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RFID ITEM-LEVEL QUANTITY AUDITING FOR APPAREL SUPPLIER DISTRIBUTION CENTERS

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RFID Item-level Quantity Auditing for Apparel Supplier Distribution Centers

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Contents

1 Overview

During the early stages of RFID adoption (2003-2006), the focus was on the use of RFID on pallets and cases moving through distribution centers (DCs) to the retail stores. This emphasis shifted in 2006 to individual items (primarily apparel) at the store. During this second phase (2006-2009), the University of Arkansas conducted a series of studies examining the use of RFID for item-level retail. First, extensive lab experiments were conducted to prove the technology works. Second, a large panel of retailers was assembled to contribute potential use cases – i.e., business problems that could potentially be solved using RFID. Third, the set of use cases was narrowed down to a small set of common use cases (i.e., inventory accuracy, out of stocks, locating product, and loss prevention) which were examined in a controlled lab setting. Finally, a series of real-world (in field) studies were conducted to determine the true value of RFID in the stores. Overall, the pilots were very successful.

The majority of the retail pilot studies applied RFID tags at the retailer DC or the store level – a practice that, while useful to determine the value of RFID at the store, is not sustainable in the long run. For RFID to be successfully used and adopted, tagging must occur as far up the supply chain as possible – preferably at point of manufacture. Thus, in January 2010, the emphasis shifted to the suppliers. Following a process similar to the retail studies, a team of researchers led by the University of Arkansas, began a 'supplier ROI' initiative to evaluate the business value of RFID for suppliers. First, in 2010, many suppliers (primarily apparel) were consulted to determine the population of potential use cases for RFID in the entire supply chain – from point of manufacture to store shelf (Phase I of the studies). The end result was a paper published in January 2011 which identified 60 use cases (as discussed in Section 2). Phase II, the focus of this paper, examined the most important use cases in depth across a variety of suppliers. Site visits, questionnaires, and observation were primarily used to collect data (as explained in Section 3). Accordingly, the purpose of Phase II, as reported herein, is to examine the most common and important use cases (i.e., in this case, primarily inventory accuracy), and report on the potential value to suppliers as they explore the use of item-level RFID.

2 Recap of Phase I

In January 2011, the RFID Research Center in the Sam M. Walton College of Business at the University of Arkansas published the first of a working paper series characterizing the potential return on investment (ROI) for apparel manufacturers and suppliers using RFID. The paper, Information Technology Research Institute Working Paper No. 156-0111, entitled "An Empirical Study of Potential Uses of RFID in the Apparel Retail Supply Chain" is available for download from: http://itri.uark.edu/104.asp?code=rfid). It is commonly referred to as Phase I of this ongoing investigation and was funded by GS1 US and the American Apparel and Footwear Association (AAFA). GS1 US has a vested interest in assuring the early onset and maintenance of standards adoption, and AAFA strives to continually provide greater value to their member base through hands-on exposure to the latest technological developments.

One of the more salient artifacts of the first paper was a diagrammatic mapping of the apparel supply chain as interpreted by the investigators (ITRI-Working Paper 156 (Phase I), page 17). This map covers the movement of physical goods, as well as processes and information flows, across the scope of the apparel supply chain. Supply chain points investigated include raw materials procurement, manufacturing facilities, international shipping ports, local shipping ports, supplier DCs, retailer DCs, store backrooms, sales floors, and finally, returns facilities for the reverse supply chain.

In total, 60 potential use cases were identified and mapped. These use cases are areas where the implementation of RFID is considered to add value to current methods or processes. For example, the receiving process at a supplier's DC was identified as having eleven potential benefits through the correct leveraging of RFID. These include the ability to speed accurate inbound audits through automatic counting of tagged items, Electronic Proof of Delivery (EPOD) automation and verification, and, therefore, faster and more automated assessment of quality metrics per upstream vendor. Such benefits might not be unique to the receiving dock of a supplier's DC, but can be applied across the map to any receiving process where RFID tagged inventory is inbound.

3 Phase II

During Phase II, several research methodologies were utilized. To begin, several field studies were conducted. Over the course of the study, DC operations were investigated at 17 apparel supplier facilities in the US. The majority of items distributed through these facilities are replenished apparel. These facilities range significantly in size and throughput. The lowest annual revenue of any firm included in the investigation was quoted at US$37M and the highest at over US$10B of which US$4B included replenished apparel. The facilities ranged in size and scope of operations.

After the field studies, open-ended questionnaires were sent to select apparel suppliers. The data collected through the questionnaires included information about throughput, current auditing processes, accuracy levels, types of products, and claims, among others.

Finally, two supplier focus groups were conducted to collect additional data. During the supplier focus groups, preliminary findings were presented and feedback was solicited regarding our early observations regarding auditing practices (in particular), inventory accuracy levels, and product movement through the facilities. During the first focus group, it became clear that inventory accuracy was not an issue, per se – rather, the issue was the amount of resources (primarily human resources) required to get inventory accuracy to an acceptable level. This difference, between the inventory accuracy use cases of retailers and suppliers, is both subtle and profound: for the retailer, inventory accuracy is poor and they want to improve it; for the supplier, inventory accuracy is high but they need to find a more efficient way of keeping inventory accuracy high. After the first focus group, the researchers paid particular attention to the processes used to ensure high inventory accuracy particularly in the pick-pack and outbound operations. In this paper, we explore the current processes used by suppliers to ensure high inventory accuracy and explore how RFID can be used to achieve the same accuracy at a much lower cost. Although many other use cases were identified in Phase I, the researchers and participating suppliers felt that inventory accuracy was the most important and immediate use case. Thus, our focus on this paper is on this primary use case. Furthermore, as explained in Section 5, the scope of the inventory accuracy use case is restricted to the supplier's DC.

4 Inventory Accuracy

For suppliers, the consequences of inaccurate shipments to their customers (i.e., retailers) can be severe. Inaccurate shipments may result in claims (i.e., chargebacks) from retailers which may include reduction in the cost paid by the retailer or rejection of entire shipments. While suppliers would like to achieve 100% accuracy, they are unable to do so, even with the most elaborate of processes, and thus, some errors occur in the distribution process. These errors obviously have negative consequences. Claims disputes come in a variety of formats depending on customer. Some retailers, upon checking for and discovering an error with a shipment, will reject and claim for only those items found in error. Some will make a claim for the batch containing the error, and some make a claim for the entire bill of lading. Additionally, some retailers pre-negotiate a reduction in cost of goods sold, in anticipation of errors. The cost associated with disputing claims can therefore vary dramatically across customers. Of course, the cost of claims can be as high as the value of the entire account. In other words, it is possible that a retailer could, upon performing spot audits, assess a vendor's error rate to be too high and ultimately, determine that the purchasing agreement should be voided and the account canceled.

The cost of deductions is not limited to the dollar amount of the claim itself. Suppliers spend a significant amount of time and effort reviewing and challenging deductions claimed by the retailer, and several suppliers indicated they assigned multiple staff members to tracing, analyzing, and challenging retailer deductions, which reflected a significant cost to the business. Most importantly, inaccurate shipments can result in customer dissatisfaction. Suppliers, who participated in this study, unequivocally indicated they are unwilling to knowingly distribute inaccurate shipments to customers. Suppliers indicate the risks of doing so are simply too great. Thus, most currently employ elaborate processes to ensure that shipments to customers are correct.

Smaller firms can suffer higher costs for equal levels of inaccuracy as larger firms. For smaller suppliers, the relative (or proportional) cost of inaccuracy on smaller inventory volumes sold as a larger proportion of product to a single RFID-using retailer, can be much more impactful than for larger companies. If a retailer were to reject an entire bill of lading due to discovering what might be a relatively small percentage of error, that rejection can account for a relatively larger percentage of sales for a small company than it does for a larger company. Additionally, smaller firms have employees doing more than one dedicated task, and proficiency across tasks is often unequal. As a result, the distribution of error in the products of smaller supplier processing smaller batch sizes can be tighter and less equally spread across a large quantity of categories and SKUs than in a bigger supplier. This can lead to a higher probability of a retailer discovering, during a spot audit of a single receiving dock, what is interpreted as a higher percentage of error than actually exists. The inability to prove and dispute item-level quantity accuracy can therefore have relatively costlier outcomes for smaller suppliers. When conducting the research for Phase I of this study, a possible reduction in the cost of claims made against suppliers was cited by suppliers as one of the greatest potential benefits of RFID implementation.

Overall, inventory accuracy is a major issue for suppliers and they often go to extraordinary lengths to ensure inventory accuracy, for the aforementioned reasons. Retailers involved in both this study as well as prior retailer ROI studies performed by the University of Arkansas RFID Research Center have stated that an accurate quantity of received merchandise is the most weighted variable when auditing incoming shipments. For suppliers, inventory accuracy starts with the product they receive in their DCs and ends with the product shipped to the retailer. In this context and within a supplier's facility, therefore, we will focus on three primary areas of inventory accuracy: receiving, pick/pack, and shipping processes. In the following sections, each of these areas and their respective current processes for ensuring high inventory accuracy is explained.

5 Current Receiving, Pick/pack, and Shipping Processes

The apparel industry represents a rather complex supply chain. Most supply chains in this industry are unique, though some similarities mark them. These chains are both global and domestic, depending on the specific items, manufacturers or retailers involved. Inventory flows through domestic and global supply chains differently. For example, some manufacturer–retailer combinations send inventory from production facilities to supplier distribution centers to retailer DCs and finally on to the retail store. In Phase II of this research, we focus our attention on supplier DCs located in the US, although the concepts presented herein may apply to any facility within the supplier's supply chain.

