Radio frequency ID technology: The next revolution in SCM

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A major advancement is taking place in supply chain management. Radio frequency identification technology has now been developed to the point at which it can provide suppliers, manufacturers, distributors, and retailers with precise real-time information on where their products are in the supply chain—information that can be valuable in terms of improving SCM efficiencies and revenue generation. Several companies in the food and consumer packaged goods industries are involved in one or more major RFID pilot programs. This article describes the critical trends and implications of applying this technology to SCM, detailing its benefits as well as the impediments to implementation.

Radio Frequency Identification Technology, or RFID, is a technique for electronic labeling and identification of objects using radio waves. Often considered the next stage in the barcode evolution, RFID is the fastest growing segment of the automatic data capture and identification market. It has fairly diverse applications, ranging from marathon races and airline baggage tracking to hazardous material management, electronic security keys, and supply chain management (SCM).

Among the best known RFID examples are ExxonMobil's SpeedPass, EZPass for toll collection, and livestock tagging. In Singapore, RFID is used for electronic toll pricing and traffic control. Every car has an RFID tag, which is read by the readers installed on all major roads. The price for driving depends on the type of road and the time of day. At the end of the month, each car owner is billed for the amount of travel on those roads.

Many auto manufacturers now sell cars whose keys are embedded with RFID tags that contain a unique identifier. When a key is inserted in the lock, it communicates with a reader built into the car's ignition system; if the key happens to be the wrong one, the car is immobilized in a matter of minutes. Several libraries and video stores have also implemented an RFID system to track their assets. The European Central Bank is considering embedding the tags in bank notes by 2005 to trace illegal transactions and prevent counterfeiting. And the US Department of Defense is placing them on all shipments of military supplies to the Persian Gulf.

Although RFID deployment in SCM is still in its infancy, it holds tremendous potential for improving processes and may fundamentally alter the way supply chains are managed today. Companies have an extraordinary ability to track each and every tagged item in their chain. In fact, RFID technology in SCM has reached a level at which it can no longer be ignored; it is already being implemented in selected areas. A number of major users like Wal-Mart, Target, and the US Department of Defense want their top suppliers to be RFID-enabled by early 2005. Some indus-

try observers see SCM as the "killer application" for RFID technology. According to Rerisi (2002), the worldwide demand for RFID tags will exceed $1 billion by 2007. The market for other RFID-related products and services is also expected to touch the billion-dollar mark at about the same time.

Currently, several major companies in the consumer products industry, including Wal-Mart, Procter & Gamble, Unilever, Gillette, Target, and Home Depot, are involved in developing and testing this technology at various levels: pallet, case, item. Although pallet level tagging in the food and consumer packaged goods (CPG) industry is a distinct possibility in the next few years, there are significant barriers to its implementation at the item level, which still seems several years away.

What exactly is RFID technology, and how is it reshaping the supply chain? What are the benefits to be derived from it? And what are the current impediments to its implementation? This discussion and selected case studies can help provide some answers to these questions.

Overview of an RFID system

In its most basic form, an RFID system consists of readers and tags capable of storing and transmitting information. As small as a grain of rice or as large as a brick, an RFID tag, or transponder, consists of a microchip attached to an antenna and embedded in a product or put on as a label. When the tag comes in close proximity to a reader, the data are captured and redirected to a computer, which is often connected to a network. With certain tags, the reader can also write information onto the tag. A major advantage of the RFID system is its ability to retrieve information without direct line of sight to the tag and read it en masse. A truck could simply drive by an RFID reader, and everything that is tagged inside the truck is read at the same time.

The memory of an RFID tag is divided into several cells: read only, read/write, or a combination. The read/write capability of a tag can be used for reading and recording data on the chip as it moves through a system. Many auto and computer manufacturers use an RFID system in which read/write tags are used to specify the build configuration of the products as they pass through the manufacturing process and then record the pertinent feedback. For example, any quality-related problem can be recorded on the tag to prevent the defective unit or product from leaving the facility without rework.

RFID tags can be further categorized as active or passive. Generally of the read/write type, active tags are powered by an internal battery source, have a longer reading range, and are used in applications in which the reader cannot be located close to the tag, as in electronic toll collection. They are larger, heavier, and more expensive than passive tags, and last for about ten years. Passive tags draw power from the readers. Lighter, smaller, and cheaper to produce, they can last for a long time and usually operate in close reading range—from a fraction of an inch to a few feet.

