



INFORMATION TECHNOLOGY RESEARCH INSTITUTE

**Does RFID Reduce
Out of Stocks?
A Preliminary Analysis**



RFID Research Center
a sub-unit of the
Information Technology Research Institute
Sam M. Walton College of Business
University of Arkansas
Fayetteville, Arkansas 72701
<http://itrc.uark.edu>

**Note: distribution in any form (electronic, hardcopy, other) is strictly prohibited.
An electronic copy of the paper may be downloaded legally at <http://itri.uark.edu>**

Does RFID Reduce Out of Stocks? A Preliminary Analysis

Bill C. Hardgrave
Information Systems Department

Matthew Waller
Marketing and Logistics Department

Sam M. Walton College of Business
University of Arkansas
Fayetteville, Arkansas

Robert Miller
Department of Accounting / MIS
Ashland University
Ashland, OH

Contact:

Dr. Bill Hardgrave
Edwin & Karlee Bradberry Chair in Information Systems
Executive Director, Information Technology Research Institute
Director, RFID Research Center

Address:
Information Systems Department
Sam M. Walton College of Business
University of Arkansas
Fayetteville, AR 72701

(479) 575-6099
bhardgrave@walton.uark.edu

November 2005
Updated: June 2006
Update: June 2007

Does RFID Reduce Out of Stocks? A Preliminary Analysis

Abstract

The interest in, and subsequent use of, passive RFID in the retail supply chain has been growing rapidly in the past few years. Several major retailers have launched RFID initiatives with Wal-Mart leading the way both in the number of deployments (stores and distribution centers) and the number of suppliers involved. At this early stage of adoption, one nagging question for retailers and suppliers is: what is the business case for RFID? In examining this question, a potential area for improvement is in the in-stock position of products on the shelf. That is, any reduction in out of stocks provides benefit for the retailer, the supplier, and the consumer. In an effort to explore this potential business case, Wal-Mart commissioned a study to examine the influence of RFID on out of stocks. From February 14 to September 12, 2005, out of stocks were examined daily in 24 Wal-Mart stores (12 RFID-enabled stores, 12 control stores) representing all store formats. Preliminary results presented in this paper suggest that RFID is making a difference: within the test stores, out of stocks were reduced; test stores outperformed control stores; and tagged items outperformed non-tagged items within test stores.

Does RFID Reduce Out of Stocks? A Preliminary Analysis

Introduction

With a June 2003 request that its top 100 suppliers place RFID tags on pallets and cases shipped to stores in the Dallas, Texas region, Wal-Mart jump-started a 50 year old technology that, until the request, had found limited (but successful) use in a variety of niche areas. Since that announcement, the RFID industry has blossomed. The Department of Defense followed Wal-Mart's mandate with its own mandate; Target, Albertson's, and Best Buy, among others, followed suit. Initial efforts focused on the largest suppliers in the retail supply chain (e.g., Procter & Gamble, Gillette, Kimberly-Clark, Kraft), but have now spread to include smaller retail suppliers as Wal-Mart and other retailers continue to deploy the technology.

Movements by major retailers may have rejuvenated the technology, but a survey of 510 companies by Frost & Sullivan found that the number one reason for planned deployment of RFID is "improved process efficiencies" – not mandates (O'Connor, 2005). Thus, companies are expecting RFID to serve as a business process enabler. Potential process improvements can be found on the manufacturing floor, in the distribution centers, and in the backrooms of stores. One area in particular has the potential to benefit the suppliers, the retailers, and consumers: reducing out of stocks.

Empty shelves are the bane of retailers. Nationally (industry wide), about 8% of all items are out of stock (at any one point in time) (Corsten and Gruen, 2003). Although an out of stock does not directly translate into a lost sale in all cases due to consumer buying behavior (e.g., sometimes, a consumer will switch to a different brand which is a loss to the supplier; sometimes, a consumer will go to another store to buy the product

which is a loss to the retailer), the estimated potential lost sales are about 3.4% for retailers and 2.6% for suppliers (Corsten and Gruen, 2003). The percentages may be low, but the implications are high: for example, a \$1 billion supplier may suffer as much as \$26 million in lost sales; a \$100 billion retailer may lose \$3.4 billion in sales annually. Thus, reducing out of stocks by even a small amount can translate into real dollars quickly.

In 2005, Metro announced an 11% reduction in out of stocks due to RFID in their test sites, but provided no details about the study (e.g., number of items, time period, stores, etc.) (Johnson, 2005). Thus, to date, very little has been done to answer the question: does RFID reduce out of stocks? This study provides insight into the answer.

