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Using RFID to Improve Inventory Accuracy

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ABSTRACT

Accurate inventory is a key to effective supply chain management and store execution, affecting forecasting, ordering, and replenishment. Prior empirical research, however, shows that retailer perpetual inventory (PI) is inherently inaccurate. Radio frequency identification (RFID)-technology enables visibility into the movement of inventories within the supply chain. This research investigates the effectiveness of this visibility in improving retail store inventory record accuracy. We perform daily physical counts of 337 stock keeping units in one category in 13 stores of a major global retailer over 23 weeks. Eight stores auto-adjusted PI based on RFID-enabled visibility; five stores were RFID-enabled but did not auto-adjust PI. The preliminary results of the study show that RFID-enabled visibility results in a significant decrease in PI inaccuracy. We conclude that this visibility can help retailers improve store execution, specifically by reducing surplus inventories and labor costs.

Keywords (Required)

Supply chain management; inventory accuracy; radio frequency identification; visibility; field experiment.

INTRODUCTION

Inventory accuracy is an essential ingredient for efficient and effective supply chain management. Key functions such as forecasting, ordering, and in-store replenishment are based on accurate inventory records. Most retailers rely upon automated ordering and replenishment systems or, at least, information from a system to provide insight into what, when, and how much to order. For these systems to be effective, retailers must have records of their on-hand inventory. Unfortunately, "*retailers are not very good at knowing how many products they have in the stores*" (Kang and Gershwin, 2007, p. 844). There is a discrepancy between retailer inventory records and actual inventory in the store. Thus, inventory accuracy is often referred to the "missing link" in retail execution (Heese, 2007). Technology in the form of Radio Frequency Identification (RFID) however, provides unprecedented visibility (Delen, Hardgrave, and Sharda, 2007) into movements of inventory in the supply chain and therefore the potential to reduce inventory, save labor cost, and improve supply chain coordination (Lee and Ozer, 2007).

Retailers as well as research studies recognize the problem. A recent AMR report identified inventory accuracy as one of the top issues for grocery retailers (Landoc, Garf, and Suleski, 2006). Studies have found that retailers only have accurate inventory information, known as perpetual inventory (PI) or what the system thinks is on hand in the store, on about 35% of their items (Raman, DeHoratius, and Ton, 2001). The implication is that ordering and replenishment decisions are based on information that is wrong more often than it is correct. Although it is recognized as a major obstacle to successful store execution, retailers have difficulty determining when, how, and in what magnitude inventory inaccuracy occurs (Kang and Gershwin, 2007). Because of inaccuracy, systems can order product that is unnecessary or fail to order product that is needed (DeHoratius and Raman, 2008). The net result is an estimated 10% reduction in profit due to inventory inaccuracy (Heese, 2007).

In order to combat inaccuracy, companies can increase the frequency of physical counts but this considerably increases labor costs and may not be effective due to the sheer volume of differentiated products stocked by retailers. In a busy consumer packaged goods store, serving a sizable population that may stock several variants of a product, the chances of human error are high. Maintaining additional safety stock is an option to guard against stockouts, but this measure increases inventory holding costs. RFID technology, which is an alternative to physical counts and safety stock, can potentially help companies automate the process of identifying and eliminating the source of errors (Morey, 1985).

There is good reason why a rigorous test of model predictions in the field is necessary to encourage firms to adopt the technology. Dutta, Lee, and Whang (2007) point out that very few companies would implement a new technology such as RFID based on pure faith, but would need value assessments, tests, or experiments. They argue (p. 653) that such empirical-based research requires "*a well-designed sample, with appropriate controls and rigorous statistical analysis*." Observations from the field also provide motivation for future analytical research while providing a realistic basis for model assumptions.

Lee and Ozer (2007) make a very strong case for the potential impact of RFID technology as a means for improving supply chain management. They argue that while industry reports and white papers are filled with estimates of the benefits and value of RFID, these claims are not substantiated. They provide two analytical models that suggest the potential benefits of RFID in inventory management. One stylized model assumes *perfect visibility*, so that the manager optimizes stock levels in full awareness of inventory errors. A second stylized model is called an *informed* policy, as it recognizes the existence of inventory errors without being able to observe the errors. The value of RFID, therefore, is quantified by the cost difference between the perfect visibility and informed models. This valuation however hinges on the ability to precisely determine inventory errors in the perfect visibility condition. There is currently no theory or empirical test that supports this assertion.

