
RFID Technology and Applications in the Retail Supply Chain: The Early Metro Group Pilot

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Abstract

RFID (Radio Frequency Identification) recently has gained enormous attention in various industry sectors, the media, and in academic research. This paper focuses in early RFID applications in the retail supply chain. It takes a quick look at the available literature and then explains the technological issues including the need for standardization and the challenges on the data, network, and application layers. The study then outlines RFID based applications along the retail supply chain. It takes the case of Metro Group's Future Store, a brick-and-mortar supermarket belonging to the world-wide fourth largest retailer, to investigate the advantages and challenges experienced with early RFID applications. The paper differentiates between RFID tags on pallets and cases on the one hand and RFID tags on items on the other. Finally, the paper closes with a brief summary and an outlook on RFID in the retail supply chain.

1 Introduction

The use of RFID (Radio Frequency Identification) in the retail supply chain and at the point of sale (POS) holds much promise to revolutionize the process by which products pass from manufacturer to retailer to consumer. The basic idea of RFID is a tiny computer chip placed on pallets, cases, or items. The data on the chip can be read using a radio beam. RFID is a newer technology than barcodes, which are read using a laser beam. RFID is also more effective than barcodes at tracking moving objects in environments where barcode labels would be sub-optimal or could not be used as no direct line-of-sight is available, or where information needs to be automatically updated. RFID is based on wireless (radio) systems, which allows for non-contact reading of data about products, places, times, or transactions, thereby giving retailers and manufacturers alike timely and accurate data about the flow of product through their factories, warehouses, and stores.

2 Literature Setting and Research Approach of section

Management research and academic management literature on the use of RFID in the retail supply chain is still scarce. The technical aspects of RFID business applications have been highlighted in recent engineering and computer science publications (e.g., Glidden et al. 2004). Consulting-oriented papers have also offered in-depth technological overviews of state-of-the-art developments (e.g.,

among many others, Das 2002; Harrop 2004). Certainly, the technology has recently also been covered in management-related academic journals, which have focused on different aspects of electronic business and supply chain management (e.g., Angeles 2005; Asif and Mandviwalla 2005; Juels et al. 2003; Loebbecke and Wolfram 2004; Loebbecke 2004, McGinity 2004; Singh 2003).

The main discussions of RFID applications currently appear in magazines, such as *Information Week*, *Infoworld.com*, and *RFID Journal*, in pamphlets written by technology consultants, and in the daily press. These publications focus mainly on case studies and discussions of business opportunities.

However, as of early 2005, actual RFID applications in the real world, beyond lab studies or pilot projects, are still so new that academic research into their impact, lessons learned, and recommendations has not been published.

Therefore, this work takes a positivist view and investigates the observable parts of the phenomena under study. It explores the technological issues (Section 3) and the actual RFID based applications with their observable and measurable impacts (Section 4). It focuses on 'how' RFID based applications are organized and set up. With regard to the focus on 'how' (Yin 2003) and due to the required depth of investigation, an explorative case study (Sections 5 & 6) was chosen as the most appropriate research design (e.g., Benbasat et al. 1987; Yin 2003), with eight in depth-interviews, site visits, and company documents analysis for data collection.

3 Technological Issues

Using RFID, product data is automatically transmitted by radio signals. The key component of RFID technology is the RFID tag (called a transponder), which is a minute computer chip with an antenna. This tag is attached to transport packages (pallets or cases) or individual products (items). An RFID tag can carry an impressive array of data. Passive or semi-passive tags 'identify' themselves when they detect a signal from a compatible device, known as an RFID reader. As a tag passes through a radio frequency field generated by a compatible reader, it transmits its stored data to the reader, thereby giving details about the object to which it is attached.

RFID systems operate in 'free air', i.e. non-regulated frequencies of the wireless communications spectrum (called the radio frequency spectrum). National regulations for radio communications vary and are established by different bodies. In the US, regulations are less restrictive than in Europe, where the relevant spectrum is partially reserved for mobile telephone networks or medical services.

