SUPPLY CHAIN BASICS:

Technology

How Much—How Soon

USDA

U.S. Department of Agriculture
Agricultural Marketing Service
Marketing Services Program

July 2007

Agricultural Handbook 728-1

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Introduction

Globalization has made the world smaller. Companies are more closely connected to their suppliers and customers than they used to be, and the supply chain has become a web of connections between suppliers and receivers. The Internet has been a major factor in this globalization. Companies can now exchange data with ease and speed, and much of the exchange can be automated. The result is a growing complexity of the supply chain as company networks become integrated into a global network.

A simple exchange of data among individual companies is no longer sufficient. Companies in the supply chain need to communicate with each other, and a common "language" is required to facilitate this communication. Barcodes are one form of that language, but the language requirements are rapidly becoming more complex as more is asked of it. The changing language and its attendant technologies create the need for a new, more robust set of standards for recording and exchanging product information on a global scale. They also create new opportunities in the areas of product availability and safety, customer service, and supply chain efficiency for both consumers and businesses. As component prices drop and consumer fears of privacy invasion are addressed, the adoption rates for these technologies will accelerate.

The new solutions are built on systems—such as barcodes—that have been in use for many years. More than 30 years ago, the introduction of the barcode initiated a transformation of the consumer packaging industry that brought greater convenience to consumers worldwide. Barcodes are in widespread use today, with more than 5 billion scans a day according to some estimates, and are an established element of retail sales.

Companies are increasingly requiring labels such as barcodes, smart labels, and radio frequency identification (RFID) tags on shipments to help automated systems manage inventory and to track their products. Labels produced to meet customer requirements are called "compliance labels" because the labels are designed to comply with a customer's requirements. Compliance labels usually follow formats defined by the customer. New standards are now being implemented to expand and improve the applicability of technologies to monitor and record product information. RFID, the Global Data Synchronization Network (GDSN), and the Electronic Product Code (EPC) global network are examples of new technological platforms that employ common product identification and information standards.

At the same time improvements are being introduced to the "old" barcodes. According to a recent survey,[1] the highest technological priority for supermarkets was conversion to the 13- or 14-digit barcodes that allow for more uniform coding, easier data exchange between companies, and for more information about the product to be included on the labels. These changes will give barcode users access to the global networks that use them.

Smaller growers and distributors should consider taking these steps:

- Become knowledgeable about the new technologies and new ideas in barcodes.

1. 11th Annual State of the Industry Report on Supermarket Technology. *Supermarket News*, January 31, 2005.

- Find out about the benefits of implementing the new solutions by reading articles, searching in magazines and on the Internet, and talking to people in the industry.
- Participate in conferences to experience the technology firsthand and to discuss it with experts.
- Visit companies that have installed these systems to find out what's involved.
- Let bigger companies work out the details before committing funds in a new system.

Small- and medium-sized growers and distributors need to start preparing to become an integral part of synchronized data systems that can satisfy changing consumer needs. Too much delay in adapting to this new business environment may result in the loss of customers and competitiveness. Implementation of these new technologies, however, should enable businesses to provide more personalized service and build lasting relationships based on individual needs.

Getting Started With Barcodes and RFID

Explanations of how new technologies work and how they help grocers increase food safety and security while maintaining control of their inventory are contained later in this report. However, producers of agricultural products must still ask themselves:

- What's in it for me? Why should I adopt any new technologies?
- What's the minimum technology? What is the least I can do to play in this game?
- What's a PLU, and do I need one?
- What's a UPC, and how do I get one?
- What do I do now?

What's in It for Me?

Many small farmers and manufacturers of food products have delayed adopting barcodes and RFID technology; the added trouble and expense don't seem worthwhile, and their customers aren't willing to pay a premium for it, so why bother? The answer is market access.

Access to markets is the main incentive to smaller producers for adopting this technology. What grocery store is not scanning its customers' purchases at checkout? Soon the grocery store that buys fresh peaches and tomatoes will be demanding more in the way of packaging, identification, and record keeping.

Producers with markets that do not yet require this technology should at least examine what they would need and how much it would cost to adopt a base level of identification technology—the simplest level that would be accepted by their customers.

The sad truth is that customers are not likely to pay a premium for a barcode or an embedded RFID chip. It's a real cost, and one that is fast becoming just another cost of doing business, but that can't be easily passed on to the customer.

What's the Minimum Technology?

You need to ask your customers. What do they really expect from you? Your customers must tell you. Customers frequently require:

- Individual item marking ("stickering")
- Carton marking
- Pallet marking
- PLUs and UPCs (and RFID tags, if you are selling to the largest firms)

What's a PLU?

Items like tree fruit, which are normally sold by the pound, are often individually labeled with a PLU. PLU stands for *price look-up code*. Unique numbers are assigned to each important fruit and vegetable variety. For example, Empire apples have been assigned PLU 4125 by the Produce Electronic Identification Board[2] (PEIB), which is administered by the Produce Marketing Association[3] (PMA). A label bearing a trademark (the grower's name), the variety, and the assigned PLU is attached to each apple.

Grocers like PLU-marked produce because it eliminates many errors at the cash register. If your competition is labeling its produce and you are not, you are at a distinct marketing disadvantage.

2. http://www.pma.com/Template.cfm?Section=UPC_and_PLU_Codes&Template=/ContentManagement/ContentDisplay.cfm&ContentID=827
3. http://www.pma.com/

Because produce items are not unique, standard PLUs may be used. Standard PLUs may be obtained from any large wholesaler or cooperative handling those items. Producers of unique or new items may have to request a new PLU from the PEIB.

Labeling equipment for attaching labels to fruit and vegetables is available both new and used. Listings for them may be found in regional fruit and vegetable trade journals, the Yellow Pages, and on the Internet. In addition, devices are already available that laser-engrave PLUs directly on the skin of produce. Clamshells, 3-pound bags of fruit, 5-pound bags of potatoes, and many other products are unpacked from a master carton and displayed and sold by the retailer in consumer-sized packaging. Items in these smaller packs are not labeled individually, but the clamshell or bag is marked—usually with branding and nutritional information and, most importantly for the sake of this discussion, with a UPC.

What's a UPC?

UPC stands for *uniform product* code. UPCs are unique codes used in barcoding products. They are assigned by GS1 US[4] (formerly the Uniform Code Council) for a fee. Fees are set on a graduated scale depending on a supplier's sales volume and earnings. A number of other firms offer to sell barcodes also. Some of these are probably legitimate businesses that get their codes from the right sources, but others may not be. Therefore, it is important that anyone seeking to begin using UPCs contact GS1's US office, using the following information, to determine whether or not any particular UPC is valid.

GS1 US Customer Service

7887 Washington Village Drive, Suite 300

Dayton, OH 45459

Phone: 937-435-3870

Facsimile: 937-435-7317

E-mail Address: info@gs1us.org

Office Hours: Monday – Friday, 8:00 a.m. to 6:00 p.m., EST

Website Address: www.gs1.us.org

What Do I Do Now?

You need to begin with the most basic labeling and work your way up to the more complex technology. How complex you need to get depends on your customers.

CARTON MARKING

Savvy marketers have branded their produce for years in the hopes of building brand loyalty. Washington Apples, Vidalia Onions, and Indian River Grapefruit are examples of successful branding efforts. In all likelihood, these branding efforts began with unique, custom-printed cartons.

