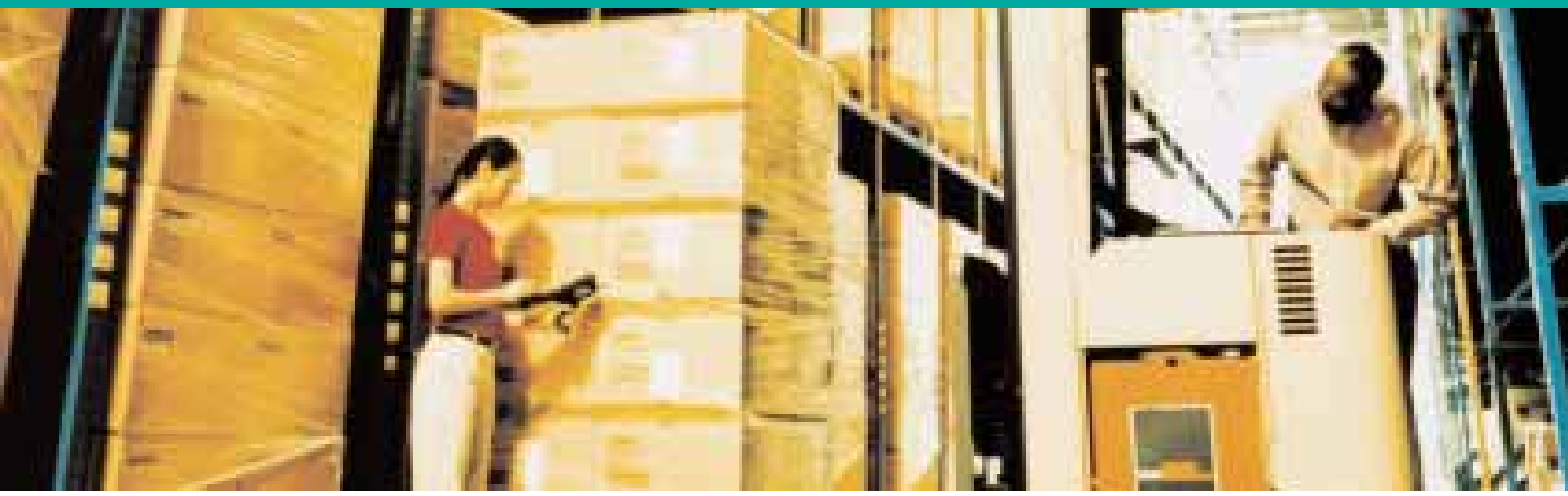
SAP University Thought Leadership Supply Chain Paper



Center for Supply-Chain Research

The RFID-Enabled Warehouse

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Penn State

2004

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RFID DEFINED

Radio Frequency Identification …or RFID… is a class of technology that has been with us for several years in the form of active transponders to track rail cars and containers, EZ Pass tags for road and bridge tolls, and even the ExxonMobil SpeedPass. The history of RFID extends back to the *Identification Friend or Foe* (IFF) systems introduced in the 1940's by the United States military. In its newest incarnation, the passive "Smart Tag" is being heralded as the missing link to enable all objects in the supply chain to know what they are, where they are, what condition they are in, and what they can do.

RFID is also often referred to as Automatic Identification, or AutoID. It is aimed at performing many of the functions of bar coding, but has the advantages of convenience since "line of sight" is not required and content is expanded since an RFID tag can contain more information. RFID is envisioned as becoming the principle data capture means of "sense and respond" systems and autonomic, self-healing "adaptive supply chains". See Figure 1 for a classification and the future of RFID.

Many analysts have concluded that RFID is one of the most "disruptive technologies" in the last 10 years, one that will have a lasting and dramatic impact. That is nearly a foregone conclusion.[1] The past year saw ample evidence of this prediction. Supply chain powers such as Wal*Mart and the Department of Defense declared RFID an important part of their future and mandated its adoption to their suppliers. There are two enabling forces behind this recent activity – standards and cost. EPCglobal, a worldwide standards organization, has worked with industry leaders to develop a standard for communicating information between the various supply chain parties. This year an important standard was introduced and is called the Electronic Product Code (EPC). In addition, newer technologies have been developed to reduce the cost of the RFID tags – an integral piece of RFID enablement; and with increased competition and volume, the prices of hardware components such as labels and readers continue to fall.

Recently, EPC global decided on a global standard for tracking goods with RFID tags carrying an EPC code. The global standard, the EPC global's Generation 2 specifications, combines aspects from two previous proposals that were supported by RFID vendors. With the Generation 2 specifications created, RFID vendors can begin developing tags and readers based on these standards.

Predictions of the eventual benefits of RFID are across the board, including enabling of the reductions of large swaths of supply chain inventory, substantial reductions of warehouse and store labor, and the prevention of billions of dollars of lost sales. One large consumer products manufacturer


has predicted that the adoption of RFID will lead to reducing its total supply chain inventories by as much as 50%. One prediction of direct benefits to Wal-Mart is $8.4 billion per year.[3]

But if RFID is a disruptive technology, it is also an emerging one, and there will be challenges. Many of the predicted benefits are predicated on using RFID tags at the item level – something that might be years away. The RFID technology itself is currently not as reliable as barcodes, but improvements are being made to ensure better accuracy. There are also significant costs related to the information systems that must be developed and installed. One of the key challenges faced by managers is the justification of the large installation costs. In its initial manifestations, RFID's main deployment will be aimed at improving efficiency in warehousing. Indeed, the Wal*Mart and DoD mandates only require suppliers to have RFID tags on cases and pallets. Still, this technology increases costs for vendors as they adjust to the new requirements.

The objective of this white paper is to explore the implications of RFID on warehousing: what it is, how it will work, what will be its benefits, what will be the implementation challenges, and what are some best practices for going forward. The first section of the paper will provide more background on RFID. The next section will examine how RFID will be used in warehousing, how it will provide benefits, and provides a review of challenges to implementation. The last section of the white paper will provide prescriptive advice on how companies should proceed in realizing the "RFID-Enabled Warehouse".