Overview of RFID

Fundamentally, RFID is one example of a family of auto identification technologies which also includes the ubiquitous barcode. Since the mid-1970s, the retail supply chain (and many other areas) has used barcodes as the primary form of auto identification. Given the success of barcodes, the question arises ‘Why move to RFID?’ The answer lies in the numerous advantages of RFID relative to barcodes. Examples of these advantages include: (1) RFID does not require line of sight; (2) RFID allows hundreds of tags to be identified at one time; (3) RFID allows hundreds of tags to be read per second; (4) RFID tags can store more data; and (5) the data on RFID tags can be manipulated. These advantages have prompted many companies (e.g., Wal-Mart) to aggressively pursue RFID as a way to improve the supply chain (and, thus, reduce costs and increase sales).

In its simplest form, an RFID system consists of a tag (attached to the product to be identified), an interrogator (i.e., reader), one or more antennae attached to the reader, and a computer (to control the reader and capture the data). At present, the retail supply chain has primarily been interested in using passive RFID tags. Passive tags are powered by radio waves created by a reader and transmitted via its antennae. The passive tag will remain powered only while it is within the read field. While in the read field, the powered tag will respond to the reader by reporting the data contained within.

RFID Data

As a case moves from the supplier, to the retail distribution center (DC), and then on to the retail outlet¹, it passes through a number of RFID read fields. Readers capture and record the case's tag data as it passes through these points. Figure 1 provides an overview of the key read points in a generic distribution center. As product is delivered to the distribution center, read portals (created by stationary readers and antennae on each side of the delivery door) capture the pallet and case data. The product is stored in the distribution center for an indeterminate amount of time, then individual cases are put on the conveyor system to begin the sorting process; the conveyor system may contain multiple read points. Finally, the individual cases are sorted and shipped out the shipping doors which contain read portals similar to the receiving doors.

¹ Currently, RFID is operating in an abbreviated supply chain from the point of departure from the supplier's facility through the backroom of a retail outlet.

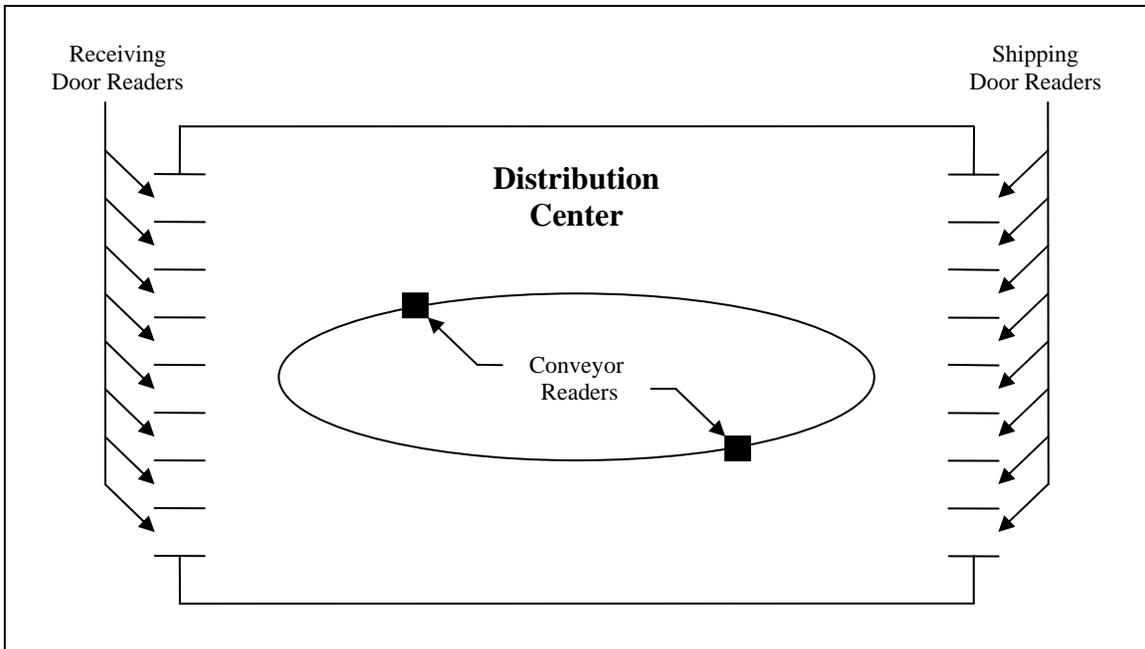


Figure 1. Generic Distribution Center Read Points

Figure 1 provides the read points most cases experience as they move through a general merchandise DC. The actual reads for a single case may vary depending on the type of product (e.g., bagged pet foods are not placed on conveyors) and the type of DC it enters (refrigerated/grocery DCs are different from general merchandise; e.g., grocery DCs have stretch wrap machines where readers can be placed, but may not have conveyors).

At the store level, the readers are confined to the backroom area – no readers are on the sales floor (see Figure 2). Receiving doors have read portals similar to those found at the DC dock doors and capture reads from the individual cases as they are unloaded from the truck. The product then moves to the sales floor (where readers are placed next to the doors going to the sales floor) or onto backroom shelving. Eventually, all products should be moved to the sales floor and the empty cartons returned through

the sales floor doors (a second read is captured at this point) and placed into the box crusher for disposal (the last read point).