In retailing, a numeric, article-specific code (called the Electronic Product Code - EPC) is stored on the RFID chip. The EPC is comparable to a conventional barcode. As soon as the chip comes within 1 meter of an RFID reader, it sends its numeric code to the reader. The reading device recognizes the EPC stored and may match it with other pieces of data - such as the price, the size, the weight, and the expiration date of the product - stored in various databases.

3.1 Towards RFID Standardization

To achieve large-scale RFID usage in the retail supply chain, RFID technology needs to be standardized. That process is currently underway. On the global front, two international bodies are involved: EPCglobalTM (www.epcglobalinc.org) and ISO, the International Organization for Standardization (www.iso.org).

EPCglobalTM was created in Fall 2003 as a joint venture of EAN International (www.ean-int.org) and the Uniform Code Council (www.uc-council.org). The

launch signaled the drive toward a worldwide, multi-industry adoption of the EPC, key identification aspects of RFID, and its network of links to Internet technologies. EPCglobal™ is working on the structure of the data stored in the transponder. It aims to define naming standards to foster the use of RFID technology between suppliers and retailers. Comparing EPC to the traditional EAN code, EPC stores only the serial number on the chip while EAN has extensive information on the chip. Hence, for the EPC only the serial number needs to be coded and understood. The serial number then provides access to databases containing information about specific products.

The ISO standards for RFID, on the other hand, cover the physical characteristics of RFID labels and cards, the air protocols, the anti-collision and transmission protocols, and commanded set and security features.

As these two standardization bodies work on their separate issues, RFID choices made by players along the value chain can be both, EPC- and ISO-compliant.

3.2 Technical Challenges on Data, Network, and Application Layers

Any RFID enabled process begins with an RFID reader reading an RFID tag: The reader hits the tag with a radio beam and reads the data on the tag. Some readers are designed to simply pass the tag read along to an attached computer, relying on the computer to do validation (e.g., reading a check sum, elimination tag collisions, etc.). Other 'smart' readers have the ability to validate data and even perform basic filtering.

With traditional barcode technology, the laser beams must have an unobstructed view of the barcodes to read them. Radio waves, in contrary, do not require line-of-sight; the signal can pass through materials, such as cardboard or plastic. With no line-of-sight required in RFID, multiple tags can be read simultaneously, even when hidden from sight. An RFID portal, for example, can read all the goods on a pallet with one pass. A barcode scanner would require each item to be scanned individually.

This RFID process presents challenges relating to the data, the network, and the application. An RFID reference architecture addresses all three.

Data Layer

On the data layer, the RFID Reference Architecture (RRA) determines what to do with the data gleaned from the tag. The following are examples of applications with increasing requirements for managing data:

- Querying applications: A conveyer belt that automatically routes cases to their destination needs to be able to simply pass the tag data on to the appropriate system, receive the response, and then purge the tag scan from its memory.
- Mixed goods applications: Assume a reader on a picking cart scans - say, every five seconds - all tags within range (e. g. placed on the pallet). Such an application needs to be able to constantly evaluate each scan's results against expected results and alert the operator of exceptions.
- Smart Shelf applications: 'Smart shelves' keep track of the products placed on them. Scanning a 96-bit EPC-compliant RFID tag every five seconds in a distribution center that holds approximately 500,000 cases generates 32,958 GB of data every hour. The majority of this data should simply confirm the existence of the requisite number of cases on each shelf, and should therefore be disposable. The RFID Reference Architecture (RRA) needs to be able to filter and process such large amounts of data.