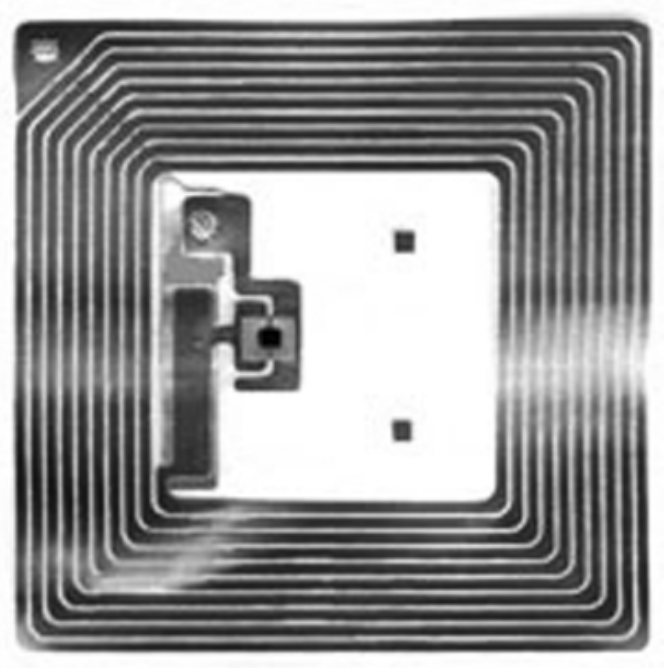
RFID technology works on a number of frequency bands. Low-frequency tags are used in applications where the range is generally less than 10 inches (tracking work-in-process inventory, access control), while high-frequency tags are used in areas of a few feet (smart cards). Ultra-high-frequency tags are used in applications such as toll payment in which high-speed reading is vital and the distances can run to several feet. Generally, as the frequency goes up, both tags and readers become more expensive.

Overall, RFID tags are awfully difficult to counterfeit and have extremely high data integrity. Practically maintenance free, they can provide fairly reliable operation even in such harsh operating environments as dust, snow, fog, corrosion, vibration, and shocks.

Item-level tagging and monitoring in a retail environment also requires smart shelves to be installed in the store. These shelves are capable of providing real-time information about the products on them, information that can be used to monitor the stock level, manage expiration dates, expedite express/self checkout, and enable retailers to remotely change the displayed product prices.

MIT Auto-ID Center

Lately, some of the most visionary and fascinating work in RFID technology as applied to SCM has come out of the



MIT Auto-ID Center. Established in 1999, the Center was given the goal of developing a low-cost, open-standard RFID infrastructure for SCM. In the process of development and testing, it has worked closely with several major users and providers of the technology. Several consumer groups have also participated in privacy-related issues. Over the years, the Center has established labs at the University of Cambridge (England), University of Adelaide (Australia), University of St. Gallen (Switzerland), Keio University (Japan), and Fudan University (China). Since its inception, it has been the most visible and prominent organization in the field. Recently, the Center split into two new organizations: EPCglobal Inc., and Auto-ID Labs. As a joint venture between the Uniform Code Council and EAN International, EPCglobal will be responsible for developing and administering the RFID technology developed by the Auto-ID Center. All the university labs now come under Auto-ID Labs and will continue to research and develop new technologies in this area. Several companies in the CPG industry involved in RFID pilot programs in SCM use Auto-ID Center's technology.

The RFID infrastructure developed by the MIT Auto-ID Center is now known as the EPC Network and consists of electronic product code (EPC) for RFID tags, product mark-up language (PML), object naming service (ONS), and Savant (data handling). Unlike bar codes, which identify each product type, RFID tags can uniquely identify each item through an EPC numbering scheme designed for this purpose. The 96-bit version is big enough to identify 268 million manufacturers, each having 16 million different products, and 68 billion different items in each product. The EPC will be embedded on a low-cost RFID tag and will provide a pointer to the information about the object on the Internet. Tags will be applied to individual products during the manufacturing process.

When scanning an EPC tag, the reader seeks specific information about the product provided by the manufacturer on the Internet and stored in PML. A standard language based on XML for describing physical objects, PML develops layers of specific data describing the object. ONS tells the computer where to locate information on the Net about the object with the EPC tag. Based on the Internet's existing Domain Name System (DNS), ONS routes information to appropriate websites. Thus, it should be possible to pinpoint in real time the location of any product having an EPC tag.

To manage the flow of vast quantities of RFID data to the company's information system, the Auto-ID Center has developed a distributed software system called Savant. In general, there will be a network of Savants constantly collecting, cleaning, storing, and moving data around in a way that does not overload the system. Savants act as the nervous system of the network.

