The Prospects for Improving ERP Data Quality Using Auto-ID†

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Automatic data capture first began with the invention of the bar code in 1954. However, it was not until 1974 that industry fully developed the technology and the first standards became widely recognized (Haberman 2001). Since that time, many firms have benefited from bar codes as a means of automatic data capture for raw materials, work in process (WIP) and finished goods. The use of bar codes has drastically reduced the amount of labor needed to conduct many basic business transactions. At the same time, bar codes have also improved data accuracy by reducing human input for data entry.

Now a new technology offers the potential to go much further. By wirelessly networking physical objects, Auto-ID will improve supply chain data flows and provide the infrastructure needed for new levels of interconnectivity (Dinning and Schuster 2002). Auto-ID allows for mass serialization and greater granularity of data that will redefine the ways companies share information and conduct all forms of financial and logistical transactions. Auto-ID enables mass-assignment of serial numbers to all products and their components (referred to as mass-serialization hence). This in turn will enable tracking and allocation of costs, and enforcement of policies at a level of granularity not currently possible. In addition, mass serialization also offers the opportunity to create “smart products” that can sense and respond to changes in the physical environment (Brock 2000). All of these developments will have an important impact on Enterprise Resource Planning (ERP) systems that form the backbone of many businesses.

Some evidence exists that practitioners are already viewing Auto-ID technology as a means of improving ERP performance. A recent online survey conducted by the American Production and Inventory Control Society (APICS) indicates that inventory accuracy is the top goal in implementing Auto-ID technology (Table 1). Inventory accuracy was also a priority when the first manufacturing planning and control systems became a reality during the 1960s.

TABLE 1

What is your main goal in implementing an Auto-ID solution?

Improve inventory accuracy	55%
Trading partner requirement	13%
Increase inventory turns	10%
Reduce out-of-stock situation	9%
Enhance supplier relationship	9%
Improve fill rates	4%

Sample size 658 respondents
Survey conducted online, April 2004.

A general definition of accuracy includes obtaining the correct value for a measurement at the correct time. In dynamic systems, timeliness is very important for data input into ERP because measurements of inventory and other values for business processes are constantly changing. The use of cycle counting and bar codes are important in achieving improved data accuracy and contributed a great deal to the early success of ERP.

Practitioners are also looking to Auto-ID as the next step toward improved data accuracy with the promise of increased volumes of data obtained through 1) greater granularity through mass serialization, and 2) the potential to blanket the supply chain with fully automatic read points.

However, deeper questions remain concerning how to implement the technology. These questions drive at the nature of ERP and the basic characteristics of Auto-ID in gathering data. This article provides an overview of Auto-ID technology and its role in improving the accuracy of data for ERP systems.

ERP AND DATA

In many respects, the history of ERP represents increasingly sophisticated databases that over time have improved tactical and strategic business planning. One of the hallmarks of ERP involves modeling a business in terms of costs, manufacturing plans, and profitability. In this role, ERP uses data as the raw material for the modeling process.

Essentially, ERP serves an "uncertainty absorption" function (Miles 1980). It is impossible to know with certainty all future outcomes that might occur for a business. However, with enough data and proper methods of modeling, reasonable projections of future outcomes become feasible. Having data allows for the possibility of calculating risk, where several different outcomes are possible, and a probability calculated from the data can be assigned to each outcome (for example see Allen and Schuster 2004).

The major achievement of ERP systems in practice is that business decision making has moved from an *uncertainty basis* where no comprehension of risk exists, to a *risk basis* where ERP serves the important function of mitigating uncertainty. The result is much more effective business decision-making based on the rational analysis of data available rather than pure conjecture.

With this in mind, any new technology that improves the accuracy, timeliness and volume of data will make a large contribution to ERP. For many years, the primary methods for capturing data needed for ERP calculations included manual entry and bar codes. Table 2 summarizes the history and pros/cons of data entry for ERP systems, starting with the inception of material requirements planning (MRP), manufacturing resource planning (MRPII), the current ERP systems, and ERP with Auto-ID.