To summarize, RFID is known to provide visibility (Delen et al., 2007), visibility is presumed to improve inventory accuracy, and inventory accuracy has been shown to impact profitability (Lee and Ozer, 2007). Roth (2007) discusses deductive approaches to operations management, particularly in experimental studies and in validation of assumptions used in analytic models. The current research studies the hitherto unexplored linkage between RFID-enabled visibility and inventory accuracy.

INVENTORY ACCURACY

Various studies have shown the inherent fallibility of inventory accuracy. For example, Kang and Gershwin (2007) found inventory accuracy (exact match) to be about 51% and only about 75% when relaxed to ± 5 units. Similarly, Raman et al. (2001), in a study of 370,000 products across a single chain, found 65% inaccuracy; 20% of which differed by six or more units. Likewise, in a study of 166 items from 121 stores, Gruen and Corsten (2007) found PI inaccuracy (physical inventory - information system inventory) to be 55%.

There are two basic categories of PI inaccuracy: *overstated* PI and *understated* PI. Research indicates that about half of the time, PI is overstated (i.e., PI shows more inventory than is actually in the store, also known as phantom inventory), and about half the time PI is understated (i.e., PI shows less than what is in the store, also known as hidden inventory) (Gruen and Corsten, 2007). Each of these two types of PI inaccuracies have a detrimental effect on the retailer. For overstated PI, the most serious and directly related problem is out of stock – the system thinks it has inventory on hand (i.e., phantom inventory), thus fails to order new inventory. For understated PI, the most pressing problem is excess inventory (i.e., hidden inventory) because the system thinks it does not have as much as it really does, thus ordering unnecessary inventory. This unnecessary inventory potentially results in excess holding costs, excessive markdowns which impact margin, reduced turns, and breakdowns in store execution (which can lead to execution-related errors such as out of stocks) due to the inefficiencies created by the extra inventory. The retailer who participated in this study had interest in studying the impact of RFID-enabled visibility on understated PI accuracy as means to reduce inventory costs. Therefore the current research focuses on this understated direction of inaccuracy, though we expect the results to generalize to the overstated direction as well. For example, Hardgrave, Langford, Waller, and Miller (2008) provides some indirect evidence of the impact of visibility on overstated PI accuracy, as their study showed that RFID could reduce out of stocks.

USING RFID TO IMPROVE INVENTORY ACCURACY

In this study, we are interested in RFID's ability to improve inventory accuracy. The RFID tags used in this study were at the case level. Although item-level tagging would bring more granularity into the movement of products in a store, but at the current time is expensive for low-value products. Yet, the potential is that data from an RFID-enabled environment, at the pallet and case level, can help improve processes and make a case for RFID adoption.

For stolen items (i.e., unknown stock loss), RFID has the potential to partially help at the case level. For example, a case of product taken out the back door might indicate possible theft (RFID would read the box as it passes through the door). This insight can be used to adjust PI by the quantity of units associated to the case. Similar to stolen items, RFID can help track damaged/spoiled goods only to the extent that the full case is put into the trash compactor containing an RFID reader. When this occurs, PI could be adjusted accordingly. At item level, RFID can help identify individual items as they are put into the trash compactor or other disposal units.

Returns create understated and overstated PI inaccuracy when not handled properly (e.g., two items are returned but not added to the PI count). Based on RFID, the system could read the items and adjust the counts as necessary. Mis-shipments from the DC create both overstated and understated PI inaccuracies and can be corrected using RFID at the case level. Consider two potential scenarios. First, the wrong truck arrives at the wrong store. Without RFID, there is no way of knowing this error occurred until the truck is unloaded and the shipment verified. With RFID, as the truck is unloaded and boxes are sent through an RFID portal, the system could indicate that the shipment was in error and either correct the receipts or provide an alert to reroute the load to its proper destination. Second, for individual cases that were incorrect (rather than the entire truckload), the system would read and know what was received automatically instead of relying on the shipment documentation from the DC or manual barcode scanning.