RFID: HISTORICAL BACKGROUND

RFID History

Radio frequency identification (RFID) is a form of an automated data collection system. It first appeared in tracking and access applications during the 1980s. These wireless Automatic Identification and Data Capture (AIDC) systems allow for non-contact reading and are effective in manufacturing and other business operations. RFID has established itself in a wide range of markets including livestock identification and automated vehicle identification (AVI) systems because of its ability to track moving objects.

By itself RFID has limited use, but coupled with applications that convert the raw data into useful information, a solution can be designed that provides incredible benefits to an organization. In today's business environment, where supply chains are getting leaner and at the same time more responsive, RFID solutions in many cases provide the needed functionality to produce significant benefits, including: 1) cost reduction; 2) increased data accuracy; 3) improved workforce efficiency; 4) streamlined business processes; and 4) improvement in an organization's ability to execute.

How RFID Works: The Components

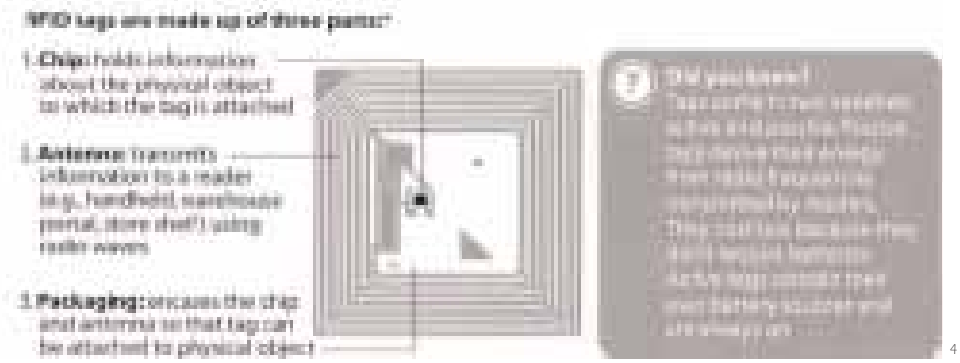
Figure 1:
Understanding RFID and its Uses

Technology

RFID's biggest advantage is being a non line-of-sight communication technology. Eliminating the need for line-of-sight communication allows products, cases and pallets to be automatically scanned in larger volumes and at higher speeds, allowing for greater improvements in efficiency. RFID solutions consist of four basic components: 1) tags; 2) readers; 3) antenna; and 4) software. Each will be discussed briefly below.

Tags

RFID tag is a device that is placed onto, or in some cases into, the pallet or SKU. Basically, a tag is an electrical device that uses radio frequency antenna to communicate with the RFID reader. Information is stored in the tags that describe the object. Figure 2 is a schematic of a basic RFID tag.



Tags can be differentiated as being active or passive. These can be seen in the pictures below. The active tags are self-powered whereas the passive tags use the signal from the RFID reader as the source of power. While the distinction between tags might seem minimal, the impact on their capability is significant in both read range and data storage.

Active tags use a battery-powered transponder that emits a constant signal containing identification information. Active tags have the greatest range of all RFID tags, including search and read/write capability.[6] Today, they have up to 128 Kbytes of storage space, but could hold more in the future.

Passive tags have no battery, but instead rely on an antenna as the power source, drawing power from the reader's electromagnetic signal. Passive tags have a much more limited range (less than 2-3 yards), have limited storage space (as of now,128 bytes, but could hold more in the future), and lack data manipulation capabilities.[7]

Passive Tag

Active Tag

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Readers

Fixed Reader

Mobile Reader

8

RFID tag readers are simply devices that scan the RFID tags. RFID tags have an antenna that transmits and receives information. The reader decodes and reads the information. The RFID reader converts the radio waves from the RFID tag into a form that can be passed along to an information system. The cost of the readers corresponds directly to the level of functionality needed. Readers that must scan multiple items, moving quickly on a high-speed conveyor or through a dock door are significantly more expensive than the basic hand held readers.

Antenna

RFID tag readers use an antenna to communicate to the RFID tag through the tag's antenna. Some readers have integral antenna while other can have various types and sizes of antenna fitted to them. The


antenna is a critical component in the RFID system, as it has to be built for the coverage area. The antennas vary depending upon the facility location, size, area, and volume. Usually, an antenna operates in the 3-15 MHz range.

Software

Software and middleware are the most important pieces of an RFID solution. These packages are needed to make use of the information read by the reader to integrate the RFID technology with all the other systems operating in the warehouse: warehouse management systems (WMS), transportation management systems (TMS), event management systems (EMS), order management systems (OMS), and enterprise resource planning (ERP) systems. The ability to capture, store, rationalize, and integrate information captured by RFID technology, including product information, location, volume, and transactional data, allows organizations to more efficiently pick/pack, ship, route, track and distribute materials. This operational improvement can result in lower inventory levels and improved labor and equipment productivity. Integrating the information from RFID tags into an EMS or ERP system allows alerts and alarms to be sent when a certain set of conditions has occurred, e.g., inventory is running low or products have been idle too long. The information from RFID will also be useful when integrated with reporting software. Companies will be able to quickly target problem areas in their warehouse and identify areas of improved efficiency.

However, due to the lack of system standards, there can be compatibility issues that arise in the software implementation process. Standards are currently being developed at EPC global, the main organization responsible for setting industry-wide standards. Stand-alone, the RFID system is nothing more than data transmission. But through integration with other enterprise applications, the true value of the RFID system can be realized.

RFID Mandates: Current Drivers of Adoption

Wal*Mart Mandate

Wal*Mart has mandated its top 100 suppliers to install RFID tags on all shipments into Wal*Mart's Dallas, Texas, distribution centers by 2005. The remaining suppliers have until 2006 to adopt the RFID technology.[9] The Wal*Mart initiative will then have two stages of tags required. Suppliers must use 96-bit Class O tags that will be programmed at the factory by Matrics Inc. Subsequently, Wal*Mart will use 96-bit Class 1, version 2 tags with one-time read-write capabilities that are available from Alien, Texas Instruments, Phillips and Intermec.[10] Many suppliers still express concern about being completely compliant by 2005.

U.S. Department of Defense Mandate

The Defense Department (DoD) set a January 2005 deadline for its 43,000 suppliers to begin tagging cases and pallets of low-cost items and individually tagging items worth $5,000 or more with RFID tags. Extensions may be granted to suppliers with existing contracts in place, who will not be required to comply until new contracts are negotiated.