Today, to be accepted in the broader marketplace, produce cartons need to combine brand information with unique identification. Plain, unmarked boxes are no longer acceptable. Handwritten labels are not sufficient.

Generic apple or vegetable cartons are better than unlabeled cartons, but still lack branding or any kind of unique identification. If custom-printed cartons are not economically feasible for small producers, then a printed label or even a stamp may be applied at the packing shed to generic cartons that are readily available from most major packaging firms.

4. For more information about GS1 US, see page 8.

The information on the carton should include:

- Farm
- Location
- Product name, variety, and size
- Weight or size of container, or count of product (for products sold by the number in a carton)
- UPC (barcode) and PLU

PALLET MARKING

Pallet labels are expected in business. Even though a bill of lading presents a more complete picture of the delivery, the contents of a pallet should be quickly identifiable by a printed label with a barcode, UPC and PLU numbers, a written description of the product, and names and addresses.

The use of an RFID identification tag on the pallet is possible for smaller producers because of the relatively small number of tags required. Again, one must comply with the requirements of the customer.

"SLAP AND SHIP"

One approach to using technology is to do the least amount possible. "Slap and ship" is a way of describing a minimal approach to identifying and labeling farm and food products that does not require buying or renting any equipment. At its most basic level, the slap and ship method includes:

- Learning the customer requirements for label identification
- Arranging to have adhesive labels or tags, cartons, or bags printed that contain the required information, with appropriate codes in place
- Applying the labels or tags

Listed below are the types of basic information that should be included on packaging labels when using the "slap and ship" method, depending on your current use of technology.

"Slap and Ship" Labels (no barcodes, no RFID)

- Producer
- Address
- Product
- Weight
- Size

"Slap and Ship" Labels (with barcodes)

- UPC
- Optional—label information from the above list

"Slap and Ship" Labels (with RFID)

- RFID tag
- Optional—label and barcode information from the previous two lists

It should be noted that while this basic approach may meet the identification requirements of the customers, it doesn't allow the producer or distributor any of the additional benefits of using barcode or RFID technology, such as more efficient tracking and management of product inventories, or improved data recording to enhance product security, safety, and traceability. Furthermore, any information that is unique to the shipment, such as shipment dates, order numbers, customer, etc., would not be available unless labels were specially ordered for this purpose.

A NOTE ON APPLYING TECHNOLOGIES

The labeling methods mentioned above work best if applied in succession, with the adoption of more complex technologies following the adoption of simpler technologies. Adding barcodes and PLUs to printed labels, for example, is easier once one has mastered the art of using printed labels on packaging materials. Similarly, the adoption of RFID technology is easier to master once one has successfully used barcodes and PLUs on printed labels.

Equipment for Barcodes and RFID

Barcode and RFID equipment includes printers, scanners, and application equipment. The equipment described below is the minimum necessary to start with barcodes or RFID.

BARCODE EQUIPMENT

Barcodes are "mature" technology, so prices for equipment are reasonable, the equipment is reliable, and it's easy to use.

The minimum equipment needed to read barcodes is:

- Handheld scanner
- USB (or other connection type) cable
- Optional stand for hands-free scanner operation
- Computer

The scanner reads the barcode information on both incoming and outgoing shipments. The USB cable connects the scanner to the computer to download the information. For some operations no special software is required—information from the scanner may be downloaded directly into the word processing or spreadsheet program already installed on the PC. This basic type of package can be purchased for less than $200 (excluding the cost of a computer).

In order to place barcodes on outgoing shipments, carton labels must be made or purchased. A barcode printer may be needed. They start at around $500.

A second option is to purchase preprinted labels. Their cost is around $80 per 1,000. This is a good option for food shippers with only a few products.

RFID EQUIPMENT

RFID equipment is more complicated and expensive than barcoding equipment. It may be necessary to hire a consultant experienced in implementing RFID systems to assemble the right mix of equipment and software. In many respects the situation is similar to that of barcodes 25 years ago, before widescale implementation caused standards to be agreed on, and before competition and economies of scale lowered prices.

To add RFID tags to your products, you will need:

- Reader—handheld for about $4,000 or stationary for $8,000 to $10,000
- Printer—about $4,000
- Supply of tags— about 20 cents each for small orders

A basic setup, as listed above, will allow the user to read the tags on incoming and outgoing shipments, as well as print tags for outgoing shipments.

"Slap and Ship" RFID

A second option is to use preprinted RFID tags at a cost of about $1.25 each. This option typically requires a 1- or 2-year contract with the tag supplier, who also provides any other needed equipment, such as a reader used for verification of the tags. There is usually little or no cost other than the tags.

UPC and Barcode Basics

Automated checkout systems were first conceived in 1932, but they were not technologically feasible at that time. Several code formats were developed in the 1940s, 50s, and 60s, including bull's-eye codes and numeral codes. In 1972, a Kroger store in Cincinnati started using bull's-eye codes.

On April 3, 1973, a committee of grocery industry leaders adopted a proposal from IBM establishing the Universal Product Code (UPC) as an industry standard for product identification. The Uniform Code Council (UCC) was founded to maintain and manage the UPC system. The first scan of a barcode took place in 1974. The system was successful and quickly spread from groceries to other retail products.

The technology was revolutionary at the time. In the years following their acceptance, barcodes have brought more accurate and faster check-out to consumers and retailers while improving supply chain efficiency. Barcodes have become a part of everyday life, from purchases in grocery stores to ticket identification at entertainment venues.

Foreign interest in UPCs led to the adoption of the European Article Numbering (EAN) code format—a coding system similar to UPC—in 1977, administered by EAN International. Recently UCC and EAN International have cooperated to create global standardization of product codes. In 2005 they created a new international organization named GS1[5] (which stands for One Global Standard), headquartered in Brussels, Belgium, to manage the EAN/UCC systems. Any country can become a member of the GS1 upon agreeing to adhere to its standards and setting up an organization to oversee and manage the issuance and use of those standards. In the United States GS1 US[6], headquartered in Lawrenceville, NJ, has taken on that role.

Any company can obtain a UPC by applying to GS1 US and paying an annual fee. The company receives an identification number and guidelines on how to use it.

A barcode symbol is a pattern of dark bars with light-colored spaces. The bars are usually black and white, although different colors can be used as long as there is enough contrast between the two colors for the barcode reader to read the code clearly. The bars provide encoded information that uniquely identifies the product. The code is repeated below the bars in Arabic numerals.

The most popular barcode in use today consists of 12 numbers. The first number identifies the coding system being used, and the last number is a check digit, used by the reader to ensure that it has read the number correctly. Of the remaining 10 digits, the first five are the manufacturer's code, assigned by the UCC, and the last five are the product code, assigned by the manufacturer to each product.

5. http://www.gs1.org/
6. http://www.gs1us.org/gs1us.html

FIGURE 1. Typical 12-digit barcode

0 12345 67890 5

SOURCE: GS1

Here is what each number in the illustration above represents:

- "0" on the left identifies the coding system being used.
- "12345" is the Manufacturer's Code. It was assigned by the UCC to the manufacturer.
- "67890" is a Product Code, assigned by the manufacturer to the product.
- "5" on the right is a Check Digit; it is the product of a mathematical calculation performed on the code, and verifies that the code has scanned correctly.

