Assessing the Impact of RFID on Return Center Logistics

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As many manufacturers, retailers, distributors, and logistics firms adopt RFID, the technology is becoming pervasive in the supply chain. Although its advocates include retail giants such as Wal-Mart, not all companies are enthusiastic about its benefits. It is not clear whether RFID is a boon or a curse to the supply chain—its market growth may just be an issue of compliance. To establish the real benefits of RFID, we conducted a field study with GENCO, a third-party logistics company that deployed RFID in the outbound logistics operations at one of its return centers. Our analysis found that the RFID implementation had a significant impact on the GENCO outbound process. The number of customer claims fell substantially following the RFID deployment. After controlling for other factors in our model, we confirmed that RFID was a key factor that contributed to the positive results at this return center. The current study underscores the potential of RFID for today’s businesses.

Key words: RFID; business value; process-level analysis; reverse logistics; supply chain.

For many retailers, RFID lacks ROI. (Kharif 2005)

Since Wal-Mart adopted and mandated the use of RFID tags for its suppliers (RFID Journal 2003a, b), there has been a growing interest in the use of this technology in the supply chain. Widely adopted by manufacturers, distributors, retailers, and logistics companies, many have touted this technology as a way to improve supply chain efficiency and increase profitability (Clarke et al. 2006). Gartner predicts that the RFID market will grow from $504 million in 2005 to $3 billion in 2010 (RFID Update 2005). Retail giants, such as Wal-Mart and Gillette, have reported optimistic news detailing real and anticipated savings because of their pioneering RFID efforts (Faber 2005); these retailers are driving market growth. Similarly, a test IBM traffic system in Sweden that uses RFID has reduced rush-hour congestion by 25 percent (Termen 2006). These reports suggest that RFID is being adopted extensively and that it is beginning to deliver what it promised—at least to some.

However, not all is well in the RFID world. There have been conflicting statements about its value. Industry Week reported that manufacturers have been finding it difficult to financially justify its implementation because they have been unable to make a good business case (Katz 2005). Gozycki et al. (2004) describe a recent case study that examines a retailer’s financial analysis of an RFID implementation decision, indicating the challenges of quantifying the benefits of RFID. Instead, manufacturers and suppliers may be adopting RFID solely to comply with demands from key customers (e.g., Wal-Mart or government/defense agencies such as the Department of Defense; Katz 2005). Many appear to be limiting their RFID projects to meet the minimum requirements needed to comply with these customer demands. Such ambiguity about RFID’s value is not limited to small manufacturers; it also applies to larger manufacturers, logistics firms, and partners throughout the supply chain (Kharif 2005, Moad 2006). These facts have cast doubts on whether
RFID will become a cost-reducing panacea for supply chains—or a cost-producing white elephant.

A key determinant of the success of a firm’s RFID implementation is the degree to which that company can change its business processes to leverage the technology most effectively. To derive benefit from any technology, a firm needs to redesign its business processes or identify innovative uses for that technology (Bresnahan and Greenstein 1996). Clarke et al. (2006) have emphasized that RFID should be used less as a glorified barcode and more as a tool to leverage business intelligence for strategic planning. They suggest using RFID to plug information black holes in the supply chain and thus to help reduce stockouts and improve fill rates. As we describe in this paper, it is also useful in reverse logistics processes. These all suggest that the ROI of RFID—the effectiveness and value of such uses of RFID technology—has yet to be established unequivocally.

To investigate the benefits of RFID, we conducted a field study with GENCO, a third-party logistics company that recently deployed the technology in the outbound logistics operations of one of its return centers (RC) to reduce customer claims. The scale of operations at this RC is large—on average, it processes more than 3,400 pallets and 800,000 items each month. GENCO customers file a claim when the goods they receive are damaged or do not tally with shipping documents. Although GENCO’s process already had a high accuracy rate and met customer expectations, GENCO sought even higher accuracy. Its intent in implementing RFID was to improve warehouse operational accuracy and quality of material flow, enhance customer responsiveness, and reduce shipment errors. Senior management felt that RFID might also deter fraudulent claims from GENCO’s buyers. In a sense, RFID would be a silent supervisor that would monitor and record the details of material movement and alert the dock staff of errors. Potentially, it could provide testimony on the accuracy of claim flows, resolve discrepancies between customer claims and GENCO-recorded details, and invalidate fraudulent claims.

Our analysis confirmed that the RFID implementation had a significant impact on the accuracy of GENCO’s outbound logistics process. Following its deployment, the number of claims fell substantially. After controlling for several factors in our model, we established that RFID was a key factor that contributed to the positive results at this RC. GENCO management forecasts of RFID’s positive impact on logistics operations were accurate.

For readers who are not familiar with RFID technology, we provide a brief overview in the next section. In subsequent sections, we provide GENCO’s rationale for deploying RFID, a synopsis of its RC operations, and a description of its processes prior to the RFID deployment. We then discuss the details of the implementation and its effect on GENCO’s processes, including some of the implementation challenges. Finally, we provide an analysis of the benefits GENCO derived from the implementation, interpreting our results from senior management’s viewpoint, and summarize its benefits. Our field study thus provides supporting evidence of the potential contribution that RFID can make to the bottom lines of operations similar to GENCO’s.