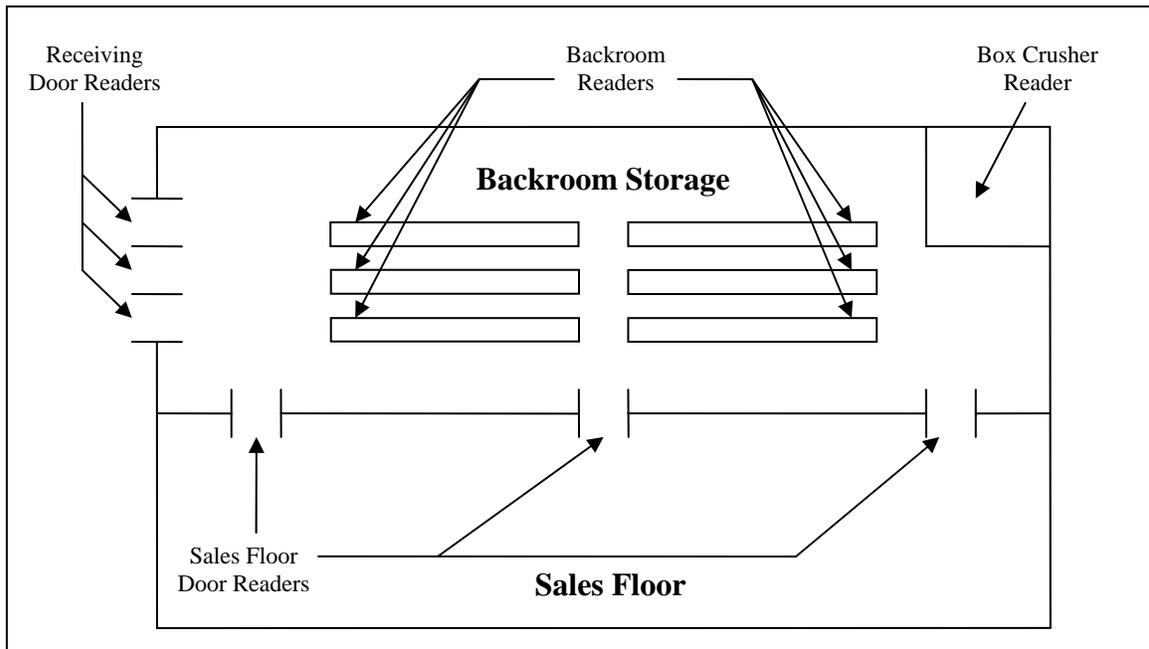


Figure 2. Generic Retail Store Read Points

Table 1 traces the movements of a single case of product (SGTIN: 0023800.341813.500000024) from its arrival at the distribution center to its end of life at the box crusher. This particular case of product arrived at distribution center 123 on August 4, was put on the conveyor system on August 9, and departed shortly thereafter. It arrived at store 987 about 12 hours after leaving the DC, went almost immediately to the backroom, where it stayed until the following day where it went to the sales floor, returned about 45 minutes later, and then went to the box crusher for ultimate disposal.

<u>Location</u>	<u>EPC</u>	<u>Date/time</u>	<u>Reader</u>
DC 123	0023800.341813.500000024	08-04-06 23:15	inbound
DC 123	0023800.341813.500000024	08-09-06 7:54	conveyor
DC 123	0023800.341813.500000024	08-09-06 8:23	outbound
ST 987	0023800.341813.500000024	08-09-06 20:31	inbound
ST 987	0023800.341813.500000024	08-09-06 20:48	backroom
ST 987	0023800.341813.500000024	08-11-06 15:01	sales floor
ST 987	0023800.341813.500000024	08-11-06 15:47	sales floor
ST 987	0023800.341813.500000024	08-11-06 15:49	box crusher

Table 1. Sample RFID Data

Turning RFID Data into Business Value

The data contained on a tag is fairly simple, and the read points are primarily discrete and prescribed. Thus, how can the data from an RFID-enabled environment help improve processes and, in particular, reduce out of stocks? One possible answer lies in the automatic creation and subsequent execution of ‘picklists’.

To replenish stock on the shelves, Wal-Mart currently uses two basic methods: (1) stock shelves directly from delivery trucks (i.e., product moves directly from trucks to the sales floor to be stocked); or (2) create a ‘picklist’ of inventory on-hand that can be taken to the sales floor. Picklists are created by visually inspecting the shelves for out of stock items (or near out of stock) and then using a handheld scanner to add that item to a picklist (if the system shows product availability in the store). Picklists can also be created by using a handheld device to scan barcodes on cases of product stored in the backroom (known as a ‘reverse picklist’). The system then identifies, via an indication of existing store level inventory, whether or not the case will fit on the shelf. If it can fit on the shelf, the associate ‘picks’ the case (i.e., places on a cart) and takes it to the sales floor

to be put on the shelf (many cases are picked before going to the sales floor). Both methods of creating picklists are laborious and rely upon the accuracy of the system to suggest availability in the backroom (for example, in some cases, the product is not available in the backroom – rather, it is located somewhere else on the sales floor). Nationally (industry wide), about 25% of out of stocks are attributed to problems with replenishment efforts at the store level (i.e., the product is available in the back room but not on the shelf) (Corsten and Gruen, 2003).