The price is not encoded in the barcode. The barcode identifies only the product. This design allows the store to change the prices without re-coding all the products.

The group of numbers represented by barcode is also referred to as a Global Trade Item Number (GTIN), the term for all the different trade item numbers valid within GS1, including UPC and EAN codes. The barcode is read by scanners in retail stores to capture the GTIN, which is used by computer systems to track sales and orders.

Standard GTINs are composed of 14 digits, rather than 8, 12, 13, or another number of digits, as found in the legacy codes that preceded GTIN. Each GTIN is a globally unique 14-digit number used to identify trade items, products, or services. GTINs are the fundamental elements of GDSN. With them, different companies can exchange information about products and services. They can also replace other numbers used to identify products, such as part numbers and catalog numbers.

Companies that wish to accommodate GTIN coding must change their 12-digit codes to conform to the 14-digit standard. This can be done by adding zeros in front of the number. Figure 2 shows examples of changes from legacy codes to GTIN codes.

Barcodes are created by computers using barcode software and are printed by barcode printers to make labels. The labels are then attached to the products or their boxes. Ordinary laser printers can also print barcodes, but they produce poor-quality labels that may be difficult to read. Barcodes can also be printed directly on products or packaging.

FIGURE 2. Examples of accommodating the 14-digit GTIN

DATA STRUCTURE/DATA STORAGE EXAMPLES

	Original Encoded Data	Full 14-Digit GTIN
USS-12 (UPC)	012345678905	00012345678905
EAN/UCC-13 (EAN-13)	0123456789104	00123456789104
EAN/UCC-8 (EAN-8)	01234565	00000001234565
EAN/UCC-14 (ITF-14)	10012345123457	10012345123457

SOURCE: GS1

At the other end of the supply chain, information from barcodes is decoded by devices called barcode readers—such as those found at cash registers—that use low-power laser beams. Readers translate information from barcodes into digital signals and send them to computers.

A company starts using barcodes by registering with the GS1 US. GS1 US then issues the company a manufacturer code that becomes an integral part of the company's barcode (see figure 1), and for which the company pays an annual fee. The company then assigns codes to its products.

Types of Barcode

Hundreds of barcode *symbologies*—classes of code—have been created over the years, but only about two dozen are widely used. Each symbology has its own pattern of bars, dots, and spaces and its own rules for encoding data. There are two basic types of barcode: linear and two-dimensional (2-D).

LINEAR CODES

Linear codes, the most widely used, encode data in bars and spaces on a single line (one dimension). A key feature of linear barcodes is their vertical redundancy, which means that the same information is carried vertically by the full height of a code. This is useful in case of partial damage or obstruction of the label because a scanner may still be able to read it. The UPC symbol shown in figure 1 is the best-known example of a linear barcode.

2-D BARCODES

Two-dimensional bar codes encode data in two dimensions: horizontal and vertical. 2-D barcodes can carry much more information about the product on a label than just an identifying number, eliminating the need to retrieve that information from the computer network. Additional information may include the origin of the product, the name and address of the grower and processor, and information about the conditions in which it was produced. Matrix symbologies feature blocks or lines in a grid or geometric pattern. One of the most popular 2-D symbols, PDF417, is capable of encoding 1,800 text characters.

FIGURE 3. 2-D Stacked barcode

SOURCE: http://en.wikipedia.org/wiki/PDF417

2-D Stacked symbology employs multiple rows of bars and spaces in order to encode several linear symbols stacked on top of each other, as in figure 3.

FIGURE 4. 2-D Matrix barcode

SOURCE: http://en.wikipedia.org/wiki/Aztec_Code

2-D Matrix symbology encodes data by placing black dots inside a matrix, as in figure 4.

Symbologies differ primarily by the type and amount of data they can hold. Some symbologies offer full alphanumeric coding, while others encode only numbers. Symbologies may be of fixed or variable length, but must be compact enough to be recognized by the reader.

There are a wide variety of symbologies to meet any needs. The most important variables are the amount and type of data to be encoded, and the space available to print the barcode. 2-D barcodes can encode thousands of characters. The data capacity of variable-length barcodes is limited by the size of the symbol, which is, in turn, limited by the barcode reader. Many barcode readers used in distribution, manufacturing, and inventory control require a specific number of digits.

Barcode readers support multiple symbologies. Most readers recognize more linear than 2-D symbologies, but usually recognize a few common 2-D formats. When selecting a symbology, remember the more exotic the barcode, the fewer readers can read it. For some uses—such as in security applications—this may be desirable. In general, however, it is advisable to stay with popular, widely used symbologies. Symbology support varies by the manufacturer and the model. Most readers can identify several symbologies and decode them successfully, a feature called *auto discrimination*.

Pricing for 2-D barcodes is similar to that of linear barcodes, and uses the same software and printers. The only difference is found in scanners—or *imagers*, as scanners for 2-D barcodes are sometimes called. Imagers for 2-D barcodes begin at about $400, twice as much as linear scanners.

Barcode Quality Issues

Barcode reading is extremely accurate, with an error rate estimated at one error per more than 3 million characters if the barcode label is unobstructed and of good quality. However, some physical problems can hinder accurate reading:

- Folds
- Creases
- Corner wraps
- Flaps
- Laminates
- Perforations
- Products showing through the packaging
- Packaging that hides barcodes
- Patterns
- Blisters
- Embossing
- Text
- Heat shrink
- Wrinkles in material
- Abrasion on label
- Reflecting glare, such as in blister packaging
- Curved surfaces
- Barcode colors other than black and white

Some of these problems can be avoided with clear communication among the companies involved. Items that require agreement include:

- Specifications for each barcode
- Quality requirements for all barcode ingredients, such as packaging and ink
- Exact symbol location and size
- Auditing and feedback procedures
- Internal and external training

Printing Barcode Labels

The first step in producing barcode labels is the creation of a layout, using barcode label software. After the label is designed, it is sent to a printer that supports the barcode symbols. Data is read by measuring the printed bars in thousandths of an inch, so a printer capable of printing to these specifications is required. The ink and label material must support the print quality by not bleeding, running, or otherwise defacing the symbol.

There are several barcode printers that interface with a variety of computer systems. Ethernet, USB, parallel, serial, and other cables are available to connect the printer to the computer. Barcode printers also offer 802.11b and Bluetooth technologies for wireless connections. Management tools enable remote monitoring, configuration, and troubleshooting of networked printers.

Two thermal printing methods are used to print barcodes: direct thermal and thermal transfer. Each method uses a thermal print head. *Thermal transfer* printing uses a heated ribbon to produce durable, long-lasting images on a wide variety of materials. *Direct thermal* printing creates an image directly on the label material. Thermal transfer printers are used for permanent or long-lasting labeling applications. Direct thermal printers are used to produce shipping labels, receipts, and other short-term print jobs.

Barcode printers can print on tags and tickets, wristbands, polyester, and other synthetic materials. Different colors are also available, but color should be used cautiously because barcodes with too little contrast between the bars and the background may be difficult to read.

There are also some security features available for authentication, counterfeit deterrence, and secure data encoding. Label quality is protected by coatings and adhesives that offer resistance to temperature extremes, moisture, acids, and other hazards to label quality.

Thermal printers can also print and encode *smart labels*, which contain an RFID chip embedded within the label media.