With RFID technology, stores will have a better view of which cases have been delivered to the store, taken to the sales floor, or stocked in the backroom. This enhanced visibility, combined with the point of sale data, will provide a better view of the inventory on store shelves as well as in the backroom, thus reducing the inaccuracy of inventory records. For example, a truck making an excess delivery at the store creates understated PI inaccuracy as store records based on shipping invoices will not record this inventory. However, with RFID, as the truck is unloaded and boxes are sent through the RFID portal, the system would read and automatically record the actual receipt thus averting inventory inaccuracy.

Additionally, RFID can be used to verify the accuracy of manual adjustments made by store personnel. With manual adjustments, one common mistake made by store personnel is to enter a quantity of zero when they see no product on the shelf, yet, a case may be 'hidden' in the backroom. An incorrect 'zero' quantity causes two problems: (1) the inventory count is now understated; and (2) an order is issued by the system for unnecessary product. With RFID, the system will know if the product is in the backroom. Therefore, reduction in incorrect manual adjustments alleviates understated PI problems. With this enhanced visibility, these stores can generate automated inventory adjustments based on case receipts and the casepack quantity. RFID technology provides enhanced visibility of the in-store as well as backroom inventory. This enhanced visibility, coupled with the point-of-sale data, would help the system to auto-correct any discrepancies in the system PI. Therefore, our central hypothesis is:

Hypothesis 1: Inventory Accuracy will improve with RFID-enabled visibility.

METHOD

The study included 13 retail stores (323 SKUs) in a metropolitan area, ranging from approximately 40,000 square feet to approximately 220,000 square feet. Figure 1 presents the layout of the sales floor and the backroom. The category selected for the study was aircare (e.g., air freshener) products. All products in this category were shipped from the same distribution center to the stores included in the study. All products in the category were physically counted daily for 23 weeks by an independent firm (12 weeks for baseline). Each day they arrived at the store between 4PM and 8PM to ensure consistency. The count for each store typically took between 30 minutes and one hour, depending on the foot length of shelving at the store. The individuals who did the counting received training at the start of the counting period and followed standardized counting procedures, beginning from the bottom left hand corner of the shelf and working their way to the top right corner. They had had electronic devices on which they recorded the physical count for each SKU. In most cases a single individual completed the daily count at proximal two stores. We were emailed a data file on a daily basis.

After approximately 12 weeks of this initial baseline counting period, all cases of products in the category being shipped to all thirteen stores were tagged with RFID units. Eight of the thirteen stores were designated test stores, and the remaining five stores served as control stores. In each of the test stores, commencing at a certain date (this date was staggered across stores) using a series of business rules based on RFID reads, the system made adjustments to PI automatically. In this particular instance, the company used half case pack size as their preliminary indication of error. That is, only those cases that were off by more than half case pack size were eligible to be corrected. The system made all determinations – whether to adjust or not – automatically, with no human intervention.