With RFID, stores will know what cases have been delivered to the store, taken to the sales floor, or stocked in the backroom. Combined with point-of-sale data, a much more accurate view of inventory – both on the shelf and in the backroom – can be provided². As product is sold, picklists can be generated based upon a knowledge of items on the shelf (from point-of-sale data) and RFID-generated information of product in the backroom (i.e., tag reads in the backroom). In essence, the picklist process is changed from reactive (i.e., looking at the shelf or backroom to determine what needs to go to the shelf) to proactive (i.e., creating the list in real-time based on sales).

The new ‘automatic picklist’ initiated by Wal-Mart is enabled by the data provided by RFID technology environment and is currently the principal driver in reducing out of stocks.

Research Methodology

Scope

To investigate the impact of RFID, a group of test stores was chosen at random from among the 104 RFID-enabled stores at the time. In total, 12 test stores were

² RFID is currently used at the case level only; individual items are not tagged. RFID information, combined with point-of-sale data currently available, will provide much more accurate inventory counts.

selected: 6 Supercenters, 3 Neighborhood Markets, and 3 Division-1 (i.e., traditional Wal-Mart) stores. All stores were in the Dallas, Texas area. Twelve control stores were then chosen based on geographic location, size of stores (square footage), and annual sales. These stores (6 Supercenters, 3 Neighborhood Markets, and 3 Division-1 stores) were located in Texas and southern Oklahoma.

Scanning Out of Stocks

From February 14 to September 12, 2005 (29 full weeks³), the test and control stores were scanned daily. A national merchandising group was contracted to perform the scanning. An 'out of stock' was defined as any empty shelf space. Almost all sections of the stores were scanned for out of stocks, with the exception of some areas such as bakery goods, variable weight produce and meat, fresh flowers, books and magazines, live animals, fabrics, tires, firearms, plants, tobacco, and jewelry.

The daily scanning of a particular store started at approximately the same time each day and the scanners followed the same route each day. Thus, the same areas were scanned at approximately the same time each day in each store. This was done to eliminate any fluctuations in OOS due to the time of day. Stores were generally scanned between the hours of 2:00pm and 10:00pm. All items out of stock were scanned regardless of being tagged or not⁴.

At the beginning of the study (February 14), 4554 unique products contained RFID tags. This set of products, from almost all departments across the various Wal-

³ The analyses use Wal-Mart weeks (Saturday-Friday) as the time reference; thus the study period included 29 full weeks.

⁴In fact, the scanning crew or the stores had no idea what items were tagged. Only those directly involved in the study had knowledge of the tagged items. This was done to ensure that the stores and the scanning crews did nothing special for the tagged items.

Mart store formats, was used as the ‘test’ suite throughout the duration of the study. This same set of items was examined across both the test and control stores.

Treatment

Test stores were equipped with RFID technology (readers/antennae) at various backroom locations: receiving doors, sales floor doors, box crusher, etc. Control stores had no RFID technology. Out of stocks at each test and control store were scanned for eight weeks before RFID applications were enabled in the test stores (to establish a baseline). In this case, the RFID application was the automatic picklist. The initial picklist process (termed ‘partial picklist’) was capped at 10 items per day, per department, per store. In mid-April, partial picklists were turned on in the test stores. In late June, the cap was removed from the ‘partial picklist’. Thus, test stores had three treatments: no RFID, partial RFID (capped picklist), and full RFID (uncapped picklist).

Results

By Treatment

To determine the effect of RFID in the test stores, a weekly OOS average⁵ was calculated for treatment 1 (no RFID), treatment 2 (partial RFID) and treatment 3 (full RFID). As shown in Figure 3, test stores (across all store formats) had an average of 474 out of stocks per week during the no RFID period; 399 for the partial RFID period; and 352 for the full RFID period. Thus, improvement from each treatment is 16% from no RFID to partial RFID; 12% from partial to full RFID; and 26% from no RFID to full

⁵Due to a distribution center realignment, 3 Supercenters, 1 Neighborhood Market, and 1 Division-1 store stopped receiving tagged product during the course of the study. These stores were replaced with similar stores but, due to their late entry, only had 2 treatments – no RFID and full RFID. Only stores experiencing all three treatments are included in this analysis. Also, only control stores matched with the remaining test stores were included in the analysis.

RFID. Recall that each treatment period included several weeks of observations.

Overall, from no RFID to the full implementation of RFID, a 26% improvement was observed.