For suppliers who own manufacturing facilities, the focus on US DCs is likely due to their ability to control this portion of the supply chain. The DC is on local soil, has good infrastructure, practical access to technical support, and is probably the most cost effective place to begin putting readers in an effort to realize any potential benefit from RFID. For suppliers who do not own their own manufacturing facilities, their DC(s) is the node in the supply chain where they have control and, thus, represents the most logical point for initial deployment.

From a supply chain perspective, the supplier DC is also a point of inventory aggregation. Thereby, it is an opportunity to inject, through centralized, accurate assessment of inventory quantity and quality, inventory integrity into the flow of inbound inventory manufactured in numerous remote locations.

Generally speaking, inventory is received into the DC, then either cross-docked for immediate (or near immediate) shipping or stored for later use (e.g., in pick/pack). Within the DC, several value-added processes likely occur. One of the most significant and relevant to this study is the pick/pack process.

Figure 5-1 provides an illustration of the process flows that are generally found in the supplier DCs. Of particular interest in the Phase II research is inventory accuracy as pertaining to receiving, pick/pack, and outbound processes.

In general, supplier DCs perform four overall functions; inventory receiving, storage, value added services, and shipping. Building promotional products and pick/packing are examples of value added services. The extra item-level processing and handling caused by value added services is capable of introducing additional inaccuracy into inventory and value added services are therefore of special interest when considering how RFID might reduce inventory inaccuracy.

Cycle counting and physical counting are two methods used by suppliers to correct inventory inaccuracy. Cycle counts are generally performed on stored inventory, and physical counts are generally performed on inventory that is being actively worked on. Items are often stored according to their velocity through the facility. This is an attempt to optimize material handling processes such as pallet put-away/pick travel distances and times. Slower moving items that are received, handled, and shipped in bulk (carton-level, not item-level), are most often stored in high bay racking, while faster moving items that might go through pick/pack are stored in lower, closer racking.

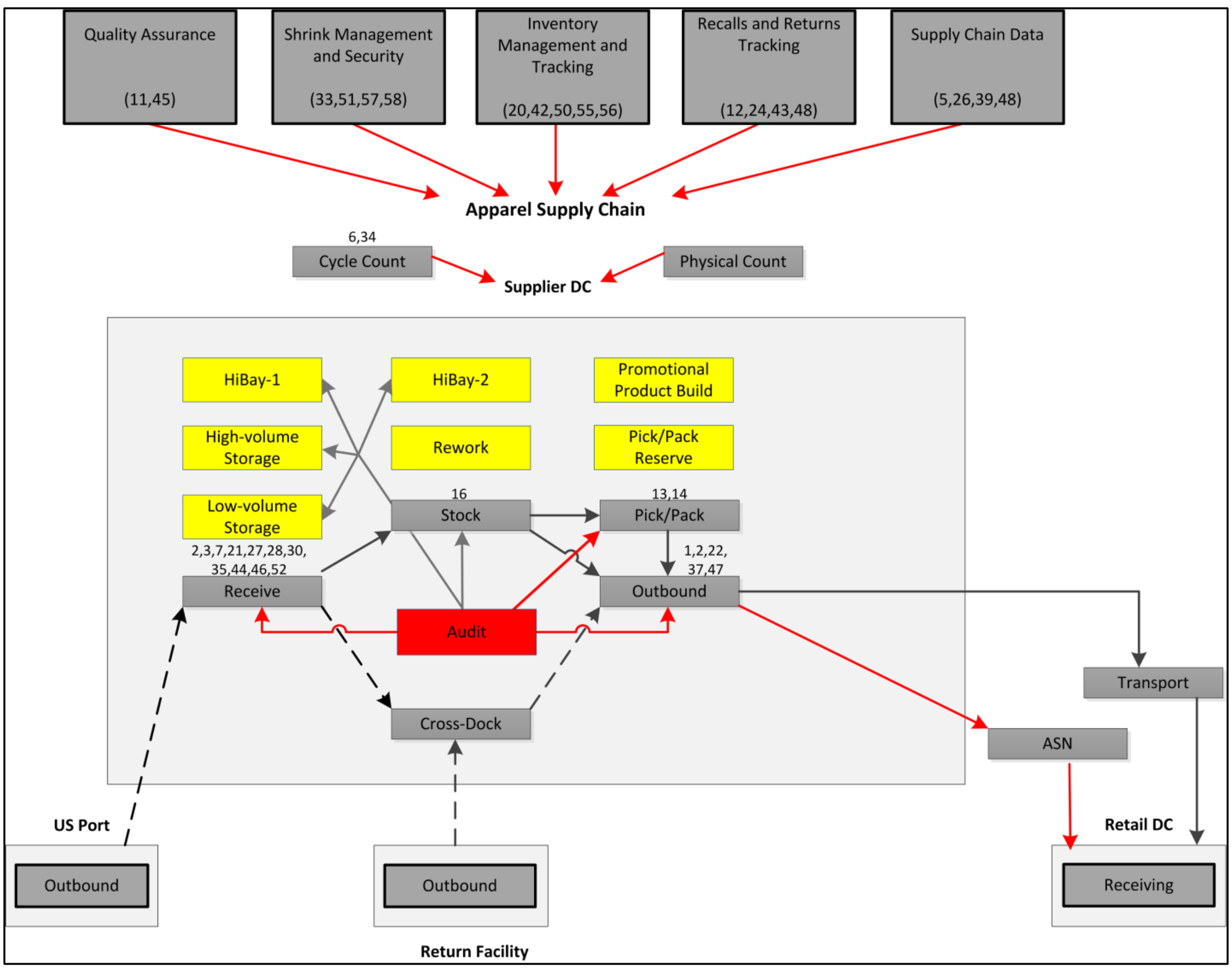

Figure 5-1: Expanded Schematic of Supplier DC Functional Areas

5.1 Ensuring Inventory Accuracy

The US DC represents the last point of contact a supplier has with inventory prior to it reaching the retailer. Thus, suppliers are careful to ensure that the quantities shipped to retailers are correct. Suppliers in this study used a variety of techniques to ensure high inventory accuracy. A commonality found is that each supplier has some type of audit process, usually at multiple processes within the DC (as shown in
Figure 5-1).

So, what exactly is an audit? Generally speaking, an audit refers to an acceptance sampling process. "Acceptance sampling is used by industries worldwide for assuring the quality of incoming and outgoing goods. Acceptance sampling plans determine the sample size and criteria for accepting or rejecting a batch based on the quality of a sample, using statistical principles."[1] Once a sample is taken from a batch, each item (or carton, depending on the location of the audit) is checked for accuracy. This is commonly referred as an audit. If the number of defects (errors) in the sample is greater than some predetermined number, then the batch is "rejected." If the number of defects in the sample is less than a predetermined number, then batch is accepted and continues through the distribution process.

As noted, each supplier which participated in the Phase II research had a minimum of one process area performing item-level quantity audits within their DC. An item-level quantity audit is defined as an audit wherein the total number of any batch of inventory is counted for accuracy. In every instance, these audits require a manual count of each item within a carton. In almost all cases, each item was barcode scanned in addition to being manually counted. At times, such a process requires two full time employees. One employee removes the items from the carton and barcode scans each item. The second employee repackages the items while, again, barcode scanning each item to double check the item-level quantity audit process. While the audit processes may at times seem extreme, suppliers indicate they are willing to engineer such time-consuming and labor-intensive processes to ensure high levels of inventory accuracy.

5.1.1 The Receiving Process

The majority of facilities investigated relied on manual unloading of floor-packed containers using accordion conveyors, followed by manual sorting processes differentiating predominantly between style, color, and size. Approximately half of all facilities investigated included some form of electronic audit process at the point of receiving. This process currently utilizes barcode scanning and carton weighing whereupon rejected cartons would be diverted to a manual audit station for inspection. In one facility, the audit station was staffed by up to six full time employees (FTEs). In contrast, some facilities rely purely on a manual item-level quantity and quality audit of a percentage of inbound items, normally 5% or 10% blanket audits across all incoming cartons.

[1] http://www.sqconline.com/acceptance-sampling-accept-or-reject-batches

Some facilities employ roaming auditors who will pull a random number of cartons from a received container, most often somewhere between 5 and 10 cartons, and perform a spot check on the contents. If a single error is found within any of these cartons, a further batch of cartons is pulled from the container and again checked for errors within. If further errors are discovered in this second batch the entire container is marked for manual item-level auditing.

After cartons are received they are routed to a variety of destinations determined by their current status, normally ranked foremost by velocity. If they are a high velocity item that gets cross docked they may skip the warehousing area of the building entirely and make their way directly through automated sortation to shipping. Otherwise they may be stored in a manner of high-bay, high velocity, or low velocity pick/pack reserve racking areas in preparation for pick/pack, rework, or promotional operations, or a combination of all three. Several facilities have designated pick/pack reserve areas where products required by future pick/pack operations are staged; while other facilities simply pull pick/pack product directly from their standard warehouse locations.

Per product received, manually performing item-level quantity audits takes a prescribed and relatively constant amount of time. Receiving and processing cartons of items into a supplier DC can occur at a much faster rate than manual item-level quantity auditing.