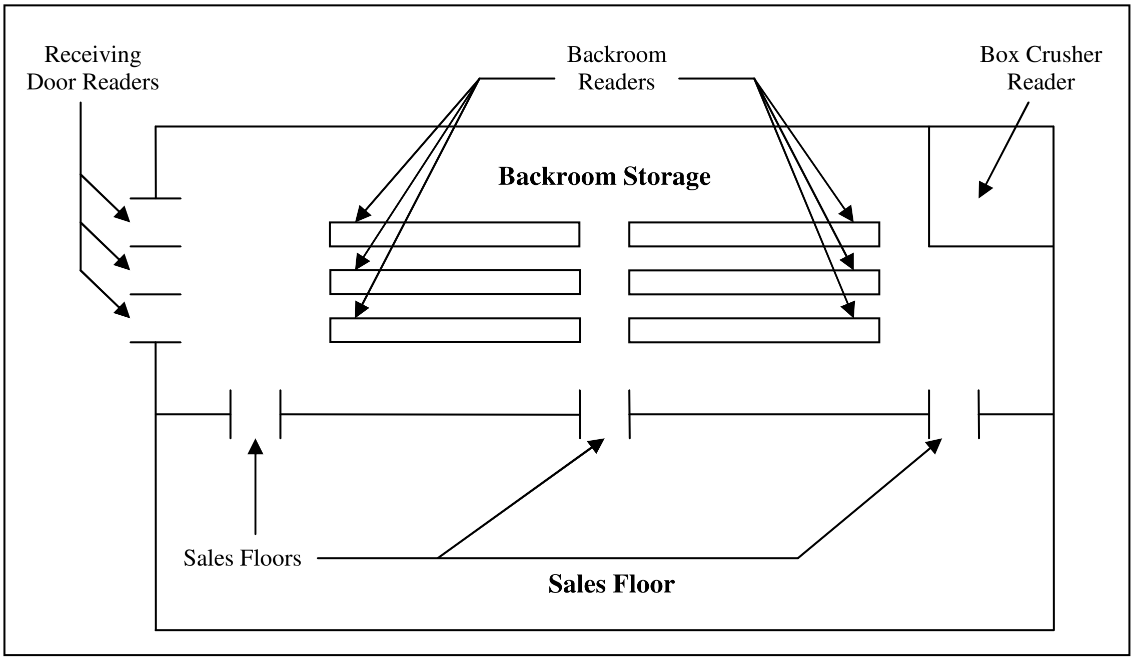

Figure 1. Generic Retail Store Read Points

RESULTS

Comparison of Test versus Control Stores

We conjectured that the presence of RFID would decrease PI inaccuracy over time. To test for this effect, PI accuracy was calculated for each product for each day during the study's baseline and treatment periods by comparing the daily physical inventory count (i.e., on-hand) against the system's PI. For purposes of analysis, PI accuracy is divided into three categories: perfect (PI = on-hand); close (PI is within $\pm$ 2 units of on-hand); inaccurate (PI off by more than 2 units). Unless otherwise noted, we focus on the 'inaccurate' category.

During the course of the study, the PI inaccuracy in the test stores declined, as expected. However, to ensure that this decline in PI inaccuracy was attributed to the presence of RFID, the control stores must also be considered. As shown in Figure 2, understated PI inaccuracy in the test stores decreased 13%, relative (12% in test and 1% in control) to the control stores (note: scales in Figure 2 are not omitted to protect confidential company information). This 13% is calculated by the following formula:

([Test stores post inaccuracy – Control stores post inaccuracy] –

[Test stores pre inaccuracy – Control stores pre inaccuracy]).