**RFID—The Technology**

The RFID technology has come a long way since Marconi first transmitted Morse code-based signals in 1896; however, at a rudimentary level, it is essentially composed of three components (Figure 1). The tags and readers are the hardware components; the third component, the middleware, is the software that acts as a bridge between the data that the readers read from tags and a database. For a more complete description of the RFID technology, its emerging standards, and its potential uses, we refer the reader to Bhuptani and Moradpour (2005).

**Tags:** An RFID tag is a small transponder attached to the object to be tracked. The tag holds data that are transmitted to a reader when interrogated. Typically, a tag consists of an integrated circuit with memory. There are currently three types of tags deployed: passive, semipassive (or semiactive), and active. Passive...
tags are low cost and do not require battery power. These tags, when interrogated by a reader, reflect the radio waves that the RFID readers emit. In contrast, active tags have their own power, can transmit data, and are consequently more expensive. The semipassive or semiactive tags use the RFID reader’s radio field to draw limited power for simple operations.

**Readers:** Readers, which are the interrogators, track the tags. They collect and process information that is embedded in the tags. For passive and semipassive tags, readers also provide the power to activate tags. A reader’s radio field depends on its power and the associated frequency. The frequency determines the range, suitability for different materials, and data-transfer rates. A low frequency—less than 135 KHz—typically entails a lower data-transfer rate. It is best for metal and liquid goods, which low-frequency radio waves can penetrate, but which higher-frequency waves cannot penetrate easily. The high-frequency range, approximately 13.56 MHz, is more common. The typical retail and supply chains rely on ultra-high frequencies—in the range of 433 MHz and 860–930 MHz. An antenna is often used as a channel between tags and readers for data transfers.

**Middleware:** Although the tags and the readers have some software hardwired, middleware translates signals into usable data and facilitates the actual data operations. These software applications help in monitoring and managing the data that RFID tags and readers transmit and read. The data are then aggregated and standardized according to the specific application functionality. They can then be fed into the existing IT databases for reporting or other purposes.

Companies are adopting RFID for a variety of reasons and in a variety of situations (e.g., industrial automation and tracking material movement through the supply chain). They are also using it in access control, hospitals, tollbooths, and for animal and human identification. However, interoperability is a major concern. Because there could be numerous applications of the same tag as it travels through the supply chain, it is necessary to standardize the information embedded in the tags and the methods used to harness this information. To this end, EPCGlobal has created global RFID standards; the reader can find the details of these standards at http://www.epcglobalinc.org.

**GENCO’s Return Center Operations**

**Prior to RFID Implementation**

GENCO is a third-party logistics provider for many large US retailers, including Sears Holdings Corporation (SHC). It processes returns on behalf of SHC at its four RCs in McDonough (Georgia), Grove City (Ohio), Fogelsville (Pennsylvania), and Woodland (California). An RC receives returns of merchandise that customers have returned to the retailer’s stores, damaged merchandise, or pristine products (e.g., unsold seasonal merchandise).

There are two subsystems for the material flow. The “inbound” side commences from the receipt of goods from SHC and continues until their placement in storage pallets. The “outbound” side begins when the merchandise that has been taken from storage is “dispositioned.” This occurs in one of three ways: the merchandise is returned to the manufacturer; it is sold at auction in small quantities to individuals; or it is sold in larger quantities to one of GENCO’s 3,000+ salvage dealers. We now describe the inbound and outbound systems for the GENCO RC in McDonough.

**Inbound Process**

Incoming pallets and shipments from SHC retail stores, which contain customer returns, damaged goods, or marketing returns, enter the facility at the inbound receiving dock. (Note that marketing returns are the unsold, out-of-season products, or special buys and deals.) The retailer provides guidelines that enable GENCO to determine which products to send back to the manufacturers, auction to individuals, or sell to salvage dealers. The main processing steps in the inbound side are as follows. First, an operator scans the barcoded label on the pallet and examines the goods visually. The pallet is delivered to a scan station where a worker opens every carton and scans each UPC code. As a result of this scanning process, product information is entered into a database to ensure that the RC acknowledges SHC inventory in the system. This scanning, which currently uses UPC and SHC SKU barcodes, helps GENCO to record inventory updates. The GENCO application then generates an internal system license plate (SLP) that a “putaway” process uses to assign items to cartons or pallets. Multiple scan lines perform this sorting and scanning operation.
When GENCO employees scan a product, they also obtain information that enables them to decide the disposition mode (Figure 2). Although the two main dispositions are vendor return and salvage, there are other possibilities; some items are dispositioned through a separate electronic auction, whereas others are dispositioned to salvage. (The decision on how to disposition a product is based on criteria such as vendor preference, the value of the product, and the cost of disposition.) We focus on the salvage-dispositioned product.

