Ubiquitous Communication: Tracking Technologies within the Supply Chain

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M. Eric Johnson
Center for Digital Strategies
Tuck School of Business
Dartmouth College

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Abstract

Information integration and total supply chain visibility are viewed as integral parts for supply chain excellence. Real time and accurate information on the status of goods in a supply chain requires the integration of several evolving technologies that enable tracking of items, cartons, totes, containers, trucks, ships, rails, and other conveyances continuously. In this article, we examine tracking technologies in the context of a case study of an integration project at a major retailer, focusing on the business case for investment. The case examines how technologies like Radio Frequency Identification (RFID) and Global Positioning System (GPS) can be used to improve supply chain performance and aid in reducing supply chain shrinkage. Based on the results of that case and others, we discuss some of the key lessons for engineers and managers interested in implementing tracking technologies. Finally, we discuss the benefits of automated identification and tracking as compared with traditional legacy systems like bar codes.

I. Introduction

For decades, the physical operating layer in logistics lived in disconnected isolation from the information layer of supply chain management. The movement of products within a manufacturing or distribution facility was nearly invisible. Of course, the information systems could show that they were somewhere in the facility, and possibly the designated storage location, but little beyond that – particularly if the items were in-transit. The same was true outside facilities. Goods that were shipped to a warehouse were "on the road, boat, or air," but little more was known other than possibly when they were received at their destinations. Today, all that is changing. The race to connect the physical logistics layer and the information layer is accelerating. Many technologies are emerging to close the gap including wireless devices (e.g., RFID tags, 802.11 and bluetooth-enabled devices, pagers, cellular), global positioning systems (GPS), and legacy tracking, including EDI links and bar coding, all linked to the massive information backhaul capabilities of the internet. When the connection is complete, the ubiquitous communication capability will make physical items visible throughout the supply chain.

However, while there is much excitement about the technologies for tracking, implementation in real supply chains has been inhibited by costs, lack of uniform standards, and the inability of many firms to develop the compelling business cases required to justify the sizeable investments. In this article, we will examine some of the most popular tracking technologies and consider their impact on supply chains. While we will focus on Radio Frequency Identification (RFID), we will also examine other technologies and their integration to create tracking solutions. After looking at some of the technologies, we will present a case study of a tracking project at the U.K. retailer Woolworths. The case examines how technologies like RFID and GPS can be used to improve supply chain performance and aid in reducing supply chain shrinkage. Using the case study, we will discuss many of the benefits of tracking and the barriers of implementing new technologies.

While Woolworths began in the United States, and has since vanished, the once U.S. subsidiary operations in the U.K. and Australia have continued to thrive in those countries by evolving their business models. In the UK, Woolworths competed in a range of retail formats from traditional general merchandise to large-scale Big W stores that offered a huge spectrum of merchandise. Woolworths managed an extensive distribution network that suffered from many supply chain problems such as accurate forecasts and reliable inventory information that would facilitate effective asset management. Like all retailers, Woolworths also faced significant product losses across its supply chain from theft and mislocation.

Shrinkage impacts all retailers, from direct merchants like L.L. Bean to large box retailers like Staples, and the problem is global. Total retail losses are estimated at €30 billion/year across Europe. Wal-Mart alone was estimated to lose nearly $1 billion to shrinkage each year. In a 2005 study conducted by the Tuck Business School in cooperation with the Merchant Risk Council, we found that supply chain losses within the U.S. retail supply chain (not including store theft) total nearly 1% of sales revenue. Product leakage occurs across the supply chain, from inbound freight to warehousing and outbound distribution. Beyond the losses, shrinkage also contributes to inventory inaccuracy — both in stores and in warehouses. This inaccuracy often leads to customer service defects, lost sales, and customer dissatisfaction (Raman et al (2001), DeHoratius and Raman (2004)). The Woolworths case shows how a novel integration of RFID and GPS technologies can help reduced shrink and improve inventory accuracy.

After discussing the lessons from the case, we will examine the barriers to implementing new tracking solutions, including costs, standards, and the ability to financially justify evolving technology. Then we will discuss legacy tracking solutions, such as bar codes, comparing them to new automated approaches. Finally, we will conclude with a look to the future evolution of RFID and related technologies.

II. Technology of Tracking

While there are many technologies that enable wireless, automated tracking — including active and passive RFID, 802.11, blue-tooth, pagers, and cellular — by far the most attention has been focused on RFID. RFID is a means of storing and retrieving data through electromagnetic transmission to an RF compatible integrated circuit. The technology uses small radio transponders, called "tags," that are attached to the objects being tracked. The tags communicate with a reader (or antenna) when a tag is within range of the reader. The reader then passes information about the object to a host computer that processes the information and, in turn, passes the information over internal networks and the internet. Thus, as the tagged objects move in the supply chain, the movements can become visible through a web-interface.