New Ideas in Barcodes

Many suppliers are considering installing RFID systems because of regulatory pressure and retail mandates, but are concerned about the expense of the technology. Its expense is slowing the adoption of RFID technology in many organizations.
In the meantime, some technology companies are developing improvements in the "old" barcodes to provide an alternative for the companies that don't need to install RFID systems. One such company is Image ID,[7] which developed Visidot technology to simultaneously read multiple barcodes on boxes placed on a rotating pallet.

REDUCED SPACE SYMBOLOGY

Reduced Space Symbology (RSS) is a family of linear symbols capable of encoding the 14-digit GS1 GTIN in a small space. RSS is designed to give the benefits of full product identification, as well as providing full-feature barcodes where space is limited. It is specifically designed for the space-constraint identification of such products as cosmetics, candy, hardware, medicines, and *variable-measure* items—products like meat and produce that are usually sold by the pound in variable-sized packages.

A proposal now being considered by GS1 would incorporate the RSS barcode as one of GS1's standards by January 1, 2008.

RSS barcode standards have seven different configurations:

- RSS-14, which can be scanned omnidirectionally (in any direction)
- RSS-14 Stacked, which has the smallest footprint that still contains the complete code, enabling optimal use of space

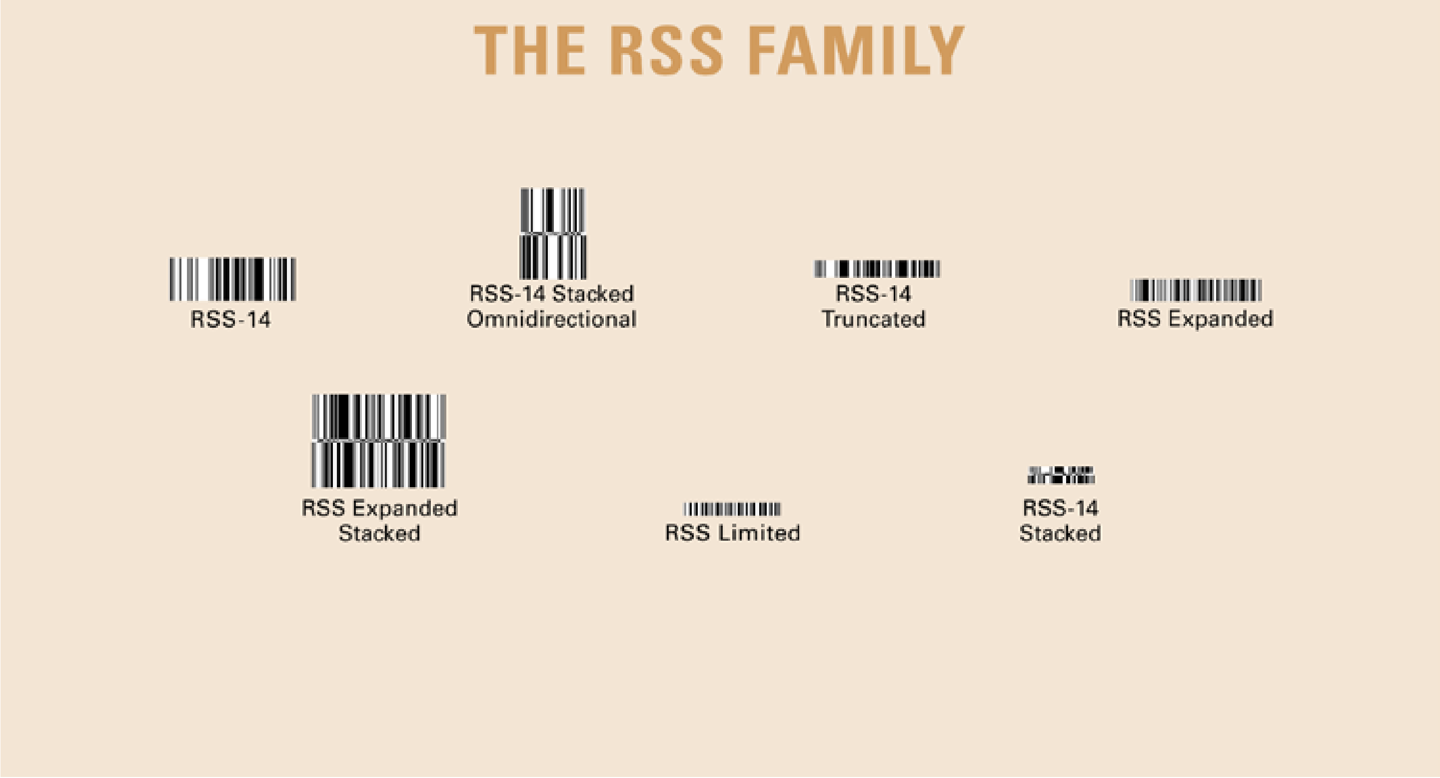
7. http://www.imageid.com/

- RSS-14 Truncated, used for very small items
- RSS-14 Stacked Omnidirectional
- RSS-14 Limited, which has the smallest footprint but cannot encode the full range of 14-digit barcodes and cannot be read omnidirectionally
- RSS Expanded, which can encode up to 74 numeric or 42 alphabetic characters to enable the inclusion of additional information
- RSS Expanded Stacked, which combines the features of expanded and stacked configurations

Some of the benefits of RSS include:

- Package size reduction
- More panel space for brand or regulatory information
- The ability to code products that cannot be efficiently coded by other methods
- Suitability for healthcare products sold at retail

FIGURE 5. RSS family of symbols



SOURCE: GS1

RFID

Radio Frequency Identification (RFID) wirelessly exchanges information between a tagged object and a reader/writer.

An RFID system is composed of:

- One or more tags (also called transponders), which include a semiconductor chip and antenna
- One or more read/write devices (also called interrogators)
- Application software and a host computer system

Radio waves are used to transfer data between the RFID tag and read/write device that need to be tuned to the same frequency. The reader sends a signal, which is received by all tags within the active field that are tuned to this frequency. Tags receive the signal through their antennae and selected tags respond by sending their data. If multiple tags are present in the field, RFID has anti-collision procedures that determine the order of response so the reader reads all tags, and reads each one only once. The reader then transfers data to the host computer.

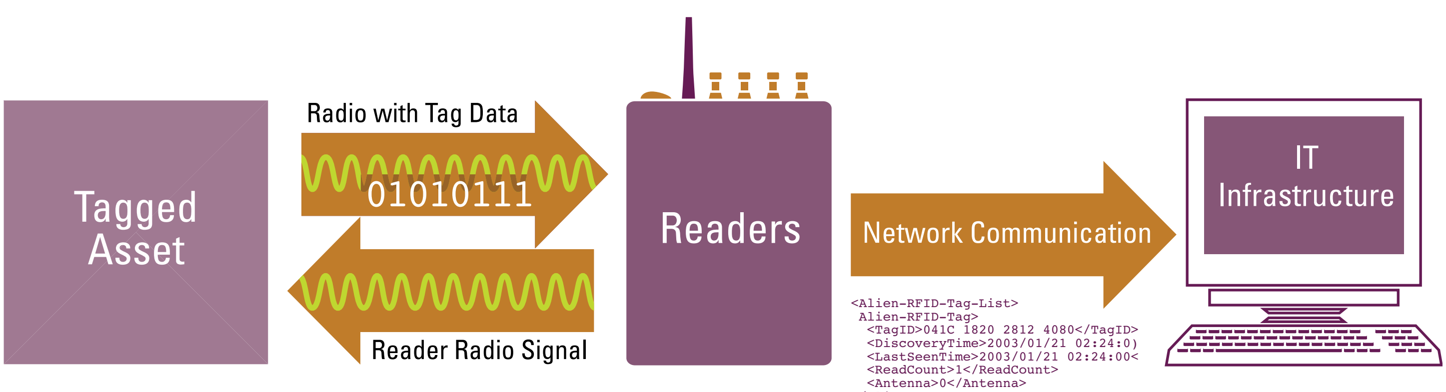
Tags can hold many kinds of data about the item, such as serial numbers, configuration instructions, times when the item traveled through checkpoints, and information provided by various sensors. Tags can be attached to many different items: tractor-trailers, pallets, cases, or products on a store shelf.