TABLE 2

	MRP (1960s)	**MRPII** (1980s)	**ERP** (1990s)	**ERP + Auto-ID** (2004)
Data Capture	Manual	Barcode + Manual	Barcode + Manual	RFID
Data Type	SKU code	SKU code	SKU code or item serial number	Mass serialization – a serial number for each item or component
Pro/Con	Improved planning capabilities – limited data available, accuracy problems	Speed collection of data and improved accuracy, Batch mode – delays in updates	Standardized collection of data, some lot control – limited serial number control, lack of middleware, mature technology	Granular data at serial number level, middleware to manage serial numbers, common standards, real time – initial stages of development, technology to read tags must be refined

In the case of bar codes, data is gathered through close proximity optical scanning. Updates to ERP occur in batch mode. While this approach increases the amount and accuracy of data available for ERP calculations, there are several limitations to bar code data capture systems. The biggest drawback affecting ERP is timeliness of inputs because of the difficulty in configuring true high-speed, fully automatic data collection points.

In contrast, Auto-ID technology offers the potential to increase by an order of magnitude the amount, accuracy, and timeliness of data within businesses and supply chains. With Auto-ID, real-time streaming data, filtering, processing, and response are possible (Schuster et al. 2004).

Though the basic technology has been around for many years, recent developments have made Auto-ID feasible for wide scale implementation within a broad range of industries. The next section discusses the general factors that have contributed to the emergence of Auto-ID Technology.

RFID VS AUTO-ID TECHNOLOGY

A great deal of confusion exists concerning the meaning of two terms, radio frequency identification (RFID) and Auto-ID. While RFID has been in existence for more than 50 years, Auto-ID represents a new technological development (Sarma et al. 2000). Though both technologies share commonalities, several important differences exist.

The term Radio frequency identification (RFID) generally refers to a class of technologies consisting of tags and readers or interrogators. Tags are attached to objects and relay identity information to readers through radio frequency electromagnetic fields and waves. Many different types of tags exist operating at different frequencies with different modes of coupling, communication, and power sources (Scharfeld 2001). The origins of the technology trace to World War II where ground based radar began identifying friendly aircraft equipped with a transponder. The first situations where business used RFID to improve operations did not occur until the 1970s. Early applications included tagging of animals and rail cars. Table 3 gives a brief timeline of RFID.

TABLE 3

A Brief History of Radio Frequency Identification

1940s	1960s	1980s	1990s	Today
●WWII Friend or Foe	●EAS	●Railcar Tagging	●Security Access & Control	●Low cost tags
		●Animal Tracking	●Highway Toll Passes	●IT Infrastructure
			●Vehicle immobilization systems	

Through the 1980s and 1990s RFID experienced additional growth. Some of the more popular applications included security and access control, vehicle immobilization systems, and highway toll passes. Along with this growth came a proliferation of different technological formats leading to fragmentation of not only the technology, but also the markets. The technology found success in "closed systems" where tags would be applied to a consistent set of objects and be read in well-known and controlled conditions. As a result, there were very few direct data links to ERP systems because of the time and expense of interfacing proprietary RFID systems with ERP. Each interface had to be custom designed to work properly with highly fractionated and proprietary RFID technology that did not support supply chain wide applications where ERP systems must operate.