Currently, RFID tags are available in many different configurations, employing different technologies that have cost and performance trade-offs. Tags are often broadly segregated into two major classifications: passive and active. Pure passive, or "reflective," tags do not contain an internal power source and are less expensive to manufacture. These tags typically have a short range (2-3 meters) and rely on the energy radiated by the reader to power the circuit. For example, to track merchandise leaving a warehouse, readers could be positioned at the dock doors. As tagged merchandise comes within the range of the reader, the readers send signals to the tag and it would respond by transmitting its unique identification number. That number could be associated with the merchandise, so the system could quickly identify the merchandise and record its movement. Until recently, the costs of these tags (typically $0.20 or more) have prohibited wide-scale adoption for disposable packaging. Many industry analysts and researchers have predicted that a sub-$0.05 tag will represent a tipping point in mass implementation (Bartels (2005)) for item-level tagging. However, to achieve such costs requires large chip manufacturing volumes creating a chicken-and-egg problem — low costs are required for high adoption, yet high adoption is required for low cost (Yates (2005)). Of course, there are many other passive tags that have been employed in applications where the tags could be attached to a more permanent conveyance such as a pallet or tote (Johnson (2003)). These tags cost anywhere from $0.50 to $10 or more depending on the technology, data storage capability, and operating range of the tag. Readers, on the other hand, typically cost $1000 to $2500 depending on their connection requirements. Wireless readers used in outside applications are more expensive while ones that could be connected by cable inside a building are at the lower end of the cost range.

Active tags contain both a radio transceiver and battery. They have a substantially larger range (100+ meters), and are considerably more expensive to manufacture, and require periodic battery replacement. Active tags have the ability to transmit their location and other information intermittently with the signals being monitored by readers in the vicinity. Active tags typically can store far more information that could also be updated through interaction with the reader. Simple active tags cost as little as a few dollars or hundreds of dollars, again depending on the technology, range, and capabilities. Readers also range in cost from $1000 to $10,000 or more for tower readers in outside applications. For example, the U.S. military has installed thousands of active tags on assets (e.g., truck and containers). These tags can transmit over long distances and operate on long-life batteries that last for years without interruption. The tag can be programmed to hold a substantial amount of information describing the contents of the container, its shipment origin, destination, etc. They can also be used to detect tampering or other security breaches (Machalaba and Pasztor (2004)).

While RFID enables tracking at each discrete point in a network where a reader has been installed, many supply chain managers have also begun focusing on higher resolution systems that allow truly ubiquitous tracking. Such systems typically employ longer-range wireless communication systems such as off-the-shelf pager or traditional cellular communications along with GPS location systems. The costs and supply chain capabilities of these technologies have all greatly benefited from their wide-spread consumer use. These maturing technologies have become far more accessible and cost-effective in the past five years. For less than $100, pocket-sized GPS devices allow items to be tracked exactly anywhere on Earth at any moment. With no more than a clear view of the sky, salellite-based GPS enables location visibility ensuring that products are never lost in the supply chain. GPS itself is enabled by a constellation of 27 Earth-orbiting satellites (24 in operation and three extras in case one fails). The U.S. military developed and implemented the satellite network as navigation system, latter opening it for commercial use. A GPS receiver locates four or more of these satellites, calculates the distance to each, and uses that information to deduce its own location based on the principle of trilateration. With an accurate location reading passed by over an existing wireless pager/voice network (e.g., AT&T, T-Mobile and Cingular GSM/GPRS digital wireless networks) to a server, items can be tracked over the internet anywhere in the world.

Companies competing in the supply chain visibility space fall into one of four categories:

1. Hardware providers: Companies focused on developing a specific technology like bar code readers, RFID devices and readers (e.g. Texas Instruments, Alien Technology, Symbol, Intermec, Philips), or GPS hardware (e.g., Global Tracking Communications, Advanced Tracking Technologies).

2. Focused application providers: Companies who deliver solutions for specific tracking needs. Examples include Savi Technologies, which focuses on active RFID-enabled networks for transportation tracking and security; WhereNet, which provides RFID tracking solutions operating in confined spaces like factories or warehouse; and @Road, which provides GPS-tracking solutions for trucking companies.

3. Visibility dashboard providers: Firms that capture and present tracking data using visualization software, typically in a web-interface. Examples here include companies such as Blue Sky Logistics and SeeWhy that provide logistics tracking dashboards. These firms focus on reporting and metrics, with the underlying tracking information gathered by others.

4. Integration service providers, who work to pull all the pieces of technology and systems together to provide a complete solution. Many large technology consulting firms are competing in this

area (e.g., Accenture, IBM, and HP) along with smaller specialty providers like RedPrairie or Savi Technologies.

Of course, there are many other firms who offer applications that leverage the tracking data for supply chain planning forecasting, or execution. For example, TrueDemand Inc. offers forecasting tools based on warehouse movement data that aids in replenishment planning and RedPrairie offers RFID supply chain execution solutions that facilitate order processing. However, in the end, few firms have successfully integrated all of the elements required for a large-scale supply chain tracking system. Integrating all the players and the technologies has proved exceedingly difficult because vertical integration of tracking technology is messy and cumbersome. There are companies who have developed tags and barcodes that can be attached to assets. In addition, several companies have figured out how to provide event and logistics management from the software end. Unfortunately, the tags and barcodes are useless without a system to read them. And most of the software applications are linear in nature and tend to only focus on one or two internal business processes. The entire supply chain network for a customer is more complex than that. It's a challenge to integrate all the levels of the chain, especially from RFID tag to reader to software to enterprise, so that all levels can experience real-time visibility simultaneously.

