# Automated identification and data collection in global supply chain

Ganesh Vaidyanathan
gvaidyan@iusb.edu
School of Business and Economics, Indiana University South Bend
South Bend, Indiana 46634, USA

## Abstract

Firms have invested in information systems to reduce inventory, cut labor costs, speed manufacturing, improve profitability, and enhance supply chain management. These systems allow companies to compile previously unheard of amounts of information from one end of an enterprise to the other. However, data collection techniques need to be employed to complement these information systems. Automated identification and data collection technologies allow enterprises to track components and parts through assembly, to track equipment and supplies, to speed fulfillment, and to automate purchases. More and more businesses will adopt these technologies in conjunction with existing data-capture tools to achieve the desired benefits. Managers are figuring out where to deploy what technology and their decisions will be the key to achieving the best return on investment. These technologies can work in conjunction with other data-capture solutions to provide businesses with more options to meet specific needs. This paper offers insight to different data capture technologies that offer different capabilities and compares the technologies by exploring various implementation issues.

**Keywords:** Data collection, Automated Identification, Supply Chain, SCM, Smart label, RFID, Barcode

## 1. INTRODUCTION

Firms are facing intense competition and rising customer expectations for efficient services and cheaper products. Firms are increasingly using information technology to attain accuracy, speed and efficiency to gain sustainable competitive advantage and deliver superior business results. The capture of reliable, accurate data and efficient use of such data in information systems can provide higher quality products and services to customers. Automatic identification and data capture (AIDC) refers to the methods of identifying objects, collecting data about them, and entering that data directly into computer systems (i.e. without human involvement). By using these data that are automatically captured and by streamlining workflows, AIDC solutions introduce greater efficiency to a wide range of applications. AIDC technologies include Radio Frequency Identification (RFID), bar coding, smart labels, smart cards, biometrics and other forms of automated data capture. These technologies may be used to streamline processes in supply chain to increase efficiencies. The applications of RFID in particular are wide-ranging and include the manufacturing and distribution of physical goods, minting bank notes, shipping operations, among others (Angeles, 2005). So, why do firms hesitate to move towards Radio Frequency Identification (RFID)? What are the factors that make RFID or traditional and advanced barcodes a better solution than each other? Will smart labeling replace or complement RFID? Will RFID replace or complement barcodes? What are the problems inherent with these AIDC technologies? This study focuses on these questions and establishes a trade-off using these technologies in supply chain management (SCM).

With the advent of these technologies and as these technologies mature, figuring out where to deploy what technology will be the key to achieving the best return on investment (Douglas, 2005). An online survey of more than 350 IT executives found that mandates from government and major retailers encouraged 46 percent to take the first steps toward adopting RFID to provide information about product movement in the supply chain, thereby reducing logistical challenges and costs (Emery, 2004). RFID use in the industry has been viewed as both immediate as well as in the distant future. Just as Internet, companies will have no choice but to use RFID (McGinity, 2004). However, RFID has a long way to go before it's as profitable as it could be (Elliot, 2005). Meanwhile, barcodes have been used in many industries for many purposes that include asset tracking, labeling, circuit board identification, shipping, distribution, and receiving. Many companies are contemplating on what technology might be appropriate for use to make their supply chain management systems much more effective and efficient. There is also a need to understand effective implementation strategies as well (Angeles, 2005). In this section, RFID, bar codes and smart labels are reviewed. The next section discusses the comparison of these technologies. The third section explores the implementation issues of barcodes, RFID, and smart labels. The final section includes the conclusion and future areas of research.