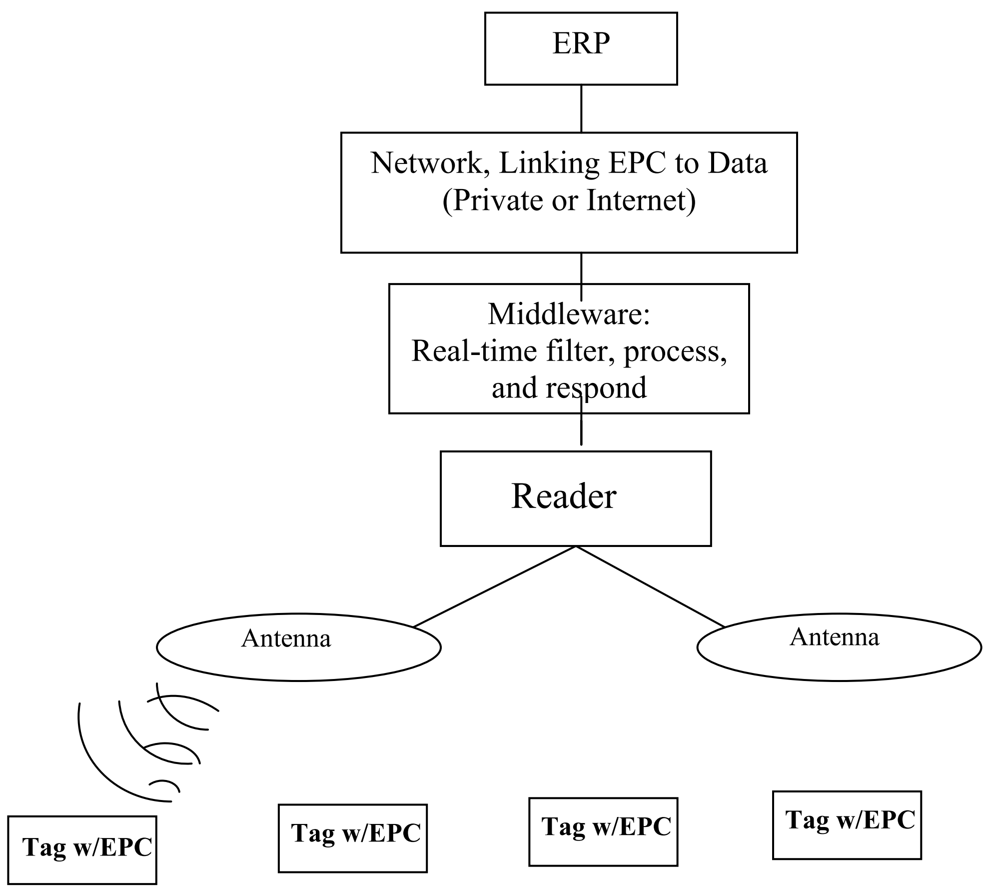
Though RFID has offered some highly innovative applications, the technology has never achieved mass use in supply chains in part because the cost of the electronic tags remained relatively expensive and open standards did not exist. This all changed during the late 1990s. The MIT Auto-ID Center and its community of sponsors formed to develop a system and standards driven first by the needs of users. A user driven process coupled with specialized technology design and development of high-speed, high volume manufacturing techniques for tags provided useful technology standards, high demand, and a path towards low cost. Projections show that the new generation of tags will reach a price point that allows individual tagging of cases and pallets. At some time in the future, the price might be low enough to tag individual consumer goods.

Given the scale of supply chains that include billions of items, a need exists for a comprehensive information technology infrastructure to manage the large amount of data potentially available from linking objects to the Internet. With such an infrastructure, the practical possibility exists of ERP systems having continuous communication with objects located anywhere within a supply chain. This *Internet of things* will create unprecedented interconnectivity, and have an important impact on the ERP systems of the future.

The infrastructure needed to manage the Internet of things is Auto-ID technology, an intricate yet robust system that utilizes RFID. Release 1.0 of Auto-ID technology is managed by EPCglobal, a wholly owned subsidiary of GS1. GSI is a result of the merger between the Uniform Code Council (UCC) and European Article Naming Service (EAN). The UCC was responsible for implementing standards for bar codes beginning in the 1970s. This has been one of the most successful efforts in establishing universal standards during the entire recorded history of commerce. Arguably, bar codes top the list for innovative technologies developed during the 20th century.

An important feature of Auto-ID technology includes open standards and protocols for tags and readers, IT infrastructure interfaces, and data codes and formats. This means that all components, whether hardware or software, can interoperate, regardless of vendor. DIAGRAM 1 provides a simplified schematic of Auto-ID Technology.

DIAGRAM 1



With this structure, identification of individual units becomes possible though the electronic product code (EPC), which has the capability for unique identification of trillions of items. Unique identification on this scale results in useful information for track and trace (Koh et al. 2003a; Schuster and Koh 2004), the authentication of objects located anywhere in a supply chain (Koh et al. 2003b), and the management of versions of the same item code (Engels et al. 2004).

THE ADVANTAGES OF AUTO-ID TECHNOLOGY

Bar codes relay a small amount of information that identifies the manufacturer and links to a description of the object. Non-profit standards groups such as GS1 administer the numbering system used for the bar code ensuring a unique identification without duplication by other firms.

