

# Industrial Strength Barcode Tracking Systems Implementation Handbook

Second Edition

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*Written Expressly for Project Managers, Information Technologists, Engineers, Operations Managers and Supervisors of Manufacturers, Distributors, Food and Drug Processors, Laboratories, Repair Depots, Engineering Contractors and other Industrial Organizations who need to Implement or Upgrade a Barcode Tracking System*



## Preface

This handbook was written by Dr. Peter Green who is a leading expert in implementing industrial strength barcode tracking systems. It is based on over a decade of his personal experience in implementing over 70 industrial strength barcode tracking systems for clients.

Dr. Green deliberately chose the words “Industrial Strength” rather than just “Industrial” in the title as some of the places where the techniques detailed in this handbook have been applied would not at first appear industrial. These include applications as diverse as DNA testing, medical supplies distribution, and tracking training materials for the US Navy. But each of these applications has needed the industrial strength techniques discussed in this handbook for successful implementation.

This handbook is intended for use by project managers, information technologists, engineers, operations managers and supervisors of manufacturers, distributors, food and drug processors, laboratories, repair depots, engineering contractors and other industrial organizations who need to implement or upgrade a barcode tracking system

In this handbook, we will use the term industrial organization to refer to organizations as diverse as manufacturers, distributors, food and drug processors, laboratories, repair depots, mineral extractors, and defense and building contractors. We will use the term facility to refer to a single manufacturing plant, distribution center, laboratory complex or repair depot that exists at a single geographic location.

This handbook is divided into a set of chapters, each covering a different topic. Each chapter can be read on it’s own but, if you are new to implementing barcode tracking systems, it is probably best to start at the beginning.

If you have any suggestions for changes, additions or improvements to be included in the second edition of this handbook, please send them to [Peter.Green@BellHawk.com](mailto:Peter.Green@BellHawk.com).

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## Introduction

### About this Handbook

This handbook gives an introduction to the principles and practice of implementing industrial barcode tracking systems. Its intended audience is the managers, industrial engineers, and information technology staffs of mid-sized industrial organizations that need to:

1. Capture operational data in real-time so that people within the organization have the information they need to operate efficiently.
2. Prevent mistakes by providing real-time point-of-action warnings whenever an employee is about to make a mistake.
3. Capture tracking and traceability data so that the source of defects can be quickly determined and so that defective materials can be quickly and efficiently recalled.
4. Get customer orders out on time and provide customers with timely information about shipments so as to provide superior customer service.
5. Minimize inventory and other operational costs by accurately tracking the utilization of materials, labor, and equipment resources.
6. Efficiently capture data that can be used by ERP, accounting and CRM systems for planning, accounting and customer support.

The focus of this handbook is on industrial (as opposed to retail, medical or agricultural) barcode tracking systems that operate within buildings, as well as in yards attached to buildings (as opposed to field service applications).

This handbook covers systems used by manufacturers, industrial distributors, food and drug processors, laboratories, defense contractors, test and repair facilities and other organizations in the middle of the supply chain. These organizations face unique challenges as the data capture is often performed by personnel who do not have a high degree of computer literacy. Also the physical environments are often challenging in terms of wireless data communications and the physical environments in which the equipment has to operate.

In this handbook, we provide an overview of the barcode technology and methods used to capture data. We also provide guidance as to project management issues that an organization will face in implementing a barcode tracking system.

## Why Use Barcodes?

In an industrial organization, there are many things we need to keep track of, including:

1. The real-time status of customer orders and related jobs.
2. Raw, intermediate and finished goods inventory status.
3. Work-in-Process status in production, processing or secondary operations.
4. Receiving and put-away of incoming materials from vendors.
5. Picking, packing and shipping of materials for customers.
6. Quality control and test data.
7. Which employee worked on each activity and how long it took.
8. Documents and certificates related to materials.
9. Scrap, rework and wastage of materials and resources.
10. Utilization of equipment and machinery.



This tracking data is most efficiently captured by the material handlers and production employees who are handling the materials and doing the work.

We also need to prevent these employees from making mistakes by providing point-of-action warnings in real-time when these employees are about to make a mistake, such as picking the wrong material for a customer order or job.

Many industrial material handlers and production workers do not have a high level of computer literacy. Also, for many of these workers, English is a second language. As a result they have great difficulty entering data directly into the complex screens of an ERP or accounting system without making many mistakes.

The traditional solution to this has been to have material handlers and production workers write the tracking information down on a paper form and then, sometimes, subsequently have another person enter this data into a computer, so that it can be viewed or analyzed.