Supply chain benefits from RFID technology

Potentially, RFID technology can create opportunities in everything from global supply chain visibility to express/self checkout to thwarting theft and counterfeiting. More specifically, tracking products in a supply chain can lead to benefits in inventory reduction, improve collaboration among the partners, and enhance revenues through improved pricing and fewer out-of-stock situations. The magnitude of the benefit depends on the level of tagging (pallet/case/item) and the area of application in the supply chain. According to Roberti (2002, 2003), a full-scale RFID deployment could save Wal-Mart about $8.4 billion a year, while Procter & Gamble estimates that it could cut its inventory of $3.5 billion by half and save $400 million annually.

A number of manufacturing companies have been using RFID technology in closed-loop applications for real-time tracking of parts, components, and subassemblies through the manufacturing process. Parts with read/write tags are used for monitoring the status and performance of operations during the production process. For example, a tag might include operating instructions for a machine or operator, allow for feedback to be written on it once the operation is executed, and automatically notify the company's ERP system on the status of the process. Tagging in such a setting can reduce paperwork and lead to productivity gains in manufacturing operation efficiency, specifically in the use of bottleneck resources. Several automotive and PC manufacturers have been early adopters of this technology in their manufacturing operations.

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In most distribution operations in the CPG industry, pallet-level tagging can lead to more efficient consignment veri-

fication and the potential elimination of misdirected shipments. This can be of enormous benefit when the shipment consists of non-identical loads or pallets with mixed cases. Because RFID readers do not require direct line of sight to read, stacks of multiple pallets can be read simultaneously and inventoried without opening them, which leads to efficient receiving, checking, loading, and unloading of trucks. Tags can also include information about the assigned location of the pallets in the warehouse (leading to better use of storage space), with new information being written on them as the pallet moves through the supply chain. Unscheduled movement of a pallet can alert managers about a personnel error or possible theft. Moreover, warehouse employees could quickly locate recalled products without having to segregate inventory or track the movement of each product from location to location.

RFID technology can also lead to the automation and streamlining of several supply chain processes with a consequential reduction in logistics costs. A delivery of loaded pallets could trigger an electronic payment to the vendor, thereby rendering paper invoices obsolete and shortening the order-to-cash cycle (an important supply chain performance metric). Chep, a UK-based pallet rental company, is testing pallets with embedded RFID tags.

Pallet and case level tagging can result in fairly significant benefits for shipping, warehouse, and distribution center operations. Industry observers believe that even at the pallet level, RFID technology could lower supply chain costs 3 to 5 percent by efficiently locating and routing merchandise from factory to store shelf. It is one of the reasons why Wal-Mart is requiring its top 100 suppliers to start using RFID tags on pallets by January 2005.

Impetus for collaboration

In SCM, strategic collaboration across the supply chain in real time is increasingly being seen as a key requirement for competitiveness. Among the main causes of supply chain inefficiency are lack of collaboration and lack of visibility, which often result in the "bullwhip effect"—an amplification of demand variability as the demand moves upstream, according to Lee, Padmanabhan, and Whang (1997). Decisions based on this distorted information often lead to excessive levels of inventory and/or poor utilization of resources. In April 2001, Cisco faced a similar problem that ultimately resulted in a $2.25 billion inventory write-off. Its parts inventory shot up by more than 300 percent between third and fourth quarter 2000. Just a few months prior to this, Cisco was having a hard time meeting its delivery schedule due to a shortage of critical networking components. It is now in the process of building an "eHub" to improve visibility and synchronize planning across its supply chain. The eHub will eventually include more than 2,000 of its suppliers, distributors, and contract electronic manufacturers.

Supply chains often suffer from the bullwhip effect. Most inventories in a chain are due to variability in supply and demand. Visibility can help identify the sources of variability and gradually lead to its reduction, resulting in much more efficient inventories. In the CPG industry, according to Roland Berger Strategy Consultants (2003), reducing the inventory of finished goods by one day can free up an average of $7 million for a manufacturer.

Studies by Lee (2002) and others indicate that firms pursuing collaboration have also improved their financial performance over those that have not. However, despite such importance, collaborative endeavors continue to encounter plenty of resistance. The EPC Network would provide real-time information on the Internet about where products are in the supply chain. This information directly affects some of the *critical improvement areas targeted by many companies,* such as demand management, planning and forecasting, and order management. This is especially true for firms in the CPG industry, which continue to struggle with forecasting accuracy. Thus, collaborative supply chain initiatives like CPFR could get a tremendous boost from RFID technology.