**Smart labels**

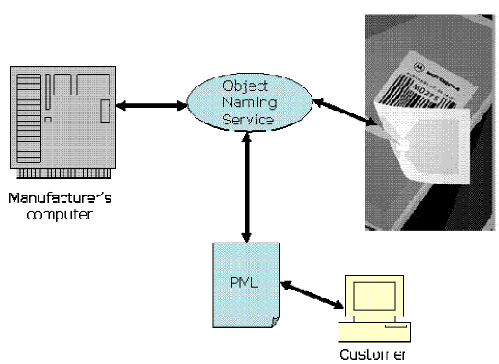


Figure 3. Smart Labels

Smart labels are shipping labels with embedded RFID tags. Smart labels allow the user to retain bar code/shipping label information in the same or similar format to what you are currently using, while adding RFID. Despite the ongoing information and digitization revolution, the paperless office does not seem to be in the imminent future. Electronic alternatives cannot compete with the current use and specifications of paper: cheap, flexible, light, foldable, portable and independent of any operating system. Using RFID technology, paper can be made to work harder and more intelligently - offering a number of significant benefits. Schreiner LogiData, part of a consortium dedicated to the implementation of intelligent paper solutions, has developed a system that allows documents to be printed on paper containing an embedded I·CODE smart label (Koninklijke Philips, 2005). The label is encoded during printing, creating a technology that offers significant advantages over traditional watermark, barcode and embossing technologies.

Each product will have to be given a unique product number. MIT's Auto-ID Center, created a couple of years ago is working on an Electronic Product Code (EPC) identifier that could replace the Universal Product Code (UPC). Every smart label could contain 96 bits of information, including the product manufacturer, product name and a 40-bit serial number. Using this system, a smart label would communicate with a network, called the Object Naming Service. This database would retrieve information about a product and then direct information to the manufacturer's computers. The information stored on the smart labels would be written in a Product Markup Language (PML), which is based on the eXtensible Markup Language (XML). PML would allow all computers to communicate with any computer system in a similar way that Web servers read Hyper Text Markup Language (HTML), the common language used to create Web pages. Smart labels offer considerable advantages in sorting and item tracking in airline baggage tagging and parcel services, supply chain management systems. Smart labels are a form of RFID application. The tags look like normal product tags, but contain an antenna and a small microchip. The tags have a serial number and an electrically erasable programmable read-only memory (EEPROM) that can store information like the EPC. The labels also have mobile communication capabilities.

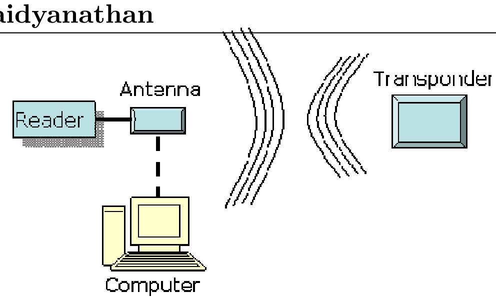


Figure 1. Radio Frequency Identification (RFID)

**Radio Frequency Identification**

Radio frequency identification (RFID) is a wireless form of automated identification technology. The main component of this technology is the transponder or tag, which in most cases comprises of a chip and antenna mounted onto a substrate or an enclosure (see figure 1). The chip consists of a processor, memory and radio transmitter. The memory will vary, depending on the manufacturer, from just a few characters to kilobytes.

These transponders communicate via radio frequency to a reader, which has its own antennas. The readers can interface through wired or wireless medium to a main computer. Transponders are also known as smart or radio tags. Transponders can either be Read Only (R/O) which are pre-programmed with a unique identification or they can be Read Write (R/W) for applications that require data to be stored in the transponder and can be updated dynamically. Another form of transponder is Write Once Read Many times (WORM) which allows an identification number to be written to the transponder once. The information is stored in the memory, it cannot be changed but the transponder can be read many times. The two most common types of RFID technologies are active and passive as shown in Table 1. The power on board of the active RFID tag means greater communication distance and usually larger memory capacity. The passive RFID transponder is powered by an electromagnetic signal that is transmitted from a reader.

The signal received from the reader will charge an internal capacitor on the transponder, which in turn will then supply the power required to communicate with the reader. Passive tags do not require on-board battery and can be detected from a distance ranging from a few inches to a few feet, whereas active tags, on the other hand, have an on-board battery, and therefore, have a far longer read/ write range and memory size (Haller and Hodges, 2002).