GENCO sells salvage items to salvage dealers based on product categories such as electronics, soft goods, and hardware. Because there is substantial variation in the average dollar value across different product categories, category identification helps salvage dealers gauge the value of the pallet that they are buying. GENCO stores items targeted for sale to salvage dealers (salvage items) in the warehouse until its asset recovery department decides on a suitable sales channel. Smaller bills of lading (BoLs), consisting of four to six pallets, are usually sold via a separate B2B auction site; larger BoLs are typically sold in bulk to GENCO’s largest salvage dealers. (Note that the B2B salvage-item auctions differ from the auctions that GENCO conducts for larger salvage BoLs.)

Outbound Process for Salvage Items Prior to RFID Implementation

In this section, we focus on the outbound process for sales to salvage dealers because GENCO initially implemented RFID in this process. The company recently implemented RFID for its entire outbound operation.

Prior to the final loading process, items are aggregated according to their category and placed onto a pallet that has an associated BoL. Each pallet is stretch-wrapped and affixed with a preprinted pallet ID that has a barcode mapped to the BoL and other pallet information. Salvage orders may consist of one or more BoLs. The pallet-level barcodes are scanned to ensure correct loading, and the pallets are then loaded onto trucks and shipped out of the outbound bays at the RC.

One of the central issues driving the RFID implementation was the inadequacy of the pallet-ID barcode for ensuring process accuracy. Because barcodes may become dirty, wrinkled, or torn, they were prone to damage even before shipment out of the warehouse. Furthermore, a barcode requires a line-of-sight to scan well. Because of problems in reading and the operational inefficiencies of finding and scanning barcodes, RC personnel were not consistent in scanning the pallet-ID barcodes on the outbound side. As a result, they did only a visual check of most of the shipments; they did not scan the barcodes. The result—an increase of inaccurate shipments and erroneous loading onto the trucks—caused customer complaints and claims.

The actual business process results in unnecessarily high costs to both GENCO and SHC and is more complicated than we describe above. The costs to GENCO include costs from both operational errors at the RC and fraudulent claims. For example, personnel must do a manual, visual search to locate any pallets misplaced within the warehouse. Also, during times of high activity, it is possible to place pallets on the wrong truck and ship them to the wrong client or location (Figure 3).

Such cases led to increased costs or losses for GENCO. When GENCO is able to locate pallets, it
ITEMS ITEMS ITEMS
Items grouped into pallets

Pallets grouped into BoLs

Order

Forklifted

Truck bays

White = Correct loading
Black = Incorrect loading

Figure 3: Outbound material flow at the RC before the RFID implementation demonstrates some incorrect loadings that lead to claims.

arranges for freight to route these shipments to the correct destination. However, it must refund to the client the value of any shipment that is truly lost (i.e., GENCO has made every effort to locate the missing product but has been unsuccessful). Tracking and correcting these errors entail significant labor resources as well as overhead costs.

Our field study focused on claims of salvage dealers who asserted that they did not receive merchandise as ordered because the merchandise was missing, damaged, or incorrectly labeled. GENCO’s inability to ensure accuracy of its process created the opportunity for an even more pernicious problem: the possibility that some salvage dealers could make fraudulent claims about merchandise that GENCO sent correctly. Neither GENCO nor the RC had an effective way of verifying or disputing the accuracy of such claims because they rarely had any barcode records on which to rely. The number of salvage claims, combined with the time and effort required to research such claims, had a direct financial impact on GENCO. This was especially true of claims for high-value items. Management opted to use RFID technology to counteract the mounting claims and increase the efficiency of the outbound dock operations.

**RFID Implementation**

In July 2004, GENCO decided to run an RFID pilot test at its McDonough RC for the outbound logistics link with salvage dealers. SHC sponsored this program because of the potential cost savings it could accrue from an expected increase in efficiency and the potential for a reduction in the number of claims at the RC. In addition, SHC believed that deploying this nascent technology could boost its image as a company on the cutting edge of technology and build its reputation in the marketplace.

GENCO modified its outbound process to incorporate RFID. In the new process, it places the RFID tags on the pallets at the stretch-wrap machine; these tags include information about the pallet, its contents, order details, BoL numbers, etc. The advantages of using RFID tags for such an operation are multifold. These tags can help employees to locate lost pallets within the facility much more easily. Locating pallets, however, is secondary to ensuring their correct loading onto trucks (Figure 4). To accomplish this, GENCO has equipped each forklift with an RFID reader and a screen. These signal to the operator whether the accompanying BoL includes the loaded pallets; they alert the operator immediately if a pallet is about to be placed on a wrong truck or if the number of pallets in the shipment is incorrect. Warnings include a flashing alert message on the forklift screen and other visual and audio warnings.

ITEMS ITEMS ITEMS
Items grouped into pallets

Pallets are RFID tagged

Pallets grouped into BoLs

Order

Forklift with RFID reader

White = Correct loading

Figure 4: Outbound material flow at the RC after the RFID implementation demonstrates all correct loadings.
The implementation was not without challenges. This nascent technology was not “plug-and-play,” and the lack of widespread industry expertise in implementing RFID forced GENCO to experiment and arrive at its own solutions to practical implementation challenges. GENCO commissioned all its equipment from Intermec; tags and readers were initially ISO compliant; more recently, they are EPCGlobal GEN2 compliant. One early challenge was a high proportion of “dead tags” that readers could not interrogate. GENCO and Intermec worked closely to find and solve problems. For example, they found that the tightly wrapped coils in which tags were packaged created cracks in the tags; this resulted in dead or unreadable tags and caused high failure rates. This problem has diminished substantially over time—tag failure rates are now less than 0.5 percent.