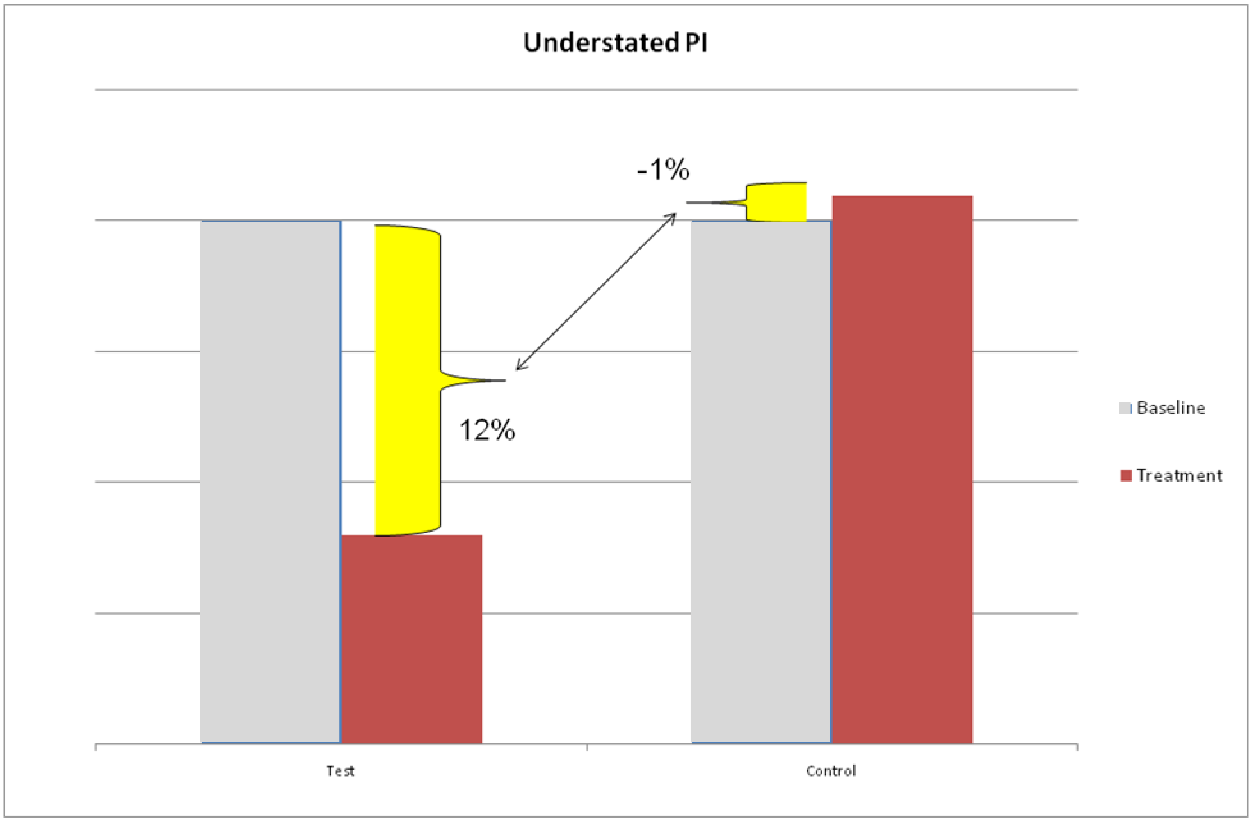

Figure 2: PI Improvement (Decrease in inaccuracy)

DISCUSSION

The present research investigated the effectiveness of this visibility in improving retail store inventory record accuracy. The preliminary results of our field experiment demonstrated that RFID technology enables visibility into the movement within the supply chain. First, we conducted a store comparison between eight test stores—i.e., stores that auto-adjusted PI based on RFID-enabled visibility—and five control stores—stores that were RFID-enabled but did not auto-adjust PI.

A decline of 13% PI Inaccuracy is significant and impressive. To further put the 13% decline in perspective, we can compare this change with the expected change (based on industry averages). As illustrated earlier, PI accuracy is generally between 35% and 50% (Gruen and Corsten, 2007; Kang and Gershwin, 2007). Let us, therefore, assume that PI accuracy is generally about 50%. Furthermore, we will assume that a large retailer will do a physical inventory one time per year and that the accuracy of this inventory is 100%. From previous studies, then, we know that PI accuracy decreases over time (between physical inventories) (Kang and Gershwin, 2007). Therefore, during the year following a physical inventory count, PI is expected to deteriorate by about 50% (from 100% accuracy at physical inventory time to around 50%), resulting in approximately a 4% deterioration per month (50% / 12 months = ~4%). Also, as suggested earlier, understated and overstated are equally likely to occur. Subsequently, understated PI would be expected to deteriorate by about 2% per month (4% / 2 = 2%). Thus, based on previous studies using industry averages, the typical retailer could expect understated PI to deteriorate by about 2% per month (or, stated another way, PI inaccuracy to grow about 2% per month). Now, contrast this expected change (based on industry averages), with the findings in this study. During the study period, test store inaccuracy (relative to control stores) *decreased* 13% -- industry averages would suggest inaccuracy should have *grown* by 10% (2% per month x 5 months). Although these numbers are not directly comparable due to 13% being a relative measure and the 10% being an absolute measure, they do provide some insight into the importance of the 13% decline in inaccuracy.

This research has three key implications for the retailers: First, RFID-enabled visibility would improve the store execution by decreasing the problem of understated PI. This understated PI, if left unchecked, can cause system to order unnecessary inventory. This unnecessary inventory, in the form of safety stock ordered to cover the uncertainties in the supply chain, costs suppliers and retailers money and decreases the efficiency of the supply chain. Second, RFID-enabled auto-adjusted PI would inhibit labor required for manual adjustments. In the absence of RFID technology, managers would have to employ labor to conduct regular physical counts of the store inventory. Finally, RFID-enabled visibility would help managers in reducing their safety-stock and saving money for the retailers. More specifically, because managers understand that the system PI is often incorrect, they are likely to hold additional inventory to reduce the problems associated with inaccuracy. However, with more confidence in the system PI, managers are likely to reduce this safety stock, further reducing their inventory.