**Barcodes**

With the adoption of UPC as the standard for retail grocery stores in the late 70's, bar codes have become an everyday experience for most people and in most industries. There are a number of barcodes that are available that include:

- Barcodes to identify a product for sale in shops, for example Universal Product Code (UPC) A and UPC E in USA, European Article Numbering (EAN) 13 and EAN 8 in the rest of the world, and in Japan Japanese Article Numbering (JAN) 13 and JAN 8
- Packaging barcodes used on the shipping cartons, for example Interleaved 2of5 (ITF) barcodes, also known as UPC Shipping in North America, EAN 128 barcodes are capable of supplying much more detail about the product, including

**Table 1: Technology differences between Active and Passive RFID**

| | Active RFID | Passive RFID |
|---|---|---|
| Power source for tag | Internal to tag | Energy transferred from the reader via radio frequency |
| Battery in tag | Yes | No |
| Power availability | Continuous | Within the field of reader |
| Signal strength from reader to tag | Low | High |
| Signal strength from tag to reader | High | Low |

dates, batch numbers, weight, quantity and dimensions

- Publishing barcodes for books that require a variation of EAN 13 or UPC A barcode which encodes the International Standard Book Number (ISBN), plus optional pricing information
- Pharmaceutical barcodes that are used in quality control and product identification for most pharmaceutical products, for example the Health Industry Barcode (HIBC) to hold production details, though these are variations of Code 39, Code 128 and EAN 128 barcode types, a specialized form, also known as 2D Pharma Code that encodes color information
- Other barcodes that are other barcode types usually used for specialist applications which include postal barcodes.

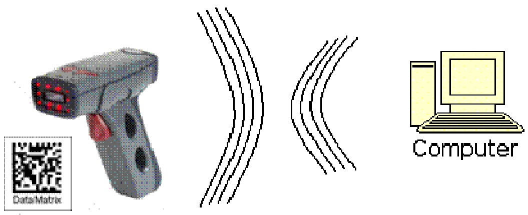


Figure 2. Data Matrix Barcode system

Apart from these traditional barcodes, new types of two-dimensional barcodes that can be used in multiple applications have emerged in markets that include Data Matrix, Portable Data File (PDF) 417, Micro PDF 417, and Reduced Space Symbologies (RSS). All these new types can encode the same information, but in less space. The error correcting, two-dimensional matrix symbology that is shown in Figure 2 is capable of encoding various character sets including strictly numeric data, alphanumeric data and all ISO 646 (ASCII) characters, as well as special character sets. The symbology has both error detection and error correction features. Each Data Matrix symbol consists of data regions, which contain nominally square modules set out in a regular array. A dark module is a binary 1 and a light module is a binary 0. There is no specified minimum or maximum for the X or Y dimension. The data region is surrounded by a finder pattern, a perimeter to the data region that is 1 module wide, which is surrounded by a quiet zone on all four sides of the symbol. Two adjacent sides are solid dark lines used primarily to define physical size, orientation and symbol distortion. The two opposite sides consist of alternating dark and light modules. These are used primarily to define the cell structure but also assist in determining physical size and distortion. There are 2 types of Data Matrix symbologies: Error Correction Codes (ECC) 000-140 with several available levels of convolution error correction, and ECC 200, which uses Reed-Solomon error correction. ISO/IEC JTC 1/SC 31, the standard for automatic identification and data capture techniques recommends ECC 200.

As shown in Figure 2, the reader having a XML rule set sends the data using a wireless interface that is either radio frequency (RF) or Infrared (IR). Bar code scanners can be equipped with one of nine basic user interfaces including integrated graphic display, wand or laser emulation, keyboard connection, serial, parallel, modem, Ethernet, wireless, or PCMCIA (PC Card).