Positioning tags and readers such that they comply with operational needs as well as ensure accuracy was another challenge. GENCO’s approach was to place the RFID equipment on the forklift instead of using dock door portals. This setup allowed GENCO to verify that the forklift driver was selecting the correct pallet. GENCO also placed RFID tags at dock doors to verify that the driver was using the correct door. The initial approach was to place the RFID tags waist high on cement columns near the entrance to the doors. However, the readers, which were installed on the forklifts, would sometimes interrogate tags moving into adjacent doors. GENCO then tested an alternative approach—placing tags on the bottom of the door. Although this improved the operational process, the forklifts sometimes hit or knocked off the tags. Finally, GENCO placed environmentally sealed RFID tags on the outside of the door frame; this solved both the problems of false reads and damage to the tags. Interestingly, although the RFID implementation had technical changes, the actual operations and processes changed very little. Indeed, it would have been difficult to isolate and identify the impact of RFID if GENCO had made changes in its processes at the same time.

GENCO also upgraded its software applications to take advantage of the RFID-generated data. It has now moved to Gen2 RFID equipment, which promises better encryption, faster reads and writes, and transparent software compatibility. However, these changes to Gen2 equipment have required changes to the middleware, hardware, and software applications.

Benefits of RFID Implementation

The advantage of RFID—as opposed to barcodes—to the outbound process is immediately apparent. RFID ensures automatic confirmation of the delivery of each pallet to the right truck as per the BoL; it also ensures that the correct number of pallets have been shipped for each BoL/order. In principle, barcodes could accomplish this as well; however, this is not true in practice because barcodes are often difficult to read and require the human intervention of scanning. Because of the additional time needed for manual scanning, the proper use of barcodes is rare. RFID tags require no intervention; therefore, a company can use them to monitor material flow at each processing point and ensure that no errors occur. Any mistake causes the generation of a message to the appropriate employee; the tags thus act as “silent supervisors,” ensuring that no errors slip by. RFID potentially reduces costs of handling claims significantly by

1. Reducing warehouse employee errors at the loading dock;
2. Reducing time to research claims—GENCO maintains a time-and-place stamp showing when and where it has sent the shipment; accordingly, it can verify the occurrence of an error and pinpoint whether GENCO or the shipper was responsible for that error;
3. Providing a disincentive for salvage dealers to place fraudulent claims. GENCO can now instantly access shipment-detail records from its database; this ensures that a dealer cannot argue about a “fictitious” claim.

A cursory look at the data collected revealed that the number of claims during the 12 months following the RFID implementation was far lower than the number of claims in the prior 12 months. Inspection of the notes attached to the claims made after the implementation showed that all these claims were for damaged items or items for which the stated and actual item description did not tally. (Note that not all claims, particularly those made prior to the RFID implementation, include notes. Thus, we could not always ascertain the reason for the claim. Because of this inconsistency in the claim description, we could
not include the claim reason as an explanatory variable. This factor is likely to be captured in the error term in our regression. However, it is unlikely to be correlated with either RFID implementation or other explanatory variables and hence will not bias our results.) Specifically, the claims incidence decreased by 54.29 percent (note that we are masking exact return levels to protect confidentiality) and the dollar value of claims decreased by 29.7 percent. Although these results are promising, there are some other issues to address before we can draw a definitive conclusion.

One potential concern with such an aggregate analysis was that it did not control for changes in the mix of products in a BoL before and after the RFID implementation. For example, the electronics and hardware product categories have high incidences of claims. Figure 5 shows the percentage change in the number of claims for different product categories.

To control for changes in volume before and after the implementation, we normalized these claims data by sales volume. Figure 5 demonstrates that declines in the incidence of claims after the implementation were widespread across the electronics, hardware, and others categories. Only the hardgoods category experienced an increase in claims; however, this increase was small and statistically insignificant. Although the data in this figure suggest that our results are not due to changes in product mix, we required further analysis.

In addition to concerns about changes in product mix, the volume at the RC varied because of seasonal factors; the warehouse had to cope with high volumes of returns following the busy holiday shopping season. Reductions in volume may also contribute to reduced claims. Clearly, if we were to isolate the effect of RFID, we had to control for the product mix, seasonality, and other relevant factors. Otherwise, we ran the risk of claiming benefits that are at least partially due to factors not related to RFID and misinterpreting the results. To do this, we pursued a regression analysis that controlled for differences in shipment composition, process complexity, and salvage-dealer characteristics. We describe this analysis in the next section.