Applications built to track serialized data (such as EAN-128 numbers on pallets) should be able to accommodate the real-time stream of single-tag reads. Data requirements are much higher for systems that deal with the more granular serialized data that comes from RFID tagging at the case level, rather than the pallet level. For example, take a distribution center that ships about 616,000 pallets to stores per year, each of which is duly recorded and serialized. Bringing that serialization down to the case level would require applications to handle approximately 46 million items, a 74-fold increase in data management and storage requirements over 'pre-RFID' requirements (Metro Group 2004a). Systems that track at the item level generate orders of magnitude more data than is currently common because each item is repeatedly scanned by the multiple readers, which report on everything within their range. The applications must be able to handle these voluminous, multiple real-time streams of data.

Network Layer

RFID driven network requirements result mainly from the design of the data layer because the network must be capable of moving the quantity of data generated by the scans. For simple applications, 10 MB Ethernet may suffice. For 'smart shelves' to track individual items, though, the bandwidth requirements challenge even today's sophisticated Gigabit Ethernet switches. But calculating required network bandwidth is straight forward.

For the physical location of readers and other hardware, RFID based systems demand constant communication between each reader and the RFID Reference Architecture (RRA), which in turn requires universal access to wireless networking throughout the physical facilities that use RFID.

Blurring the line between electronic security and physical security carries important network and security implications. With literally a computer on every pallet, case, or item, the distinction between 'data' and 'product' becomes less clear. Hence, while RFID reduces the accidental introduction of errors in the data, it increases the possibility of data corruption.

Item level RFID creates additional networking and security challenges. While the traffic between readers and the store network can be secured through encryption, the standard based data encoded on each EPC-RFID tag is, by definition, unencrypted. The contents of RFID tags can therefore be read by any reader tuned to the correct frequency. Thus, in an RFID enabled environment, it is difficult to prevent a competitor's employee from walking through a store with a handheld RFID reader and capturing the current inventory level. It is even more difficult preventing somebody from walking into the store with an RFID read-writer and, for example, flipping the 'privacy bit' that deactivates each RFID tag in the store.

Application Layer

Enterprise applications that do not need to handle the raw RFID data are minimally affected. But, these same enterprise applications may need to handle messages from other applications in real time. RFID could affect these requirements. Furthermore, the data model used by enterprise applications must support serialization at the appropriate granularity. For example, a warehouse management system must be able to keep track of which specific cases have been removed from the building and which still remain.

4 RFID Based Applications along the Retail Supply Chain

In the retail supply chain, it is necessary to distinguish between RFID tag usage on pallets and cases, on the one hand, and on RFID item tags on the other. (For an introduction to RFID technology along the supply chain see for instance Asif, Mandviwalla 2005).

4.1 Applications Using RFID Tags on Pallets and Cases

The following illustrates the potential use of RFID at the pallet and case levels throughout the value chain, from manufacturer to point of sales (POS).

- **Product Transport:** Manufacturer or retailer affixes RFID tags to all product pallets and cases before they are shipped. The tags are electronically time-stamped and then entered into the central computer of the retailer's RFID goods tracking system. The tagged pallets and cases can thus be identified and located along the entire logistics chain, all the way to the sales floor.
- **Warehouse Dispatch:** Goods ready to be shipped to a store are taken from the central warehouse to the dispatch area. As they pass through the exit gate, an RFID transceiver reads the codes on the pallets and cases and passes this data on to the RFID goods flow system. The goods then have the status of 'on route to destination'.
- **Goods Delivery to the Store Stockroom:** RFID helps match arriving goods to orders. When a truck arrives at a store, its pallets are once again identified by an RFID reader, which can handle as many as 35 pallet or case tags per second. The goods are then registered as 'in the store stockroom'.
- **Warehouse Management and Storage Processes:** Once received, the goods flow system registers the goods at being in the stockroom. Each storage location has an RFID tag, which is stored in the RFID goods flow system along with the RFID numbers of the pallets and cases stored at each location.
- **Transport of Goods into the Sales Room:** RFID readers, located at the store stockroom exit doors, identify every pallet and case that is moved into the store. These readers send the relevant RFID numbers to the RFID goods flow system, which identifies the products as 'transported into the store'.