III. Case Company Background

F.W. Woolworths, a subsidiary of its U.S. parent, was founded in the U.K. in 1909 as part of its parent company's global expansion plan. The first store opened in Liverpool, beginning a rapid roll-out throughout the U.K. While Woolworths may have begun in the United States, it quickly became one of the U.K.'s most loved retailers. Focused on product lines for the home, family, and entertainment, Woolworths always offered its customers excellent values on a wide range of products. F.W. Woolworths was subsequently listed on the London Stock Exchange with its U.S. parent retaining a majority shareholder. In 1982, Woolworths was acquired by Kingfisher, Europe's largest home improvement retailer. Following the acquisition, the new management implemented a strategy to focus the product offering, centralize accounting, invest in new information systems, rationalize the store base, reduce costs, and centralize distribution. Products were rationalized into clearly defined categories: entertainment, home, kids (toys and clothing), and confectionery. This enabled further development of the individual product ranges through the use of branded, own-brand and exclusive merchandise such as Ladybird Clothing and Chad Valley Toys.

In the late 1990s, the management extended the Woolworths brand into other retail formats and alternative channels to accelerate growth by taking advantage of changing retail trends. This resulted in the opening of the first "Big W" store in 1999 and Woolworths General Store in 2000.

Woolworths was divested from Kingfisher plc in 2001 and began trading on the London Stock Exchange. The divestiture enabled the Woolworths Group plc management to pursue (independently of Kingfisher) the recovery and growth strategies that best met its long term objectives. By 2006, Woolworths maintained a portfolio of approximately 900 stores. Over 800 Woolworths, Woolworths General Stores, and Big W superstores offered housewares, toys, sweets, apparel, home electronics, and seasonal fare with sales of over £2.8 billion. The group's other retail outlets included MVC home entertainment and electronics boutiques (about 85 shops), EUK, the U.K.'s largest distributor of home entertainment products, and music and video publisher VCI.

Woolworths faced increased competition from all sides. Traditional U.K. grocery retailers such as Sainsbury and Tesco had aggressively expanded their offerings beyond traditional food items. Pharmacy chains such as Wilkinsons and Boots the Chemist had expanded their general merchandising offerings. Finally, Woolworths' Big W supercenters faced competition from Wal-Mart, which established a U.K.

presence through its purchase of ASDA. This increased competition placed a great deal of pressure on already thin general merchandise margins.

III. Tracking Project Description

Woolworths serviced the general merchandising needs of its 800+ stores through four distribution centers (DCs). Two primary distribution centers, located in Castleton and Swindon, were geographically focused, carried the same “general merchandise” items, and serviced approximately 400 stores each.

The two seasonal distribution centers, located in Rugby and Chester, carried a revolving inventory of seasonal merchandise including everything from patio furniture to Christmas decorations. Merchandise bound for the stores was typically transferred to the stores in either a large steel roll cage or a reusable plastic tote box. Large items were shipped in one of 100,000 roll cages while smaller items where shipped in totes (Figure 1). Totes destined for the same store were stacked on one of 16,000 dollies (roll cages without sides). Distribution center employees wheeled these roll cages and dollies onto trucks for delivery to the stores.

Woolworths had first experimented with RFID in 1999 as a security system for tracking individual products. The project, which involved tagging clothing moving from a distribution center to a single store, was not a success. The tags were too expensive, too unreliable, and did not provide the read range the company needed.

So in 2003, when Woolworths began work on a second experiment, the goal was to define a manageable project scope in terms of the products, vehicles, stores, and distribution centers to be included. Woolworths distributed the dollies and their associated totes (up to 10 per dolly) only from its Swindon warehouse; all 800+ stores were covered from this site. Therefore, this closed loop was ideal for a “proof of concept” and did not require tagging all 100,000 roll cages. The system would track these dollies (and the associated totes) out of the warehouse, to the stores and back again.

From Woolworths’ previous RFID initiative, they felt that item-level tracking, was not economically justifiable. The £4 average consumer “basket” price did not support a passive chip implementation. However, they believed that a unique “Russian Doll” strategy could achieve item-level visibility without item-level tags. The strategy combined a number of technologies focused on reducing both process losses and theft from the point of pick through the point of delivery to store, including:

- Bar codes on the individual items and on the tote boxes.
- Short and long range RFID devices to track movements within the DC.
- Portable RFID readers to track movements from the DC to stores.
- Global Positioning System (GPS) to track vehicles on route.
- A Wireless Wide Area Network (WAN) to transmit data back to the control system.
- 16,000 active RFID tags.
- Integration services with Woolworths’ fulfillment and transport planning systems.

By using this unique combination of technologies, Woolworths had complete visibility of the movement of each tagged dolly, increasing security of both product and distribution assets (see Johnson (2004) for detailed description of the technologies used).

The outbound distribution process began in Woolworths’ national distribution center in Swindon via two technologies:

- Automated Storage and Retrieval System. A high density rack retrieval system that used automated robots to stock merchandise stored in plastic totes on the shelves and later extract merchandise bound for the stores. This process, which required no manual intervention, was used primarily for high-value items. Totes retrieved from the rack were sent to a picking area where items were sorted for each store order.