Still, RFID by itself is not capable of providing other data/information required for a more meaningful collaboration among supply chain partners. With a growing trend toward outsourcing supply chain processes, including manufacturing, the accuracy, speed, and reliability of data exchanged between partners is of vital importance. In a survey of 50 major global manufacturers by Forrester Research (Radjou 2000), 38 percent of the companies cited poor visibility in plant operations as their biggest problem, while 32 percent cited poor communication as the most important problem. Poor communication may result from how information is shared. In general, companies tend to use multiple communication channels to exchange data. In the Forrester survey, 62 percent of the manufacturers share their production schedules manually with their supply chain partners. Between retailers and vendors, the most common methods of such communication are email, telephone, and fax. What is required is visibility across several dimensions—demand patterns, order status, inventory at all levels, production schedules, sales/marketing initiatives, and so on—of the supply chain, with technology playing a greater role in communications and in the seamless integration of collaborative decisions into the partners' business processes. Automatic electronic sharing of the data serves to speed up the workflow, enabling more activity to proceed in parallel while remaining synchronized. Data synchronization in supply chains will prevent errors due to miscommunication and can lead to tremendous benefits in terms of transactional efficiencies.

On the whole, the EPC Network offers a compelling case for collaboration by providing an Internet-based infrastructure that is global, open, scalable, and flexible.

Why is inventory shrinkage detrimental to profitability?

The low-margin nature of the retail industry makes control over inventory and stock an important factor in profitability. Often, retailers cite lower inventory levels as one of the major reasons for improved profit margins. An inventory system that does not square well with the actual level of physical inventory in a system is of little practical use.

Hollinger and Davis (2003) estimate that inventory shrinkage—the unexplained loss of stock due to theft, miscounts, misplaced items, and so on—costs the retail sector about $31.3 billion a year, or 1.7 percent of total annual sales. Among the sources of shrinkage are employee theft (48 percent), shoplifting (32 percent), administrative and paper error (15 percent), and vendor fraud (5 percent). Recent years have seen an upward trend in shrinkage due to employee theft and shoplifting, creating a general lack of confidence in current surveillance systems. Moreover, there has been an increase in the number of empty packages found on the shelves—evidence of a sophisticated effort by shoplifters to defeat the anti-theft labels attached to the packages.

Overall, the impact on the bottom line from shrinkage is significant and often ends up being paid for by the consumer in terms of higher prices. RFID systems could provide a store's security staff with a powerful tool to curtail employee theft and shoplifting. The tags could be linked to a security monitoring system to track the product from the shelf to the register and out the door. Security could be alerted if a product leaves the store without being paid for. And because each item would have its own unique identification, return or resale of stolen goods would be difficult.

Inventory errors have also been a constant source of inefficiency in retail supply chains. A BearingPoint (2003) survey reports that of all the obstacles preventing inventory integrity in the retail industry, receiving errors are at the top, followed closely by errors in selling and physical counting. Inventory that cannot be located is often classified as *dead inventory*, a constant and irritating problem for many companies. With RFID technology, locating dead inventory is an effortless task. In fact, item-level RFID could possibly eliminate inventory errors completely. Overall, inventory control and monitoring is considerably less manual and can greatly improve productivity.

What is the impact of stockouts?

Product availability at the shelf level has often been identified as a key performance indicator for the retail supply chain, yet few companies measure it. On-shelf availability of products is extremely important for continued growth and profitability of both manufacturers and retailers. From a practical standpoint, stockouts result in lost sales and consumer dissatisfaction. Even for products with strong brand loyalty, frequent stockouts might be enough to trigger a switch to a different brand or store. In a study based on in-store interviews of customers who experienced stockouts, Emmelhainz, Stock, and Emmelhainz (1991) found that 32 percent switched brands, 41 percent bought a different size or variety, and 14 percent went to a different store.

In the retail industry, stockouts are real and fairly significant. Approximately 11 percent of the top 2,000 items sold in a grocery or a mass-discount store are out of stock at any time. In a 1996 study of national supermarket chains conducted for the Coca-Cola Research Council by Andersen Consulting, average stockout was reported to be about 8.2 percent (15 percent for advertised products). This represents about a 6.5 percent loss of category sales volume. If one takes into account alternate purchases, the net loss to retailers is 3.1 percent; for manufacturers, the loss is 5 percent of sales. Though not surprising, studies show that an average shopper avoids making a purchase in a stockout situation rather than inquire about the product's availability. In a recent study, Roland Berger Strategy Consultants (2002) puts average stockouts at approximately 7.4 percent; for fast-moving and/or promoted products, the average is around 13.1 percent. A key finding of this study is that retail ordering and forecasting account for about 47 percent, while the shelf stocking policy (product is in the store but not on the shelf) accounts for an alarming 28 percent of stockout situations. Recent supply chain initiatives like ECR, VMI, and CPFR may have reduced supply chain inventories, but they do not seem to have much impact on stockouts at the retail level.