RFID technology is not new; it was invented in 1948 by the U.S. Department of Defense (DoD). It is already used in many applications including:

- Electronic Toll Collection (ETC)
- Rail car identification and tracking
- Intermodal container identification
- Access control
- Animal identification
- Automobile immobilizing

RFID technology is the foundation of the EPCglobal Network (see EPC and EPCglobal Network). EPC is the most popular RFID standard, and is already in use in more than 100 countries. Some of the world's leading food retailers, such as Wal-Mart, Ahold, Tesco, Metro Group, and Carrefour, along with scores of other companies have already adopted EPC RFID technology.

FIGURE 6. Basic elements of an RFID system



SOURCE: Alien Technology Corporation

Wal-Mart and the U.S. DoD have provided the major incentive for spurring adoption of EPC and RFID technologies. Wal-Mart issued a mandate to its top 100 suppliers to start delivering their products with RFID tags to five distribution centers serving 500 stores by January 1, 2005. Compliance with that mandate was high, even though the quality of the data collected with RFID technology still had plenty of room for improvement. A year later, Wal-Mart's RFID pilot projects were showing tangible benefits in reduced inventory and out-of-stock conditions, and the company enlarged the scope of the project to 1,000 stores.[8]

A Deloitte survey[9] disclosed that 70 percent of retailers on the European market with revenues of more than $5 billion would implement some form of RFID technology in the 18-month period beginning January 1, 2005. It is estimated that global expenditures on RFID technology will increase from approximately $1 billion in 2001 to around $3 billion by 2007 and around $20 billion in 2015. A survey completed in October 2005[10] reveals that retailers alone spent about $400 million on RFID in 2004 and are predicted to spend $4 billion in 2011.

Some projections estimate that by 2010 about 50 percent of RFID tags will be sold in East Asia and another 33 percent in North America. The goals further into the future are to produce 10 trillion tags a year. However, the costs have to come down significantly—probably to less than 1 cent per tag. To reach that price level, tags will have to be printed on packages as barcodes are today and will have to be based on something less costly than silicon chips. In September 2005, Alien Technology announced it would cut the price of its labels to 12.9 cents, while Avery Dennison cut the cost of its inlays to 7.9 cents. Previously the best tag price was about 15 cents and required a large order.[11] Chip tags are certain to go down in price as volumes increase.

RFID Tags and Readers

RFID tags have two elements: a computer chip and an antenna. They are usually mounted into an insert which is then encapsulated to form a finished tag. There are many types of tags, each appropriate for different environmental conditions. Tags that perform best on cardboard boxes may not be the best choice for pallets, metal containers, or glass. Tags can be as small as a grain of rice and as large as a brick. They have substantially different performance characteristics, such as memory and power requirements.

Tags have different ranges of durability. For example, "smart labels" or "smart tags" are not very durable and are used for disposable applications. They are produced by special printers that have the ability to print barcodes and other information on the outside and also write to the memory on the RFID chip inside the label (see barcode printers section for more information).

RFID readers can be stationary or portable. Stationary readers can be placed to read items traveling through dock doors, conveyor belts, loading bays, gates, doorways, etc. Readers can also be attached to forklifts to automatically identify pallets that are being transported. Readers can also fit into smaller mobile devices such as PC cards and handheld devices. These devices can be connected wirelessly or with cable to fixed or mobile computers. Mobile RFID readers can be used to read

8. *The Dallas Morning News*, March 2, 2006.
9. Deloitte and Retail Systems Alert Group, as reported in *Rfid Gazette*, March 2005 http://www.rfidgazette.org/2005/05/rfid_more_justi.html
10. Frost & Sullivan, *Food Production Daily*, March 2006. http://www.foodproductiondaily.com/search/search.asp?KEYWORDS=%22Frost+&+Sullivan%22&period=all
11. *Food Production Daily*, October 18, 2005.

and write tags in remote locations. They can also be used with barcode scanners to address applications where both technologies are needed.

RFID Limitations and Benefits

There are some limitations to RFID technology, including:

- Susceptibility to interference from other radio transmissions
- Sensitivity to interference from frequency changes
- Insulation by some materials—especially water and metals—that absorb radio frequency signals

These limitations can affect the performance of this technology. However, most problems can be controlled by appropriate design and equipment.

Designing, implementing, and managing an efficient RFID system is a complex undertaking. It requires knowledge of data collection techniques, mobile computing, wireless networking, manufacturing and distribution processes, and other elements of technology.

FIGURE 7. Portable RFID reader

SOURCE: PSC Inc

There are, however, several benefits of using RFID, including:

- Flexibility of tag placement, because the orientation and positioning of the tags does not matter.
- Simultaneous and automated reading of multiple tags, which permits greater reading speed and frees personnel for other tasks.
- Suitability of the technology for harsh environments.
- Memory capability of tags, which allows information to be written and changed several times.
- Suitability where security is important because knowledge of encoding algorithms and encryption is needed to gain access.

An RFID system's read range can vary from a couple of inches to about 300 feet, depending on the equipment. The presence of metals or liquids can diminish the read range. The read range is typically greater than the write range. *Active tags*—those equipped with batteries—operate at wider ranges than *passive tags*—those without batteries. Range also depends to a large extent on frequency.

FIGURE 8. Common RFID frequencies and passive ranges

FREQUENCY BAND	DESCRIPTION	RANGE
125 - 134 KHz	Low frequency	To 18 inches
13.553 - 13.567 MHz	High frequency	3 - 10 feet
400 - 1000 MHz*	Ultra - high frequency (UHF)	10 - 30 feet
2.45 GHz	Microwave	10+ feet

*Most RFID systems in the UHF band operate between 860 and 930 MHz.

SOURCE: GS1

There is no single frequency that is best for all applications, although the UHF band is the most widely used because it can carry the most information.

RFID tags can be placed on reusable shipping containers and can remain there for hundreds of uses as long as they are not damaged.

In order to get the most benefit from RFID technology, users must accurately define their needs. A good way to start for a lot of businesses is to use RFID as an enhancement of the existing data management system.

Applications of RFID

RFID technology excels at automated identification of products (as well as people and animals in some cases). It has certain features that no other identification technology can provide. Most importantly, RFID allows companies to track their products continuously in real time. This is possible because items can be identified individually instead of as a class of products.

In the future, RFID tags will carry not only information about the product but also instructional information, such as instructions to a production line about how to assemble a finished product, to the distributor about where to deliver it, to the store about when it was purchased, and perhaps even to a microwave oven about how to cook it. Declining prices of components will help implement these visions.