Unfortunately, this paper-based approach has many problems:

1. It does not validate the data as the data is written on the paper form. The worker can enter anything they want, often making mistakes such as transposing digits on a part number.
2. There is no point-of-action validation that the employee is making the correct operational decision, such as picking the right material or using material that has passed inspection.

3. There is usually a significant delay in keying in the information into a computer, if it is entered at all. Typically there is at least a 24 hour delay between when an activity occurs and when the data is available to supervisors and managers. With lean manufacturing practices, the velocity of materials quickly increases to the point where 24 hour old data is only useful for historical analysis.
4. Often, much of the data ends up in a filing cabinet, where it is never looked at until something goes drastically wrong, like a product recall. Then it is nearly impossible to retrieve and analyze this data in a timely manner.
5. Manually keying data into a computer is expensive in terms of labor hours and error prone. Often errors made by employees writing down the wrong information and mistakes made in keyboard data entry have to be found and corrected by managers and IT staff who are paid much more per hour than the workers who made the mistakes in the first place.

The cure to this problem is to use barcode scanning to capture the data. Barcode scanning is a point-and-capture process and can be used by workers with limited computer literacy. Also:

1. Data capture is highly accurate. If the barcode scanner beeps than the data is captured with almost 100% accuracy.
2. Data can be validated in real-time to make sure that the user has scanned the correct barcode. Also point-of-action real-time validation can be performed and the operator immediately warned if they are performing a wrong action, such as picking the wrong material or performing a job step out-of-sequence.
3. The data can be made immediately available to managers, supervisors and customer service personnel so they can efficiently run their operations by making decisions based on real-time information.
4. The data can be automatically retained in a database so it can quickly and efficiently be accessed and analyzed in the event of a product recall or other operational problem.
5. Accurate inventory, labor and equipment utilization data, as well as job status data, can be automatically fed to accounting and ERP systems, so as enable accurate planning and cost-accounting to take place. Also the status of customer orders and shipment can be fed in real-time to CRM systems and to customer systems to facilitate a high level of customer service.



In this handbook we will look at how to use barcodes to track materials and operations from the receiving dock to the shipping dock inside industrial plants.

## Using Barcode Tracking Systems to Cut Operational Costs

Some of the ways our clients have cut their operating costs by implementing barcode tracking systems are:

1. By tracking customer orders in real-time. This enables our clients to ensure that their customer orders get out on-time without a last-minute rush. This avoids the payment of expensive overtime. It also avoids the payment of late-shipment penalty fees imposed by many large customers or the need to pay for expedited shipping charges to avoid these penalties. In many cases, savings from these sources alone has more than paid for the cost of the tracking system in less than 12 months.
2. By preventing employee mistakes, such as picking the wrong material for a job or a customer order. Barcode tracking systems can warn an employee when they are about to make a mistake. This can result in major savings due to reduction in scrap and wasted resources processing defective materials. It also avoids having to ship replacement parts to customers to replace defective parts.
3. Elimination of the need for expensive expediting and wasted time by customer service people when handling customer order status inquiries. With a barcode tracking system, customer service people can immediately see the status of customer orders without the need to call an expeditor who will then spend a lot of time searching the facility until they find the customer order. This greatly improves customer satisfaction and eliminates the cost of expediting orders.
4. Elimination of wasted time spent trying to find inventory. Without a barcode tracking system it is easy for inventory to be placed in the wrong place (such as an overflow location) or incremental inventory inaccuracies to creep in, resulting in lost labor time searching for the missing inventory. With a barcode tracking system, all the locations in which items are placed are tracked, in real-time, enabling rapid location and retrieval of the inventory without any wasted time.
5. Elimination of wasted inventory due to spoilage. In many industries, such as food processing, materials have a limited shelf life. If materials are not used by their expiration dates then they must be scrapped. With a barcode tracking system, the materials can be used in an age-first order, thus avoiding this problem.
6. Avoiding stock-outs and purchasing too much raw material or making too many intermediate materials. Without a barcode tracking system to keep accurate real-time track of physical and allocated inventory as well as materials being made and on-order, it is easy to make or order too little or too much material, each of which can have major cost consequences.
7. Prevention of employee theft or misappropriation by accurately tracking assets and materials in real-time. Often it is not clear, with manual tracking methods, whether lost inventory is the result of carelessness or malfeasance. With a barcode tracking system, the causes can quickly be determined and appropriate management action taken.

8. Elimination of the time taken by employees writing information down on paper forms and then having someone else key this data into a computer. With a barcode tracking system, data entry can be performed directly by material handlers and factory-floor workers, eliminating the labor cost of keying-in the data. Even more importantly, the electronic tracking system prevents most of the data entry mistakes which can take many hours of expensive supervisor and IT department labor to track down and fix.