For manufacturers and retailers that manage hundreds of items, RFID technology combined with smart shelves provides a powerful mechanism to help boost revenue by ensuring that store shelves are always stocked with their products. The system can monitor stock levels continuously, and retailers need not depend on store employees to keep an eye on the shelves. In fact, an RFID system sensing low stock level could alert an employee to retrieve more stock from the storeroom and/or place an order for more with the retailer/manufacturer's distribution center. These systems are also being designed with features to sense "unexpected events" in the supply chain, such as irregular demand or supply patterns. Thus, reducing out-of-stock situations is a major benefit of RFID technology. Companies can also better understand the reasons for stockouts and the effect on consumer behavior and profitability.

Why is correct pricing so important?

A recent McKinsey study by Marn, Roegner, and Zawada (2003) reports that optimal product pricing is perhaps the fastest and most effective way to enhance profits. An improvement of 1 percent in price typically leads to an 8 percent increase in operating profits—an impact far greater than from a comparable improvement in cost or volume.

Improving revenue and profits through pricing (also known as *revenue management* or *yield management*) is an area yet to be explored by many firms. However, devising and constructing complex pricing schemes to fully capture product and service value can be difficult and tricky. Dutta et al. (2002) note that it requires expertise in such areas as game theory, auctions, bundling, and mathematical programming.

Revenue management has been practically limited to a handful of industries, such as airlines, hotels, and car rental companies. Airlines pioneered the practice of yield management by controlling the availability of seats through differential product and pricing policies to maximize profit. According to Boyd (1998), American Airlines estimates that intelligent yield management adds about $500 million a year to revenue, while Cross (1997) reports that the Marriott hotel chain estimates benefits to be about $100 million a year. Revenue management as practiced in the airline industry is not directly portable to manufacturing and retail industries due to market and cost structure. However, conceptually there are several parallels for deploying it effectively.

There has also been an increase in the number of empty packages found on the shelves—evidence of a sophisticated effort by shoplifters to defeat the anti-theft labels attached to the packages.

Two commonly used pricing mechanisms for revenue enhancement are *dynamic* and *differential* pricing. In a dynamic pricing scenario, prices vary frequently depending on such as factors as product, market conditions, distribution channels, and customers. In differential pricing, the characteristics of the different market segments are used to set prices. Of late, many manufacturing companies are discovering revenue management as a new tool to gain a competitive advantage. Dell practices both pricing mechanisms. According to Byrnes (2003), pricing for its corporate customers differs from that for individuals. In addition, Dell's prices vary significantly from week to week, reflecting market trends and the company's inventory of parts and components.

Between 1995–1999, revenue management initiatives at Ford Motor Company contributed about $3 billion to its profit pool and helped advance the company's understanding of the impact of rebates, low-interest financing, volume discounts, and product configurations on sales and profits. Ford has been working meticulously over the past several years in developing and implementing a pricing policy reflecting the unique mix of benefits sought by different market segments. For example, Explorer customers prefer deals involving cut-rate loans, whereas Crown Victoria and Focus customers like cash rebates. Ford uses real-time demand data to raise and slash its incentive programs.

Even though retailers regularly discount products, notes Tedechi (2002), the use of mathematically based pricing and revenue management software for product markdown is fairly recent. Pricing software can help retailers improve their profit margins and still be competitive in the marketplace. With RFID technology providing timely and accurate information about demand and inventory in the supply chain, an in-depth knowledge of market conditions can enable a firm to use revenue management tools and techniques to optimize price, product mix, promotion, and other sales efforts to enhance its profitability. Adopting electronic shelves and digital price labels can help make frequent price changes an effortless task for retailers. Pricing mechanisms can also be used to control demand variability. Moreover, linking pricing and other marketing decisions with supply chain decisions will result in better allocation of resources and may eventually lead to a demand-based management system.

Overall, then, RFID technology can be a huge impetus to total supply chain optimization. How well companies are able to derive value out of it will depend considerably on the level of visibility, information sharing, and coordination across the supply chain. It may well form the basis for future competitive advantage.

Selected RFID case studies

Several pilot programs and actual implementations involving RFID technology are currently going on in supply chains. Here we briefly describe some of the case studies in the areas of SCM, manufacturing operations, and asset tracking.