Therefore, the higher the number of categories that are simultaneously received, the higher the percentage of any category that can be audited, and therefore the higher the confidence level of the accuracy for that category. Unfortunately, at constant receiving and auditing rates, the more one category is audited, the less another category might be, and the lower the level of confidence in the accuracy of those less audited categories.

For example, if one single SKU is received and processed out into the DC at a rate of 4,000 cartons per hour, an auditor item-level quantity auditing 240 cartons per hour will audit 6% of the entire SKU. However, if 4 different SKUs are being received at the same rate at the same time, the same auditor could potentially audit up to 24% of a single SKU. While this would provide higher levels of confidence in the accuracy of that one particular SKU, it would, of course, mean that the other three SKUs might be neglected and not receive any percentage of receiving item-level quantity audit unless additional auditors are assigned to each of the other SKUs (as shown in Figure 5-2).

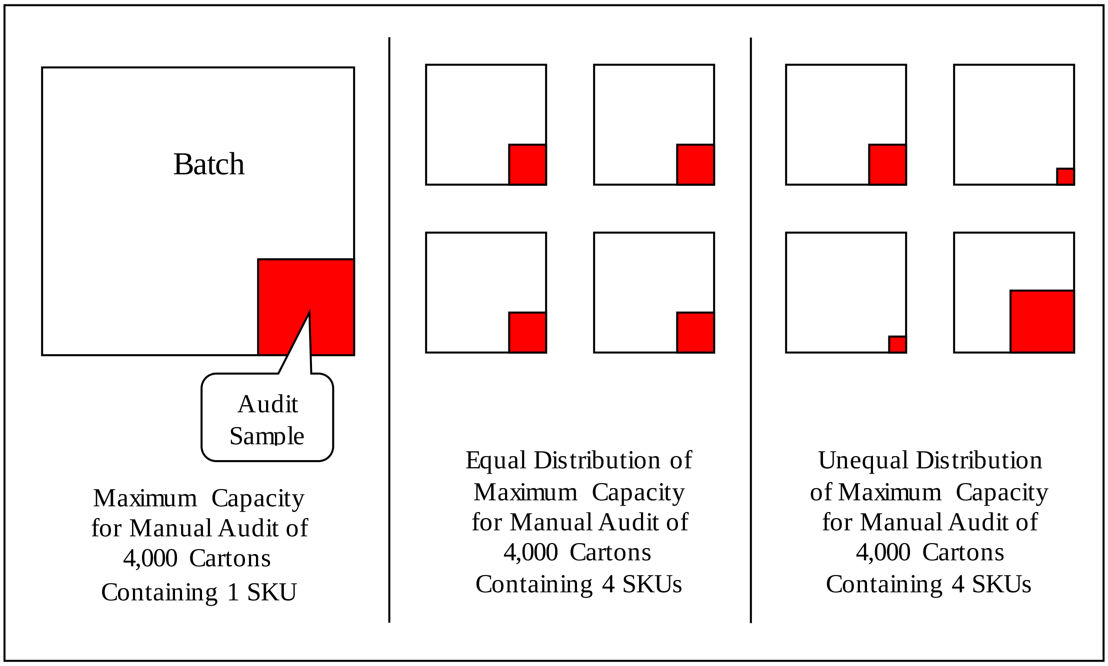

Figure 5-2: Potential for Unequal Distribution of Audit Sampling

In reality, while a manual receiving audit is almost always performed for verification purposes, it is often preceded by some form of electronic audit system. Most electronic audit systems in use today will barcode scan and weigh each box and compare it against a prescribed tolerance of upper and lower weights for the particular item it is believed to contain. Any box that gets flagged for audit because it is outside the prescribed weight limits then gets double checked by an employee, often one of several receiving area audit full-time employees, who rescans and reweighs the carton before determining whether to open the carton and physically count the number of items or induct the carton back into the normal flow of inbound goods without opening it. Many factors can determine an employee's decision making process at this point.

This results in a varying percentage of each received SKU being item-level quantity audited, and the balance between SKUs that receive a greater or lesser degree of auditing is often highly subjective to human interpretation and intervention. For example, certain cartons known to be received from a vendor who has a history of higher quantity rejection rates might be manually selected for auditing by an auditor who recognizes the outside of these particular cartons. This attention focus can mean that other error-prone cartons from other vendors might never be subjected to necessarily intensive audit levels and thereby might never be flagged as a potential source of error needing higher levels of audit practice. In this way, the system has the potential to never identify what it doesn't know.

Most suppliers had procedures for adjusting assumed on-hand quantities based on average error rates discovered at receiving dock audits. These adjustments are an assumption of population accuracy based on sample accuracy. This derivative of true accuracy often needs to be based on very high accuracy and confidence levels in order to do justice to actual inventory errors. Additionally, even when accurately estimating populating accuracy, such adjustments often don't shed light on what type of problems the errors are.

5.1.2 The Pick/Pack Process

Pick/pack refers to the process of individually handpicking single items from a carton of homogeneous items, barcode scanning that item and then adding it to a carton of other handpicked, disparate items from other homogeneous cartons. This creates a carton with a mixture of items for a specific customer.

Pick/pack operations varied greatly among participating suppliers. All except a single facility involved in this study had pick/pack operations, and most had significant floor space dedicated to pick/pack processes with one facility performing 100% pick/pack of all inventory moving through the DC. One supplier has approximately 200,000 individual items being pick/packed per day.

Most pick/pack areas consist of several tiers of gravity-feed shelving called the pick/pack reserve area. This is where cartons containing homogeneous items are staged for the pick/pack operator. These cartons can be brought directly from receiving or from storage locations in the DC depending on how urgently they are needed at the pick/pack area. The operator moves between these reserve shelves and a single, linear conveyor in the center of the pick/pack area. Often, operators work opposite each other, filling different empty cartons from both sides. This is believed to make the most efficient use of available floor space. Although cartons are often alongside each other on the conveyor, each operator is supposed to fill a separate carton. In this way the operator is able to keep track of which items have been picked and placed into the carton. The conveyor feeds empty cartons for the operator to fill before they move downstream towards the shipping area, often converging with other pick/pack out-feed conveyors along the way. Another form of pick/pack operations involves a pick/pack operator manually pushing a cart containing a box to the proper pick/pack reserve area, retrieving an item to put in the pick/pack box, and then moving to the next pick/pack reserve area, and so on until the picklist has been filled.

Supplier visits revealed that pick/pack operations may represent the single largest opportunity for process improvement in the supplier distribution environment because pick/pack operations introduce a higher level of inherent inaccuracy relative to other full carton distribution processes.

As with other manual audit processes within the DC, pick/pack audits can be subject to biases injected by the auditor. For example, each employee performing pick/pack operations may be required to mark each completed carton with their initials. Downstream at the audit station, the auditor may perceive that cartons identified by certain initials contain relatively more errors than cartons without these initials. This thinking is based on the auditor's perceptions over time and may be factual or erroneous. As a result, the auditor may audit more of these cartons than other cartons in order to discover more errors, or, conversely, fewer of these cartons in order to avoid having to do extra work when errors are discovered.

This interjection of bias into the audit process can lead to spiraling inequality of distribution in the quantity of each batch sampled, thereby decaying confidence in the accuracy of the pick/pack process and the outbound shipment. Measurement of true accuracy is not achievable through such methods.

During the data collection, we learned that suppliers were often randomly auditing the outbound accuracy of only 5-10% items exiting a pick/pack process. While auditing up to 10% of pick/pack items may seem satisfactory, note the probability of inadvertently "accepting" a batch may be higher than expected.

For example, consider a "typical" pick/pack batch of 400 cartons, where each carton represents a store-specific purchase order. If the batch has a defective rate of 0.5%, meaning that the batch contains 2 cartons with an error, what is the probability that an error is detected by the random audit processes currently in place at most supplier DCs?

To estimate this probability, we use the hypergeometric probability distribution, where the probability of i successful selections (n) taken from a sample of N and a population of M

$$P(x=i)=\frac{\binom{n}{i}\binom{m}{N-i}}{\binom{m+n}{N}}=\frac{m!\,n!\,N!\,(m+n-N)!}{i!\,(n-i)!\,(m+i-N)!\,(m+n)!}$$

.

We present the probability of detecting an error based on sample size in Figure 5-3.