RFID tags on pallets and cases mainly require process innovations along the inter-company value chain.

4.2 Applications Using RFID Tags on Items

RFID tagging on item level allows to uniquely identifying each individual product or item. While it is still in its early development, impressive opportunities have currently expected and discussed are:

- New types of services in stores, such as personalized advertising displays and self-check-out (e.g., Loebbecke and Wolfram 2004), aimed at increasing customer loyalty and promoting sales.
- Electronic price labeling in stores, making price tags easier to understand and more current.
- Improved theft protection in stores, because products cannot be taken out of this store without payment (or notification of theft).

5 Applying RFID Technology: The Case of Metro Group' Future Store

5.1 Company in Brief

With € 56.5 bn sales in 2004, Metro Group is the third largest retailer worldwide employing more than 540,000 staff in 30 countries. Table 1 provides some company figures.

The operating business of Metro Group is divided into six sales divisions which act independently in the market with their individual brands and specific sales concepts: (1) 'Metro/Makro Cash & Carry', the world's market leader in self-service wholesaling, (2) 'Real hypermarkets', (3) 'Extra supermarkets', (4) 'Media Markt' and 'Saturn', the leading consumer electronics centers in Europe, (5) 'Praktiker' home improvement and DIY centers, and (6) the department stores of 'Galeria Kaufhof'. So-called cross-divisional service companies provide services to all sales divisions right across the group, like procurement, logistics, IT, advertising, financing, insurance, catering, and real estate. Overall, Metro Group realizes about half of its turnover with food retailing.

Year	2002	2003	2004
Sales	€ bn 51.5	€ bn 54.0	€ bn 56.4
Sales Abroad	46%	47%	49%
Earning before Interest and Taxes (EBIT)	€ mill 1.427	€ mill 1.590	€ mill 1.809
Earning before Interest, Taxes, Depreciation, Amortization (EBITDA)	€ mill 2,416	€ mill 2,615	€ mill 2,980
Consolidated Net Income	€ mill 502	€ mill 571	€ mill 933
Market Capitalization (Based on Year-End Stock Price)	€ bn 7.47	€ bn 11.46	€ bn 13.26
Business Premises	2,310	2,370	2,447
Countries with Metro Group Presence	26	28	30
Selling Space (Square Meters)	10,939,000	11,436,000	11,899,000
Staff on Annual Average Total (Fulltime Equivalent)	235,283	242,010	251,556

Table 1: Metro Group Company Figures 2002- 2004
(Source: Metro Group 2004b&c)

5.2 Project Launch

In 2002, the Metro Group together with several important industry partners launched the Future Store Initiative (FSI). From the beginning, the FSI has had the vision to introduce and integrate a set of state-of-the-art technologies in a real-world supermarket, the 'Future Store', which is built in one of the brick-and-

mortar supermarkets ('Extra' distribution channel) belonging to Metro Group's Extra distribution channel. The Future Store is located in the small town of Rheinberg in Germany.

Since April 2003, in the Future Store, Metro Group tests the first application of RFID technology world-wide under real-life conditions, even including tests on item level. To increase feasibility and to split the cost among partners in the value chain, tags are prepared by brand manufacturers (e.g., Kraft, P&G, and Gillette) and then attached to the items by Metro Group in the Future Store.