Some of the important benefits from implementing RFID systems include:

- Reduction of inventories
- Safety, security, and traceability
- Reduction in out-of-stocks
- Automated proof of delivery
- Reduced shrinkage
- Identifying expired products
- Shipment tracking
- Product recalls

REDUCTION OF INVENTORIES

Inventories are typically held at many points of the supply chain—the producer warehouse, shipper warehouse, distributor warehouse, retail warehouse, and the retailer's back rooms. The more uncertain each of the companies in the supply chain feels about product information and demand, the more inventory it holds. Better information provided by RFID should enable lower inventory levels at all points of the supply chain.

SAFETY, SECURITY, AND TRACEABILITY

RFID helps satisfy the new regulatory safety, security, and traceability requirements. Information carried on tags can be updated in real time and, along with data recorded in the network, provide history of product movement and changes of ownership.

REDUCTION IN OUT-OF-STOCKS

Although retailers make every effort to keep shelves stocked, according to some estimates, as much as 10 percent of shelf space is empty at any given time. The problem is growing despite industry efforts because of the increasing number of products and the resulting competition for shelf space. An RFID system can automate parts of the purchasing process, enabling products to be reordered in time to avoid empty shelves.

AUTOMATED PROOF OF DELIVERY

Proof of delivery formalizes the transfer of ownership of the product from producer to buyer. It is usually handled manually, which often leads to discrepancies between the producer and retailer versions of deliveries. In many cases, a portion of the products are provided free by producers because they have no way of proving that their delivery was different from what the retailer says it was. By automating this process with RFID, these discrepancies can be reduced or eliminated, saving time and money for both sides.

REDUCED SHRINKAGE

RFID can keep an inventory of products and warn employees of theft attempts.

IDENTIFYING EXPIRED PRODUCTS

It is difficult and time consuming to monitor the shelf life of products. Tagging the products allows automated monitoring in real time and alerting employees to expired products.

SHIPMENT TRACKING

Readings from cases and pallets being assembled into a customer order can be used to automatically produce a shipping manifest. The Serial Shipping Container Code (SSCC), commonly used on shipping labels in the form of barcodes, can be easily coded into RFID. The manifest data can be automatically read at the receiving location, expediting processing of the shipment.

PRODUCT RECALLS

In connection with product tracking, recalls can be targeted to the exact products affected, rather than whole groups of products.

Recent Developments in RFID

RFID technology encounters some additional difficulties when used with produce because of its high water content and the metal cans of canned items. Research at several testing labs around the country is leading to solutions, however.

To overcome water absorption problems, readers for tags on produce need either a clear line of sight or more powerful tags, such as active tags with their own power source. One approach is to place tags on the outside of each case or pallet. Readers may also have to be placed in more locations to assure proper reads. Some leading produce companies, for example, have been sending produce tagged on a pallet level to Wal-Mart distribution centers. These include Fresh Express, Tanimura and Antle, and Lighthouse Salads.

Food is a low-margin business, so many food retailers are slow to require RFID compliance from their suppliers. Such companies are reluctant to spend money on technologies for fear that some of the components may become obsolete in the near future. This may not be bad news for many food suppliers—by the time they are obliged to adopt RFID technology, they can expect to participate in a system where many of the initial "bugs" have been eliminated.

Some leading food suppliers are working with Wal-Mart and others on a voluntary basis. Unlike other retailers, Wal-Mart requires most of its suppliers to ship in standardized, reusable containers with a constant pallet footprint, which makes it easier to place tags and position readers.

EPCglobal has released standards for Generation 2 RFID devices. Thanks to these standards, devices that were previously incompatible will now be able to communicate with one another, and be used interchangeably. It should also attract larger manufacturers of hardware and software that should bring about needed reductions in prices of the components. Tags currently cost about 15 cents when bought in large volumes (millions of tags).

Tags equipped with temperature sensors cost $5–$8 each. Current technology allows remote monitoring of the temperature inside the container but, because temperature can differ at different locations inside the truck, it is important to be able to measure the temperature inside the products. Devices to measure temperature at this level are being developed. These tags will also be able communicate with each other, so reading one will gather information about a whole load, including out-of-sight tags.

Implementing RFID

During the last couple of years there has been a flow of news from Wal-Mart and DoD about their efforts to implement RFID technology. Many other companies have adopted this technology, and adoption is spreading to smaller companies and their suppliers.

Here is how the Piggly Wiggly Carolina, a Piggly Wiggly grocery chain franchise operating 113 stores in South Carolina and Georgia, is implementing RFID, according to Rachel Bolt, assistant director of information systems.[12]

"Retail giants are demanding RFID, but smaller retailers aren't looking at it," Bolt explains. The irony of this? "The smaller [retailers] will benefit more because we're more resource-strapped [than large retailers]. If big retailers are getting value from it, then the smaller ones will for sure," she says. She says she will not announce an RFID mandate to her suppliers, or even request that they begin using the technology. Instead, Piggly Wiggly Carolina is preparing itself to utilize RFID technology in the future by synchronizing the product data Piggly Wiggly Carolina exchanges with its 600 suppliers.

The coding, as well as business practices, must be synchronized. For example, suppliers need to send Advance Shipment Notices (ASNs) on a reliable basis. Piggly Wiggly Carolina started requiring its suppliers to begin using ASNs in June 2005. "[Getting] suppliers [set up to begin sending] ASNs is no minor task," says Bolt. "But you have to have ASNs before you can begin using RFID" because you need to know what EPCs you'll be receiving in order to automate the receiving process. Once synchronization is completed, Piggly Wiggly Carolina's receiving department will be able to read the electronic documents' listing of forthcoming shipments of goods, as well as carton identifications, content descriptions, transportation details, and other critical information.

Once Piggly Wiggly Carolina is able to process EPCs, they will be able to receive ASNs with EPCs and use RFIDs to check inventory into their distribution centers. They are working with the consulting firm GXS,[13] which has provided them with an RFID compliance package that consists of software, services, and help in adapting their business to the new technology. GXS emphasizes the importance of data synchronization as a critical first step for companies to take advantage of RFID.

12. RFID Journal, January 17, 2006, http://www.rfidjournal.com/article/articleview/2085/1/1/
13. http://www.gxs.com/

Barcodes versus RFID

Barcodes and RFID are complementary, rather than competing, technologies. They are not mutually exclusive. Here is a simple scenario that illustrates that idea:

- If an RFID tag doesn't read properly, it is important to have an associated barcode label to scan
- If both the RFID and barcode don't work, it's useful to have text under the barcode to manually enter the data

Conceptually, barcoding and RFID are similar. Both provide rapid and reliable identification and tracking capabilities. The most obvious technical difference between the two is that barcoding scans a printed label with an optical laser, while RFID scans a tag using radio frequency signals. However, the most important differences lie in their capabilities. RFID can uniquely identify objects and track them in—or near—real time.

Because of the low cost of barcode labels, and their well-established standards and global deployment, barcoding is widely accepted. RFID use has only recently been adopted.

Many companies use their barcode systems to benchmark RFID technology so they can gauge its performance. This helps them determine the efficiencies gained from implementing RFID. The decision of when to use RFID technologies should be driven by business need; it should be accepted like any other technology—when the benefits justify the cost and effort of implementing it, or if a buyer requires it.