• Pick-to-Light System. Employees selected small items destined for each store using a pick-to-light system that resulted in better than 99 percent accuracy. In the pick-to-light system, workers were guided visually by lights to the exact bin locations where the required articles were stored. These items were picked and placed into plastic tote boxes. In cases where the tote held high-value items, the entire tote would be shrink-wrapped to discourage theft.

All of the plastic tote boxes had unique bar codes. Totes destined for the same store were scanned and then stacked on dollies using an automated stacking system. In the past, the dollies had no unique identifier. For the pilot, Woolworths attached a Savi EchoPointTM active (battery-powered) RFID tag on each dolly. The simple active tag was developed by Savi Technologies to be low cost (about £5) and was disposable with a battery life of about 4-5 years.

The dollies were recorded as they moved toward the dispatch bay. A short-range device, called a SignPost, located under the track of the sorting system, emitted a low-frequency signal that activated the RFID tag. To conserve energy, the tag spent much of the time in a suspended state until it was activated by a sign post (or reader). When activated, the tag broadcast the information it contained, which was read by long-range readers installed in the rafters of the building (readers could recognize tags from up to 100 meters away). The software system associated the bar codes that were scanned on the totes with the RFID tag on the dolly. So the system knew which items were put in specific totes and which specific totes were put on a specific dolly.

Woolworths also tied Savi's SmartChain real-time logistics platform in with its transport planning system. That way they could track which vehicle was in the dispatch bay at a given time and the destination of the vehicle. Medium-range SignPost readers, which could wake up a tag from about 20 feet, were installed over the dispatch bays. When the dispatch bay team loaded dollies onto a vehicle, the tags on the dollies were activated and read, and the system compared the ID numbers to the truck's delivery instructions. If the wrong dollies were being loaded, the system alerted staff with flashing lights (Figure 2).

Once the vehicle had been loaded with the right dollies, the doors on the truck were closed and an encrypted seal (an electronic lock activated by a randomly generated code), was placed on the doors. The code had a four-digit number that the driver punched into his handheld computer. The vehicle was then ready to make its first delivery. Each driver had his own portable kit that included a Symbol PDT8100 handheld scanner. The unit also had a GPS-enabled wireless communication system, so Woolworths could track the truck's movements between the distribution center and the store. The GPS transmitter was set up to send a signal at different intervals along the trip. Since the cost of monitoring was based on how often the transmitter broadcasted, the interval could be lengthened if the goods in transit were inexpensive, or set for every five or ten seconds if there was high-value merchandise in the truck.

When the driver arrived at the store, he keyed in a four-digit number used to identify the particular store and the system would confirm his exact location by "geo-fencing". If he said he was at store "1234," the system knew the location of that specific store and confirmed that he was at the correct location. He then entered the four-digit seal number, which was required to correspond with the number that was entered at the dispatch bay. If the code did correspond, the lock was released, and he was then given instructions on the handheld regarding which dollies and totes to unload. As he unloaded each dolly, the driver would scan it with the Symbol unit. The system would then confirm that he moved the correct dolly or tote. The system would warn him if he had delivered too many, too few or the wrong ones.

Once delivery was complete, the driver then received an electronic signature from the store manager on the screen of his PDT8100, indicating that the store had received the entire shipment. He would also accept any returns that might be going from the store back to the distribution center and then close the transaction by securing the vehicle door and entering the seal number. When he got back into the vehicle, he connected the PDT8100 to its base station, and the information from the transaction was transmitted via the Mobitex wireless network into Microlise's Transport Management Center. From there, the data was forwarded to the Savi SmartChain platform where the asset movement history was recorded. The driver would then move on to the next drop and the process was repeated. This completed the audit trail.

The system could track dollies going to any of Woolworths' stores in the U.K. The pilot, however, only equipped fifteen trucks with the Symbol handheld computers with GPS transmitters. Consequently, the company could only track shipments to 30-40 stores.

The SmartChain tracking platform formed the focal point of the tracking process. Hence the existing enterprise systems also fed data into the SmartChain tracking platform. For instance, the tote-pick control system told Savi SmartChain which picks and which tote boxes were going in each store order. The transport management system provided the SmartChain software with information about which store order went on which vehicles when the vehicles were in the dispatch bay. The SmartChain platform brought all the data together to keep track of which picked items went into which tote, which tote went onto which dolly and which dolly onto which vehicle (the Russian Doll).

Woolworths purchased Savi's EchoPoint tags for each of the 16,000 dollies in the system. Although the original goal was to track only high-risk merchandise, like expensive clothes and CDs, the company decided to extend the system to all items shipped using the dollies. The found that they could afford the same level of protection to lower-value merchandise as mobile phones and electronics.

In addition to the fifteen PortaPOD mobile units used to relay real-time data back to the Transport Management Center, Woolworths also equipped two stores with fixed RFID units to track dollies from the distribution center. The mobile PortaPods units, however offered greater flexibility and could be used to track vehicles (and therefore their contents) via GPS throughout the trip from distribution center to the store.

IV. Project Benefits

The project demonstrated the ability to integrate a unique combination of technologies (bar codes, short and long range RFID, wireless wide area networks, GPS, and existing order fulfillment systems) and deliver useful information and visibility to an extended supply chain. This was done in such a way as to be almost invisible to the user unless there was an error (almost all information was gathered automatically and only when there had been loading or delivery errors did the system notify the user).