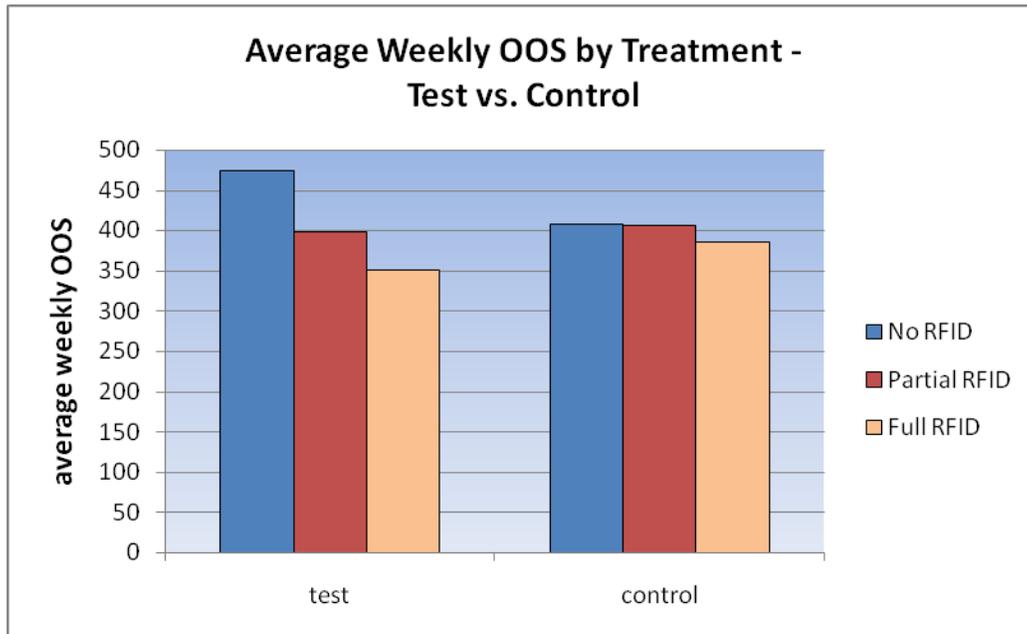


Figure 3. Average Weekly OOS by Treatment

Although a 26% improvement is impressive, it does not account for any improvement that may have occurred naturally (i.e., without RFID). To examine and account for natural improvement, it is necessary to include the control group in the analysis. Thus, also shown in Figure 3 is the behavior of the control stores during the same three treatment periods. Of course, the control stores did not receive treatments; rather, the same time frames are used across the two groups to provide a comparison. As shown, the control stores did decline slightly – from 408 units in time period 1, to 406 in time 2, to 387 in time 3. Overall, a 5% reduction in OOS. Thus, some natural improvement is occurring. Why would the control group experience a decrease in OOS? As part of an overall effort in improving product availability for its customers, Wal-Mart

has a series of initiatives unrelated to RFID technology. These initiatives are ongoing and consistent across all stores – thus, all stores would feel the effect of these initiatives. The decrease could also be due to the well-known ‘Hawthorne Effect’. The Hawthorne Effect suggests that people will alter their behavior when they know they are being observed. In this case, both sets of stores may have improved simply because people were in the stores scanning the shelves daily. It is these types of effects (planned or spurious) that required the use of two groups (test and control) of stores. With the two groups, the RFID effect can be better isolated by removing, from the improvement seen in test stores, any improvement seen in control stores.

When evaluating the improvement in the test stores (26%), the improvement in the control stores (5%) must be considered. As a point estimate, it can be concluded that the improvement due to RFID in the tests stores is approximately 21% (26% - 5%).

Trend

The analysis by treatment aggregated the data into time periods corresponding to the test store treatment periods. Another way to examine the data is weekly during the course of the study as a way of providing a trend⁶. The average weekly OOS for both the test and control stores for the 4554 products are shown in Figure 4. This graph summarizes the OOS across all store formats for the duration of the study. As shown by the trend line on the graph, both groups (test and control) experienced a decrease in OOS during the study period. However, whereas the control stores were decreasing at the rate of 1.1 items per week, the test stores were decreasing at the rate of 5.7 items per week. The reduction of 1.1 items per week could be considered a natural improvement in OOS

⁶ Note: the trend lines are for visual interpretation only. We are not attempting to draw conclusions about the suitability of linear trend to explain the data.

and is consistent with the previous analysis. Thus, 4.6 items per week would be the improvement in the test stores, above and beyond natural improvements. These 4.6 items represent a four-fold improvement of test over control.