In addition to the above tangible savings, there are also big intangible savings in using a barcode tracking system. Some of the foremost are:

1. Avoiding losing customers by shipping defective or wrong materials to a customer or by shipping critical materials late. It is very expensive to acquire customers, but it only takes one mistake to lose a big customer.
2. Preventing lawsuits due to shipping defective materials that cause harm. Also barcode tracking systems can minimize the scope and cost of recalls by limiting recalls to just the effected materials by capturing the needed data in a form that can quickly be recalled.
3. Enabling managers and supervisors to function much more efficiently by giving them the information they need to effectively manage their operations in real-time. With "Lean Manufacturing" practices, the velocity of materials goes up and so does the opportunity for mistakes. Barcode tracking systems can provide managers and supervisors with the information they need to avoid making bad decisions.

Barcode tracking systems can often pay for themselves in a few months as a result of improvements in operational efficiency and in preventing mistakes. Then they keep on paying back their investment cost, year in and year out.

## Using Barcode Tracking Technology to Increase Sales

In these challenging economic times, one of the questions all of our mid-market clients are asking themselves are “How do we increase sales or at least sustain the sales we have?” Here we suggest a technology solution that has been proven to enable our clients to win major new orders and to increase orders from existing customers.

Most of our clients are suppliers to larger organizations. They are the Tier 2 organizations in the middle of the supply chain. They supply the Tier 1 organizations that are the link to the retail customers. Many of them are being squeezed by thin margins, global competition, and the incessant need to rapidly deliver quality goods on-time.

So how do our client companies increase sales? They cannot reduce prices any more and high quality is a given. So where is the competitive edge? The answer lies in saving customers money by providing them with data as well as products.



Some of the ways our clients have increased their sales by saving their customer money are:

1. By saving them money on the receiving dock. They put a barcode label on each pallet and send an advanced shipment notice describing the contents of each pallet. This can reduce a complex receiving and ERP data entry task for their customers (that has to be performed by an expensive receiving clerk) to a single scan by material-handler driving a fork-lift truck. The result can be savings of tens or even hundreds of thousands of dollars a year to their customers.
2. By pre-applying all the barcode labels tags that your customer needs for their internal tracking processes. This saves their customers time and money in their internal tracking processes.
3. By providing their customers with all the quality control test data in electronic form for the goods that have been shipped. There is no reason that the customer's QC people have to repeat the tests performed by our client's quality control technicians. There is significant cost

savings available to customers by reducing the amount of incoming materials inspection. This is going way beyond the provision of a generic certificate of compliance to providing customers with data that will enable their quality control people to truly evaluate the materials that our clients have shipped to them.

4. By preventing the shipment of defective goods, which could cost our clients' customers a large amount of money in lost production or in defensive incoming inspection. By having electronic mistake prevention systems in place, our clients can demonstrate how they can save their customers these costs and prevent the imposition of penalties for shipment of defective products.
5. By limiting the customer's liability in the event of the shipment of a batch of defective products. By maintaining electronic tracking and traceability records, our clients are able to minimize the scope of recalls in the event of a defect or contamination. This dramatically reduces the risk and legal liability for the end customer.
6. By ensuring accurate on-time shipment of materials to customers. This can save the customer money by minimizing their need for customers' to carry excess inventory. By electronically coordinating the customer's demand with the supplier's production, both our clients and their customers can benefit from considerable cost savings. An extension to this is vendor managed inventory, whereby our client's manage the inventory in their customers' plants based on electronic feedback.

As many of our clients have realized, they cannot reduce prices (without going out of business) and all their competition is claiming to ship quality products. But, by being able to offer these additional savings from supplying data along with their products, our clients are able to compete in another dimension in which the cost savings from improved customer efficiencies more than compensates for a lack of marginal reduction in prices. Also, as these technologies require linking supplier systems with their customer systems, it transitions our clients from being a vendor who can be replaced at will to a valued supplier partner, who cannot be as easily replaced.

All these potential cost savings are not lost on the Tier 1 organizations. So they are starting to mandate that their Tier 2 suppliers be able to provide the data to enable them to make these cost savings. Some well known examples are the US Department of Defense and Veterans Hospital Administration and retail chains such as Wal-Mart but many other examples are starting to occur up and down the supply chain.

In summary, barcode tracking systems can enable organizations to increase sales by competing more effectively in global markets and also quickly pay for themselves in increased efficiencies and cost savings.