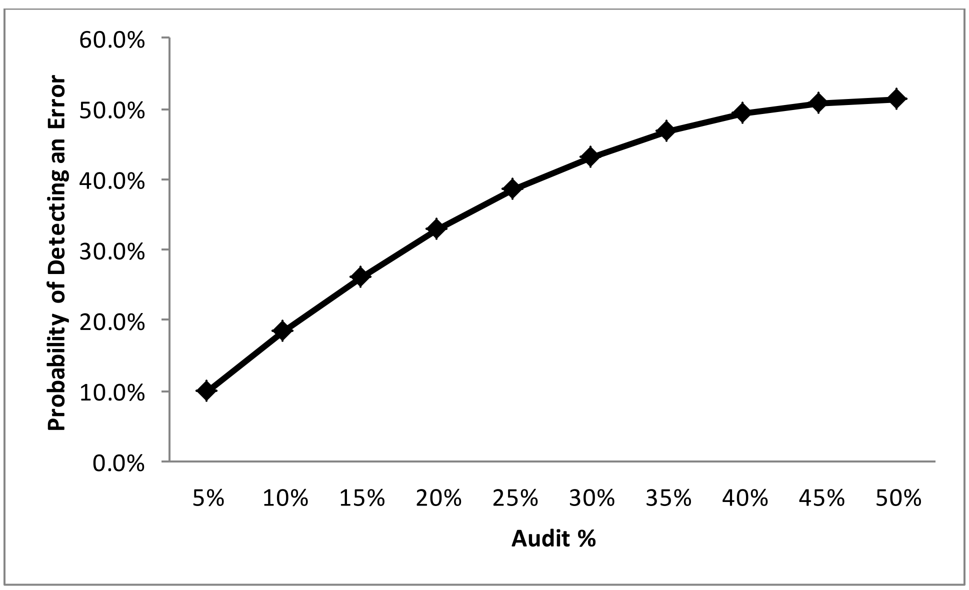

Figure 5-3: Sample Size and Probability of Detecting a Single Error

From Figure 5-3, note that the probability of detecting an error is quite low when using some current audit processes. If a 10% audit methodology (i.e., 40 cartons are audited) is used, then there is only an 18% chance that at least one error will be detected. Obviously, this means there is an 82% probability that both errors escape some current audit processes.

Notice in Figure 5-4, the probability of detecting **both** errors is even much smaller. The 10% audit methodology only yields a 1% probability that both errors are detected.

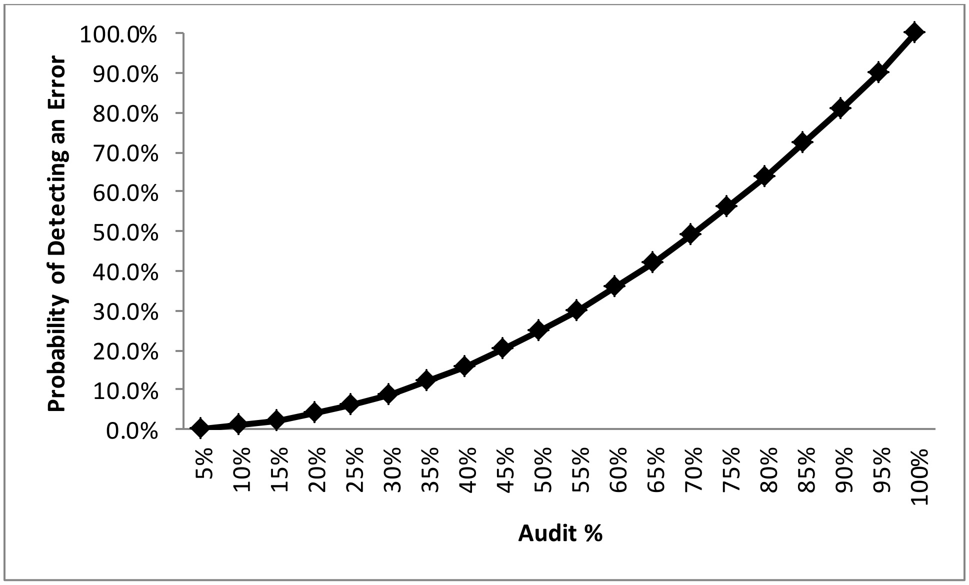

Figure 5-4: Sample Size and Probability of Detecting Two Errors

This example illustrates how easily traditional audit processes may allow pick/pack errors to ship through the retail apparel supply chain.

In some pick/pack operations, 100% of the pick/pack items were audited before the cartons were sealed and sent to outbound shipping. In these situations, pick/pack operators take their cartons to an audit station where the auditor would barcode scan each item in the carton. If a mistake was found, the auditor would leave their station, retrieve the correct item, and place it in the carton. After a 100% audit of items in the carton, the box would be sent to outbound shipping. One would assume, in these situations, that accuracy would be 100% - unfortunately, even when 100% of the items are audited, error creeps into the process due to simple human error, such as scanning the same item twice or putting an item in the wrong box. Although accuracy is very high in this situation, it is not 100%.

5.1.3 Outbound Processes

Unilaterally, every supplier interviewed stated that the accuracy of outbound processes is critical. Since shipment accuracy is directly linked to customer satisfaction, accurate shipments are a primary focus. Ubiquitously, suppliers stated that 99.9% or higher accuracy is desired of shipments leaving their US DC docks.

Outbound shipments are staged on DC shipping docks. Space available for such staging can vary greatly across both facilities and time. Increases in volumes due to back-to-school timing, promotional products, or annual retailer inventory adjustments can affect the quantity of pallets awaiting shipping at any given moment. Older buildings originally built for manufacturing operations and now repurposed for DC operations are often inefficient for this new purpose, and have limited space available for staging. Pallets can become crammed together, requiring a lot of shuffling before shipping. Both cross-docked products as well as pick/pack products are often staged for shipping using similar methods. Many shipping docks were observed to share loading bays or doors across multiple carriers and shipping routes. This prevents static floor space planning and requires dynamic adjustments in load staging depending at which door which carrier is parked. This can add levels of complexity to shipping which can affect outbound carton-level accuracy.

Item-level quantity audits on shipping docks were not commonly observed. At this inventory stage, item counts are generally considered empirically unimportant since other DC processes, such as pick/pack audits, are intended to assure carton contents. Also, suppliers generally used some method of random auditing of cartons headed to shipping (from pick/pack) for auditing. For example, one supplier randomly audited 10% of cartons at shipping for item content. Generally, though, carton-level accuracy is a shipping dock's primary concern; ensuring accurate cartons and counts placed on correct trucks.

The issue of outbound shipment accuracy is multi-dimensional. Note that Table 5-1 requires that both an accuracy level and confidence level be identified to determine the appropriate audit sample size. Confidence level is interpreted as "how much confidence do we have that we caught the errors that exist?" For example, we can specify an accuracy level of 98.350% and a confidence level of 99%, which would be translated as "we are 99% confident that our accuracy level is 98.350%."

		Accuracy Level										
		99.985%	99.350%	98.850%	98.350%	97.850%	97.350%	96.850%	96.350%	95.850%	95.350%	94.850%
Confidence Level	99%	30701	708	400	279	214	174	146	126	111	99	89
	98%	24593	568	321	224	172	139	117	101	89	79	72
	95%	19971	461	260	182	139	113	95	82	72	64	58
	90%	15351	354	200	140	107	87	73	63	55	50	45
	80%	10729	248	140	98	75	61	51	44	39	35	31
	50%	4621	107	60	42	32	26	22	19	17	15	13

Table 5-1: Zero-based Acceptance Sampling[2][3]

While high levels of accuracy are often desired, maintaining high levels of confidence of high accuracy can require relatively greater levels of effort and cost in practice, as Figure 5-5 illustrates; i.e., the higher the confidence level, the larger the number of items that must be audited.

[2] This table assumes that the lot size is several times the sample size, and thus, the size of the lot size makes very little difference (Jacobs and Chase 2008). Additionally, this table is constrained to only include ranges of accuracy and confidence levels that are relevant to our sample. Such tables can be found to include much larger ranges.
[3] Note that the desired accuracy levels and confidence levels represent ranges taken from a supplier focus group. The sample sizes are derived from McClain and Thomas (1985), p.500.

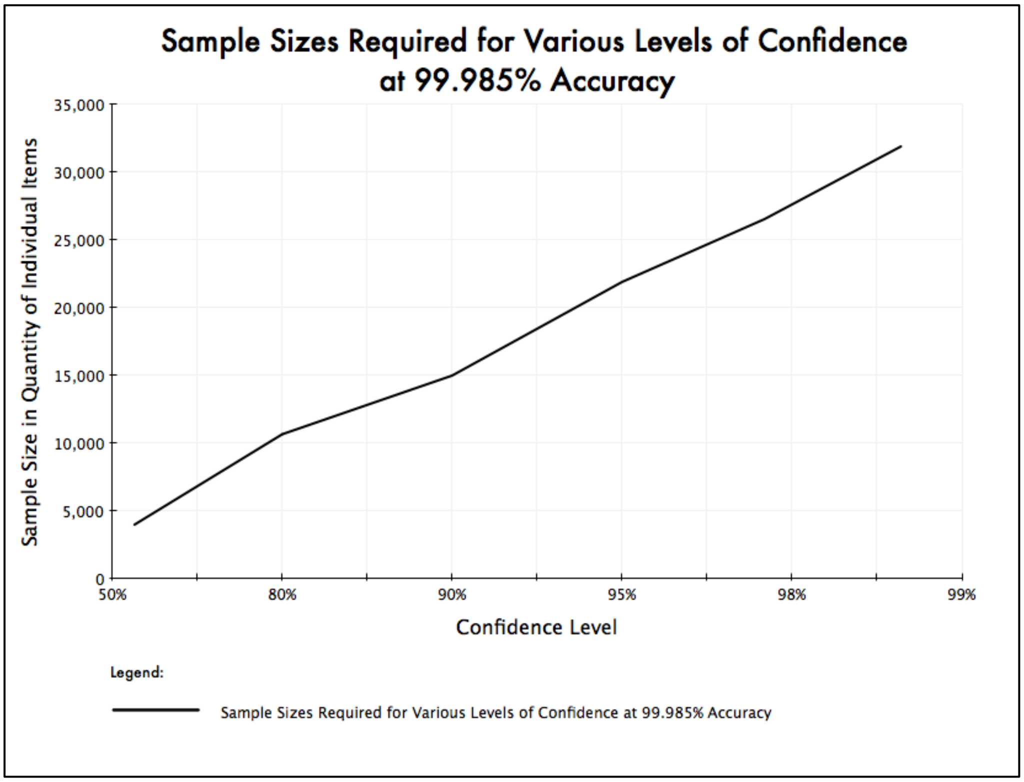

Figure 5-5: Sample Sizes Required for Various Levels of Confidence at 99.985% Accuracy

The notion of zero defects and the related concept of zero-based acceptance sampling are not novel. For example, the Department of Defense (DOD) has used zero-based acceptance sampling for decades. Zero-based indicates a batch is only accepted if the sample contains zero defects or errors. In contrast, if a sample does contain at least one defect or error, the entire batch associated with the sample is rejected, meaning the entire batch must be screened and reworked such that the errors are corrected.