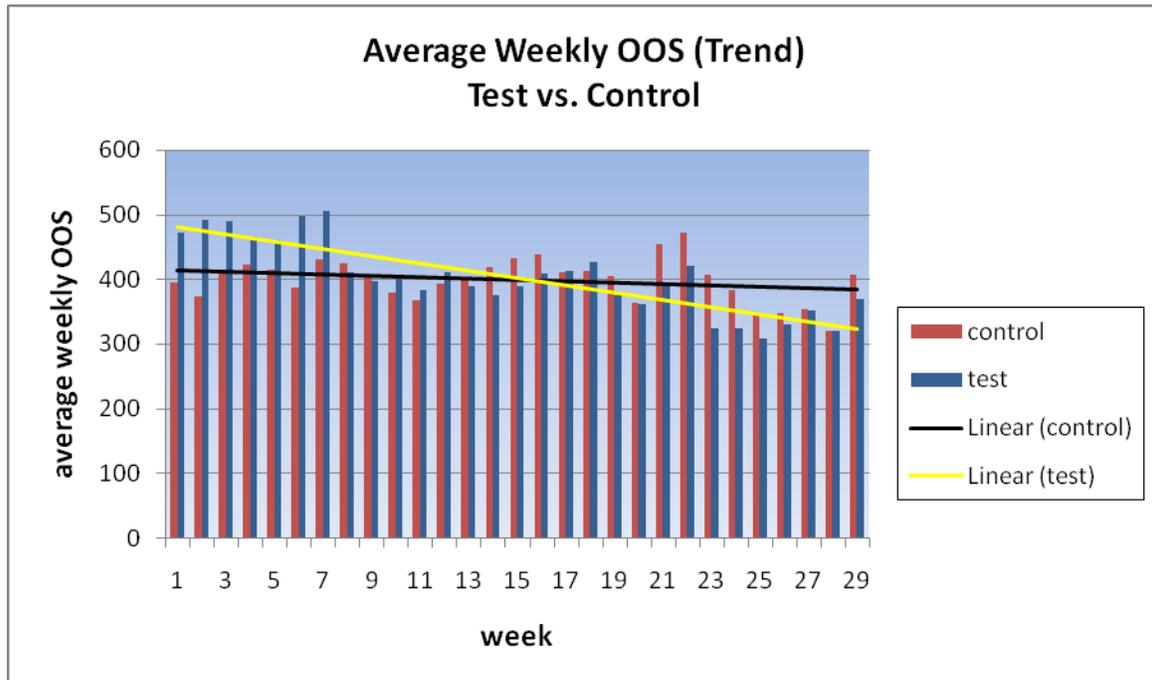


Figure 4. Average Weekly OOS – Test vs. Control Stores

Tagged vs. Non-Tagged Items

As the previous graphs have shown, RFID did make a difference (1) between treatments within a store and (2) across control and test stores. Another way to look at the effect of RFID is by examining the tagged and non-tagged items within the test stores. To provide a fair comparison between the two groups (tagged versus non-tagged), a random sample of non-tagged items were selected from the same department sub-categories as the tagged items. For example, if the department ‘Dairy’, sub-category ‘butter’ contained three tagged items, then three non-tagged items were chosen from the ‘Dairy butter’ group. For several department/sub-categories, we did not have a sufficient

sample of non-tagged items. In those instances, the tagged items were dropped (at random) until the number of tagged items equaled the number of non-tagged items. This process resulted in a final group of 3579 items for comparison. Figure 5 illustrates the results of this analysis. In this case, the tagged items are being reduced by about 5.1 units per week (which is very similar to the reduction shown in Figure 4, as expected). The non-tagged items are declining by 1.2 units per week. Interestingly, this is very similar to the slope of the control stores shown in Figure 4 (i.e., 1.1 units reduction per week).