In recent years, new research efforts have led to the development of the two-dimensional (2D) bar code that is able to carry more data about an object. This opens the possibility of embedding an entire EPC into a 2D bar code. Though 2D bar codes do provide more information storage capabilities, all bar codes have limitations including:

- The need for a direct line of sight from the scanner to the bar code,
- The ability to read only one code at a time,
- The need for human intervention to capture data or to orient packages in the case of overhead bar code readers.
- Inflexibility in supporting greater amounts of stored data and enhanced functionality (i.e. sensors).

There is always a chance the bar code will be missed or in other cases, read twice. As well, bar codes can be damaged or compromised in a way that makes them impossible to read. All of these factors contribute negatively to the capture of data using bar codes. Combined with the lack of unique identification, bar codes represent a mature technology that has reached the peak of operational usefulness.

Auto-ID is designed to overcome all of these limitations making it possible to automate the scanning process and provide real-time visibility to the ERP and other enterprise systems on the location and state of an item (even from outside the four walls of the enterprise). While still in an early stage of development, Auto-ID also offers the prospect of creating "smart products" that sense and respond with the physical world. This requires unique identification and communication between a tagged object and a control system, both important elements of Auto-ID technology. With this capability, distributed control systems can interact and give instructions to a specific object in real-time.

For example, some time in the future, smart objects within the consumer goods supply chain might dynamically change price based on sensing demand on the store shelf and communicate this information to ERP systems without human intervention. In addition, there could be real-time re-direction of pallets in cross-docking operations as demand and space availability changes with time.

Because it offers much more than merely identifying objects using radio communication, Auto-ID technology holds the potential to drive significant advances in commerce by providing the infrastructure for true automation across supply chains. All of this requires that data captured using Auto-ID be of high quality. For true automation, RFID tags must be read accurately and reliably.

THE APPLICATION OF AUTO-ID IN INDUSTRY

The initial financial support to develop Auto-ID technology came primarily from the consumer goods industries with the idea of developing the next generation replacement for the bar code. Retailers, in particular, were drivers of the first implementations of bar code technology during the 1970s. Later, other industries such as automotive, aerospace, general manufacturing and healthcare adopted bar code technology based on the early success in retailing. While the initial savings in the consumer goods industry came from reduced labor in marking prices on goods, improved pricing accuracy, and more efficient check-out from stores, other industries found savings in improved inventory accuracy and the tracking or work in process through manufacturing facilities.

With the rollout of Auto-ID, it is probable that a similar pattern of technological diffusion will take place. Likely, a single industry will initiate application of the technology, with other industries following the lead by making refinements for particular situations. The first announcements involving various adoptions of Auto-ID technology as part of future business practice by Wal-Mart (January 2004), followed by mandates from the Department of Defense and recommendations from the FDA, go a long way toward establishing technological leadership in the consumer goods, aerospace and defense, and pharmaceutical industries.

Although Auto-ID is a promising technology and ultimately will provide ubiquitous tracking and tracing of individual items, its application in open industrial supply chains is in early stages. Consequently, many challenges in the application of the technology remain, particularly on the newest component of the system, the RFID tags and readers. This was also the case during the early implementation of bar codes where read reliability was much lower than it is today. This was in part because excessive variability existed in printed bar codes and the scanners themselves.

FACTORS THAT INFLUENCE READ RELIABILITY

RFID adds an additional layer of intricacy in obtaining an accurate read as compared to bar codes. Because bar-coding is a mature technology with fifty years of testing and development, conditions necessary for successful production and use are well understood. Further, because bar codes depend on optical means for a successful read, the technology is direct and understandable. As long as the correct conditions exist, read reliability should be high.

Yet with RFID, tags are coupled to readers via radio-frequency fields and waves that are invisible to the human eye. As a result, read performance can seem highly variable and sometimes difficult to predict because it is hard to visualize the properties of electromagnetic fields. In addition, environmental factors play a much larger role in negatively affecting performance as compared to bar codes (Scharfeld 2003). Materials surrounding or blocking tags, such as liquids and metals, can absorb and reflect the radio frequency energy. Humidity, not a factor in bar code reading, can significantly reduce the read range for RFID tags. A final complicating factor is that the manufacturing process for tags has still not achieved critical mass. In some cases, manufacturing imperfections lead to poor read reliability. This type of failure is independent of environmental factors influencing electromagnetic fields, and causes complexity in achieving high reliability.