Although the project covered only a small proportion of the goods delivered to the stores, it demonstrated the capability to have complete visibility of all goods from the moment they were picked, in transit, and delivered to the store. The project eliminated incorrect deliveries of dollies to the participating stores (i.e., process errors and potentially criminal activities) and also provided useful information in the event of a criminal investigation. The system had also been designed in such as way that it could easily be extended to cover more stores and also include merchandise in roll cages.

Woolworths identified six categories of potential benefits:

1. Shrinkage. Through better visibility of inventory and its whereabouts, process/delivery errors were identified and corrected on a real time basis. The new system also provided an automated audit trail in the event of losses.

2. Bookstock Accuracy. A real-time, automated update of book stock within stores made stock records more accurate. This in turn enabled higher availability from lower inventory levels thereby improving customer service.

3. Reduced Labor Costs. The automated inventory verification process reduced manual check-in and updating of stock records. The increased accuracy also reduced the effort required to investigate stock losses.

4. Asset Management. Dollies, tote boxes, and roll cages are valuable assets themselves. This system provided greater visibility into their whereabouts, pinpointing blockages, and loss points. This tracking capability improved asset utilization and reduced unnecessary capital expenditures.

5. Transport efficiencies. Automated tracking of vehicles not only generated a security benefit, but also improved vehicle routing, driver performance and training, and vehicle availability.

6. Identification of future RFID applications. By involving warehouse workers and drivers early in the pilot, the employees quickly felt ownership of the system and incorporated it into their everyday operations. Their excitement about the project led to many other suggested applications of RFID.

Developing a leading RFID application provided Woolworths with a platform from which it could learn about its further application, develop new processes and gather previously unavailable information about its inventory and its movements, its processes, and its assets. Woolworths recognized that no single initiative would provide a complete solution to eliminate shrinkage. This project did provide clear visibility to one area of potential shrinkage (the supply chain), reduced the opportunity for loss, and brought significant operational efficiencies. In conjunction with other initiatives, Woolworths felt that the RFID pilot produced significant reductions in shrinkage throughout the supply chain. It was, however, difficult to attribute quantifiable benefits to any individual component of the strategy.

V. Building a Business Case

The team at Woolworths realized that an initial success with RFID was no guarantee of future funding. The future of RFID at Woolworths depended on a strong business case — one that could stand up against other requests for investment. With the Kingfisher divestiture, Woolworths had gone from a company with a net income of £800 million to a net income of £25 million, and as a result, an investment of £3 million would be scrutinized. Given this environment, everyone was forced to compete for scarce funding resources in a company that traditionally viewed new store construction as the surest way to growth. The team would have to demonstrate that the £2–3 million earmarked for a typical new store would be better spent on infrastructure upgrades with a much more attractive ROI. Clearly, senior management would only fund the projects with the best return for shareholders.

Given the initial success, the team believed that a return on investment of less than one year was a realistic objective for a full-scale implementation. But they knew they had to be clear on where the savings would come from. The initial benefits found during the pilot project proposal were:

• Reduced Supply Chain Theft/Loss. The "Russian Doll" concept maintained a detailed audit trail of the merchandise as it moved through the supply chain and assigned inventory accountability to each participant (i.e., loading dock employee, delivery driver, receivables clerk). This accountability should not only serve as a deterrent, but also provide important evidence for any criminal investigation.

• Improved Vehicle Utilization. A recent piece of British legislation would require all commercial carriers to install electronic recording systems in their vehicles to ensure driver compliance with regulations governing daily driving time. This new Working Time Directive was scheduled to go into effect in 2005. They viewed this requirement as an opportunity to enhance the required functionality with a GPS-enabled vehicle telemetric program. A Vehicle Telemetrics System would track and measure fuel economy, brake usage, and vehicle abuse in real-time. Preventive maintenance and measures (driving skills courses, driver evaluations, etc.) would be implemented to prolong vehicle lives and reduce vehicle downtime. Some estimates showed that transportation costs could be reduced by 8–10% using the smart system. The smart truck could be outfitted with a single black box that handled everything needed for RFID, telemetrics, and the Working Time Directive.

- Improved Asset Utilization. Both roll cages and dollies were expensive distribution assets, costing £100 and £40 respectively. Woolworths had approximately 100,000 roll cages throughout its distribution system. Individual stores sometimes hoarded extra roll cages as a safety stock or for other tasks throughout the store. Often the cages were simply forgotten, misplaced, or stolen. Each year, central logistics planners were forced to buy additional roll cages to prepare for the holiday season rush — typically 2–3% of the fleet was lost each year. Better asset tracking would allow planners to recall outstanding assets or chargeback any lost roll cages directly against the individual stores.

- Reduced Paperwork. The electronic tracking and signature system would eliminate the need for paper-based manifests and proof of receipt documents. This did not include the expected savings from resolving errors with manual data entry.