The DoD has entered into a three-year contract with IBM Business Consulting Services to help incorporate RFID technology


into its supply-chain operations. IBM's role will include overseeing pilot tests of the technology during the next few months. As a federal agency, the DoD is required to purchase a significant amount of its supplies from small businesses, minority-owned companies, and other suppliers for whom the cost of RFID technology might be out of reach.[11] Thus, the DoD has agreed to shoulder a major portion of the implementation costs.

Standards-EPC

EPC Global leads the development for setting industry standards for EPC networks that function with the utilization of RFID technology. Leading firms and industries involved with EPC networks comprise EPC Global to set these global standards. The goal of the organization is to increase the efficiency of industry supply chains and improve the flow of information between organizations. Previously, EPC network standards were set by the MIT Auto-ID Center. However, the MIT Auto-ID Center closed on October 26, 2003.

Reduction in Tag and Reader Costs

The mandate by Wal*Mart and the DoD has increased the demand for RFID in nearly all business sectors. The increase in demand over the past year is helping drive down the costs of RFID tags and readers. Experts argue that tag costs will fall to an estimated 5 to 10 cents each as the volume of tags ordered begins to increase into the billions. The same trend exists for costs of the RFID readers, which can run upwards of $10,000 for sophisticated models and as low as $200 for the most basic models.[13] As the demand for RFID technology grows, the price of RFID tags and readers will continue to fall.

RFID Implementation Examples

The following are examples of RFID system implementations in various companies in different business sectors.

International Paper

International Paper (IP) is the world's largest paper and forest products company. IP went live with their first fully automated RFID warehouse tracking system in August of 2003. Using clamp-truck-mounted RFID readers and proprietary tracking technology, inventory is tracked to within 6 inches of its location, and the information is relayed to the forklift operators via mobile computers in less than one second. A principal feature of the warehouse tracking system is the elimination of RFID portals in tracking inventory movement, including shipping and receiving locations, such as rail and dock doors. By not using portals, the system greatly improves traditional tag tracking processes. The RFID tags are placed in the cores used for paper rolls. Bar code labels on the finished rolls associate the paper with the core, and readers built onto the clamp trucks read through 70 inches of paper to identify the rolls. Additional readers on the clamp trucks use tags in the facility floor (which form a grid) to provide location data to the system as they move the rolls.[14]

Scottish & Newcastle

Scottish & Newcastle, a U.K. brewer, began to use RFID tags a few years ago to track millions of beer kegs that were sent to bars, distributors, retailers, and restaurants. The RFID technology has saved the U.K. firm $25 million dollars per year on buying new kegs to replace ones that were lost in transport or not returned by their customers.[15] In addition, the brewer uses information


from the RFID tags to track when the kegs are filled, delivered, and returned and how much beer is not consumed in the kegs.[16]

Procter & Gamble

Procter & Gamble needed to speed production at a manufacturing plant in Spain to the point of loading 33 pallets in 20 minutes onto a delivery vehicle. A team headed by Adam Vilalta of P&G decided to use RFID tags on the pallets which resulted in a 40% increase in speed of loading the pallets and 100% read accuracy.[17]

Gillette

One of the most recent and most successful RFID implementations has been at Gillette. In January of 2003, Gillette contracted for 500 million Class 1 EPC tags from Alien Technology. Gillette has been using the order to tag all pallets and cases of their Venus women's razors at their Fort Devens facility with the goal of understanding how EPC technology can be utilized to achieve "breakthrough" benefits in its supply chain. According to Gillette, the true goal of their pilot program is not to see if the tags on pallets and cases can be read automatically, but to develop business processes and systems required to sustain extraordinary levels of efficiency and productivity.[18] Gillette is also working with its WMS and TMS provider, Provia, to ensure that the RFID information can be integrated into the appropriate systems.[19] Below is an explanation of how Gillette has incorporated the tags into their processes.

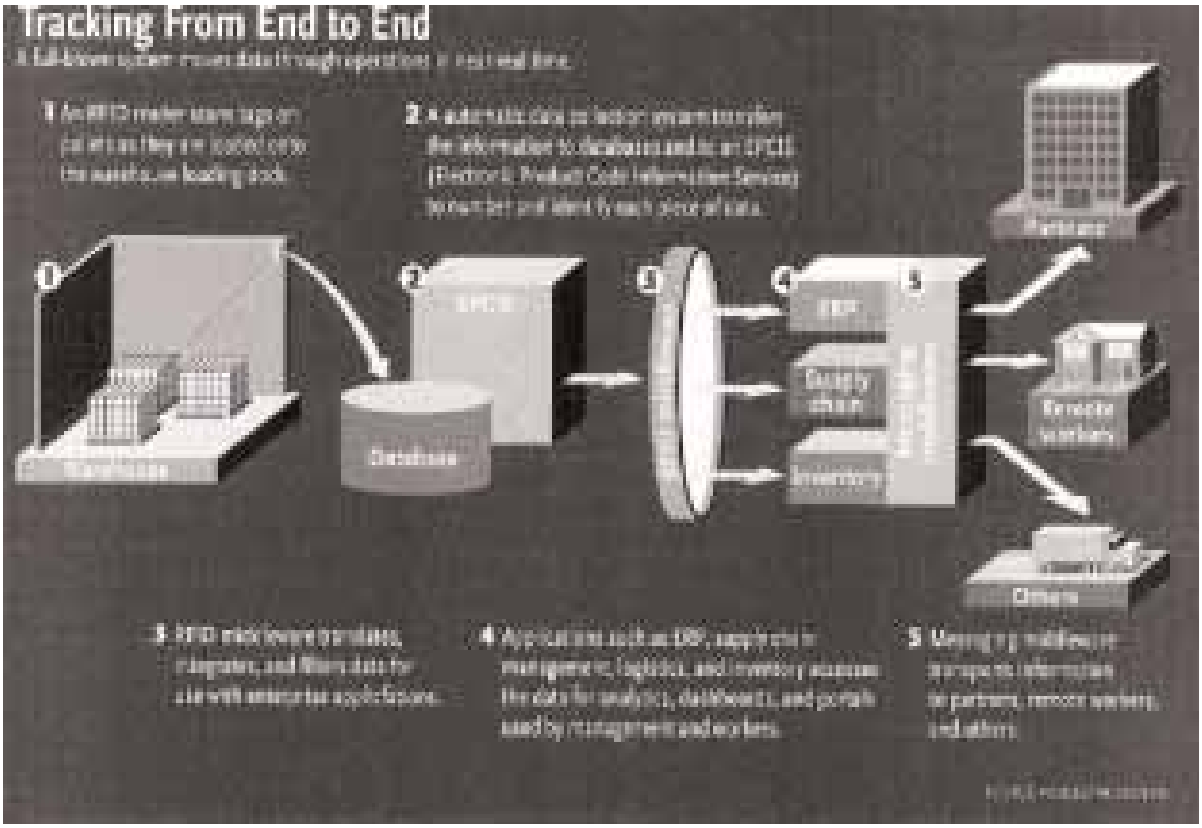
In the meantime, the DoD has reportedly conducted a number of RFID pilot programs, including the simulated tracking of food rations and the tracking of chemical suits.