Reliable and accurate reading of RFID tags is generally not a problem for a specific process if thorough testing and debugging is possible as part of the installation. However, in open system applications such as tracking an object throughout the supply chain, neither the applicator of a tag, nor the integrator of a reader installation have direct control over a single implementation. The old of model of deploying RFID is no longer applicable (Scharfeld 2003). Current research and development efforts are focusing on standardization and testing to improve tag and reader designs, thus overcoming the effect of environmental factors in achieving 100% read reliability.

During the path toward 100% read reliability, many companies are considering adopting an "inferred read" approach. By associating all items within a case to that case, or all cases on a pallet to that pallet, a successful read of some fraction of the aggregation can be used to represent a successful read of all objects in the aggregation. For example, if a full pallet contains 60 cases (each tagged), then a successful read of only one of the EPC tags implies that a complete pallet has been read. The Auto-ID approach, where information is held on the network rather than in tags, is a great advantage in facilitating inferred reads. However, the inferred reads approach assumes that the aggregation is always intact i.e. all items are in a case or all cases are on a pallet. This is a disadvantage when EPC data is needed for such management priorities as the reduction of theft.

ORGANIZING DATA FROM THE EPC

With Auto-ID technology continuously progressing towards achieving 100% read reliability the next question involves how to manage all of the EPC data obtained from tagged items within a supply chain. Properly capturing EPCs without the capability to use the data in a timely manner, because of the lack of organizing software is another category of inaccuracy. Having the right data means little if it cannot be properly applied within ERP at the right time.

Though it is early in the development of Auto-ID as a means of providing operational data, it appears ERP will hold an important role in managing serial numbers (from the EPC) needed for supply chain wide visibility (Schuster 2004b). The EPC, a fundamental tenet of Auto-ID Technology, provides the capability for unique identification of trillions of objects. However, managing serial numbers for trillions of objects is a difficult challenge for current ERP systems. As a result, there will be a measured transition from lot control, currently the only capability available in most ERP systems, to serial number control enabled by new software concepts such as the Transactional Bill of Material (T-BOM™).

With the T-BOM approach, serial numbers contained in the EPC are organized within ERP systems to provide the history of movement for an item (pedigree information), a schematic of the serial numbers for all components contained in the finished item, and a mechanism to allow a query for authentication by any party within a particular supply chain (Bostwick 2004). This is accomplished through sophisticated database technology that utilizes EPC information gathered from the middleware interface to Auto-ID.

The T-BOM represents a new generation of software intended to enhance system integration as Auto-ID technology begins to take hold in industry. Since current ERP systems use only lot control for tracking and tracing, it is important to add capabilities that handle EPC data so that that it can be queried and communicated as needed. Without these types of new structures to enhance ERP, there will be much less effectiveness in using data from Auto-ID technology.

Besides tracking, tracing, and authentication, serial data on components opens new possibilities to gain insight into complex operations. There are many situations where lack of detailed information leads to ineffective supply chain management. For example, difficulties with management of versions is a common problem in the capital asset industries where service parts for long life cycle items such as aircraft frequently undergo modification and redesign midway through the life of the asset (Engels et al. 2004). With most part numbering systems, different versions of a service part cannot be identified, inventoried, traced or tracked. In situations where there are large networks that do maintenance of deployed assets, such as airbases in support of combat aircraft, knowing the exact version of a service part in inventory is essential to providing high levels of service and readiness. In addition, the ability to track failure rates by serial number (version) is also critical to understanding overall reliability as service parts move from manufacture, to distribution and finally to installation and use (Kar et al. 2003).

Reliable data capture along with software to manage EPC data in a timely manner are critical elements for success in creating the granular information needed for the supply chains of the future.

CONCLUSION

There is no question that Auto-ID has great potential to provide detailed data about objects within a supply chain. Current forecasts put the build-out of the technology on a gradual pace with the first comprehensive applications being in place by 2008. As companies install dense ubiquitous reader networks within manufacturing facilities and supply chains, greater amounts of data will become available with improved accuracy and timeliness.

However, as with any new technology, the development of Auto-ID will take many turns in practice. It is seldom that new technology finds application without a great deal of experimentation and a number of failures. In the case of Auto-ID, the direction is clearly forward because of the overwhelming possibilities for improving productivity. The task IT professionals now face is the true measure of any innovation, finding widespread application through the efforts of many who deal firsthand with the everyday problems of business.

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