Disentangling the Impact of RFID—The Thought Process

In this section, we describe our process for analyzing how RFID influences the probability that a salvage dealer will issue a claim on a given shipment. The isolation requires controlling for shipment characteristics, salvage-dealer profile, and process complexity. This approach is consistent with previous empirical literature on measuring returns from technology deployment (Barua et al. 1995).

In the analyses that we report here, we focus on RFID’s impact on the likelihood of claims. In subsequent analyses, the data revealed that once we accounted for RFID’s impact on the likelihood of a claim, RFID had no effect on claim value. This suggests that its primary impact is on the claims incidence only. For brevity, we do not report the results of the claim-value analyses here; however, they are available from the authors on request.

We now describe the thought process behind our analysis. First, we considered the factors—the explanatory variables—that could influence the probability of a claim occurrence. These could be process, product, and dealer related. We elicited these factors during discussions with RC personnel. Certain types of products, such as electronics, were more prone to claims because of their very nature in terms of volume or value. Likewise, the workload at the center increased substantially during shopping seasons (e.g., Christmas, Thanksgiving, and bonus
days) when the return levels surged. These high volumes required hiring temporary staff. Because such staff was sometimes less familiar with all the correct quality-assurance processes than the permanent staff, this could lead to errors. In addition, we saw that some dealers filed claims more often than others. Based on our interviews, we compiled all the potential claim drivers and placed them into four categories: transaction intensity, shipment characteristics, buyer characteristics, and RFID.

Transaction intensity at the RC: We hypothesized that the more intense the shipping activity at the center, the greater the chances of dockworker errors. In turn, more errors would lead to more claims by dealers. To measure transaction intensity, we collected data on the monthly shipment volume (i.e., load) at the facility. This captures the throughput from the outbound bays and directly measures the transaction intensity at the center.

Shipment characteristics: The shipment characteristics that we felt would most likely affect the chances of a claim were the total shipment value, the average item value, and the type of items in the shipment. A claim is more likely if the value of the shipment is large than if its value is small; the customer is more likely to disregard the latter. Similarly, a claim is more likely if the average value per item is higher; otherwise, the costs and hassles associated with the claims procedure could render a claim unprofitable. For the total shipment value, we use the offered shipment value by the salvage dealer for our analysis because it captures the actual payment made for the BoL.

Value density is the average value of the individual items in a shipment. The accounting staff at GENCO indicated that value density also drove claim rates. We computed this from the ratio of (offered) shipment value to the number of items in the shipment.

The number of claims was highest in the electronics category, which seemed more prone to claim filing. Interviews at the site confirmed this. This meant that the BoLs associated with the electronics category, because items have a higher value and because salvage dealers are more likely to inspect them more thoroughly, resulted in a higher number of claims. We created a dummy variable to control for the presence of electronics in a shipment. This variable is equal to one if the shipment category is electronics and zero otherwise.

Incentive issues with the salvage dealer: GENCO does not closely monitor the transaction completion with a salvage dealer; consequently, agency issues arise. Salvage dealers may falsely claim nondelivery of pallets or items. We expected that a salvage dealer who has had a long-term relationship with GENCO would be less likely to make a fraudulent claim than one who has had a relatively short relationship. In addition, we felt that the salvage dealers who have made claims in the past would be more likely to make claims in the future, ceteris paribus. Habitual claimants will capitalize more often and seek fraudulent claims; they may also be the dealers who inspect more closely. Hence, we used prior claims and prior shipments as variables to capture the history of the business relationship with GENCO and to determine the impact of the dealer profile on claim rates.

RFID: We included RFID as one of the variables that affect claims. We believed that we could attribute the reduction in claims rate from RFID to two sources. The first is the process efficiency arising from alerts triggered when workers commit errors; this allows instantaneous problem resolution. Tags serve as an electronic pokayoke—the Japanese term for foolproof processing. Fewer errors then lead to lower claims. Second, RFID reduces claims because of its “deterrent” effect. Agency issues decrease because the tags provide monitoring by the principal; any fraudulent claim is more likely to be dismissed because tags record every movement of the goods. The combined effect—process efficiency and deterrence—implies that the claim rate should fall. Note that it is difficult for us to isolate the two sources of improvement because this would require detailed data and history. In addition, because of confidentiality and legal issues, the elaboration is sensitive.

To capture the effect of RFID, we deployed a dummy variable to indicate whether the order date was before or after the RFID implementation (July 2004). We hypothesized that error rates would be significantly lower after the implementation. Thus, we expected RFID to have a negative impact on the probability of claim, once we controlled for all the other factors.
Figure 6: Box plots for explanatory variables show little change in their distributions before and after the RFID implementation.

Data Description and Research Approach

We collected archival data from the shipment logs and the claim-settlement databases that GENCO maintains for this RC. The data included shipment and claims records from July 2003 to December 2005. The final data sample included 5,607 records for 475 salvage dealers with a wide range in the number of transactions—the highest number was 785 for one salvage dealer. Whereas the shipment data was readily available in a digital format, records of claims were available only in paper format. In general, these data did not include information on the type of claim filed (e.g., missing or damaged goods). As a result, we were unable to distinguish the effects of RFID on operational efficiency from its deterrent effect on fraudulent claims.