SCM applications

One of the best-known and most comprehensive RFID pilot programs in supply chain management involves the Auto-ID Center, Wal-Mart, Procter & Gamble, Unilever, Kraft, Coca-Cola, Gillette, and several other CPG companies. The objective is to test and validate the RFID infrastructure developed by the Auto-ID Center. Originally, the study was to be conducted in three phases, with Phase I at the pallet level, Phase II at case level, and Phase III at the

individual item level. In October 2001, the first field test began at Sam's Club and Wal-Mart stores in Tulsa, Oklahoma. Several manufacturers shipped RFID-tagged pallets and cases from selected distribution centers in the country to the retail stores. The project required placing tags and readers throughout the supply chain and wiring factories, trucks, distribution centers, warehouses, and forklifts to record the movement of goods from factory to store with no human intervention. Phase I of the study lasted for four months and was fairly successful. Phase II began on February 1, 2002, and involved tracking cases of several products. Phase III was abandoned as item-level RFID deployment continued to pose thorny technical problems and other snags.

Even though the outcome details from the study have not been disclosed, industry watchers say the technology has been working better than expected. The test runs have not been problem-free, but the study does demonstrate the viability of the technology, warranting further testing. Overall, Wal-Mart seems fairly convinced that RFID tags can dramatically improve its supply chain efficiency—hence the June 2003 announcement requiring its top 100 suppliers to tag shipping crates and pallets by January 2005. By 2006, notes Roberti (2003), the company will require every supplier to use the tags.

Target and Home Depot are also testing various RFID technologies. Outside the United States, UK-based Marks & Spencer, Tesco, and Germany's Metro AG are conducting several pilot programs. Some of the manufacturers involved in the Wal-Mart pilot program are engaged in other RFID projects as well. Gillette is conducting an item-level test at a Tesco store and is equipping two of its major distribution centers with the technology to track razor blades internally as they move from packaging to inventory, to assembly on pallets, and then onto trucks. By 2006, the company hopes to install RFID systems in most of its warehouses. In January 2003, Gillette agreed to purchase 500 million tags from Alien Technology at a price supposed to be around 10 cents apiece. RFID is one of Gillette's top priorities. Unilever is involved in a three-phase RFID study with Safeway retail stores in the UK, as well as several other projects. The company is also working with the pallet rental firm Chep to develop reusable shipping pallets with built-in tags. A few years ago, Gap conducted a pilot program in Atlanta in which denim apparel carried RFID tags. The company was experiencing huge losses on the fraudulent return of products stolen during the manufacturing and distribution process. In the trial run, it tracked the items from the factory to the store shelves and was able to reduce its labor cost for distribution by 50 percent, improve its inventory accuracy to 99.9 percent, and achieve higher sales for tagged jeans (from reduced stockouts) compared to other stores in the area not using the technology.

Manufacturing operation applications

Dell, Seagate, Boeing, and Ford are among several companies using RFID technology to track work-in-progress (WIP) in their manufacturing operations. Boeing is also involved in a pilot program to track parts on commercial airplanes. Seagate, the world's largest producer of disc drives, magnetic discs, and other tape drive systems, uses RFID to track WIP in its clean room manufacturing facilities. Tags on each disc are used to record any quality-related problems, and the information is fed into the ERP system. This has dramatically improved the accuracy of the information.

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Dell uses RFID technology in assembling and shipping its desktop PCs, notebooks, and servers in China. Each product tray starts with its own assembly and routing information written on a read/write tag. At the completion of the assembly process, product details are written on the tags for shipping and testing of the product. The technology has improved production efficiency, quality control, and visibility throughout the facility.

Ford uses RFID tags at several of its facilities to track WIP and improve production control. For example, at its Essex engine plant in Windsor, Ontario, tags carry all the instructions needed to assemble an engine and collect all the test data accumulated during manufacturing to be used in product tracking and quality control.

Asset tracking applications

A growing number of breweries worldwide are using RFID technology to identify and track incoming and outgoing beer kegs. In the UK, about 65 percent of the beer is served in draft form, requiring an inventory of 10 million kegs. About 3 to 5 percent of the kegs are stolen each year, melted, then sold as scrap. Scottish Courage uses RFID tagging to track its 2 million kegs at various points in the supply chain, eliminating shrinkage, reducing keg cycle times, improving delivery for outgoing and incoming stock, and providing an audit trail for inventory. Overall, tagging kegs can potentially save the British beer industry about $25 million a year. In the United States, with about 6.5 million kegs in circulation at any time, almost all major brewers are involved in RFID pilots.