Data Standardization and Synchronization

With the increasing globalization of business, the inconsistency of data on products and invoices has been an increasing problem for suppliers, distributors, and retailers. The AutoID center at Massachusetts Institute of Technology, in cooperation with industry leaders from many countries, developed a system of international standards that brings the benefits of RFID technology to the supply chain. The system is called EPCglobal Network and includes EPC, RFID technology, the necessary software, and other elements to form a worldwide communications network. The EPCglobal Network communicates real time data about individual items as they move through the supply chain, producing a history of product movement available to users. GS1 formed EPCglobal, Inc.,[14] a non-profit consortium of supply chain partners, to drive global adoption of EPCglobal Network.

GS1 is charged with the task of providing an Internet-based network of interoperable data pools, along with training and support for:

- Electronic Data Interchange (EDI)
- Barcodes
- GDSN
- EPC

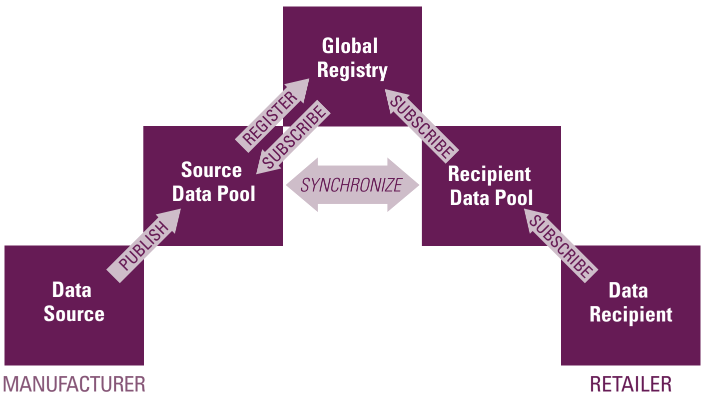
EDI is a standard format for computer-to-computer transmission of business information and transactions between trading partners. EDI information can be sent via Internet or private networks. It can be used to transmit information that would otherwise be in paper documents, such as shipping orders, invoices, and purchase orders.

Global Data Synchronization Network

EPC codes and RFID tags need clean and synchronized data to communicate efficiently within and across global supply chains. In order to set standards for more efficient synchronization of electronic data, various industry groups, along with GS1, have developed the Global Data Synchronization Network (GDSN). GDSN is an Internet-based network of interoperative data pools and a global registry that enables secure and continuous data synchronization. Some of the benefits include:

- Expanded geographic operation
- Improved inventory planning
- Reduced product introduction and promotion time
- Increased product exposure to buyers
- Fewer invoice disputes
- Fewer write-offs
- Simplified order tracing
- More accurate shipments with fewer returns

FIGURE 9. Global Data Synchronization Network



SOURCE: GS1

14. http://www.epcglobalinc.org/

THE GDSN PROCESS

In order for a company to have a product registered in a GS1 Global Registry and exchange information via GDSN, the following steps have to take place:

- Companies have to modify their internal data standards to match GS1 standards.
- Suppliers have to publish their data to a GS1 Certified Data Pool of its choice (which can be an in-house certified data pool).
- Certified data pools have to register a subset of information about each product item to the GS1 Global Registry.
- Buyers search the GS1 Global Registry for specific items through their chosen trading partners' certified data pools or select the supplier data pool to which they want to subscribe.
- Certified data pools process the exchange of information among the trading partners.

The data recorded in the GS1 Global Registry or any of the data pools can be updated at any time and is available to the trading partners immediately.

Many companies, including food retailers, are making progress in standardizing their data and are assisting their suppliers to do the same. In March 2006, Wegmans Food Market reported[15] that it had fully synchronized its product data with 416 suppliers, representing 82 percent of its cost volume, and had synchronized at least some data with 956 suppliers out of the 1,000 that had already signed up for data synchronization.

One of the largest certified data pools, 1SYNC (created by the merger of UCCnet and Transora), reported the following progress in global data synchronization efforts from January 2005 to January 2006:

- The number of items in the GDSN database grew from more than 168,000 to more than 429,000.
- The number of companies that registered with the GDSN increased from 176 to 3630.
- Synchronized items between trading partners rose from more than 168,000 to more then 900,000.

By May 2005, the international supermarket operator Royal Ahold was synchronizing data with 80 suppliers in 4 countries. The company expects to continue synchronizing at the rate of 50 suppliers a month. Some of the major tasks the firm has yet to complete include internal alignment of data and meeting GDSN requirements.

EPC and EPCglobal Network

EPC is the next generation of product identification. An EPC is a unique number that identifies an object such as a *specific* box of apples rather than *any* box of apples, as is the case with barcodes. EPCs are recorded on RFID tags that are placed on products, boxes, and pallets.

The EPC coding system is structurally similar to barcodes and other, existing numbering systems, such as UID (DoD Unique Identification numbers) and VIN (Vehicle Identification Numbers). As with barcodes, EPCs are divided into numbers that identify the manufacturer and product type. However, the EPC coding system adds more digits to identify unique items. An EPC number contains:

- Header, which identifies the length, type, structure, version, and generation of the EPC code
- Manager Number, which identifies the manufacturer
- Object Class, similar to SKU (stock keeping unit)
- Serial Number, which identifies the specific item

15. "Wegmans completes data synch with 416 suppliers." *Supermarket News*, March 20, 2006.

Additional fields may be used in order to encode information from different numbering systems.

The procedure for obtaining an EPC code is similar to getting a barcode and requires contacting GS1 US's office for information.