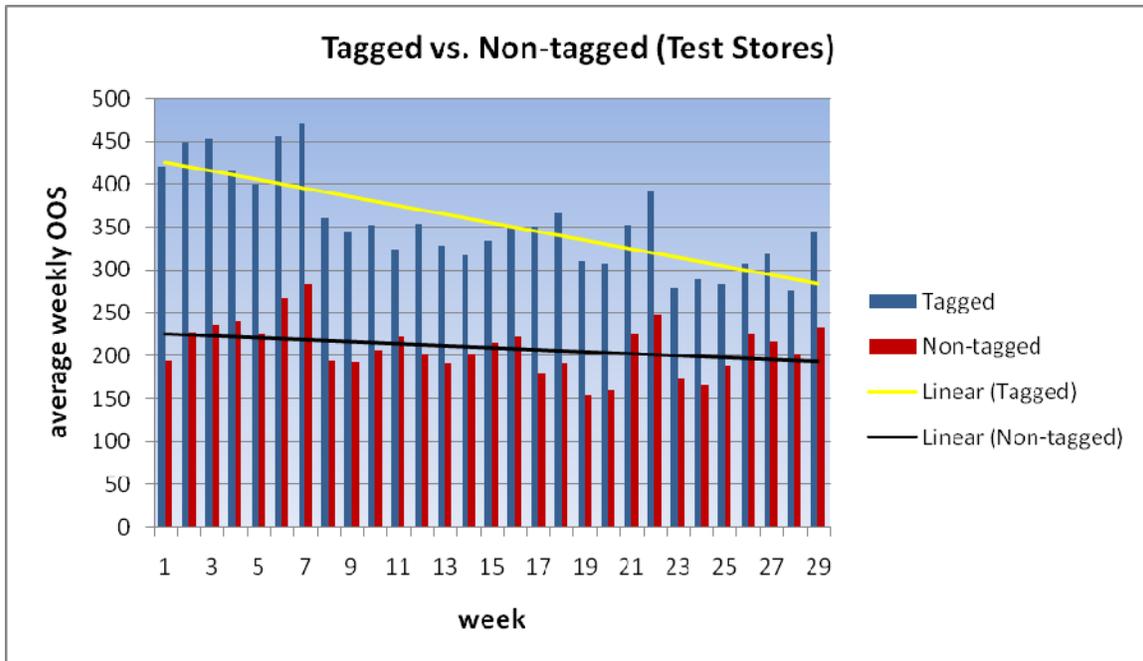


Figure 5. Tagged vs. Non-Tagged Items

The tagged vs. non-tagged analysis helps isolate the RFID change within the test stores. The similarity of the slopes of the control stores and non-tagged items suggests that non-tagged items – whether inside an RFID store or in a non-RFID store – were behaving in the same way. This analysis would, thus, detect any systemic effort to artificially influence (either positively or negatively) OOS within the test stores since

both groups (tagged and non-tagged items) would be affected equally. As shown in Figure 5, this was certainly not the case as tagged items clearly showed improvement compared to non-tagged items. Overall, this analysis ensures that any fluctuations within a store (e.g., a change in a department or store manager that could affect process execution) would be controlled for and captured in the results.

Automatic Picklist Contribution

As discussed previously, the driver for the changes represented is the new automatic picklist. As a final glimpse into the effects of RFID, we examine the new automatic picklist (hereafter, autopicklist) in relation to the manual picklists. Figure 6 shows the average daily autopicklist items as a percentage of the total items put on picklists for the ‘full RFID’ (treatment 3) period across all test stores. For example, on day 1 of this period, the autopicklist items accounted for about 25% of all items on the picklist that day (averaged across all test stores). The autopicklist is not created on Saturday and Sunday, thus the two-day gaps appearing on a weekly basis.

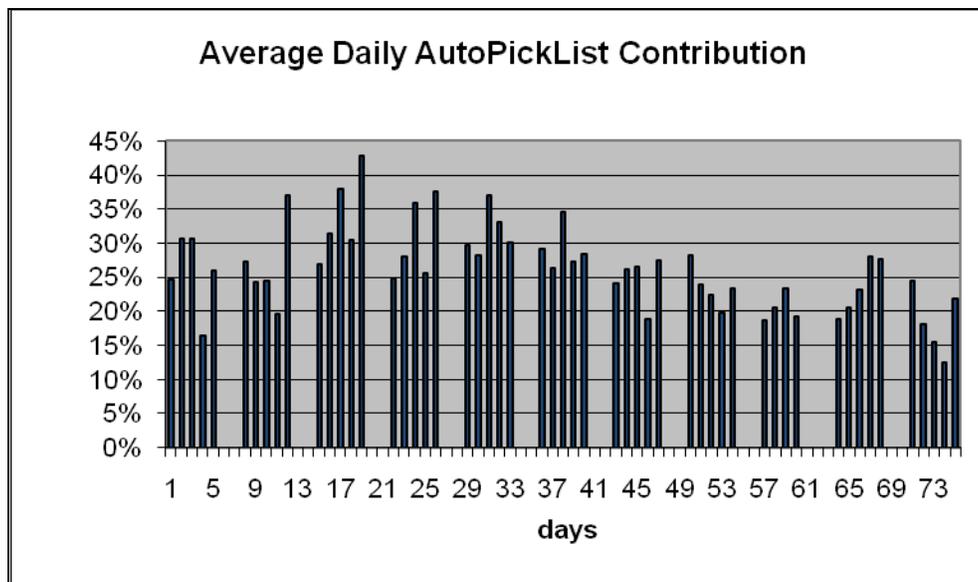


Figure 6. AutoPicklist Contribution

The contribution metric provides some interesting insight into the importance of the RFID-enabled autopicklist. First, the number of tagged items represents only a small proportion of the total SKUs contained in a Neighborhood Market, Division-1, or Supercenter (less than 10%, depending on store format), yet represent about 25-30% of all items on a picklist (for the first several weeks of this treatment). Thus, the autopicklist is finding and adding items that would not normally be added by the store associate. Second, over time, as the in-stock position of tagged items improves (as demonstrated earlier in Figures 3 through 5), the daily autopicklist contribution would dissipate (i.e., because of the improved in-stock position, there simply are not as many out of stock tagged items to put on the autopicklist). This phenomenon is clearly demonstrated in Figure 6 and supports the prior position that the RFID-enabled autopicklist is improving the in-stock position for tagged items.