Although the findings of this study are preliminary, future research should further refine these findings by using sophisticated analytic techniques such as discontinuous growth modeling. Use of these methodologies will allow researchers to examine change in the inventory inaccuracy of a SKU over time by modeling discontinuities (i.e., transitions) when the stores transitioned from manual inventory adjustments to RFID-based autoPI. Such change over time cannot be modeled by using linear models or even with the use of non-linear models. Higher-order terms in nonlinear models are likely to miss the distinct transition phase (Bliese et al., 2007) masking the true change in the PI inaccuracy over time. Therefore, discontinuous growth models serve as framework to accurately measure the transition of the dependent variable (i.e., inventory inaccuracy) over time. If such an analysis is conducted, we would expect the inaccuracy to have a significant negative decrease at the transition phase and a zero or negative slope—indicating decreasing or stable PI inaccuracy over time. Figure 3 below presents a hypothetical model of understated PI accuracy over time for illustrative purposes.

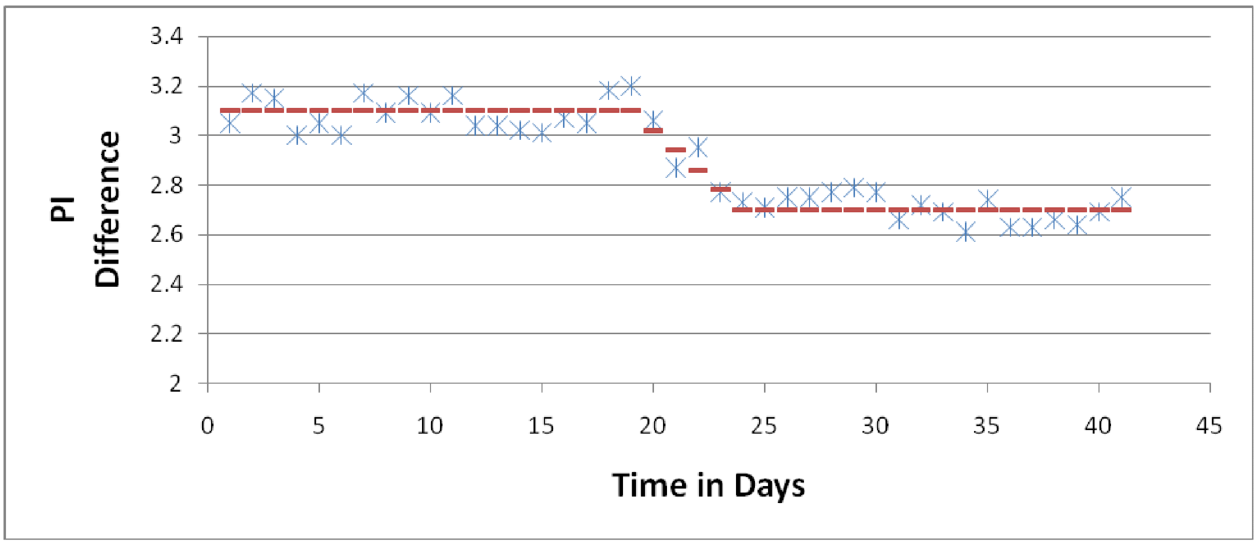

Figure 3: Model of Understated PI Accuracy over Time (Illustrative purposes only)

Another future research direction would be to examine the effect of RFID on the known predictors of inventory inaccuracy. For example, DeHoratious and Raman (2008) found several predictors of inventory inaccuracy. We would expect that RFID would ameliorate the influence of these known predictors on inventory inaccuracy.

CONCLUSION

This study has demonstrated how RFID-enabled visibility can reduce PI inaccuracy. Given that the inventory inaccuracy is one of the keys to an efficient and effective supply chain, RFID-enabled visibility can improve the overall store execution for the retailers. This would result in lower costs, higher sales, and increased customer satisfaction.

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