## 2. AIDC TECHNOLOGIES IN GLOBAL SCM

All the three AIDC technologies—smart label, barcode, and RFID are automated identification and data collection technologies. However, there are some differences as well as some commonalities between the three. Table 2 illustrates the main differences and similarities of these technologies. In conjunction with Figure 2, both smart labels and RFIDs can be used for all touch points. Barcodes, on the other hand can be used in all touch points except return management where historical information may be stored in RFIDs and smart labels. The following are some of the benefits of RFID and smart labels over barcodes:

- Transponders can be read from a distance and from any orientation, thus they do not require line of sight to be read.

**Table 2: Smart Labels, Barcodes, and RFID**

| | Smart label | Barcodes | RFID |
|---|---|---|---|
| Technology | Radio waves | Optic | Radio waves |
| Communication range | About 12 feet for a single antenna reader and 22 feet for gate readers | Bluetooth enabled (up to 300 feet) | Long-range data rich tag up to 300 feet; Passive: up to 3 meters |
| Data storage | Large read/write data storage (128KB) | Large read/write data storage (128KB) | Large read/write data storage (128KB) |
| Tracking | Instantaneous; No line of sight needed | Line of sight needed | Instantaneous; No line of sight needed; can be used in case of occluded items |
| Locate items automatically | Yes | No | Yes |
| Automatic data and document preparation | Yes; From tag | No | Yes; From tag |
| Elimination of human error in data input or retrieval | Yes | Yes | Yes |
| Real-time data tracking | Yes | No | Yes |
| Instantaneous operator feedback | Yes | No | Yes; visible LEDs |
| Ability for operator to write specifics associated with items | Yes; dates, methods, quantity or any data can be stored directly on the tag | No | Yes; dates, methods, quantity or any data can be stored directly on the tag |
| Data retrieval | Any mode: automatic, PDA or laptop | Any mode: automatic, PDA or laptop | Any mode: automatic, PDA or laptop |
| Multiple readings at a time | Can scan many tags simultaneously | Can scan and read one at a time | Can scan many tags simultaneously |
| Accuracy | Scan accuracy 100% can be achieved | Scan accuracy 100% | Scan accuracy 100% can be achieved |
| Storage scan | Can scan all cases on a pallet in a single pass | Can not scan an entire lot or pallet | Can scan all cases on a pallet in a single pass |
| Produced on-demand | Yes | Yes | No |
| Pre-printed and pre-coded for batch processing | Yes | Yes | No |
| Ability to work in heat, dust and humidity | Yes | Yes | Depends on the environment |

- Transponders have read and write capabilities, which allow for data to be changed dynamically at any time.
- Multiple transponders can be read at once and in bulk very quickly.
- RF-Tags can easily be embedded into any non-metallic product. This benefit allows the tag to work in harsh environments providing permanent identification for the life of the product.

For automated routing and workforce management, smart labels or RFID tags are used on trucks and trailers to track their movement in real time. Logistics operators can automatically identifies incoming trailers when they drive through the gates at their service centers. The identification information is transferred by wireless LAN from an RFID gate reader to the warehouse management system. The warehouse management system then automatically dispatches personnel to receive the incoming shipment and updates the company's shipment tracking system. Outgoing trucks are automatically identified and logged out of the yard with the RFID gate readers as well. Handheld or stationary RFID readers can save valuable time in cross docking by instantly locating needed items and accurately recording their transfer to outbound shipments. Time savings and accuracy improvements can be even greater if stores commonly receive mixed pallet and less-than-full pallet shipments.

Tracking pallets inside manufacturing facilities can result in efficient asset management benefits and can be used as the foundation for supply chain management. These pallets and other containers can be easily identified with smart labels or RFID tags to facilitate automated tracking and reduce manual handling times. SCM software can then take advantage of the accurate, automatic identification to improve asset visibility and issue management alerts when items are missing or returns are overdue. The net result is improved asset utilization with less safety stock. In manufacturing locations as well as warehouse operations, RFID-enabled forklifts can provide a real-time view of vehicle locations as well. Using smart labels or RFID, logistics providers can create shipment manifests by reading pallet tags during the loading process. Tagged pallets facilitate accurate and efficient cargo transfers and can drive excess inventory out of the supply chain by making it easier to get the right product to the right store at the right time.