At the first station in the facility, workers apply the Class 1 EPC tags manually to the cases. Gillette plans to switch to an automatic labeling machine before the end of the year. Once the cases are labeled, they are sent down a conveyor. There are readers with antennas set up on either side of the conveyor to write the EPC number to the tag. As the case continues down the conveyor, another reader confirms that the serial number was written correctly. Once confirmed, the EPC is stored in the central database. This allows Gillette to track that specific case until it leaves the facility. Next, the case is retrieved and hand-stacked on a pallet so that the EPC tags on all 60 cases face outward so they can be read. Once the pallet is fully loaded it is sent down another conveyor to the distribution center. The tags on the pallet are read as they move down the corridor. Currently, the EPC allows Gillette to automatically record how many pallets were completed and when they were transferred to the distribution center with 100 percent accuracy and no manual intervention.

Once the pallets are recorded, a forklift operator picks up the pallet and moves it to the appropriate area. Each forklift is equipped with an EPC reader, to read the tags on the pallet being carried. When the pallet is stored within the facility the reader also reads an RFID tag at the location, so the geographic location of that pallet can be entered into the system. When the pallets are ready to be picked or moved, a forklift retrieves the assembled pallet and drives through a tunnel equipped with antennas connected to an EPC reader. Software confirms that the type and quantity of products on the pallet matches those ordered. The last stage in the warehouse has antennas mounted on a thin steel column at each dock door to scan the pallets and confirm that the right pallet is being placed on the right vehicle.[20]

RFID USES IN WAREHOUSING

Warehouse Applications



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Receiving

RFID tags might have the most potential to improve the warehouse's receiving processes. Under current bar coding practices, a worker must scan each product or case before it's moved into the warehouse. RFID technology allows significant improvements in the throughput speed of product at the receiving dock. The RFID scanner reads the shipment within seconds as it passes through the portal readers. Additionally, the RFID technology eliminates the need to physically check the bill of lading and/or the packing slip. Furthermore, RFID will connect with the WMS system to indicate if a product needs a cross-dock movement. Cross-docking is one of the most efficient processes for moving inventory through a warehouse without storage. Cross-docking is initiated at the receiving dock. When a product is received and scanned, the WMS interfaces with the OMS to determine if this product is needed to fill an open order. If so, the product is moved literally "across the dock" to the outbound dock (or picking/packing) so the order can be completed and placed on the waiting vehicle. If the item is not needed to satisfy an open order, it is placed into storage. RFID will make this "open-order" identification faster and more reliable than traditional bar code scanners because it will occur when the product is pulled from the delivery rather than after it has been placed on the receiving dock floor. The benefits from


not scanning each shipment, automated bills of lading, and improved crossdock movements reduce labor costs and allow the receiving docks to handle a greater amount of product. For instance, if an incoming load is needed to refill an out-of-stock item or is scheduled to depart on a cross-dock movement, the RFID system designates the load as high priority and communicates this information to the worker.[22] In addition, the RFID system will help manage the flow of damaged goods into the warehouse. The damaged goods that are set aside can be read by the RFID technology as received as damaged. This process will significantly reduce labor hours spent on managing the damaged goods process.

An RFID system also offers greater efficiencies in warehouse systems that rely on conveyors. RFID eliminates the need to ensure that cases/items are placed properly on the conveyor so that the bar code can be read accurately with the bar code reader. Normally, this means that the bar code is "face-up" or on top of the box since many bar code readers scan from above the conveyor. RFID allows for accurate reads regardless of product position, resulting in fewer reading errors. Elimination of product positioning requirements on the conveyors will also improve the speed of overall product flow through the warehouse. This will also reduce labor costs since additional workers will not be needed on the conveyor to reposition products so the bar code is facing the proper direction.

Storage

RFID technology also provides benefits in put-away accuracy and efficiency. Forklift drivers could still rely on the current WMS system to identify the locations for pallets and products. However, an RFID system can eliminate the need to scan the bar code on the pallet and at the slot location in the racks. For example, if the pallet and slot location read by the RFID scanner do not match the WMS specification, the system notifies the driver that the product has been placed in the wrong location.[23] Moreover, the need for additional bar codes on each pallet is eliminated. This pallet identifier bar code is also called a "license plate." Since a single scanner can identify all of the RFID tags on individual products, the placement of a license plate on the pallet level would not be necessary.

Additionally, RFID has the potential to improve temporary storage at the warehouse. Since the RFID tags can be read from anywhere, products and pallets do not have to be placed in specific or assigned locations. This is called a random location system. It is also operable with bar codes. This random system allows for a much more flexible storage environment and can help to minimize honeycombing (honeycombing is a situation that arises in a racked warehouse where large empty rack slots exist among filled slots). RFID-related applications can also be used to identify product compatibility problems. If non-compatible or hazardous products are stored near each other the RFID system could alert the employees for an immediate removal of one of the products.

Pick / Pack

RFID readers can integrate with the WMS and OMS systems to ensure that the correct items and amounts are picked. Another benefit of RFID is to help measure productivity in the warehouse. Through a type of RFID-enabled time-motion measurement, management could analyze the process to set benchmarks, evaluate employees and plan labor requirements. This is also enabled by bar code systems. The difference is that with RFID systems, manual scans of products are eliminated.