## Industrial Barcode Tracking Systems as Middleware



Industrial barcode tracking systems are the link between the front office accounting, planning, scheduling and customer relationship management systems and the barcode scanning and mobile data collection devices used to collect the data needed by these systems from the production and distribution operations within a facility.

The barcode tracking systems draw the information they need to enable the collection of data and to provide point-of-action warning of potential mistakes from the front office systems. They also serve as an interface to collect data from equipment such as weighing scales and process control and test equipment and to integrate this into a detailed tracking and traceability record for materials as they traverse from the receiving dock to the shipping dock.



Industrial barcode tracking systems also interface with laser printers to print out forms, such as barcoded job travelers and picking sheets, which facilitate the collection of tracking data. They also interface with barcode printers to enable barcode labels to be printed out on an as-needed basis with minimal manual data entry.

Industrial Barcode Tracking Systems track information about materials in much greater detail than is kept in most accounting or ERP (Enterprise Resource Planning) systems. As a result they have their own tracking database in which to keep all this tracking data.



## About Barcodes

### Reasons for Using Barcodes

The reasons for using barcodes for tracking materials and work-in-process are:

1. Eliminates the need for factory floor or warehouse people to key data directly into an ERP or accounting system. These systems are often difficult for factory floor or warehouse people to use as a result of having many screens with many data entry boxes. This difficulty results from the vendors of these software products trying to produce software that has all the features needed to be usable in standard form by hundreds of thousands of organizations. Also these products are designed for use by “front-office” staff people who are well educated and computer literate. Many of the people who work on a factory floor or warehouse have poor skills in reading and writing English (often English is a second language) and are not especially computer literate. As a result they often make mistakes in keyboard data entry.
2. Eliminates the need for people in the warehouse or factory to write down operational tracking data on paper forms and the need for someone in the office to type this data into the computer. This is the classic response to operational employees not being able to do direct data entry into an ERP system. Unfortunately the same warehouse and factory workers also make mistakes in writing down data, such as transposing digits in a part number. Some of these are caught by the office data entry person and some are not. Also studies indicate that people keyboarding in data typically make at least one keystroke error in 40. This means that every fourth 10 digit part number is wrong, which is one reason that inventory data in traditional systems is never accurate.
3. Eliminates the time that valuable people such as supervisors, managers, and information technology people have to spend trying to find and correct errors in the production and material tracking data. Today, with lean staffs and high material velocities, managers, supervisors and lead people increasingly rely on the computer to help them run their operations. But, the more inaccurate the data, the less use the computer is in helping manage operations. So a lot of time is wasted finding and correcting data-entry errors, especially when they have propagated throughout an ERP systems database.
4. Eliminates time delays in collecting and entering data into an ERP system. With manual data collection and data entry there is often a 24 hour delay between an action occurring in the factory floor or warehouse and the transaction being reported in the ERP system. We speak of the “data lag” between the velocity of material through the plant or warehouse and the velocity of data. Lean manufacturing places great emphasis on minimal inventories with just-in-time delivery and high velocities of many diverse materials flowing through a plant or



warehouse. Managers and supervisors cannot keep track of this if the data lags 24 hours on the movement of materials. What is needed is real-time data.

## Advantages of Using Barcodes for Data Collection

The advantages of using barcodes for data collection are:

1. High degree of accuracy. When a barcode is scanned correctly, the scanner beeps, otherwise it keeps trying to scan as long as the trigger is pressed. The rate of false reads is about 1 misread in 10 million.
2. Real-time data entry. When a data item is scanned, it is captured and verified in real-time, and then relayed to the operational database server as soon as communications can be established. There is no more delay waiting for someone to key in data that has been written down by hand. The data in the computer now reflects the real-time status of operations and can be used as a valuable management tool to efficiently run factory or warehouse operations.
3. Real-time data validation. The tracking software can validate that the data item being captured is correct. For example that the barcode being scanned is a valid container tracking barcode and not the barcode from the employee's badge. This validation against the tracking system's database can take place in real-time with immediate warning to the operator if they made a mistake.
4. Real-Time operational mistake prevention. The tracking software can also validate that the operator is not making a mistake by checking the data just scanned against its database. It can, for example, detect that a material handler has just picked the wrong material for a job or for a customer order. The operator can then be warned in real-time that they are about to make a mistake and be prevented from proceeding with the scan sequence until they select the correct material.
5. Reduction in labor cost. It takes a lot of time to write down information, then to keyboard it, then to correct the errors. This can amount to many expensive hours each day. With barcode scanning, data collection takes place in less than 1 second per data item.
6. Multi-lingual. Barcode scanning does not require knowledge of any specific language. The employee simply points and scans. This can be facilitated by tracking software that makes extensive use of graphic icons to direct employees as to which barcode to scan. The tracking software can also make extensive use of visual positional clues, such as on a barcoded traveler or picking form, so that employees intuitively scan the correct barcode.
7. Ease of training. It is much easier to train people to scan barcodes than it is to train them how to write data down on a paper form or to enter the data directly into an ERP system. This is especially true with tracking software that only takes in one item at a time and prompts the user with icons as to which barcode to scan.