- Inventory and Availability. An additional area of potential savings that was difficult to quantify was the impact on inventory and availability. Inventory levels followed seasonal cycles, typically rising in the late summer and fall in preparation for Christmas. Woolworths achieved about 4.5 turns/year. Inventory was also linked to item availability in the store. With a more accurate stock count, availability could be improved or safety stock lowered or both. Retail studies had shown that a 1 point increase in availability could translate into .25–.5% increase in sales.

The team estimated the cost of a larger deployment to be about £2–3 million, including:

- £1,000,000 for system hardware, including tags for all 100,000 roll cages, readers for the other three distribution centers, and the additional portable units for delivery drivers. The team felt confident that the tag cost would drop from the £8 they paid for the pilot units to under £5. That would leave £500,000 to purchase 100 dispatch bay readers, the necessary signposts, and the handheld devices for the trucks.

- £400,000 for software integration. The team believed that the majority of software capability and compatibility was built into the pilot system, and therefore only minimal efforts would be required to extend the capability to incorporate roll cages.
- £1,000,000 for the vehicle telemetric system. This was the cost of enhancing the mandatory delivery truck system with GPS-enabled vehicle performance monitoring and reporting capability.

VI. Lessons from Woolworths

The pilot RFID implementation was viewed as technical success and won the *Supply Chain Solution of the Year Award* at the *European Retail Solutions Award Conference*. Reporters from both the U.S. and Europe visited the distribution center to see the system in action and hear how they had brought many leading edge technologies together to build the first such commercial tracking system. Yet, despite accolades from the press and the program's initial success, developing a clear business case to move forward with the other distribution centers was more difficult than many expected. Several of the potential benefits, while real, were simply not large enough. For example, the asset utilization and paper work reduction were clear, but amounted to a few hundred pounds. The vehicle utilization telemetrics appeared to have large potential, but the RFID and GPS system are only a part of the whole on-board Telemetrics project. It was hard to attribute much of the benefit to the RFID tracking project alone. Equally important, transportation had been outsourced, so determining who would invest and how the benefits would be shared was challenging.

Possibly one of the largest benefits was improved availability yielding improved customer service. Inventory record inaccuracy is a significant problem (Raman et al (2001), DeHoratius and Raman (2004)) that impacts the execution abilities of even the best retailers. Clearly, shrinkage results in inaccurate inventory records, making replenishment more difficult. Beyond losses, Woolworths also suffered from replenishment mistakes such as inventory delivered to the wrong store. This led to inaccuracy at both stores — one store with more of a product than reported in the inventory system and the other with less. A recent study of Wal-Mart's RFID pilot (Hardgrave, Waller, and Miller (2005)) examined store "out of stocks" over a six-month period at twelve Wal-Mart stores — six using carton-level RFID and six control stores who had not implement RFID. Throughout the study, store shelves were audited each day, and the number of SKUs without any stock (out of stocks) were recorded. Over the six-month period, both groups of stores reduced their out of stocks — with the RFID stores outperforming the control group. Controlling for the improvement in all stories, the authors of the study attributed a 16% reduction in out of stocks to RFID alone. They argued that RFID delivered this benefit by improving store inventory accuracy and the backroom and shelf stocking processes. For example, the high quality and timely inventory information make it possible to better track inventory in the store and move it more quickly to the shelf when needed.

Inventory inaccuracy and poor operational processes erode the stores' ability to reach the efficient frontier in transforming inventory into service (Figure 3). Thus, stores are not able to fully convert inventory into service (shelf availability). With improved information and operating processes, the stores could either improve their service (without increasing inventory) or reduce their inventory (without reducing service).

While it seems likely that Woolworths could improve it's out of stocks, creating a direct link between inventory inaccuracy and product availability was a little more challenging. Managers argued that it was realistic to believe that improved accuracy could (modestly) yield a 1 point improvement in availability (without increasing inventory). This would yield about £6.75M of revenue (.25% of 2.7B). With 28.5% gross margins, this translated into roughly £1.9M of gross profit — thus less than a two-year payback on the project. However, the availability argument had been used for many improvement projects (such as bar codes, shipment audits, improved totes) in the past — so some in management were skeptical.

Likewise, shrink reduction appeared to be a significant benefit. While the RFID project at Woolworths would not have a big impact on store losses (e.g., shoplifting), it certainly would impact the 56% of the total losses attributed to supply chain (56% of £75M is £42M). Just a 10% reduction in supply chain losses alone (£4.2M) would pay for the project. This appeared to be the most compelling. Yet, Woolworths realized that no technology can eliminate theft, and thieves will certainly find ways to circumvent the tracking system. Thus the potential savings were hotly debated within the firm.

Along the potential benefits, the project also had several important risks:

1. Timing: Given the rapidly changing RFID landscape, such as lack of standards, rapidly dropping costs, and increasing technical capabilities, there were many incentives to wait. This was a key concern of Woolworths' executives. There was significant concern that buying too early would result in an expensive system with limited capabilities.

2. Cost: The full-scale rollout could cost far more than projected. One key area of concern was the software integration. Some had argued that integration work from the pilot could be leveraged resulting in only £400,000 requirement for full-scale integration. Many others argued that this was very optimistic given the rapidly evolving technologies. Moreover, the were some within Woolworths that argued that to fully capture the benefits of RFID, they needed to first replace their exiting warehouse management systems and further redesign (or build a new) distribution center that was optimized for the tracking systems. This represented a roughly £50m investment

3. Feasibility: While the pilot was a technical success, there were still many uncertainties about the feasibility of a full-scale rollout — particularly reliable reads from the RFID devices in a wide range of operating environments.