Shipping

An RFID reader can confirm that each item is placed onto the correct outbound vehicle, which can improve the accuracy of the shipping process. This verification can be made as the product moves through the portal of the outbound dock door. These processes allow for an automatic double check of the items loaded into the trailer against the bill of lading (a bill of lading must accompany each shipment tendered to a carrier; it is, among other things, a description of the shipment) or manifest (a manifest identifies the products and their locations in the outbound vehicle). It should also be noted that the use of RFID could greatly reduce the amount of employee theft in a warehouse. Placing RFID readers at exits of the facility and employee areas ensures that all items leaving the building are accounted for, regardless of the removal method.

Companies can expect savings in labor and other efficiency benefits from RFID. Table 1 summarizes where RFID cost savings lie within warehouse operations in terms of percentage savings.

Table 1: Cost savings in a distribution centre through RFID

Task	Labour Cost	Estimated savings with Auto-ID
Receiving	5%	80–100%
Put away/replenishment	20–30%	20%
Picking	30–50%	50%
Shipping	5%	80–100%
Check-in	20–40%	80–100%
Overall		40–60%

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What are the Benefits of RFID?

Labor Productivity

Worker productivity levels will increase in the receiving area of the warehouse. Instead of manually scanning each inbound shipment and verifying it with the purchase order, the increased automation from the RFID technology permits employees to eliminate manual operations in the receiving function which will allow products to move to storage or the outbound dock faster. Other tasks that receiving can complete more efficiently with RFID are: 1) facilitating the return process of damaged or unsaleable goods; 2) improving quality control (on order integrity); 3) increasing put away rate; and, 4) minimizing errors in placement of shipments (crossdock or storage). Forklift drivers will also have an easier time putting away items in assigned and unassigned slot locations. There would be no need to scan an additional barcode on a pallet at the slot location. Furthermore, RFID technology would eliminate the need for physical inventory counts and reduce cycle counting. Moreover, employee's work location can be tracked through RFID technology revealing the amount of activity recorded. These studies will increase work productivity by providing employees with incentives to work more efficiently and effectively.

Inventory Reduction

By installing RFID technology into a warehouse, organizations reduce many of the challenges associated with inventories. RFID tags provide more visibility to the products so their location is more easily determined in the warehouse. This increased visibility reduces the likelihood of a stock-out occurring because of misplaced inventory or


inaccurate inventory levels. Cycle service levels will also improve due to lower safety stock levels and the overall faster throughput of product at a warehouse. According to an inventory management report, RFID technology will reduce total system inventory by approximately 5%.[25]

Facility/Equipment productivity

RFID technology allows more data to be processed faster through a WMS. The WMS uses the acquired information to improve the operations of the warehouse. If vehicles are scanned as they enter the inbound gates of the warehouse, dock utilization improves because the WMS can more effectively assign vehicles to unloading doors based on order priority. If the product is not needed right away, the WMS would assign the vehicle a position in the yard. RFID technology also removes the need to manually place bar coded items on conveyors in a specific orientation so that barcode readers can read them.

Other Benefits

There are several other benefits to the warehouse using RFID technology. Shrinkage, which is product stolen by employees along with misplaced items, will be reduced because the warehouse will have a better understanding of where the products are located and it will be more difficult to move products out of the warehouse without being detected. Forecast accuracy will also increase due to higher levels of visibility of product throughout the supply chain. This improvement will positively affect the overall efficiency and effectiveness of the warehouse in areas such as: 1) order cycle times; 2) safety stock levels; 3) fulfillment accuracy; and, 4) cycle service levels.

Barriers and Challenges to Implementation

The immaturity of standards is also a barrier. Delays in arriving at the current Generation 2 specifications have pushed back implementation for many developers of RFID-related technologies.

Reliability

The reliability of the RFID tags is still an issue with many of the tests and pilot implementations. For example, RFID accuracy from Wal*Mart's latest implementation average between 70-75%.[26] Most of the general issues with accuracy are related to multiple reads and no reads because of readers inadvertently scanning adjacent products and/or double scanning the same product. Another challenge is that products containing metal or liquids will reflect or absorb, respectively, the signal from the RFID scanner. Metal racking systems could also pose a problem for reflected signals. Additional problems occur with data overload from the high-speed movements of products. "No-reads" create a unique problem for RFID technology at the present. With bar code technology, the reader can detect if it did not read a bar code. With RFID technology, a no-read goes undetected. For example, assume a pallet contains 50 boxes with each having an RFID tag. The stacking pattern is uneven so a simple row by column calculation cannot determine the number of boxes on the pallet. If the pallet is scanned and five of the boxes on the inside of the pallet pattern are not counted, the count shows 45 boxes total on the pallet. This could have challenging impacts on inventory accuracy in the warehouse.


Some of the solutions offered to solve these problems include arranging packages in a certain method to avoid errors and developing completely separate strategies to scan, store, and ship products that have material that interfere with reads such a liquids and metals. Rich Fletcher, a visiting scientist at the Packaging and RFID Special Interest Group of the MIT Auto-ID Labs, expects a rough solution to handling items with liquid and metal to be available in a year, and a more finished product that could be used in all supply chains within a few years. However, there are currently niche RFID applications available today that can be used with certain types of metal-foil packaging. Fletcher hopes that guidelines eventually will be developed to help retailers and CPG companies place RFID antenna in appropriate locations. In the meantime, it is recommended that retailers and suppliers leave space between RFID labels that contain the antennae and that they take the placement of labels into account when stacking boxes. The end objective is to develop built-in labels so that end users will not have to be concerned with the placement of products or the RFID tags.

IT Infrastructure Issues

One of the major concerns is the potential bandwidth requirement for an RFID system capturing all the available data from every RFID tag in a given warehouse. The potential volume of information from real-time scans moving between multiple applications for every single case or pallet in a warehouse can easily overwhelm even the most robust information systems. Hewlett-Packard uses RFID in its facilities in Memphis, Tenn.; Chester, Va.; and Sao Paulo, Brazil. These sites generate 1 to 5 terabytes of data a day.[28] Therefore, organizations must analyze the potential data from an RFID tag and determine what information needs to be captured in real time and what information can wait for a batch update. The information systems also need to be robust enough to handle the speed increases associated with a successful RFID implementation. Shorter scanning intervals, faster product movements and shorter order cycle times must be handled without sacrificing system integrity.