Vehicle tracking is another area that has benefited from RFID technology, and one that may grow considerably in the near future. Several companies use a real-time vehicle location system to manage their fleet. Ford uses it at several plants throughout North America and Europe. At the end of the assembly process, an RFID tag is hung on the rearview mirror of each vehicle to help Ford locate the vehicle in the plant's parking lot and alert authorities if its movement is unauthorized. At the time of shipping, the system can check for any quality-related issues that need to be addressed first. Previously, it took the company hours to find its vehicles; in some cases the cars sat in the parking lot longer than necessary. In the North American railroad industry, RFID tags are attached to the undercarriages of railcars and locomotives in the depots and switching stations. The system has eliminated errors in identifying the vehicles and reduced both the trackside workforce and the number of delays.

Impediments to RFID adoption in supply chains

If RFID technology is to realize its full potential in the global supply chain, it has some serious stumbling blocks to overcome. Such problems include the lack of universal standards, the high cost of tags and readers, the absence of application software to take advantage of the data generated by the RFID system, and the current state of the technology.

Even though RFID is not new, the industry has not yet been able to develop open global standards that could make technologies more interoperable and easier to deploy with a minimum duplication of resources. Several issues related to standards such as tag specifications, allocation of frequencies, and communication systems needs to be resolved. Without global standards in place, it is difficult to find a suitable frequency spectrum that can be used worldwide for RFID. Incompatibilities like this can seriously hamper global implementation of the technology. Most RFID systems in use today are based on the vendor's own proprietary systems and are limited in terms of their scope in the supply chain. One reason for this is the protocol incompatibility between various systems. Many organizations are working toward resolving these issues. It is likely the standards developed by EPCglobal may become the worldwide standards for RFID deployment in supply chains.

Another major obstacle in the widespread adoption of RFID technology for SCM is the cost. Many of the current systems deployed in manufacturing operations, transportation, yard management, and distribution are in closed-loop applications (such as WIP tracking and trailer location) and use expensive RFID tags with read/write capability and larger memory and range. These tags employ proprietary information and are used again and again. Currently, most passive tags sell for around 50 cents and active tags for over $5; the price depends on the production volume. In the coming years, most of the tags deployed in the supply chains will be passive. Moreover, the prices should drop as annual demand starts to run into several billion tags a year. Wal-Mart claims that the tags can be purchased for as little as a nickel apiece. However, even that is not cheap. For most consumer products, the cost needs to be in the range of a penny or less for item-level tagging to be economical. Most RFID readers sell for about $1,000 or so, others as much as $5,000. Of course, if the demand for tags picks up, then the price for readers is also likely to drop significantly.

With RFID technology generating a tremendous amount of data on a continuous basis, there is a clear need to develop application software capable of fully exploiting it. Basically, what is required is the ability to extract the pertinent information from these data streams and intelligently route it across the supply chain network. Many organizations are also involved in developing smart agent technology capable of taking self-corrective actions for many of the routine problems. However, for such systems to work without any hiccups in real time requires seamless integration, visibility, and a high-level collaboration across the chains. It may also require companies to make significant changes to their business processes. Many existing information systems can accept data from RFID scanners, but not many are built with RFID capabilities in their IT infrastructure to facilitate a full-scale deployment across the supply chain.

Other technical problems with the current state of RFID technology should be mentioned. For example, metal containers like soda and coffee cans have the propensity to scatter radio waves, whereas products like liquid detergent tend to absorb them. Interference from other wireless devices and networks also poses a technical problem. And the reliability of the readers continues to be a concern. Many organizations are working on these glitches, and some are even close to a solution.

Finally, there are several privacy issues to consider in the use of this technology. Because firms have the capability to link products to customers, many consumers feel RFID technology is too invasive. The ability to remain anonymous could be eroded. Among several alternatives under consideration is the ability to disable the tag at checkout.

Ultimately, a full-scale deployment of RFID technology in most supply chains will provide compelling benefits and competitive advantages. It is therefore vital for companies in the food and CPG industries to start exploring specific RFID applications in their

supply chains. The objective should be to gain an understanding of the technology and to acquire capabilities in this area. Initial projects should be targeted in areas where tracking products is likely to provide the greatest insights. Likely target areas may include locations or products with excessive inventory levels, substantial inventory shrinkage, counterfeiting, or stockouts. A phased approach similar to Wal-Mart's is a good way to get started.

Open global standards, cost, and integration with existing information systems will be the key requirements driving full-scale RFID deployment in supply chains. Many barriers to the technology are rapidly being worked out. However, widespread deployment at the item level requires significant investment and is still several years away. From a technology perspective, there is a distinct need for additional research and testing. Presently, the technology has many niche applications in tracking high-value items (such as pharmaceuticals, garments, and DVDs), products moving through assembly, yard management, security, and so on.