4. Benefits: While the benefits looked compelling, the pilot could not fully validate the assumptions. Given the nature of the pilot, it was not possible to show (with hard data) that shrinkage would be reduced.

Faced with these risk, Woolworths decided to postpone a full-scale rollout for a least 1–2 years. The management felt that there were many other investment opportunities which appeared more compelling, including new stores and a new e-commerce operation — all multimillion £ investments. One executive commented, "Woolworths will invest in RFID when the time is right for us, but with trade as it is at present there are other things we must do first."

The Woolworths experience is not unique. While Wal-Mart appears to be showing progress in developing a compelling business case, many of their suppliers are still unclear if RFID and the tracking information will clearly benefit them (Overby (2005)). Likewise, there are many firms who have conducted pilots, but have not yet felt confident enough in the business case to move to a full-scale rollout (Johnson (2004)). Given these difficulties in building a clear business case, one might wonder why RFID? Why not bar codes? In the following section, we will examine the benefits of RFID over barcodes.

VIII. Barcodes and RFID

RFID and other automated identification technologies have captured the imagination of engineers for years and held great promise in many applications. For example, many had dreamed of the RFID-enabled grocery store (Collins (2004)), eliminating checkouts. However, the cost and capabilities have long made the concept unviable. Yet RFID is steadily finding its way into everyday life, from automotive toll lanes that eliminate coins to building security systems that eliminate security guards. RFID offers many significant advantages over traditional bar code data collection. First, it doesn't require "line of sight" with the reader or even human interaction, so mis-reads are far less likely. Second, the tags can withstand harsh environments including rain, snow, and heat. Third, there are no moving parts that could be jarred loose. Fourth, the tags can hold vast amounts of information and be changed and reprogrammed. Fifth, RFID allows for simultaneous reading of multiple tags. And sixth, the data can be secured or locked. The key drawback in many applications remains its cost. For example, barcodes on consumer products could be implemented for less than $0.01 item. Many argue that the true costs are often hidden and that within a supply chain, bar coding for inventory and transportation management may cost as much as $0.10–$0.20 per read in direct labor and infrastructure cost.

For years, the common bar codes found on any product in a grocery or discount stores are the known as UPC A codes. It is simply a twelve-digit number that has four parts. The first number denotes the type of bar code (e.g., "0" or "7" indicate the regular type found on most products, "2" indicates the product is a store weighted item like bulk food). The next five indicate the manufacturer and the following five identify the product code. Finally the last number is called the checksum, which is a number used to do a simple test that determines if the code was read correctly (Figure 4).

There are many other code types including UPC–E used on small products (takes less space) or EAN–13, which is the 13 digit European standard. EAN–13 is basically identical to UPC-A with the leading two digits representing the country code. The U.S. began migrating to EAN–13 in 2005. Two-dimensional codes (like UPS's maxicode used on packages holding up to 93 characters) or PDF-417 codes hold more information — in some cases hundreds of characters.

The simplest RFID devices hold a little more information than a bar code but are equally static. Typical passive devices (write once read many) hold less than 2KB of data with so-called simple devices containing a 96-bit number. Of course there are advantages like the tag robustness (i.e., it can be encased so it is not easily damaged by water or trauma) and there is no need for direct line of sight. More expensive passive and active tags allow for all kinds of options like the ability to store new information, update that information, and broadcast that information (active tags). For example, a simple passive device that can be embedded into a shipping label is being piloted by many manufactures and retailers (including Wal-Mart). These labels can easily be applied to the outside of a carton or to a pallet of goods.

RFID devices operate at several different frequencies with the most common being low-frequency (around 125 KHz), high-frequency (13.56 MHz), and ultra-high-frequency or UHF (860-960 MHz). The different frequencies have different operating characteristics that make them more appropriate for specific applications. For example, low-frequency tags conserve power and are good for penetrating objects with high-water content, such as fruit while high-frequency tags are more effective with objects made of metal. Although there is much talk of a $0.05 chip, in 2006 Gen 2 passives (simple, 96-bit EPC, short range) generally cost $0.20 to $0.40 U.S. However, many chip manufacturers offered discounts on large quantity purchases (10M or more). Tags embedded in a thermal transfer label typically cost $0.40 or more (RFID (2006)).

Of course, there are many possibilities with more sophisticated passive and active tags, such as including sensors for temperature, humidity, etc. Many such capabilities could be very useful — for example in monitoring the temperature of meat in transit or monitoring a container for security breaches. But these capabilities all come with costs. The future of tracking supply chain technologies all hinge on the migration of the cost performance curve (Figure 5). Clearly there are numerous applications as the costs are reduced. If technological developments and manufacturing volumes shift the curve back — making the adoption less expensive, the possibilities are nearly endless.

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Figure 1: Totes on dollies and roll cages waiting for shipment.

Figure 2: Dock door with RFID reader and indicator lights.