Another problem that must be resolved is the difference between storing UPC bar codes, which are 11 digits, and storing RFID serial numbers, or EPCs, which are 13 digits. The Uniform Code Council, a standards body for the retail and manufacturing industries, state that their Sunrise 2005 initiative requires all U.S and Canadian companies to be capable of scanning and processing up to 14-digit bar codes by January 2005. According to the UCC, this will require a replacement of legacy systems with RFID ready systems or undertaking of a Y2K-like reprogramming plan.[29]

Cultural and Social Issues

According to one supply chain professional, the biggest corporate cultural issues involved with implementing an RFID system is changing from current processes that function efficiently and produce reliable results, to unfamiliar new processes that might not even improve the current efficiency and reliability of the system. This professional argued that many employees would have to modify their daily tasks to accommodate the changes that RFID requires. This might prove to be difficult, especially if the employees cannot directly see or understand the overall benefits of RFID to the warehouse.


STRATEGIES AND RECOMMENDATIONS: A PHASED APPROACH

Some of the other social and cultural issues are not directly applicable to warehouse processes, but they include developing a technique to turn RFID tags off to alleviate customer worries about being tracked after purchase. However, there are still issues related to figuring out how to turn the tags back on so that the information stored on the tags can be used to pinpoint returned or defective items.

Dealing with Mandate Compliance

There are two overriding strategies to RFID implementation. Some companies utilize a "slap and ship" approach, or doing the minimum level of investment to slap tags onto a subset of outgoing shipments to comply with the current mandates. The second approach relies on larger investments to develop an internal capacity that impacts the supply chain upstream, in an effort to both comply with mandates and capture operational efficiencies from RFID.

"Slap and Ship"

The main goal of the "slap and ship" strategy is to invest the minimum amount of capital into an RFID implementation to comply with the mandates set forth by both Wal*Mart and the DoD. Organizations employing this strategy are not looking for a short or long term ROI on their investment; they are only concerned with being compliant with their customers so that they are able to continue doing business. However, this minimalist approach is often more involved than most firms are prepared to handle. Issues involving the correct programming of the tags and the tracking of the goods in the pilot implementation are just a few of the basic requirements for the Wal*Mart and DoD mandate. There are also many IT infrastructure and software issues that need to be addressed. According to EPC global's product manager Sue Hutchinson, "I think people are coming to the realization that they're going to be looking at communication to their back-office systems and middleware challenges sooner than they thought."[30] The "slap and ship" approach might work well for organizations not prepared to invest significant amounts of capital in RFID, but the costs involved with becoming compliant with these mandates should not be underestimated.

Building Internal Capacity

The goal of building an internal capacity to utilize RFID is to attempt to apply RFID technology to various processes within the warehouse to gain a maximum return on investment. Organizations that are employing this strategy are not just looking to become compliant, but rather to develop the ability to leverage RFID technology to provide significant cost reductions and other competitive advantages at the warehouse. This strategy involves more and requires significantly more amounts of capital investment and pre-implementation planning. Organizations must conduct an analysis of the current business processes and information systems as well as determine which areas in the warehouse will produce the greatest return. Organizations must also begin to develop pilot implementations to gain first hand knowledge of how RFID will affect their processes. These are the first steps to a successful, complete RFID implementation. After the initial tests, organizations need to develop a full RFID implementation plan incorporating the best practices learned from the pilot programs. Organizations building an internal capacity are more interested in the long term ROI of RFID, rather than viewing RFID as just a short term "slap and ship" expense for doing business.

IT Strategy

One proposed way to help alleviate the IT needs is a form of computing architecture

called edge computing. This architecture allows for processing of large amounts of data to occur at the edge of the enterprise's network rather than in large corporate data centers.[31] This strategy reduces the bandwidth required to move the data to a corporate data center and reduces the need for centralized processing power to analyze the data.

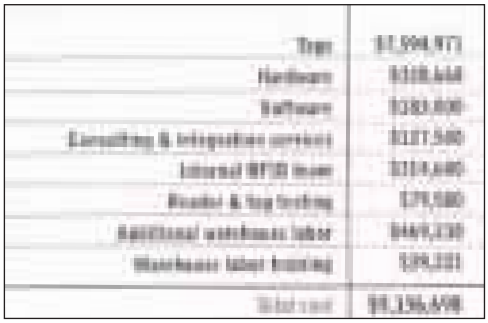
Making the Business Case

Hardware, Software, and Re-Engineering Costs

RFID technology does not come without a cost. The cost of RFID hardware is a significant increase compared to the cost of bar code technology. Today, RFID tags alone cost between 25 cents to 30 cents per tag down from 40 cents the year before.[32] The complicated technologies involved along with the input materials are the source of the high cost. RFID tags consist of a smart chip, antenna, bandwidth, and batteries (some tags). However, manufacturers of the RFID tags are progressing to drive down the costs of the tags to an estimated 5 to 10 cents each. For this to occur, RFID manufacturers need companies to order a higher volume of tags to lessen the per tag costs of material, labor, and manufacturing costs through greater economies of scale. Lower costs will allow organizations to reap more benefit out of the RFID technology especially on those products with lower selling prices. For example, placing an RFID tag valued at 30 cents on a $1000 television does not pose an economic problem. Placing the same tag on a 50 cent candy bar does. Until the costs per tag are lowered, organizations will continue to debate the cost/benefit of RFID technology. Organizations must also decide how much bandwidth they want to invest into supporting the RFID technology. The cost of transmitting and storing the increased amounts of information from the RFID tags will come with a higher price, so planning is essential to lower overall costs. Readers at a warehouse will run from $200 for low end products to $2500 for forklift installations to $10000 for dock door and high-speed conveyor installations.[33]

Furthermore, it is estimated that costs for implementing RFID readers, software, and IT infrastructure will run close to $400,000 per distribution center.[34] Costs for implementing RFID technology into a firm's entire supply chain have been estimated to be approximately $35-$40 million.[35] Fortunately, fixed costs represent a large percentage of the costs accompanying an RFID implementation. Operations at the distribution center will alter due to the change in process of the RFID technology. The new process will require the company to train employees to take on other tasks at the warehouse such as maintenance of software. Firms should expect a cost of approximately 10% of the software system for maintenance at the distribution center.[36]

Below is an example of a fictional $12 billion manufacturer who ships 15.6 million tagged cases to Wal*Mart. The listed costs represent the start up and maintenance costs for one year.