## 3. IMPLEMENTATION ISSUES IN SUPPLY CHAIN

Smart labels overcome the limitations of barcode technology, providing improved product distribution, automated check-in and check-out, and inventory control. In the case of RFID and smart label implementation, the environment needs to be taken into consideration during implementation. Metal, electrical noise, liquids, extreme temperatures, and physical stress can create a challenge and may affect their performance. In the case of smart labels, the information about a product can be stored in a central database, and only the native serial number of a tag is used, or all information can be stored on the EEPROM directly in the labels. A combination of both approaches is common. However, there are problems associated with smart labels. Most smart labels are not write-protected. Meta-data like "Best before Date"
are also stored in the user data area. Competition can read the contents of smart labels and
customer is traceable by anyone. Customers can change the EPC and no one will detect it when using self-checkout. Attacks can be launched on medical drugs and age-restricted material since attackers only need a publicly available RFID reader/writer.

Most supply chain applications focus on tagging cases or pallets holding merchandise to create inventory visibility. A key question has been the feasibility, security, and privacy of *item-level tagging,* in which each individual item is given its own RFID tag (Molnar and Wagner, 2004). Item level is a term that usually refers to fairly small items in high volume. For smart labels or RFID to work as an antidote to in-store theft and fraud, tagging is needed at the individual item level. Since current generation of RFID tags lack access control, anyone can see information on tags including unintended third parties. Even when opaque rather than transparent labels are used, unauthorized third party readers can build databases linking static ids to real objects (Good et al., 2004).

A number of other issues in using smart labels or RFID include tag orientation, reader coordination, multiple standards, stored data, range, cost, and customer concerns (Want, 2004). Although RFID does not require line of sight to operate, the reader cannot communicate effectively with a tag that is oriented perpendicular to the reader antenna. If a number of products are placed in a random orientation inside a shopping basket, some will be oriented in a direction that makes them invisible to the reader (Want, 2004). As electronic tags become more common, many mobile hand-readers will be in use within close range of each other, thus effectively garbling the data for systems in proximity to each other (Want, 2004). Many firms were surprised by pushback and social reaction to a trial deployment of RFID tags in retail stores (Want, 2004).

Due to the order of magnitude difference in cost, passive tags are expected to be used much more widely. However, they can respond only once for each RFID reader's signal, which limits the design of a wireless communication protocol. This limitation has become a crucial issue for environments where a large number of tags should be identified almost simultaneously, thus leading to what is called an *anti-collision* problem (Lee et al., 2004).

The problems with RFID implementation has been noted in many studies. Survey respondents to a study said the top three business risks of using RFID today are that technical standards are not final, there is a lack of clear business benefits or return on investment, and there is a lack of industry-wide adoption (Emery, 2004). Furthermore, many companies have already invested in some form of data-capture technology, and they will loathe abandoning them altogether for RFID (Douglas, 2005). In many instances, human readable labeling or instructions provide a valuable secondary process confirmation beyond the systematic use of bar coding or RFID (York, 2004). The cost of the tags has also received a large attention. To offset the costs, a new wave of plastic RFID chip that can be printed on foil the same way a newspaper is printed on paper is under study (Blau, 2005). RFID has been implemented in different ways by different manufacturers while global standards are still being worked on. RFID may be implemented as a proprietary system, for example, the ExxonMobil's SpeedPass. Therefore, if every company comes up with their own SpeedPass type of system, a consumer would need to carry many different devices with them. Since RFID works on radio waves, they may be easily jammed at the right frequency within their network. This could be huge security and privacy issue. Barcodes have different set of issues. The line of sight need of the barcodes makes it difficult to automate many scenarios in industries. The data storage limit of a single barcode makes it less logical to usage in scenarios where multiple data needs to be accessed. In this scenario, multiple barcodes need to be processed at a given time.