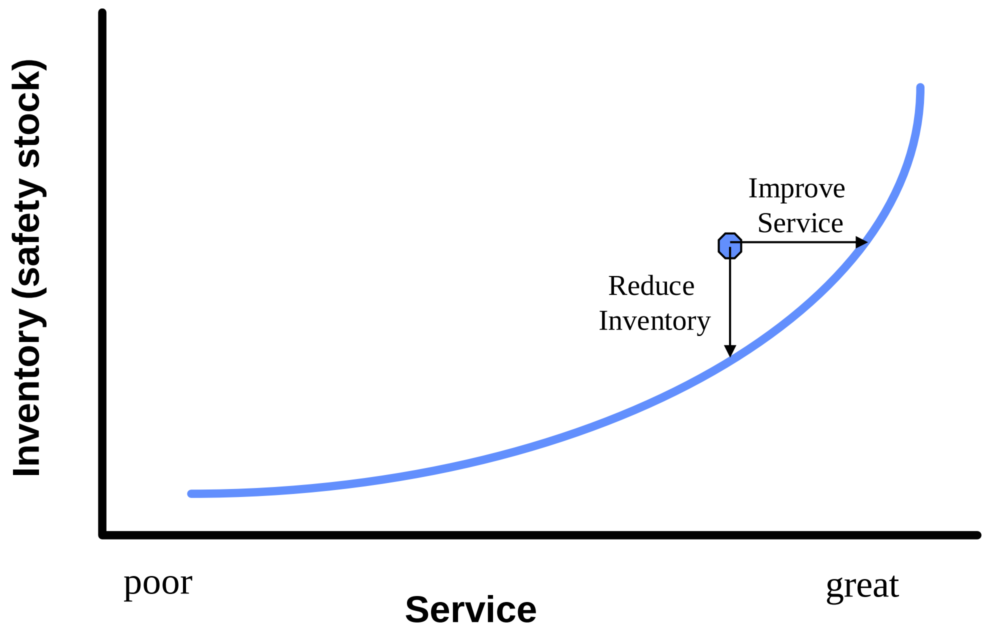

Figure 3: Using tracking systems to move to the efficient frontier.

UPC -

1 (type) + 10 (mfg/prod) + 1 (checksum)

EAN-13

3 (country code) + 10 (mfg/prod) +4 (supplements)

UPS (MaxiCode) — 93 characters

PDF-417 — 100’s-1000’s characters

Figure 4: A selection of barcodes.

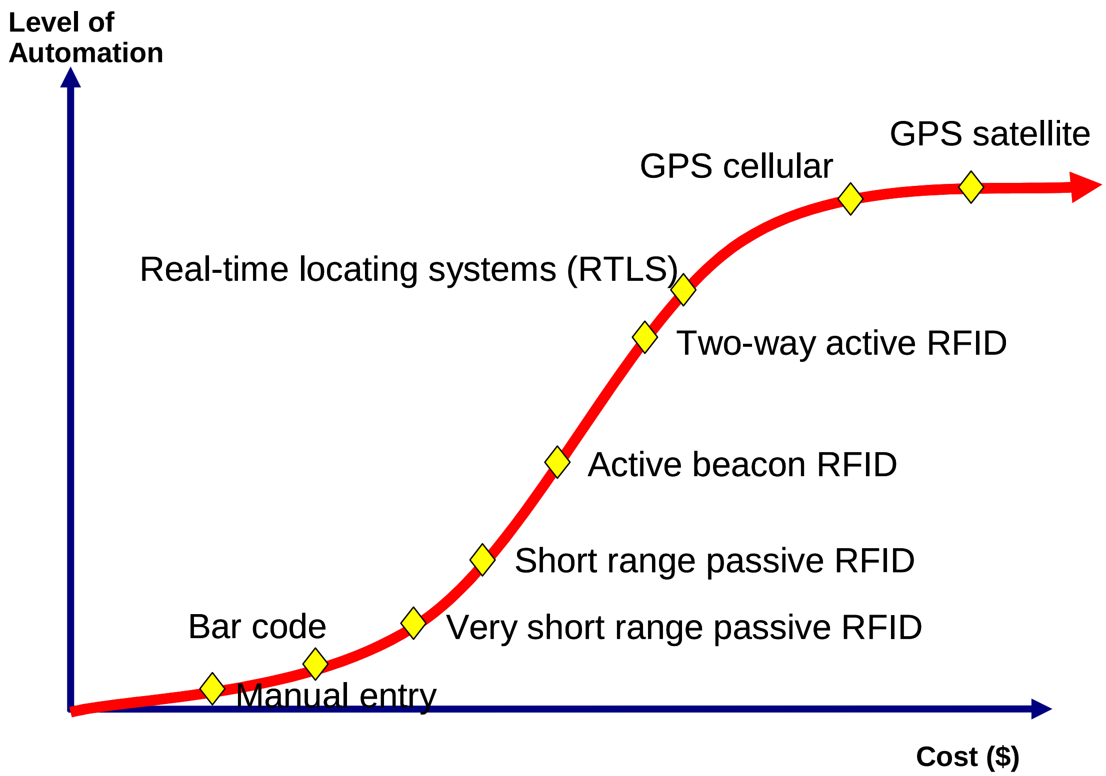

Figure 5: Cost and automation capabilities of tracking technologies (Johnson 2003).