In the context of supplier DC outbound accuracy, creating a zero-based acceptance plan requires that the supplier make two determinations: desired outbound accuracy and the level of confidence, to determine the required sample size. That is, a supplier must not only determine an accuracy target but it must determine the level of confidence needed as to whether actual shipments are actually that accurate. Together, these decision criteria drive the size of the sample required. To illustrate, see the zero-based acceptance sampling plan in Table 5-1. Accuracy levels are across the top of the table. This can be interpreted as the level of outbound accuracy the supplier expects to achieve. Further, the confidence level can be found vertically on the left side of the table. The confidence level can be interpreted as the supplier's confidence level in achieving the expected accuracy level. Finally, a sample size is given for each corresponding value of accuracy and confidence levels.

Notice that as the accuracy level and/or confidence level required decrease, the required sample size of the audit decreases. For example, if a supplier requires a 99.985% accuracy level with a 99% confidence level, then the supplier must audit 30,701 units (sample size) from the batch. However, if the supplier is willing to compromise on the level of confidence to, say 80%, the number of necessary audited units decreases to 10,729. Obviously, the sample sizes described above appear to be quite "large" when high levels of accuracy and confidence are required. This illustrates the challenge of using traditional audit methodologies that suppliers face in their distribution environment with respect to achieving high shipment accuracy.

As can be seen from Table 5-1, the required sample size can sometimes be staggeringly high. In many cases, the sample size may be much larger than the actual batch size (which, of course, means that the entire batch is audited). As shown in Table 5-2, below, which is the MIL-STD-105E zero-based acceptance sampling plan, the entire batch (represented by "A") must be audited when the batch (lot) size is relatively low and the acceptable quality level (AQL) is relatively low.

$$AQL = 1 - desired\ accuracy\ level$$

	Acceptable Quality Level (AQL)															
LOT SIZE	**.010 %**	**.015 %**	**.025 %**	**.040 %**	**.065 %**	**.10 %**	**.15 %**	**.25 %**	**.40 %**	**.65 %**	**1.0 %**	**1.5 %**	**2.5 %**	**4.0 %**	**6.5 %**	**10.0 %**
1-8	***A***	***A***	***A***	***A***	***A***	***A***	***A***	***A***	***A***	***A***	***A***	***A***	5	3	2	2
9-15	***A***	***A***	***A***	***A***	***A***	***A***	***A***	***A***	***A***	***A***	13	8	5	3	2	2
16-25	***A***	***A***	***A***	***A***	***A***	***A***	***A***	***A***	***A***	20	13	8	5	3	3	2
26-50	***A***	***A***	***A***	***A***	***A***	***A***	***A***	***A***	32	20	13	8	5	5	5	2
51-90	***A***	***A***	***A***	***A***	***A***	***A***	80	50	32	20	13	8	7	6	5	4
91-150	***A***	***A***	***A***	***A***	***A***	125	80	50	32	20	13	12	11	7	6	5
151-280	***A***	***A***	***A***	***A***	200	125	80	50	32	20	20	19	13	10	7	6
281-500	***A***	***A***	***A***	315	200	125	80	50	48	47	29	21	16	11	9	7
501-1200	***A***	800	500	315	200	125	80	75	73	47	34	27	19	15	11	8
1201-3200	1250	800	500	315	200	125	120	116	73	53	42	35	23	18	13	9
3201-10,000	1250	800	500	315	200	192	189	116	86	68	50	38	29	22	15	9
10,001-35,000	1250	800	500	315	300	294	189	135	108	77	60	46	35	29	15	9
35,001-150,000	1250	800	500	490	476	294	218	170	123	96	74	56	40	29	15	9
150,001 - 500,000	1250	800	750	715	476	345	270	200	156	119	90	64	40	29	15	9
500,001 & Over	1250	1200	1112	715	556	435	303	244	189	143	102	64	40	29	15	9

Table 5-2: Zero-Based Acceptance Sampling Plan[4]

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[4] http://guidebook.dcma.mil/226/tools_links_file/stat-sample.htm

Depending upon how a supplier defines a batch, it is quite possible that the supplier must audit all items in each of the outbound cartons to insure the level of accuracy desired. In many instances, suppliers indicated that a single shipment to a retailer represented as a batch.

6 The RFID Solution

Passive Gen 2 UHF RFID tags have been found to work exceedingly well with apparel items. Read rates of 99.99% are not uncommon and have come to be expected of the technology when used with apparel. Closed cartons and even pallets of items can be successfully read in an instant. For example, during the course of this study, data from two RFID conveyor read points from one supplier was collected and analyzed. Each read point consisted of a single reader with three antennas mounted around a conveyor carrying cartons of tagged items. The size of the cartons and the type, number and density of items varied significantly over time across read points. The maximum number of tagged items per carton was 72, and the maximum speed of each conveyor was approximately 400 feet per minute. In each case, every carton passing through each read point contained tagged items. Each RFID read point was able to perform item-level quantity audits in excess of 99.99% of all cartons.

Every supplier involved in this phase of the study is receiving RFID tagged inventory into their US DCs. These RFID tags are not applied in the US DCs. Rather, inventory is tagged during manufacture in off-shore facilities. These tags uniquely identify every selling unit at the item-level through adding serialization to each SKU. What this means is that each apparel item, for example, of style “A” and size “medium” in a batch of several thousand items has its own unique number stored in the RFID tag.

As each of these items moves through the supply chain, there are numerous opportunities for RFID readers to instantly capture the unique number from each item, without requiring the line-of-sight needed by barcodes. RFID has a proven track record in the apparel industry due to the successful readability at the pallet, carton, and item levels. A pallet of items in cartons is normally read at locations such as receiving docks, shrink-wrappers, and exit dock doors. When cartons are de-palletized, common practice is to read each item in the carton as it passes through readers positioned on conveyors.

This method of reading items within each carton passing along a conveyer is how RFID is replacing or supplementing manual pick/pack item-level quantity audits. Each carton contains numerous items that have been handpicked and placed in the carton. In most situations, this carton travels from pick/pack via conveyor towards outbound shipping. Along the way it passes a manual pick/pack audit station where it might be selected for manual audit. An RFID reader, which can easily be placed along this conveyor, reads the unique identity of *every* tag in *every* carton passing out of pick/pack. Data collected from such item-level RFID quantity audits yields consistent returns in excess of 99.99% of tagged product audited. This is almost a 100% audit on *all* tagged items. Because most pick/pack processes are performed to satisfy a particular purchase order for a retailer, RFID provides almost a 100% audit per purchase order.

Data from RFID readers used in item-level pick/pack audits was collected during the course of this study and compared with data collected from manual item-level pick/pack audits along the same conveyor lines. The RFID system identified up to an additional 4.8% pick/pack inaccuracy. These inaccuracies would previously not have been identified.

Please note that RFID audit functions in supplier DCs do not satisfy item-level *quality* audits wherein such things as the direction of material weave, or ink color and positioning of stamped labels, for example, is audited. The logical answer to preventing such problems with product quality is to deploy RFID higher upstream in the supply chain in an attempt to begin eliminating such things as bundle misidentification during sewing that result in the need for stringent downstream quality audits. However, for the purpose of this study, the immediate ability to achieve accurate item-level *quantity* audits through RFID is the given focus.

Manual pick/pack quantity audits have been observed to audit a wide range of total batch size. RFID pick/pack quantity audits have been observed to audit over 99.99% of all tagged products. This is true for all tagged product, not just product exiting pick/pack - RFID readers are capable of auditing over 99.99% of almost any open or closed apparel carton containing tagged items, such as cross-docked cartons, or cartons being staged for pick/pack reserve or rework, or cartons being cycle counted in storage bays. This transforms DC inventory visibility from the carton level to the item level.

Item-level quantity audit automation provided by RFID is capable of seamlessly scaling between batch sizes since RFID simply performs a 100% audit on all batches; thereby eliminating assumptions in inventory accuracy, labor assignment issues, and undiscovered inaccuracy injected by faulty auditing. When quantities shipped through a DC increase, for a back-to-school period for example, the percentage of items audited may decrease which can increase the error rate or the number of auditors can increase to keep the audit percentage the same (which will increase costs) – either way, errors or costs will increase. With RFID, there is no increase in cost or error as (near) 100% is being audited regardless the quantity being shipped through the system. Figure 6-1 below represents this graphically.