Because of the recent major announcements by Wal-Mart, Target, and the DoD requiring top suppliers to tag pallets and cases by early 2005, RFID technology is a topic of great interest to many companies. In situations like this, vendors and consulting companies may make excessive promises and hype about its benefits. Although moving quickly in a competitive environment is important, doing so with a clear business objective is absolutely imperative. Companies still need to develop a business case with a blueprint for implementation before making a significant investment. It takes time for most technology to become ubiquitous, and when it does, it seldom looks like the original. Finally, a word of caution: RFID technology will fail to realize its potential in supply chain management if in the long run all supply chain partners are not able to derive the benefits from it. ❍

References and selected bibliography

Andersen Consulting. 1996. Where to look for incremental sales gain: The retail problem of out-of-stock merchandise. Coca-Cola Retailing Research Council study report.

BearingPoint. 2003. Inventory management 2003: Communication and technology bear renewed promise. *Chain Store Age* @ www.bearingpoint.com/solutions/tech_infra_integration/inventory_mgmt_study.html (December).

Berinato, Scott. 2001. What went wrong at Cisco. *CIO Magazine* @ www.cio.com/archive/080101/cisco.html (1 August).

Boyd, Andrew. 1998. Airline alliance revenue management. *OR/MS Today* @ lionhrtpub.com/orms/orms-10-98/boyd.html (October).

Byrnes, Jonathan. 2003. Dell manages profitability, not inventory. *Harvard Business School—Working Knowledge* @ hbsworking knowledge.hbs.edu/item.jhtml?id=3497&1=dispatch (2 June).

Cross, R.G. 1997. *Revenue management: Hard-core tactics for market domination*. London: Orion Business Books.

Deady, Monica. 2003. Tracking the elusive SKU. *CFO Magazine* @ www.cfo.com/article.cfm/3007958 (1 January).

Dutta, Shantanu., Mark Bergen, Daniel Levy, Mark Ritson, and Mark Zbaracki. 2002. Pricing as a strategic capability. *Sloan Management Review* 43/5 (Spring): 61-66.

Emmelhainz, Margaret A., James R. Stock, and Larry W. Emmelhainz. 1991. Consumer responses to retail stockouts. *Journal of Retailing* 67/2 (Summer): 138-147.

Grosvenor, Franklin, and Terrence A. Austin. 2001. Cisco's eHub initiative. *Supply Chain Management Review* (July-August): 28-35.

Hollinger, R.C., and J.B. Davis. 2003. 2002 National retail security survey, University of Florida @ web.soc.ufl.edu/ srp.htm

Kurt Salmon Associates. 2002. Survey of supply chain effectiveness. Grocery Manufacturers of America @ www.gmabrands.com

Lee, H.L. 2002. Aligning supply chain strategies with product uncertainties. *California Management Review* 44/3 (Spring): 105-119.

———, V. Padmanabhan, and Seungjin Whang. 1997. The bullwhip effect in supply chains. *Sloan Management Review* 30/3 (Spring): 93-102.

Leibs, Scott. 2000. A profits drive. *CFO Europe.com* @ cfoeurope.com/displayStory.cfm/1736529 (September).

Marn, Michael V., Eric V. Roegner, and Craig C. Zawada. 2003. The power of pricing. *McKinsey Quarterly* 1: 26-39.

MIT Auto-ID Center. 2002. Technology Guide @ archive.epcglobalinc.org/aboutthetech.asp

Muller, Joann. 2003. Outpsyching the car buyer. *Forbes* (17 February): 52.

Radjou, Navi 2000. Manufacturing deconstructed. *Forrester Research, Inc.* (July).

Rerisi, Edward A. 2002. RFID: Technology evolution, market segmentation analysis and player profile. Allied Business Intelligence report (May).

Roberti, Mark. 2002. RFID: From just-in-time to real time. *CIO Insight* @ www.cioinsight.com/article2/0,1397,1496892,00.asp (12 April).

———. 2003. Analysis: RFID-Wal-Mart network effect. *CIO Insight* @ www.cioinsight.com/article2/0,3959,1265594,00.asp (15 September).

Roland Berger Strategy Consultants. 2002. An in-depth look at DSD categories. Grocery Manufacturers of America @www.gmabrands.com

———. 2003. GMA logistics study: Key industry trends for food, grocery, and consumer products supply chain. Grocery Manufacturers of America @ www.gmabrands.com

Tedechi, Bob. 2002. Scientifically priced retail goods. *New York Times* (3 September).

Vijayan, Jaikumar, and Bob Brewin. 2003. Wal-Mart backs RFID technology. *Computerworld* @ www.computerworld.com/softwaretopics/erp/story/0,10801,82155,00.html (16 June).

Welch, David. 2003. Ford tames the rebate monster. *Business Week* (5 May): 38.