[37]


Short term ROI

Finding a ROI in RFID technology might be difficult in the short term because of the high start-up costs, related to meeting Wal*Mart and the DoD mandated compliance. Initially, a firm's warehouse should expect to reduce inventory levels by 5%. This reduction will occur because organizations will have a better understanding of how much product is available and where incoming shipments need to be placed, allowing for greater emphasis on crossdocking. In addition, operating expenses will decrease since more products will move at a faster throughput with the increased amounts of hands-free movement. Based on labor reductions alone, organizations will reduce operating expenses by 7.5%.[38] These reasons illustrate how ROI opportunities exist in the short term at a warehouse. Larger manufacturers with higher volumes will discover more opportunities for ROI due to the affects of RFID technology on warehouse efficiency gains.

Long term ROI

With increased visibility of inventory, organizations can deliver the right product to the right place at the right time with more efficiency. Procter & Gamble feels they can counterbalance the RFID infrastructure and tag costs by freeing up $1 billion in working capital and $200 million in inventory carrying cost per year.[39] Other organizations believe fulfillment levels on store floors will also improve. Reductions by 7% in stock-outs will exist since RFID technology increases the visibility of inventory.[40] Woolworths, a UK retailer, discovered an improved availability of their products on the shelves by 6%.[41] Customer service will improve by reducing customer order lead time by 67%.[42] In addition, shrinkage reductions due to the enhanced security of RFID will aid in creating higher fulfillment levels, customer service, and productivity. An IBM study showed that RFID technology over the long run could cut warehouse picking errors and labor costs by 36%.[43] The faster companies integrate the RFID technology into their warehouses the more ROI will accumulate as the RFID technology evolves. The following is a summary of the positive benefits organizations have experienced after RFID implementation.

ROI Checklist

- Reduction in inventory carrying cost
- Reduction in stock outs
- Reduction in shrinkage
- Reduction in labor costs
- Improved customer service
- Improved fulfillment rates

Another important fact concerning the long-term ROI is the potential for RFID-related savings once the tags can be fully implemented throughout the supply chain down to the item level. At this point there are predictions of huge costs savings due to complete product visibility even at the retail level. As viewed below, tagging at the item level conveys value to retail in areas such as shelf replenishment, shelf out-of-stocks, and point of sale data. It can also reduce the amount of theft at the retail level.


Table 2: Level of RFID tagging needed

Level of tagging required	Case	Item
Receiving & check-in	X	X
Backroom stock visibility	X	X
Backroom replenishment	X	X
Plan-o-gram compliance (Marketing programmes)		X
Product Life Cycle Management (Obsolescence - expiration dates)	X	X
Shelf replenishment		X
Shelf out-of-stocks		X
Point of sale		X

[44]

Requirements for Implementation

The implementation of an RFID system is not a task to be underestimated. Business leaders must first evaluate their organization's current position and role in the supply chain. They must understand the total cost/benefit of an RFID implementation, not just the hard dollar amounts. For some organizations, sharing this type of inventory visibility information can pose a legitimate threat to the company's profits.

Process requirements

Business leaders must investigate and understand their current practices and processes and identify areas where enhanced information and visibility from RFID can provide the largest and fastest returns. Involving personnel from each major process in the warehouse will allow managers and employees to work together and identify those areas that can benefit from RFID.

Organizations should then begin pilot implementations that focus on these high return areas to maximize ROI. However, business leaders must understand that a complete RFID implementation is a long-term process. "Given that an enterprise resource planning (ERP) system implementation averages nearly two years, an RFID implementation will take even longer."[45] Pilot testing is an invaluable step to a full RFID implementation. However, many industry experts warn firms to not underestimate the costs of scaling up to a full RFID environment. The cost of problems arising from the additional product and data volumes and environmental variables from a completely enabled RFID warehouse can be significant. Additionally, any new processes designed must be able to accommodate both the RFID tags and bar codes.[46] Receiving, storing, picking and shipping processes should not break down every time there is a misread or no read. The ability for employees to override discrepancies in the system is necessary to realize improvements in efficiency.

Business leaders must also assess the capabilities of their current information systems as well as identify the amount of resources available to complete an RFID implementation. RFID tags alone only produce data. Organizations must be able to capture, process, and analyze all the real-time time data produced to help make decisions regarding their warehouses. If the information systems are not capable of handling this type or amount of data, the organization will fail to realize the full potential of an RFID implementation.


Perhaps the most efficient place to start an RFID implementation is with the Wal*Mart mandate. Implementation at the pallet level is less costly than individual or case-level tagging, and many organizations are already set up with a WMS that tracks individual pallets using other auto-ID technology.[47] This strategy can lower the initial investment costs and can reduce the number of changes that are required to other systems and processes.

Hardware Requirements

Tags

One of the first issues that must be addressed with RFID tags is when the tags will be placed on the cases/pallets. Will items already have RFID tags installed or will it be necessary to develop a process at the warehouse to tag all incoming items? Will corrugated manufacturers build the tags into the boxes? Organizations must also consider how pallet loads created at the warehouse, especially rainbow pallets (pallets of mixed products), will be properly identified and tagged. For one major manufacturer, the current rainbow pallet process will be completely re-engineered with the implementation of RFID.

The selection of the type of RFID tags is also an issue. In nearly all cases, the use of passive tags is ideal for consumer packaged goods and other products that are close proximity of the products to the readers (within 4-5 feet) and require low-cost tags. However, depending on the type of product, the value of the product, the environment in which the tag must function, and speed and distances at which the tags must be read, active tags might be the most ideal option.