5.3 RFID Based Applications

The involvement of numerous manufacturing partners paired with different classes of products and applications at the factory, warehouse, distribution centre, stockroom, and shelf provide perhaps the most comprehensive look at how the use of *RFID on pallets and cases* impacts the infrastructure, processes, and relationships in a retail deployment, even though RFID on transport packages is limited in the Future Store environment

Further, *RFID item level tagging* is tested for the first time under real-life conditions for selected products in the Future Store: 'Philadelphia' cream cheese (Kraft Food), 'Pantene' shampoo (Procter & Gamble), and 'Mach 3 Turbo' razor blades (Gillette). The respective *Smart Shelves* are equipped with readers that inform the Future Store staff when the shelves have to be replenished. Smart Shelves have bottom-integrated RFID readers and are linked with the central RFID goods flow control system. If an article is removed from or added to the shelf, the display detects the movement and updates the inventory in the system. Thus, the system registers automatically if goods are inaccurately deposited by customers or the shop assistants and if goods are missing, thereby preventing out-of-stock situations. Smart Shelves automatically recognize when the expiration date has been exceeded and informs the staff accordingly. In the future, the system could analyze the filling up of shelves, release early warning functions, and compile priority lists for replenishing at proper times depending on availability of goods in the warehouse, value of articles, order urgency or duration of being out of stock.

Investigating an additional RFID application on item level, Gillette experiments with RFID tags for anti-theft protection. Kraft Food wants to gain experience with the management of expiration dates and out-of-stock issues, and Procter & Gamble runs tests on innovative marketing concepts. All of them aimed at regaining more control along the supply chain. Additional tags on CDs, DVDs, and videos not only allow customers to view trailers of certain films and sample music CDs, they also serve for theft prevention and have a function similar to that of conventional 'Electronic Article Surveillance' (EAS) devices.

Even though, the overall roll-out of item level tagging is not expected to take place before 2008, selected applications in the end-consumers' turf can be pictured that would increase customer demand and thus create a 'pull-effect'.

- An 'intelligent fridge' could inform its owner when an RFID tagged carton of milk is close to empty or the milk is approaching its expiration date. Such a refrigerator could conceivably send such messages directly to the retailer, thereby requesting replenishment.
- An 'intelligent washing machine' could possibly read the tags on the clothes and automatically initiate the correct washing program. It could even alert the

owner when no appropriate washing program is possible, such as when the clothing in the machine should not be washed together.

6 Assessing Metro Group's Early RFID Based Applications

6.1 Advantages Resulting from Metro Group's Early RFID Applications

As one of the first larger retailing companies with substantial RFID exploitation, Metro Group's RFID tests show that RFID tags attached to pallets and cases enable tracking the transport and whereabouts of goods throughout the supply chain. The measurable fast and convenient data transfer has supported Metro Group in accelerating their workflows, increasing the transparency of their inventory, and improving the effectiveness of their processes. In more detail, Metro group finds the following advantages of their RFID usage:

- Warehouse and stockroom inventories can be monitored more accurately and replenishment orders can be issued faster.
- Time lost from ordering incorrect supplies can be avoided.
- Store requirements can be uncovered earlier, and deliveries received faster, thus improving the availability of the store's merchandise.
- Employees can recognize shelves about to run empty sooner; 'out-of-stock' can be reduced.
- Merchandise can be accurately located at all times.
- Inventories in warehouses, stockrooms, and shop shelves are more visible and trackable.
- Improved logging of sales indicates when and under which conditions goods are sold, improving management oversight.
- Quantities ordered can more accurately reflect demand.
- Manufacturers can plan production better.
- Less storage space is needed, reducing warehousing and handling costs.

Beyond the process improvements in stores, use of RFID has further affected Metro Group's retailing activities and the overall retail value chain by offering: (1) Automation benefits from RFID providing savings in labor costs or time, (2) new process benefits, from RFID enabling more efficient, faster, or less complex processes, and (3) collaborative benefits, from data sharing among manufacturers and retailers. Furthermore, by gathering purchasing data at check-out, the Future Store - and even stores in general - can use item level RFID data to provide product information to consumers on the one hand and customer information to stores on the other.

6.2 Challenges Resulting from Metro Group's Early RFID Applications

Those advantages have not come for free. Hence, the advantages have to be balanced against potential disadvantages.