As a result of radio waves being easily distorted, deflected, absorbed, and interfered, there may be false reads when using smart labels and RFIDs (Angeles, 2005). The barcodes are much better in this sense since the 2-D data matrix does not give out a false read at all. A portal reader could pick up tag information from nearby products as the RF signal may get reflected by the metal buckle worn by a manufacturing operator (Angeles, 2005). There are database implementation issues as well. The volume of data that is collected from RFID needs to be checked for data integrity. There are concerns in how the data is collected and interpreted as well as how to integrate these technologies in a firm's SCM software (Angeles, 2005).

## 4. CONCLUSION AND FUTURE RESEARCH

The problems that have surfaced on smart labels and RFIDs are due to the fact that they are subjected to diverse applications than barcodes. The benefits that can be derived from implementing these technologies may far outweigh the cost of the tags and the issues they face. The technologists need to figure out how to enhance the range of RFID signals and figure out hoe to cut back on the interference issues. The solutions providers and consultants need to figure out how new smart labels, barcodes, and RFID equipment can work with customers' existing business practices. The standards organizations need to work on how to make smart labels and RFID open technologies. Organizations need to determine how to make customers desire these technologies in their products. Studies need to be conducted to understand the return on investment of RFID implementations in industrial applications. A framework of these technologies in global SCM will provide managers a practical view of how to integrate technologies and use them for automated identification and data collection in supply chains.

## 5. REFERENCES


Angeles, R (2005). "RFID technologies: Supply-chain applications and implementation issues." Information Systems Management, 22(1): 51-75.

Blau, J (2005). "German researchers move forward on plastic RFID chip." ComputerWorld, January 13, 2005.

Croxton, K.L (2003). "The order fulfillment process." The International Journal of Logistics Management, 14(1): 19-32.

Croxton, K.L., S.J. Garcia-Dastugue, D.M. Lambert, and D.S. Rogers (2001). "The supply chain processes." The International Journal of Logistics Management, 12(2): 13-36.

Douglas, R (2005). "Barcodes vs. RFID." Globeandmail.com, February 10, 2005.

Elliot, M (2005). "Bar codes are forever." Industrial Engineer, 37(3): 28-30.

Emery, G.R. (2004). "IT execs prepare for an RFID revolution." Washington Technology, 06/29/04. accessed online at http://www.washingtontechnology.com /news/1_1/daily_news/23875-1.html on July 27, 2005.

Good, N., D. Mulligan, J. Urban, J. Han, L. Quilter, D. Wagner (2004). "Radio Frequency Id and Privacy with Information Goods." Workshop on Privacy in the Electronic Society'04, October 28, 2004, Washington, D.C.

Haller, H., S. Hodges (2002). "White paper: The Need for a Universal Smart Sensor Network." Auto-ID centre Institute for Manufacturing, University of Cambridge, United Kingdom, accessed online at http://www.ifm.eng.cam.ac.uk/automati on/ publications/ w_papers/cam-autoid-wh-007.pdf, accessed on July 26, 2005.

Koninklijke Philips. (2005). Philips Website. http://www.semiconductors.philips. com/markets/identification/products/ico de/, accessed on July 26, 2005

Lee, J., T. Kwon, Y. Choi, S.K. Das, K. Kim (2004). "Posters: Analysis of RFID anti-collision algorithms using smart antennas." Proceedings of the 2nd international conference on Embedded networked sensor systems, November, Baltimore, MD, 265 – 266.

McGinity, M (2004). "RFID: Is This Game of Tag Fair Play?" Communications of the ACM, 47(1): 15-18.

Molnar, D., D. Wagner (2004). "Privacy and security in library RFID: issues, practices, and architectures." Proceedings of the 11th ACM conference on Computer and communications security, Washington, D.C., October 25-29, 210-219.

Smith, H., B. Konsynski (2003). "Developments in practice X: Radio frequency identification (RFID) – AN Internet for physical objects." Communications of AIS, 12: 301-312.

York, C (2004). "RFID Strategy: Bar Coding Does the Same Thing as RFID…Right?" Industry Week, December 14, 2004.

Want, R (2004). "The magic of RFID." Queue, 2(7): 40 – 48.