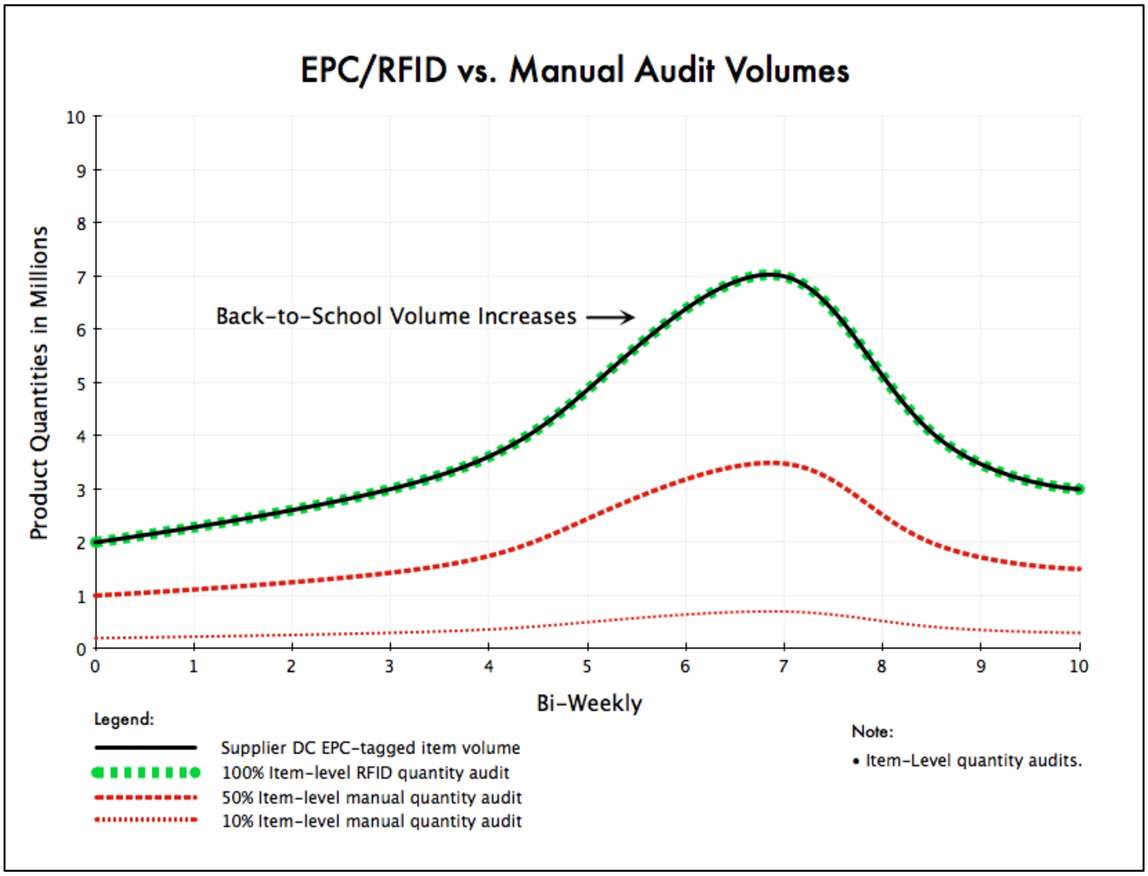

Figure 6-1: RFID vs. Manual Item-Level Quantity Audits

For almost every supplier investigated, the pick/pack audit is, perhaps, the most important audit point. The desire to ship highly accurate shipments combined with the pick/pack process's capability to introduce a higher level of inherent inaccuracy than many other DC processes makes this audit point critical to full measurement of outbound inventory accuracy through item-level RFID quantity auditing.

As a result of the relative complexity of pick/pack processes and potential biases of manual pick/pack audit processes, the opportunity for errors in pick/pack shipments to retailers is likely higher than full carton shipments and thus offers a significant opportunity for RFID. *RFID can be beneficial by seamlessly auditing 100% of the cartons exiting the pick/pack process.*

The level of confidence can be influenced by many variables of which audit sample sizes are most significant. Being able to audit an entire batch provides a much higher level of confidence in that batch's accuracy than, for example, only being able to audit perhaps 5% or 10% of the batch (as discussed in Section 5).

6.1 Manual Scanning Speed and Inventory Volumes

Scanning speed and inventory volumes are the two primary variables affecting manual item-level quantity audit costs. There are many lesser influences, predominantly operational factors such as customer-dedicated conveyor lines or customer-dedicated process areas which might separate RFID-tagged product handling from non-tagged product handling.

Manual audit speeds varied significantly between suppliers, from 120 items per hour to more than 1800 items per hour. In cycle counting audits using professional inventory companies, we have observed auditing speeds between 250 and 500 items per hour. The University of Arkansas RFID Research Center has performed numerous studies analyzing both the increased speed and accuracy of RFID over traditional, manual-based methods of inventory counting. As reported in a 2008 white paper on Dillard's RFID initiative, a handheld RFID reader reduced the amount of time needed to cycle count inventory (compared to a handheld barcode scanner) by 96% while simultaneously increasing the accuracy of the count. Additionally, because each RFID tag being counted has only one unique identifying number, RFID always counts only once every tag the reader sees. The ability for RFID to count individual items within cartons of apparel faster and more accurately than humans has been accepted as standard practice.

The audit speed is affected by many things, such as the type of item and the location of the item (i.e., in a carton or outside a carton). Often, faster barcode scanning requires additional employees to both prepare the inventory for scanning by opening cartons and/or arranging merchandise so barcodes are visible, as well as closing and sealing cartons after scanning. This can triple the cost of labor used to perform manual audits.

Inventory volumes are also a critical factor in determining manual audit costs. Since audit speeds have an upper limit, sufficient sample size audits, or 100% audits, on higher volumes require more auditors. Higher inventory volumes may cause inventory processing speeds to surpass manual item-level quantity audit speeds, thereby inhibiting 100% audits without the addition of auditors. If inventory volumes are low, 100% manual item-level quantity audits may be possible, especially when scanning speeds are high.

In any scenario where high inventory levels prevent manual auditors from keeping pace with sample sizes needed for desired accuracy and confidence levels, RFID quantity audits prove superior. For example, with a throughput of 100,000,000 items annually, how many auditors are required to achieve a 100% audit (provided by RFID)? For this example, we will assume a scan rate of 1000 per hour, 250 work days, and 8 hours per shift, although any values can be substituted.

$$\frac{\text{Unit Volume}}{\text{Annual Labor Hours}} \text{ x } \frac{1}{\text{Barcodes Scanned per Hour}}$$

$$\frac{100{,}000{,}000 \text{ (Items)}}{250 \text{ (Annual Work Days) x } 8 \text{ (Hours per shift)}} \text{ x } \frac{1}{1000 \text{ (Items Scanned per Hour)}} = 50 \text{ FTEs}$$

Note that 50 full-time employee (FTE) auditors are required to audit (i.e., barcode scan) 100 million items in total (annually).

To derive a base wage cost per item for these 50 auditors, we calculate their annual wages and divide by the number of items they audit (assuming $10 per hour).

$$\frac{\$10.00^{5}\ \text{(Minimum Wage+Benefits) x 8 (Hrs per shift) x 250 (Annual Work Days) x 50 (Auditors)}}{100{,}000{,}000\ \text{(Items)}} = \$0.01/\text{Item}$$

The 1 cent derived above denotes the auditor wage cost per item when using manual auditors to scan 100% of 100 million items passing through an audit point within the supplier DC. As discussed above, supplier DCs often have three audit points: receiving, pick/pack, and outbound. Performing 100% manual item-level quantity audits at each of these points would require an additional 50 auditors at each point, or 150 auditors in total. This raises the auditor wage cost per item to 3 cents per item.

The basic cost equation above calculates auditor wage cost per item when using manual auditors to scan 100% of 100 million items. However, this does not include total compensation and only accounts for the cost of auditors needed to perform actual audit scanning. As stated earlier, in order to manually scan large volumes in a timely manner, faster scan rates are desired. Faster scan rates, however, often require additional employees to assist with pre and/or post handling of cartons. Manually scanning each item within each carton requires an open carton which these additional employees may need to open if the carton is sealed before auditing, such as on the receiving dock, or seal and move after auditing has taken place.

Let’s assume that only a single additional employee is required to assist three auditors with pre and/or post audit carton management such as that described above. In our example, a supplier with volume of 100 million items being audited at receiving, pick/pack, and outbound points within the DC, would require 50 employees to assist auditors. This brings the total number of people required to perform 100% manual item-level quantity audit to 200 employees, with each of these employees dedicated to the audit process.

In turn, again using the same calculation as above and assuming minimum wage for these employees assisting auditors, this brings the total cost of compensation per item audited to 4 cents per item.

It is important to note that manual auditing practices have several ancillary implications. For example, it is likely that auditors will be working multiple shifts and 2nd shift hours may cost more than 1st shift hours. Auditors are employees, and all employees utilize internal support resources such as training, and managerial oversight at additional cost. Common human resource issues such as unannounced sick days may add additional burden and cost. Sick auditors may require replacement with temporary untrained auditors, thereby perhaps leading to inaccuracies in the audit processes performed by the temporary auditor.

[5] Note that the wage rate assumed for these auditors is minimum wage. This is a conservative estimate since auditors positions are often considered more skilled than, for example, loaders and packers, and they are therefore often paid above minimum wage. Additionally, auditors often hold FTE positions and receive benefits. An hourly wage rate of $10.00 per auditor is used in the above calculation.