The business transformation needed to capitalize on the technology and the new technology infrastructure investments required pose serious challenges (see also Chircu, Kauffmann 2000). So far, RFID advantages for retailers seem to outweigh the ones for brand manufacturers, simply because retailers still have had more 'room for improvement' in the logistics chain than brands which are already pretty much optimized along the supply chain.

Further, with wider tagging, deploying RFID based solutions to a wider scale beyond company walls poses vast technical and organizational challenges to all parties involved. So far, in spite of standardization and technological advancements, every retailer and manufacturer uses slightly - but importantly - different processes.

Also, in this early stage, an extra array of difficulties arises from item level RFID tagging:

- Tags on item level still pose technical problems depending on product material: If products contain metal or liquids, RFID transmission often leads to inherent problems.
- Even trickier seems the accompanying information / data management (e.g., Schmitz et al. 2003). Information creation would reach a new order of magnitude if each individual product is followed all the way through the product life-cycle.
- Delicate success inhibitors are privacy issues - both on a legal level (varying among countries) as well as on consumer perception level.

Finally, Metro Group management has seen itself confronted with privacy concerns. In spite of technological achievements and measurable customer benefits resulting from the RFID applications, privacy complaints have gained public attention and increasingly put pressure on what was meant to enhance customer convenience.

As an intermediate result, Metro Group introduced a *De-Activator* for the customer. With the De-Activator, developed by Metro Group and tested in the Future Store for the first time ever, customers can overwrite the EPC stored on the RFID chip. To do this, customers place their purchased goods on a desk with an integrated RFID reader. The tags are automatically read, the number code appears on a display, and the customer then de-activates the data by simply pressing a button. The manufacturer serial number on the chip, which is not connected to any kind of product-related or customer-related data, cannot be de-activated as of March 2005. But a new generation of chips is expected to make this possible within months.

However, taking technically successful developments off the agenda could neither be aim nor solution for Metro Group and their partners. Instead, they have undertaken efforts to improve customer understanding of the benefits that the RFID tags can offer them. Information campaigns and opportunities for 'letting them try' have been intensified in order to illustrate customer benefits of RFID tags.

7 RFID Technology and Applications Along the Supply Chain: Status and Outlook

In 2003, worldwide sales of RFID technologies were estimated at US\$ 1.3 billion (OECD 2004). Current investments have concentrated on hardware, software, and related goods. There have been limited expenditures on integrating RFID into legacy IT and logistics infrastructures. But sales for integration services, estimated at almost US\$ 600 million in 2003, have been increasing, and currently outpace growth in product sales.

The Metro Group case shows such an integration effort in the retail industry. The case has illustrated that RFID offers the potential to significantly reduce the costs of getting products to consumers in stores. In the Future Store, RFID technology and applications enabled Metro Group to (1) increase accuracy, (2) gather

information at new points in the supply chain, (3) make additional data available, (4) permit new kinds of collaborative sharing of data between retailers and manufacturers, and (5) provide interactivity between store and customer devices. Customer satisfaction and customer loyalty have improved as a result of more reliable product availability, customized service, and more convenient shopping.

Further opportunities lie in linking the relevant databases to customer devices, such as intelligent refrigerators. Thus, with RFID technologies, retailers such as Metro Group can better understand consumption patterns, manage their client relationships more individually, and tailor supply to demand.

While so far, the main uses of RFID systems in logistics operations have been in the areas of production flow and supply chain and inventory management, for the near future we foresee RFID processes and databases also to be integrated with other back-office operations, such as accounting and personnel, with implications for better management of cash flow and workers' schedules.

Obviously, RFID technology and application in the retail supply chain are still developing. Many firms in the retail industry and in other sectors increasingly investing in the technology do so under pilot programs. Many pilot implementations and research projects on potential applications are underway. They already provide fascinating insights, but still require a stronger roll-out of RFID applications for achieving necessary economies of scale and for allowing more general, quantitative insights.

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