Readers

There are two main strategies for the placement of RFID readers. One strategy is place readers at major gateways or portals within the warehouse, with the highest concentration of readers located at receiving and shipping areas. Other ideal locations for gateways are entrances and exits to the conveyor system. Managers must be sure to place these gateways in areas that promote efficient product flow and support the quick movements of large amounts of goods. Rerouting goods or slowing down the product flow to ensure proper reads should not be required if the processes within the warehouse have been reengineered to realize the benefits of RFID. The most versatile piece of materials handling equipment in a warehouse is the forklift because it can take random paths in moving products. Placing readers in locations that make the forklift a fixed-path piece of equipment dramatically decreases its efficiency. In addition, many pilot implementations are utilizing multiple readers at each gateway to minimize misreads and no reads, since a single reader cannot guarantee 100% accuracy for all reads. This is an obvious increase in cost, but the continuous savings in labor and efficiency due to more accurate reads can be significant compared to the fixed cost of adding an additional reader. However, this is not a perfect solution as multiple readers in the warehouse can disrupt each other when two or more try to send a signal simultaneously.[48]

Another option is to place readers on all the forklifts utilized in the warehouse. This allows the reader to scan for every pallet/case that is received, stored and picked into the system


without having to travel through specific gateways within the warehouse. This strategy allows for a more free flow of products and minimal disruption of the current processes within the warehouse. However, there are other obstacles to overcome. Concerns have been voiced that the readers are not yet durable enough to handle the wear and tear of being on a forklift and that there might be potential problems with the forklift readers scanning adjacent pallets instead of the one being picked.[49]

Software/Middleware Requirements

As previously stated, the implementation of RFID tags alone does not provide any direct benefits. To realize the full benefits of RFID, the implemented system must have the ability to capture and process the data created by RFID tags and to analyze that data to provide useful information to support warehouse decisions. To capture and process this data, some type of middleware must be developed and installed to interface between the RFID readers and the WMS because WMS systems are not currently capable of direct interface with RFID readers.

Many organizations are currently developing this type of middleware that can interface between RFID readers and a multitude of WMS packages. Some WMS companies are developing their own middleware that interfaces with their specific WMS package, while other general software companies are releasing packages that can interface with many different WMS packages. Currently, there is middleware available or scheduled to be released within the next year for a variety of WMS systems.[50] It is vital that an organization understand the capabilities they desire from a middleware package and then research the available software to ensure that the software package selected meets the information needs of that organization.

Two elements of the middleware package, representing a major step towards enabling RFID applications for retailers and manufacturers, are technologies developed by Auto-ID: Savant and object name service (ONS). RFID readers will be wired into a computer system running Savant, an application that manages all the data going in and out of readers. The ONS matches the EPC to the address of a server, which contains information about the product. By calling up an IP address, the ONS essentially tells you what the EPC means, working in a similar manner to the way webpages are called up on the Internet.[51]

IT Infrastructure

There are many requirements for an IT infrastructure to handle an RFID system implementation. One of the major requirements will be to assess the amount of bandwidth needed to handle the increase in data transmissions. Organizations must analyze all the data available from a single RFID scan and determine what information needs to be captured in real time and what information can wait for 24 or 48-hour batch update.[52] A plan for how and where data processing will occur must be developed; determining if all data processing and storage should occur at the warehouse or at some other centralized location will have


a major effect on the amount of bandwidth needed to support the RFID system. Furthermore, organizations must ensure that their current IT system is robust enough to handle increased frequency and speeds of product scans and the explosion in data volumes and data sharing requirements of other warehouse applications.[53]

Many experts suggest that the WMS system should support both bar-coded and RFID tags.[54] Due to the long implementation process of an RFID system, the ability to support both codes will help ensure that if a no read occurs on an RFID tagged item, the entire process does not breakdown. In some implementation, labels containing both bar codes and RFID tags are applied to products/cases so multiple reads can occur.

Labor, training

The implementation of an RFID system will have profound effects on nearly all jobs and tasks in a warehouse. Organizations must involve personnel from each process area in the warehouse to understand how RFID technology will affect each required task. This detailed level of understanding along with lessons learned from initial pilot programs will allow managers to develop the appropriate training modules for their employees. The training of employees must emphasize how RFID will make it easier for employees to complete their daily tasks as well as outline how RFID will improve the efficiency of the entire warehouse along with the rest of the supply chain. Creating an understanding among the employees about the value of RFID is critical to gain the support of the employees.


CONCLUSION

Radio Frequency Identification (RFID) was introduced during the 1980's as a non-contact application to improve manufacturing. Today, RFID technology has resurfaced because of business's push for a more efficient supply chain. The RFID system consists of four components: 1) tags-either active or passive devices that use radio frequency antenna to communicate with the RFID reader; 2) readers-devices that scan the RFID tags; 3) antenna- device used to communicate the information between the tag and reader; 4) software-the most important component which applies the information supplied by the RFID system. Wal*Mart and the DoD are the current drivers for RFID technology. Both organizations have mandated their key suppliers to tag cases and pallets with RFID by January 2005. High tag costs have concerned the suppliers who are mandated to use RFID. However, experts believe that tag cost will fall to more reasonable prices as the demand for RFID grows. Furthermore, EPC Global is responsible for setting RFID standards for every global industry.

RFID technology will positively impact warehouse applications. Receiving, Storing, Picking, and Shipping processes will all become more efficient and effective. Organizations can anticipate benefits in such areas as labor productivity, inventory reduction, facility productivity, and lower shrinkage. However, there are some current challenges that will accompany RFID implementation. The tags are not 100% reliable yet because the system can generate multiple reads and no reads. The system also must prepare to handle a large volume of data that goes with tags being placed on each case and pallet in a warehouse. Additionally, the organization must expect to change processes within the warehouse and techniques must be developed to turn off RFID tags after a purchase for privacy reasons.

Organizations can choose to implement RFID technology through two overriding strategies. An organization can implement a "slap and ship" approach to invest the minimum amount of capital into RFID to comply with the mandates set forth by both Wal*Mart and the DoD. The other strategy involves building internal capacity to utilize RFID to gain competitive advantages and significantly reduce costs at a warehouse. Organizations building an internal capacity are more interested in long term ROI, while others applying a "slap and ship" are just complying with mandates. Organizations must make a business case to evaluate the costs versus the benefits. Costs associated with RFID technology are much greater than bar code technology costs. Organizations should expect costs in software, hardware, and re-engineering. Organizations will alleviate these costs with high potential ROI created by RFID technology.

Organizations should also understand that the proper requirements must be in place for a successful RFID implementation. Requirements for this implementation include placement of tags and readers, software/middleware set-up, IT infrastructure constraints, and training of labor. Organizations must analyze their current warehouse processes and assess how they will change with RFID.

Appendix I

Suggested Readings and Endnotes

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