Discussion

The evidence presented herein is a preliminary surface-level analysis and is meant to provide initial insight into the effects of RFID on out of stocks. Views from different angles - by treatment, by week, by tagged vs. non-tagged, and by autopicklist contribution – provide a very consistent and important message: RFID appears to be making a difference. The detection of this difference is remarkable given the relatively minor adjustment facilitated by RFID technology. Simply by using RFID reads on cases that have entered the backroom, Wal-Mart was able to modify their manual reactive picklist process such that it became proactive and automatic. With RFID, associates did not have to scan the shelves to determine out of stocks – the system did it for them – and

with the assurance that the box will be in the backroom when they go to retrieve it. Wal-Mart put no extra emphasis on the process and did not change the way the associates did their job. An associate who only worked the picklist (i.e., did not create it) would not have noticed a change in the process – although they may have noticed the increased number of items and accuracy of the picklists! With only one minor change to the picklist enabled by RFID, Wal-Mart found a 26% reduction in OOS in the test stores.

Although impressive, this improvement fails to capture some of the other benefits of the new RFID-enabled picklist such as the amount of time saved in reducing (or eliminating) the manual scanning of empty shelves. This newfound time can be used to bring more products from the backroom to the sales floor or to spend more time on the sales floor helping customers. When this one simple picklist process is coupled with initiatives such as handheld readers that can be used to quickly locate product, the potential improvements in backroom processes, and in reducing out of stocks in particular, are enormous.

Conclusion

This study examined a very difficult and important question: does RFID reduce out of stocks? Daily out of stocks were scanned from February 14 to September 12, 2005 in 24 stores representing all Wal-Mart store formats. The results, viewed from several different perspectives, suggest that, indeed, RFID is making a difference. In the test stores, out of stocks were reduced by 26% and in a head-to-head comparison between test and control stores, the test stores outperformed the control stores four-fold. An analysis of tagged versus non-tagged items (within the test stores) revealed a three-fold

improvement for tagged items. Although this paper provides an overview of the findings, more recent efforts have focused on rigorous statistical modeling to better isolate the RFID effect so that the magnitude of the change caused by RFID can be determined (see Hardgrave, Waller, and Miller, 2006).

Out of stocks can be affected by many things – store personnel, the weather, etc. – RFID is only one factor among many. The key is to isolate the RFID effect to determine if it contributes above and beyond the other factors. Preliminary results suggest that it does make a difference.

References

Corsten, D., and Gruen, T., “Desperately Seeking Shelf Availability: An Examination of the Extent, the Causes, and the Efforts to Address Retail Out-of-Stocks,” *International Journal of Retail & Distribution Management*, 31 (11/12), 2003, 605-617.

Hardgrave, B., Waller, M. and Miller, R., 2006, “RFID’s Impact on Out of Stocks: A Sales Velocity Analysis,” White Paper, Information Technology Research Institute, Sam M. Walton College of Business, University of Arkansas. Available at: <http://itrc.uark.edu/research/display.asp?article=ITRI-WP068-0606>

Johnson, J.R., “Metro Reduces Out of Stocks with RFID; is Wal-Mart Next?” *DC Velocity*, August 3, 2005.
Available at: <http://www.dcvelocity.com/articles/rfidww/rfidww20050803/metro.cfm>

O’Connor, M. C., “Efficiencies Drive RFID Adoption,” *RFID Journal*, 2005.
Available at: <http://rfidjournal.com/article/articleview/1833/1/1/>

Summary of Changes:

June 2007:

- Since releasing the original paper in November 2005, we have received many good suggestions for improvement. We have (finally) incorporated many of those suggestions in the updated paper. Some of the main suggestions were centered around the consistent use of the same set of stores for all the analyses. Thus, in the updated paper, we have used the same set of stores for all analyses presented herein. We have also:
 - Changed the way we calculated average out of stock for the treatment analysis (Figure 3). Originally, we calculated a weekly average, then an average by store type, then finally a treatment average of the store type averages. In the new analysis, we have calculated a weekly average for each treatment (i.e., dropped the store type averages). This caused the numbers to change slightly, although the percentage improvement did not change.
 - Added treatment averages for the control stores (Figure 3). In the earlier version, we did not include this analysis. We had many people suggest this additional analysis, so we added it. This also addresses issues raised by those that suggested using the treatment analysis combined with the trend analysis to determine the ‘weighted’ improvement was not appropriate. Now, the improvement of the control stores can immediately be accounted for from Figure 3.
 - Changed the control store group for the trend analysis. In the original version, we used all the control stores in the analysis, rather than the control stores that matched the test stores (since we lost some of the test stores due to DC realignment). Including all the control stores over-inflated the out of stock improvement in the control store set because there were more stores compared to the test stores. For the new analysis (Figure 4), the matched set of control stores is used.
 - Changed the tagged vs. non-tagged analysis to use the same set of stores used for the treatment and trend analyses. The previous version used all stores.

June 2006:

- added reference to new sales velocity analysis