Claims in our sample were made shortly after the shipment date. When we checked the time lag between the shipment date and claim date in our data, we found the maximum time lag to be two weeks. GENCO confirmed that the lag in claims reporting is typically brief because salvage dealers make payments in advance of salvage pick up. The shipment data include the BoL and order number, the dollar value of each BoL, order-transaction date, category of items in the BoL, the total number of pallets and items in the BoL, and buyer-specific data such as the buyer’s ID, name, etc. The claim data include the BoL against which the claim was made. We first merged the claims and the shipment data based on the BoL. Based on our claims data, we then created a dummy variable to flag if a claim was filed against that particular BoL. Therefore, the unit of observation in our analysis is a BoL (i.e., we examine the likelihood of a claim against a particular BoL). As noted above, we generated other variables, such as GENCO business history and relationship, to control for the outbound process complexity and the salvage-dealer profile.

Figure 6 shows the distribution of these variables before and after the RFID implementation using box plots. The middle line of the box indicates the median, and the top and bottom edges indicate the first and third quartile. The edges of the whiskers indicate the highest and lowest values that are not outliers. For the purpose of confidentiality, we mask sensitive information such as the actual number of
claims and the shipment and claim value. Before we performed our regression analyses, we examined whether the distribution of any of our explanatory variables changed concurrently with the RFID implementation. We found that this was not the case. The mean of total prior claims increases over time because this is a cumulative variable. Similarly, for the dummy variable electronics, we compared the means before (0.2506) and after (0.2483) the RFID implementation. In total, our sample included 5,607 observations—62.1 percent of them are after the RFID implementation.

Because our dependent variable was binary, there were a number of concerns with using a linear regression model for this analysis (Maddala 1983). Instead, we used the traditionally prescribed probit model. We tested the model with logit as well as complementary log log regression. As expected, the coefficients and their signs, as well as the significance, were unchanged with respect to the probit regression. We also found the marginal effects for both logit and complementary log log models to be similar to the marginal effects of the probit model. The probit model estimates the probability of a claim occurrence for any BoL profile. See Maddala (1983) for additional discussion of the probit model. (Note that the standard deviation in some of the explanatory variables is quite large. Hence we use log(Offer), log(Value Density), log(Total Monthly Shipments), log(Buyer’s Total Prior Shipments), and log(Buyer’s Total Prior Claims) in our regressions.)

Results and Analysis

In this section, we present the results of our estimated probit model. We first present the marginal effects of each of the variables in the structural model (Figure 7). Table 1 shows the results of the probit model and parameter estimates.

**Marginal Effects**: Because the coefficient estimates of the probit model are difficult to interpret, we examined how changes in each of our variables individually influence the likelihood of a claim. In our analysis, we examined the marginal effect of RFID, which we define as the percentage change in the likelihood of a claim from a change in each of the variables. For example, the marginal effect of RFID use quantifies the change in the likelihood of a claim filed for a typical BoL before and after RFID installation. In the computation, we use the average value for all the control variables so that we have an “average” BoL profile:

\[
\text{Marginal effect of RFID} = \frac{(\Pr(\text{Claim} | \text{RFID, Other factors}) - \Pr(\text{Claim} | \text{No RFID, Other factors})) \cdot (\Pr(\text{Claim} | \text{No RFID, Other factors})^{-1})}{\Pr(\text{Claim})}.
\]

<table>
<thead>
<tr>
<th>Variable</th>
<th>P(\text{Claim})</th>
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<tbody>
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<td>RFID</td>
<td>-0.6382 (0.1282)**</td>
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<tr>
<td>log(Offer)</td>
<td>0.0516 (0.0498)</td>
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<tr>
<td>log(Offer Amount/#Units)</td>
<td>0.1978 (0.0780)**</td>
</tr>
<tr>
<td>Electronics?</td>
<td>-0.0868 (0.1656)</td>
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<tr>
<td>log(Total Monthly Shipments)</td>
<td>0.5960 (0.2777)†</td>
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<tr>
<td>log(Buyer’s Total Prior Shipments)</td>
<td>0.0231 (0.0362)</td>
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<tr>
<td>log(Buyer’s Total Prior Claims)</td>
<td>0.1404 (0.0929)</td>
</tr>
<tr>
<td>Observations</td>
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</tr>
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*Table 1: We show the probit model results for ascertaining the probability of claims.*

*Notes. Standard errors are in parentheses. †significant at 5%; ‡significant at 1%.*
Likewise, the marginal effect of the “electronics” dummy variable provides the percentage change of the likelihood of a claim filing for a BoL of electronic products compared with a BoL of nonelectronic products. We similarly calculated the impact of changes for each of the other variables on the likelihood of claims. For example, we assessed the marginal impact of the total shipment value on the likelihood of claims by computing the percentage change in magnitude of the probability of a claim filing when the shipment value increased (by one-half standard deviation).

We found that, other than RFID, only two variables (value density and total monthly shipments) had a significant effect on claims. Using the procedure described in the prior two paragraphs, Figure 8 shows how changes in RFID and other variables influence the likelihood of claims. We summarize the results below.