Manual accuracy, accountability, and reliability can affect manual item-level quantity audit overall output quality which may remain undetected, thereby eroding accuracy confidence even with 100% manual audits. For example, an auditor may simply scan one item multiple times in order to meet performance metrics.

Besides requiring additional auditors, manual audits take up physical space within the building which can be practically inconvenient or impossible to implement, as well as incrementally introducing greater degrees of error due to increased scale. Internal shrink may also increase with increased numbers of employees.

From the standpoint of inventory flow and movement within a supplier DC's four walls, implementing 100% manual item-level quantity audits may simply not be possible. Firstly, every carton needs to be opened and resealed. Open cartons present greater shrink liability than sealed cartons. To limit this liability, the location and timing of open cartons needs to be carefully managed. The duration cartons are open can be correlated to higher shrink. Specifically, the shrink risk from 100% manual item-level quantity auditing is that cartons opened for auditing are being actively worked on by a large number of people who have their hands in the cartons, perhaps in restricted physical surroundings where unwarranted behavior may be easier to mask.

Restrictions in physical space can also inhibit 100% manual item-level quantity audits. The mere act of manually auditing every carton arriving on the receiving dock, flowing out of pick/pack, or staged on shipping docks can present logistical impossibilities and may inject more error into inventory than is the process is designed to remove.

Damage to items has higher potential with every touchpoint. Box cutter blades or simply packing methods might pose new problems. Additionally, with apparel, final carton packing and presentation is often governed by numerous guidelines against which retailers claim for non-compliance. Even with auditors and/or packers well versed in these guidelines there exists a higher potential for error the more times a single carton is repacked after auditing, or when more cartons are packed and repacked.

6.2 Cost Implications

To determine the cost implications of utilizing a RFID solution to achieve 100% inbound, pick/pack, and outbound audits in a supplier DC, the variable cost of RFID (i.e., tag cost) is compared to the variable costs associated with manual auditing. In addition to such costs, as an example of one potential negative outcome of inaccuracy, claims costs to suppliers associated with observed error rates are considered. As discussed earlier, inaccuracy carries many inherent costs, up to losing the retailer as a customer. At a minimum, some type of claim (or chargeback) is inherent with inaccuracy. In Table 6-1, we provide an example using sample data to illustrate the costs. Of course, every supplier is different; thus, we invite suppliers to download[6] the

[6] The spreadsheet can be downloaded at http://itri.uark.edu/rfid-manual-audit-costs.xls

simple spreadsheet to conduct their own analysis of costs. In this particular example, we have varied only the error and scan rate between two manual audit strategies and compared them to RFID costs. Note: we are examining only the variable costs per item of manual versus RFID.

Manual Audit Variable Costs	Scenario I	Scenario II	RFID	RFID Variable Costs
Number of items	100,000,000	100,000,000	100,000,000	Number of items
Scan rate per hour	1,000	400	∞	
Labor rate per hour	$10.00	$10.00	$ -	
Number of audits	3	3	3	
Audit costs per item	$0.03	$0.08	$ 0.10	Tag cost per item
Total audit costs	$3,000,000.00	$7,500,000.00	$10,000,000.00	Total tag cost
Error rate	5%	1%	0.01%	
COGS per item	$2.00	$2.00	$2.00	COGS per item
Claims cost per item	$0.10	$0.02	$0.00	Claims cost per item
Total claim costs	$10,000,000.00	$2,000,000.00	$20,000.00	Total claim costs
Total costs	**$13,000,000.00**	**$9,500,000.00**	**$10,020,000.00**	**Total costs**

Table 6-1: Manual Audit vs. RFID

In Table 6-1, parameters are based on data collected from the participating apparel suppliers. This particular example assumes an annual facility throughput of 100,000,000 items. In Scenario I, a scan rate of 1000 items per hour yields an estimated manual audit cost of $0.01 per audit. Interestingly, the total audit costs to achieve 100% audit at three locations within the supplier facility are estimated to offset nearly 30% of the RFID tag costs for 100,000,000 items. In Scenario II, at a scan rate of 400 items per hour, the total cost of the manual audits becomes $7,500,000; thus, 75% of the total RFID cost.

While the variable costs of manual auditing offsets a sizable portion of the RFID tag costs (using the above scenarios), the incremental claims costs associated with the higher error rates of manual audits can be even more substantial. Throughout the Phase II research, the research team collected supplier error rates on inventory flowing from the supplier DC to retailers. As mentioned earlier, error rates as high as 5% were discovered during the research. At 5%, used in Scenario I in Table 6-1, notice that total claim costs are estimated to be $10,000,000. We contrast this cost with the claim costs associated with the “known” RFID error rate of 0.01%, which is only $20,000 for an annual throughput of 100,000,000 items, leading to a substantial decrease in total annual costs. In fact, total costs are estimated to almost decrease by a third when using the RFID solution to audit 100% of items, versus a manual audit program with a 5% error rate.

In addition to the comparison of manual versus RFID at the error rate upper bound, Scenario II in Table 6-1 provides a comparison of a very low manual audit error rate. Throughout Phase II, the research team also collected evidence indicating that error rates of approximately 1% could be achieved through manual audit programs. Lower manual audit error rates were correlated with slower scan speeds. Thus, Scenario II uses 1% as an error rate when scanning at 400 items per hour and makes the comparison to a RFID solution. At the 1% error rate, the total variable costs of a manual solution are approximately 95% of a comparable RFID solution (with a tag cost of 10 cents per tag).

While Table 6-1 can be used to compare the costs associated with achieving 100% audits through both manual and RFID solutions, note that the existing comparison is relatively simple. In fact, it is plausible that many additional benefits of RFID versus manual auditing exist. These additional benefits are described in Section 7. It is also important to recognize the sensitivity of the analysis presented in Table 6-1. Tag cost for the RFID solution is, obviously, the biggest factor. A 1-cent change in per tag cost can have a substantial impact. For the manual audits, the scan rates, throughput, wage rates, item cost, and error rates have significant impacts on the final costs. It is plain to see, therefore, in this simple analysis, the manual audits have many more variables that can impact the final outcome. While the values we have chosen to demonstrate in Scenario I and II are based on sample data compiled from our observations, suppliers can easily use the spreadsheet to conduct their own analysis.

It is important to recall one important point about this comparison – we are comparing scenarios involving 100% audit. As discussed earlier, it is unlikely that suppliers can practically audit 100% of their items. The number of auditors required and the associated management and facilities costs are likely prohibitive. With less than 100% manual audit, the error rate increases. We invite readers to conduct their own cost analysis using the spreadsheet and realistic values from their own companies.

Using a variety of values for the key variables for Table 6-1, yields a graphical representation of costs such as that shown in Figure 6-2. Figure 6-2 represents the marginal cost of item-level quantity audits using RFID versus the marginal cost of item-level quantity audits using manual labor. Graphically, it is easy to see the added costs of manual audits versus RFID audits. Essentially, RFID costs remain relatively unchanged regardless the number of items. By comparison, the costs of the manual audits increase as a function of the number of items. As discussed earlier, at lower quantities (and perhaps less than 100% audit), the cost per item would be relatively flat (i.e., the cost per item remains relatively constant). However, as quantities increase, the costs (at some point) per item increase because added overhead costs of managers and physical facilities, for example, would have to be added. When considering claims, the entire cost line for manual audits shifts upwards to reflect the cost of the errors that are injected into the system due to manual audits. Furthermore, it is likely that the claims cost per item would increase with additional quantities due an increasing percentage of errors (in Figure 6-2, we assume the error percentage is constant). Overall, the added labor effort and cost needed to audit higher inventory quantities, and associated claims, increase as the inventory quantity increases for manual audits. Whereas, with RFID, once initial equipment costs have been incurred, increases in audit quantities do not increase capital or operational costs. Please note: Figure 6-2 is used for illustration purposes only; the shape of the manual auditing line and the claims line would depend on the many factors presented in Table 6-1.

