting in poorer performance. Inventory record inaccuracy, i.e. the discrepancy between the recorded inventory and the actual inventory physically present on the shelf, may therefore be a substantial problem in retail environments. Complete and accurate information on the inventory level is crucial. Most of existing literature we reviewed on the inventory inaccu-

racy issue recognizes that discrepancies may stem from several factors such as theft, execution errors that lead to misplaced items or failures arising when capturing data within an inventory system, be it a warehouse, a finished goods inventory within a plant or a retail store.

The focus of our paper is on theft type errors within stores. Theft can occur in several forms such as employee theft, shoplifting, collusion when a staff member collaborates with a customer to steal products, or grazing where items are consumed by the staff or customers. A recent ECR (Efficient Consumer Response)<sup>1</sup> Europe project dealing with the shrinkage issue subsequently analyzed the causes of stock loss and proposed a systematic and collaborative approach to reduce the phenomenon throughout the supply chain. ECR defines “shrinkage” as being the stock losses stemming from process errors, damage and internal and/or external theft. The results of

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<sup>1</sup> <http://www.ecr.org/>

this research show that the scale of shrinkage in fast moving consumer goods sector is estimated to 24 milliard euros in 2003 (465 million euros is lost irreparably within fast moving consumer goods turnover weekly), which is 2.41% of the whole turnover value of the sector. The process errors present 27% of the whole shrinkage value, 7% deceptions, 28% internal thefts and 38% external thefts.

The literature addressing inventory record inaccuracy stemming from theft type errors is quite limited. Some researchers have noted the importance of incorporating inventory inaccuracy into buffer stock calculations, ordering policies, and the timing of inventory counts. Iglehart and Morey (1972) consider the frequency and depth of inventory counts so as to minimize the total cost per unit time while the probability of a warehouse denial is less than a pre-specified level. Kang and Gershwin (2004) use simulation to demonstrate that even small inventory inaccuracy may lead to costly stockouts. They also propose several approaches to reduce this problem. DeHoratius and Raman (2004) explore empirically the inventory record inaccuracy and find that it increases with sales, the number of stages in the supply chain, product variety, and the number of days elapsed since the last inventory audit. Fleisch and Tellkamp (2004) focus on the individual impacts of different types of inaccuracies on the performance of a supply chain. They use simulation and variance analysis as the research methodology. In her Ph.D. dissertation, Sahin (2004) investigates the impact of inaccuracy on the performance of inventory systems by highlighting reasons why mismatches occur between the physical flow and the information flow representing it. She builds a general Newsvendor framework to model inventory inaccuracies in order to quantify the cost of errors and evaluate if the implementation of a new technology such as RFID (Radio Frequency Identification) is cost justified. Atali et al. (2006) characterize three different kinds of demand streams that result in inventory discrepancy. The authors explicitly model how those different demands could lead to inventory discrepancies. By comparing the cost of using effective policies for inventory systems with complete inventory visibility, they quantify the true value of both inventory visibility and the elimination or reduction of some of the causes of inventory discrepancies offered by the RFID technology.

This paper investigates the effect of the inventory inaccuracy problem induced by theft. In particular, we propose a comparison between three approaches which can be used to manage a store inventory in presence of theft: we assume that in the first approach, the inventory manager is unaware of errors occurring in the store. In the second approach, we focus on the benefits achieved through a better knowledge of errors through taking them into account when formulating and optimizing the inventory policy. In the third approach, we focus on the contribution of a perfect RFID system that enables to improve the performance of the inventory system. The main contributions of the paper are answers provided in the form of analytical results (Section 3) and comprehensive insights (Section 4) to the following research questions: (1) How can we model inventory systems subject to

theft errors? (2) In presence of theft errors, what is the impact of being aware and taking them into account in the inventory policies? (3) What is the impact of an advanced identification technology such as the RFID on the performance of the inventory system? and (4) What is the critical RFID tag cost which makes its deployment cost effective?

## 2. Modeling a retail store subject to theft

In order to model theft errors, we assume that the demand in each period  $k$ , i.e.  $D_k$ , is divided into two streams according to a deterministic error parameter  $\alpha$ :

- Demand for theft, i.e.  $\alpha D_k$ , which affects only the PH (physical inventory) and leaves the IS (information system) inventory level unchanged.
- Demand for purchase, i.e.  $(1 - \alpha)D_k$ , which affects the PH and the IS inventory.

Appendix A provides further explanations on the properties of the demand process leading to these two streams. We also assume that the demand in each period  $k$  is independent and distributed according to a normal distribution with mean  $\mu$  and standard deviation  $\sigma$ . The sequence of events in each period is assumed to be as follows (cf. Fig. 1 for graphical illustration):

1. At the beginning of the period, the IS inventory  $x_k$  is reviewed and an order is placed. Because of theft errors, the PH is not  $x_k$  but is  $x_k - \varepsilon_k$  where  $\varepsilon_k$  represents the discrepancy between the PH and the IS inventory at the beginning of period  $k$ .
2. Lead time is zero: the incoming order is received. The IS inventory is therefore replenished up to a level  $y_k$ .
3. Demand for purchase and demand for theft take place: theft and demand for purchase are satisfied as long as there is an available PH. Demand occurring at zero PH is lost (no backlogs). When the PH is less than the total demand  $D_k$ , it is shared proportionally according to  $\alpha$ : a fraction  $(1 - \alpha)$  of the PH is used to satisfy demand for purchase, the other part, i.e.  $\alpha$ , is used to satisfy the demand for theft. Sales  $a_k$  and theft  $b_k$  are also deduced.
4.  $x_{k+1}$  and  $\varepsilon_{k+1}$  are updated.

Note that the last hypothesis concerning the case where the PH is less than the total demand is also assumed in the

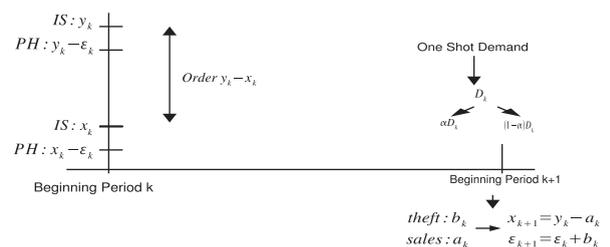


Fig. 1. The sequence of events in period  $k$ .

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