- The use of RFID reduces the likelihood of a claim by 83 percent.
- A one-half standard deviation increase in the value density, equivalent to an increase of 49.59 percent, increases the likelihood of a claim by 35.1 percent.
- A one-half standard deviation increase in the total volume of monthly shipments at the warehouse, equivalent to a 1.92 percent increase, increases the likelihood of a claim by 19.3 percent.

Clearly, RFID significantly reduces the probability that a claim will be filed when compared with other variables. However, note that once we account for RFID’s impact, the impact of changes from other variables—other than value density and total monthly shipments—is not statistically different from zero.

Slicing the data: We also examined the impact of RFID on how claims incidence varies with changes in other factors. Our intent was to assess the interaction of RFID with other variables (e.g., how RFID affected electronic items as compared to nonelectronic items at varying workloads at the RC). We present some of these results below. For confidentiality, we mask the actual probabilities; instead, we show the normalized probability, which we define as

\[
\text{Norm. Pr} = \frac{\text{Pr}(\text{Claim} | \text{RFID, Other factors})}{\text{Pr}(\text{Claim} | \text{No RFID, Other factors})}.
\]

In other words, these results show the likelihood of a claim with RFID relative to that without RFID, controlling for other factors. The insights are largely as expected. For a shipment of low-value, nonelectronic items during a period of low monthly traffic, this ratio is quite low: The probability of a claim with RFID is only 13.7 percent relative to one without RFID (i.e., the normalized probability is 13.7 percent). For a shipment of nonelectronics items of average value during a period of average monthly traffic, this ratio rises to 18.02 percent). For a shipment of high-value electronic items during a period of high volumes, this ratio is 21.89 percent. Therefore, we prove that RFID is effective in reducing claims both at the lower end of the shipment spectrum and in the worst-case scenario. We hypothesize about some of the drivers of these results below.

Figure 9 plots the ratio of the probability of a claim with and without RFID against the log of total BoL value at high monthly volume. First, we see that at high volumes and at high total BoL value, RFID’s impact was less pronounced. For example, the probability of a claim decreases by 81.9 percent when the BoL value is 22,026 (log(BoL Value) = 10) and by 84.4 percent when the BoL value is 148.4 (log(BoL Value) = 5). One possible reason for this could be that at higher loads, Genco employs more temporary workers who are not as experienced as the permanent staff in the RC processes and operations.
This could lead to errors that RFID cannot control, or improper use or interpretation of RFID technology. Second, because of time constraints in high-volume situations, the forklift operators may not wait for the confirmation that the reader has read the RFID tag correctly.

We also plotted the normalized probability of claims against the log of average value per item (value density) in a BoL for different volumes and found a similar trend. Figure 10 shows these results.

For below-average, average, and above-average monthly shipment volume at the RC, the probability ratio with and without RFID increases marginally as the average item value increases. The higher intercepts indicate that an increase in process complexity or transaction intensity, as measured through the increase in monthly volume, increases the ratio of the likelihood of claims with and without RFID. In short, RFID reduces the likelihood of claims for all shipments; however, this is more evident for lower-valued items at low volumes than for higher-valued items at higher volumes.

RFID was most effective for low-value BoLs shipped at low volumes. One possible reason for this could be that errors, as opposed to breakage, fraud, or inaccuracies in the BoL, could cause a larger proportion of claims for such low-density shipments; therefore, RFID could cause a larger decrease in claims. In addition, at lower volumes, because of shorter time constraints, the forklift operators are likely to be more patient in waiting for correct RFID reads. Thus, RFID was more successful.

As our probit estimates indicate, the average value of an item in a BoL is more significant in predicting the claims incidence than the total value of the BoL. To understand why, consider this example. Suppose that the BoL consists of 10 televisions with a total value of $20,000 and an average price of $2,000. Contrast this with a hardware order that consists of 10,000 spare parts with a total value of $20,000 and an average price of $2. Clearly, if a single unit is missing or damaged from each order, there is a higher likelihood of a claim in the first instance.

Similarly, the total number of shipments in a month affects the likelihood of claims. A higher total indicates that the process was more complex in the given month; therefore, we can expect a higher error rate and a higher claims incidence.

When we performed sensitivity analysis for all the significant variables in our estimated model, we developed the following key insights:

1. The likelihood of claims falls significantly, to a low normalized probability of 13.7 percent, after RFID implementation.

2. Changes in other control variables, such as monthly shipment volume, value density, shipment category, or total value, do not affect the impact of RFID deployment. The normalized probability in the most extreme scenario, electronic goods BoL of above-average value shipped at above-average volumes, is still lower than 20 percent.
Although we have depicted the significant impact of RFID on claims, these are only the immediate tangible benefits that GENCO saw. Other benefits were harder to quantify or measure. One such benefit is the operational efficiency that RFID introduces as both the technology and the learning curve improve at the facility. Because of lower errors, customer satisfaction also increases as salvage dealers receive their goods as per the Bol.