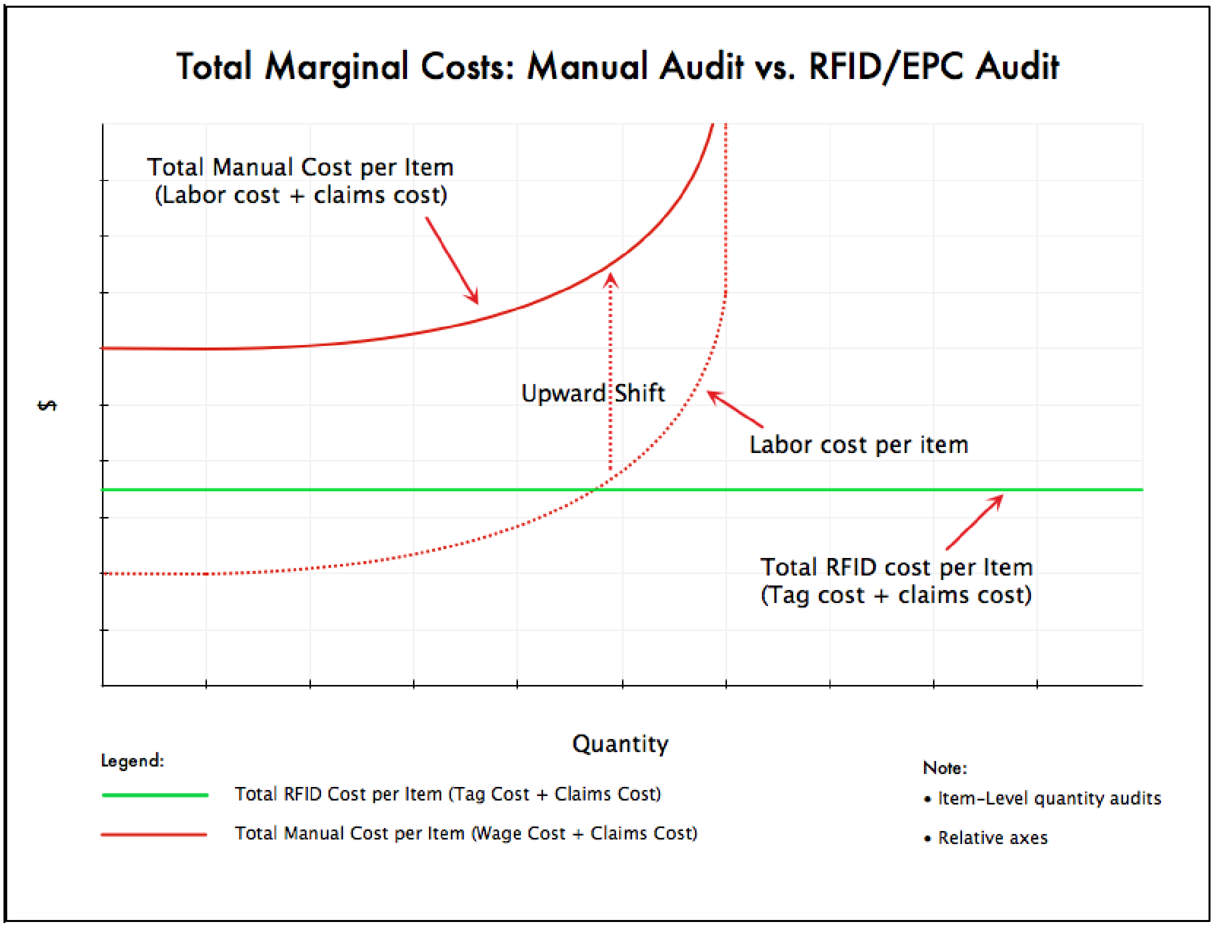

Figure 6-2: Total Marginal Costs of Manual vs. RFID Item-Level Quantity Audits

Another way of viewing this benefit is by type of error in the system. Type I errors are false positives, meaning that you incorrectly reject a batch (or, incorrectly order additional audits based on the results of the audit). Either way, the supplier has incurred additional costs unnecessarily. Type II errors are false negatives, meaning that you failed to reject a batch that should have been rejected. In this case, the error can be costly for the supplier as they are sending an inaccurate shipment. RFID assists with the costs associated to both types of error.

In type I errors, after the initial fixed cost of installing RFID equipment, there is little to no marginal cost associated with performing audits on additional numbers of items. As fast as a conveyor can, for example, move cartons past the reader, an audit can be performed on each tagged unit within the carton. In turn, this means there is little or no cost associated with what might otherwise be unnecessary type II auditing. Additionally, type II errors, which are the probability of shipping a customer an inaccurate PO, present a significant opportunity for reduction when almost one hundred percent item-level auditing can be performed on each outgoing carton's contents.

7 Additional Benefits of RFID

7.1 Electronic Proof of Delivery (EPOD)

It is possible that retailers may use RFID electronic proof of delivery (EPOD) as a system of record. Retailers might use RFID item-level counts to prove receipt of goods, or to claim against suppliers for any inaccuracies in goods received. It is likely that suppliers, once presented with claims originating from RFID data captured on a retailer's receiving dock, will want to ensure that they possess item-level RFID shipping data as a countermeasure capable of disputing any RFID claims made by the retailer.

7.2 Process redesign

RFID has the ability to create visibility into the contents of cartons and, thus, enable innovative processes. RFID creates the ability to count and verify the contents of cartons without opening the carton. Such changes potentially eliminate the need for cartons to be screened or audited by both the retailers and suppliers. Further, suppliers have explained that the ability to verify the accuracy of unopened, cross-docked cartons would allow them to confidently and dynamically assign certain vendors Direct-Customer-Delivery status, thereby avoiding any need to cross-dock that merchandise. Such channel redesign may have significant cost reduction implications.

7.3 Through-Channel Visibility

Many apparel suppliers are faced with limited availability/timing of partner data from either upstream or downstream in the chain. Inventory can arrive before an associated ASN. At the retailer's receiving dock, an entire BOL is rejected because of some quality error which is difficult to pin-point or trace to cause. Retailer requirements can alter rapidly resulting in, for example, a sticker color change being requested on product that has passed the point of manufacture and has already entered the supply chain, requiring an entire shipment to be unpacked, reworked, and repacked as it passes through the supplier's DC. There are no returns on transcontinental inbound product. It is accepted in entirety, and sometimes with no verifiable documentation on contents. Being required to accept everything arriving on your receiving dock encourages high levels of accuracy and confidence in what inventory items you're injecting into your supply chain.

7.4 Reducing Inventory Holding Costs

Suppliers have stated how very high levels of accuracy and zero tolerance of defects are desired. These levels are sought for several reasons. At constant inventory levels, increased product accuracy results in increased customer service. Increased customer service can have far reaching consequences, many of which are hard to characterize or predict in dollars. More measurable is the effect of maintaining both type I and type II customer service levels while internally reducing inventory levels as a result of greater inventory accuracy.

7.5 Lowering Cost of Goods Sold

Any ability to more accurately measure, and therefore more confidently prove, the quality of a trading partner's level of professionalism, allows the potential for renegotiated contractual terms with that partner. For example, a US brand owner might receive product from a third party contract manufacturer into their local DC on US soil. The agreed upon purchase price and payment terms might be linked to the level of consistent quality of the received merchandise. For every 0.5% of *discovered* error in quality, there might be a pre-negotiated, associated reduction in the overall purchase price.

The ability of RFID item-level quantity audits to discover a greater degree of inaccuracy has been proven in the earlier discussion on accuracy and confidence. Therefore, early adopters of RFID item-level quantity auditing will gain a competitive advantage over their merchants and capitalize on increased reductions in purchase price.

7.6 Increasing Price

Through greater levels of inventory accuracy, the overall quality of shipped product can be raised. Verifiable accuracy of outbound shipments from a supplier to a retailer can have two major effects on price. Firstly, through the ability to ship more accurate inventory, the number of potential claims against inventory accuracy can be reduced. A reduction in claims, and the associated costs of both lost payment for mis-shipped inventory as well as claims disputation, have the equivalent effect of an increase in purchased price paid to the supplier.

8 Challenges

8.1 Manufacturing facilities

Deploying RFID within an established manufacturing facility, often offshore and with questionable technological infrastructure, is currently not the primary thrust of suppliers' efforts. Operations managers within manufacturing facilities have expressed optimistic enthusiasm for many of the potential benefits uncovered during the first phase of this study. However, the degree of physical infrastructure and cost of support needed, limit the current effectiveness.

Additionally, many legacy systems employing the use of barcodes for inventory tracking or incentive-based pay systems are still relatively new, skeletal, or limited or have not yet realized amortization tables for their capital expenditure. Making implementation even more difficult, barcode tracking is sometimes not yet in place, and manual systems of record are maintained, whereby data capturing and interchange infrastructure is needed before systems can be deployed in some manufacturing facilities visited during the study. Additionally, there was observed a change-management paradigm in some manufacturers who believe their current methods for managing inventory, while inefficient, are sufficient; and resist the potential benefits discussed in phase I of this study.

8.2 Legacy data systems

As with many older industries that began evolving long before the relatively nascent spectrum of computer hardware and software, the apparel manufacturing segment is rife with disparate legacy data support systems which are often only connect through a simplistically formatted single stream of limited forwarded information. Sophisticated, synchronous networks coordinating purchase orders across, for example, all ticket printers within an enterprise, are rare. However, data management within supplier DCs was discovered to be more refined.

9 Conclusion

In this study, we further explored use cases discovered during Phase I of this research. In particular, inventory accuracy was examined. Unlike retailers who focused on improving inventory accuracy, the focus of suppliers was on the cost to keep inventory accuracy high. Suppliers spend an extraordinary amount of time and money to ensure inventory accuracy is high – to avoid claims and keep a good relationship with their customers (the retailers). As demonstrated herein, manual audits are currently used at receiving, pick/pack, and shipping to ensure high inventory accuracy. In almost all cases, a sampling method is used (e.g., selecting 10% for auditing), rather than conducting 100% audits. Likely, 100% audits across three audit points (receiving, pick/pack, and shipping) are not practical. Conversely, with RFID, 100% audits are possible. Furthermore, the cost per item does not increase with RFID, as it does with manual audits. As an illustration of the costs of manual audits versus RFID, we chose two scenarios with different scan speeds and error rates. In Scenario I, more than 100% of the tag cost is realized. In Scenario II, ninety-five percent of the tag costs can be realized from this one use case. Note the significance of this – in Scenario II (a scenario which favors manual auditing), three quarters of the cost of a tag could be covered from one single use case and, as indicated in Phase I, there are 59 additional uses cases yet to be examined! We view the results as further evidence that RFID, compared to existing manual methods, provides not only a viable alternative, but in this case, provides both a financially attractive and practically feasible solution.