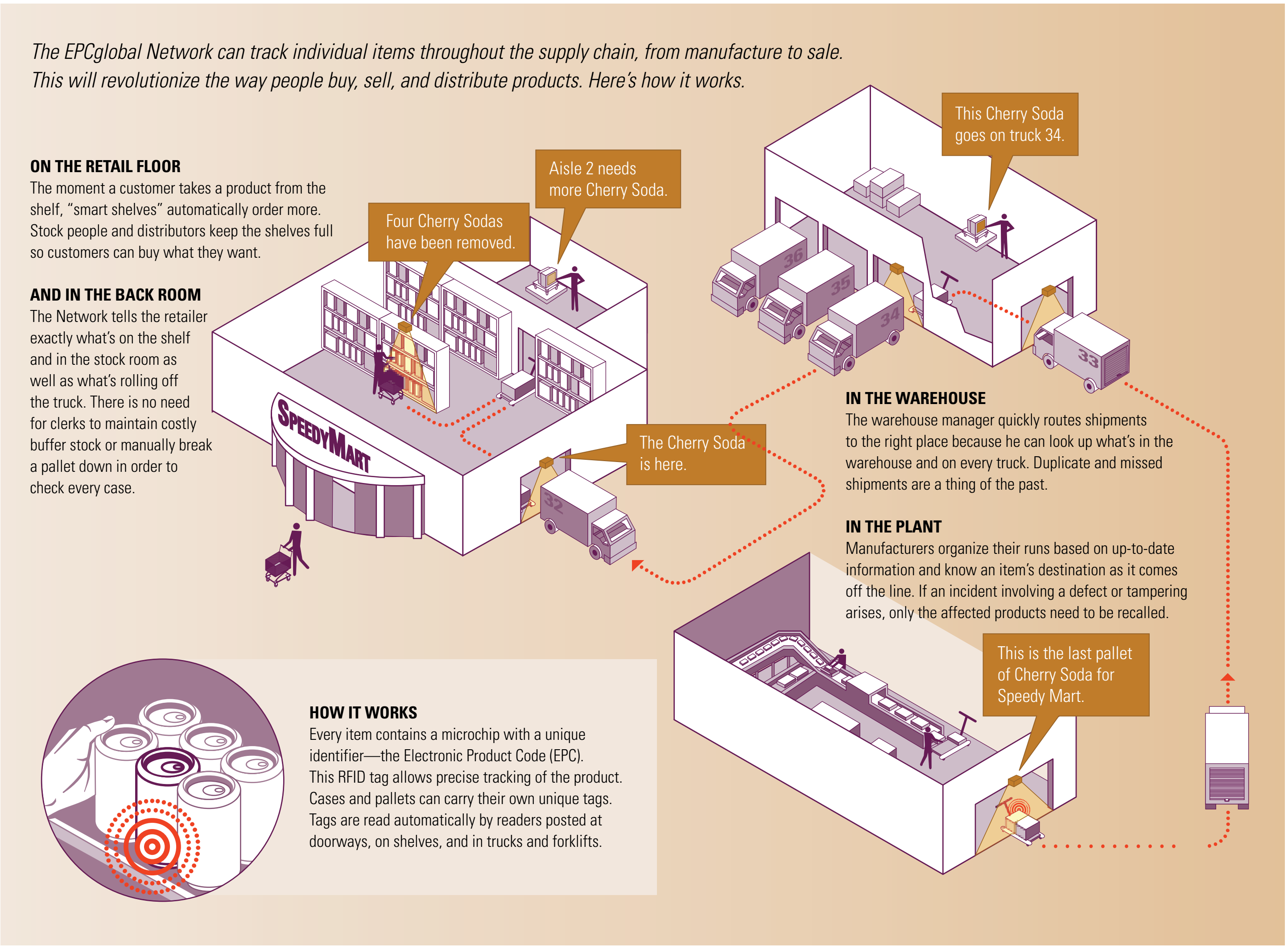
The EPCglobal Network communicates data about items as they move through the supply chain, creating a product movement history. Prior to the creation of EPCglobal Network there was no vehicle for data sharing and communication at this level in global supply chains.

The system also allows immediate transmission of changes in information about product characteristics, product sizes, weight, name, price, classification, transport requirements, etc., along the supply chain.

The EPCglobal Network itself is composed of five basic elements:

- EPC
- The ID System—tags and readers
- Object Name Service (ONS)—a local application system that carries the information about where to find data about a particular EPC

FIGURE 10. How RFID can automate the supply chain



SOURCE: http://xplane.com/clients/autoid/

- Physical Markup Language (PML)—a software language common to the entire EPCglobal Network
- Savant—software technology that manages and moves information

These components work together to make data about products available on the EPCglobal Network. RFID tags are placed on objects that need to be identified. Readers are placed at multiple locations throughout the supply chain. Readers read those tags and record the time and location of the objects. Software controls and integrates the data.

Collected data is placed on the EPCglobal Network in real time. The network provides a vehicle for sharing that information with registered users.

The EPC global information network is built with an open architecture. It is designed for active RFID (tags equipped with batteries to produce stronger electronic signals) but is capable of supporting other data collection technologies such as passive RFID (tags without batteries) and barcodes. It also accommodates Global Positioning System (GPS) used to track ships and trucks.

The network is designed on a *nested visibility* concept that allows various elements of shipments to be tracked along the supply chain. For example, boxes on pallets tagged with passive tags can be shipped inside a container tagged with an active tag. The active container tag can be tracked by RFID readers and GPS and the container can be tracked in real time.

The EPCglobal Network offers three distinct improvements over the existing methods of exchanging information between companies:

- Unique identification of individual items.
- Ability to read identification tags without clear line of sight, as is the case with barcodes. This allows for simultaneous reading of multiple tags as they move past readers within frequency range, such as boxes moving through warehouse doors or sitting inside a container.
- Real time data about movement (and also status, such as security or storage temperature) of the individual objects to the authorized users of the Network.

Operations Management Software

Because of its price and complexity, smaller independent retailers are at a disadvantage when implementing information technology packages. Several technology companies are addressing this issue. One of the solutions lies in subscription-based applications that are hosted by vendors that serve as Application Service Providers (ASPs).

One example of this approach was described in *Supermarket News*.[16] Balducci's, an 11-store supermarket chain located in several Northeast and Mid-Atlantic States, signed up for an ASP solution offered by Tomax[17] from Salt Lake City—an operations management suite called Retail.net. The software is hosted by Tomax. The package centralizes and automates collection processes and handles inventory management, vendor management, and pricing and promotions.

The subscription was less expensive than purchasing the package outright, but equally important for the company was the shorter implementation time. Balducci's estimates that 3 to 9 months were saved in putting the system in place. Balducci's is satisfied with its decision to upgrade its technology.

Before implementing the new process, data collection was handled manually, and then input into a spreadsheet. Errors happened frequently at each of the many stages that data was collected and manipulated. Now the data is significantly more accurate. Centralized data also provides a higher level of visibility and allows people in the company to work with the same data in making decisions.

Other ASPs offering similar services are StoreNext,[18] ECR Software,[19] and NCR.[20]

16. *Supermarket News*, February 7, 2005
17. www.tomax.com
18. www.storenext.com
19. www.ecrsoft.com
20. www.ncr.com

Conclusion

Technology can bring substantial benefits to businesses. Initial reports from companies that have started implementing these changes—including Walmart, DoD, Wegmans Food Market, Piggly Wiggly Carolina, and others—are encouraging even when accompanied by descriptions of temporary setbacks and difficulties.

Because each company's situation is different, decisions about when to upgrade technology and what solution to choose should be approached thoughtfully, on a case-by-case basis. Begin with a detailed analysis of business processes, which should help decide where to adopt a new technological application and which technology might be most appropriate and cost-effective.

For some businesses, customer mandates or government requirements may accelerate the move toward adopting new technologies. For example, companies involved in any part of the food business are increasingly required to maintain and exchange detailed information about their products for safety, security, and traceability reasons. Businesses will have to comply with these requirements in order to retain and increase access to their markets.

Glossary of Abbreviations and Acronyms

		Page
ASN	Advance Shipment Notices	18
ASP	Application Service Provider	24
DoD	Department of Defense	13
EAN	European Article Numbering code	7
EDI	Electronic Data Interchange	20
EPC	Electronic Product Code	1
ETC	Electronic Toll Collection	13
GDSN	Global Data Synchronization Network	20
GPS	Global Positioning System	23
GS1	One Global Standard	4
GS1 US	United States branch of GS1	4
GTIN	Global Trade Item Number	8
ONS	Object Name Service	22
PEIB	Produce Electronic Identification Board	3
PLU	Price Look-Up code	3
PMA	Produce Marketing Association	3
PML	Physical Markup Language	23
RFID	Radio Frequency IDentification	13
RSS	Reduced Space Symbology	11
SKU	Stock Keeping Unit	21
SSCC	Serial Shipping Container Code	17
UCC	Uniform Code Council	7
UHF	Ultra High Frequency	15
UID	Unique IDentification (DoD term)	21
UPC	Universal Product Code	4
VIN	Vehicle Identification Number	21

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