The benefits of RFID are also highly visible to the workforce. During a visit to the RC, we saw numerous instances in which an alert prevented the sending of an order without all of its pallets correctly loaded or stopped a forklift driver from driving into the wrong truck bay. As of this date, we have not been able to record or capture such benefits; therefore, we do not see the absolute impact of RFID. Consequently, we have significantly undercounted the RFID benefits that we present in this paper.

Conclusion and Discussion

Like any new technology, RFID has received its share of bouquets and brickbats. Despite major advocates such as Wal-Mart, the attitude of organizations—including other manufacturers and retailers—has remained taciturn at best. We conducted this study to ascertain whether RFID does indeed provide benefits—specifically for a logistics company—and if so, to identify the business drivers of these benefits. At a GENCO RC, our field site, we examined the reverse logistics of its outbound operations. The rationale for this particular deployment was the direct impact of the technology to improve operational efficiency for these operations and, in turn, to enhance financial performance and customer satisfaction. Prior to the RFID implementation, operational inefficiencies resulted in many claims from GENCO’s customers because of the erroneous processing of shipments. Moreover, GENCO was unable to identify whether these claims were a result of errors from its own warehouse staff or from shipper mistakes. A false claim could potentially slip through because auditing every claim was time consuming, costly, and not always feasible. Although GENCO barcoded all of its outgoing shipments, technical and human limitations prevented the company from capturing the benefits accrued from time-stamping each step. GENCO then judiciously identified technology-based solutions and the need for RFID tags, as opposed to other measures. Management hoped that the deployment of these tags would unobtrusively record each shipment, alert operators of errors instantly, and help in resolving claims because it would be possible to retrieve data from a real-time tracking system.

Management thus challenged us to determine whether the technology deployment had indeed paid off from a business process perspective. We conducted rigorous statistical analyses of the claims and shipment data. Using the claims incidence as our dependent variable, we estimated a probit model. Our explanatory variables included RFID, transaction-intensity-specific parameters such as total monthly shipment volume at the facility and shipment-characteristic variables such as the shipment value, average item value, and shipment category. We also included buyer-specific parameters such as prior transaction history and prior claims history to control for incentive issues.

Our analyses confirmed that the RFID deployment substantially reduced claims from salvage dealers. Not only did the process become more efficient, but RFID might have acted as a deterrent to fraudulent claims. Our numbers showed that after the RFID deployment, GENCO was able to eliminate the necessity of resolving disputes with dealers. The information intelligence that RFID provided raised efficiency, and potentially honesty, in the outbound logistics process.

Specifically, after the RFID implementation, the claims incidence fell by 83 percent. The deterrent effect of RFID on claims, as we discussed earlier, was robust enough to withstand other model specifications. We found RFID to be the solitary independent variable that explained 45.12 percent of the variation in the data in comparison to the full model. Compared with other control variables, RFID emerged as the strongest parameter, leaving no doubt that the technology is the key driver in the improvement of process performance.

Our study does have its limitations. We could not separate the impact of RFID on the overall improvement in operational quality and the agency issues with the salvage dealers. Furthermore, because of confidentiality reasons, we were unable to disclose the
full financial impact. GENCO management expects the long-run ROI to be significant because of declining tag costs and substantial intangible benefits. Tag costs have fallen from $1.09 per tag at the start of the implementation in July 2004 to $0.18 in November 2006. GENCO’s floor and claims operations were also streamlined. Because personnel spent less time tracking pallets or researching claims, there were both tangible cost benefits and an increase in employee morale. In addition, GENCO is using this implementation as a marketing tool to generate new business.

RFID’s benefits, as measured through its impact on the claims incidence, were only part of the exciting findings. There were significant intangible RFID benefits as well; for example, the worker and supervisor satisfaction and comfort level with RFID was very high. This shows that if technology can assist human decision making by making the process pokayoke, the gains can be significant, ensuring smooth operations and making Crosby’s goal of achieving zero defects attainable. (For details of Crosby’s quality framework and the zero-defect model, we refer the reader to Crosby 1979.) These benefits will only increase as the cost of RFID hardware, including tags, decreases and will provide organizations with increasing incentive to deploy RFID at more micro levels. Encouraged by these results, GENCO has expanded its RFID deployment to all of its outbound operations at the McDonough RC. We anticipate that its entire network will benefit from the greater visibility and monitoring of the value chain.

We also foresee that GENCO will leverage the data gathered by the RFID tags to provide business intelligence that will enable the company to be more proactive in managing its logistics process. The results that we documented in this study are the initial returns that GENCO was able to gain by rapid deployment. The implementation planted the seed for wider deployment; we will watch with keen interest to see the next round of benefits that GENCO will harvest.

GENCO has shown it is a learning organization and that it can leverage business technology to transform its business processes to create more value for itself and its customers.

Our study underscores the potential of RFID for today’s businesses. RFID not only provides tracking of goods through the supply chain, but also provides the potential for an organization to share this information with its partners along this chain. This takes information integration beyond e-commerce or traditional EDI. We need to develop an understanding of where and when we can apply RFID, and the information empowerment it provides, most profitably. We believe that this understanding will lead to reduced costs and enhanced value for all stakeholders.

References