## Different Types of Barcode

Some of the common types of barcode used in industrial plant are:

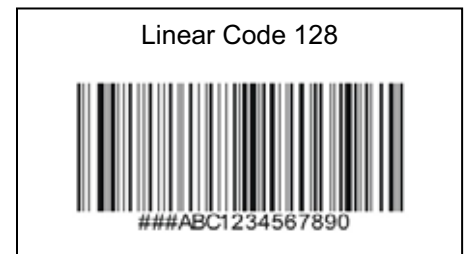
**UPC barcodes:** placed on finished goods for retail distribution. These consist of a set of bars and stripes that are scanned by a linear or one dimension (1D) barcode scanner. The bars and stripes are coded to hold the UPC assigned manufacturer's code and the manufacturer's assigned product code. UPC codes have consisted of 5 digits for manufacturers followed by 5 digits of product code but are now being extended to include more manufacturer digits as they are coming to be used world wide. The barcode has edge bars for use by the scanner in recognizing the barcode and also has a built-in checksum for error detection.



**Stacked barcodes:** designed for use by the medical community and other end users wanting to track serialized and dated products. The barcode holds 70 alphanumeric characters consisting of the UPC code plus a serial number and a date. They can be small enough to be placed on a pill casing so that hospitals can verify and record drug dosages using barcode scanning. Stacked barcodes are scanned using two dimensional (2D) barcode scanners, which are typically much more expensive than one dimensional (1D scanners).



**Linear barcodes:** used for product and material tracking and data entry throughout factories and warehouses. These barcodes have a number of ways of encoding data in the bars and stripes according to their code designation, such as code 39 and code 128. Code 128 is the most commonly used as it can represent all 128 ASCII characters that can be typed into a keyboard. Typically code 128 barcodes hold about 16 characters and numbers in a 2x1 inch barcode. They can also be scanned using robust, inexpensive barcode scanners making them ideal for industrial use.



**Two dimensional barcodes:** used for transferring larger amounts of data. A typical 2D barcode can hold over 1000 ASCII characters in a 2x1 barcode but requires an expensive 2D laser or imaging scanner to read the barcode. They are typically used for transferring data on shipping labels between plants and/or warehouses. Typical data encoded in a 2D barcode might include part number, quantity, lot number, manufacturer, date produced, as well as other product specific data such as color or physical properties.



## 2D Versus 1D Barcodes

One dimensional or 1D barcodes can hold about 16 characters in a 2"x1" barcode whereas a two dimensional or 2D barcode can hold over 1,000 ASCII characters.

A 1D barcode can hold an identifier, such as a "license-plate" tracking number, a location number, a lot number or a part number. A 2D barcode can hold a large amount of information such as the part number and description, the quantity, the unit of measure etc. for many items in a container. We see contrasting examples of this in the use of an SSCC (standard shipping container code), which is a GIAI (global individual application identifier) standard barcode that uniquely identifies each shipping container from a US Department of Defense Military Shipping Label (MSL).



The SSCC contains the company code and a unique serial number, issued by the company, for the pallet or box being shipped. The 2D barcode in the MSL, by contrast contains over 180 data items relating to the contents of the pallet or other shipping container. But, it is noteworthy that the MSL also has a 1D tracking barcode, its TCN or tracking control number.



So, why would we not always use 2D barcodes? The reasons are scanner cost and performance.

A simple contact imaging barcode scanner that plugs into a PC and can read a 1D barcode can be purchased for under \$100 and a short range (up to 2 feet) 1D laser scanner (puts out a red scanning line) can be purchased for under \$250. A short-range 2D laser imaging scanner of equivalent performance costs around \$750, or about a 3:1 difference in cost. Two dimensional imager scanners are slightly less, typically costing around \$500 for an industrial unit.

Another issue is range. 2D imaging scanners are only really effective close-up as otherwise the 2D barcode only becomes a small part of the picture being imaged and cannot be read. A 2D laser scanner has very limited range. This is because the laser energy is distributed over a two dimensional space, whereas a 1D scanner focuses its energy in a very narrow straight line. Also 1D barcode scanners can be made to modify the arc they scan to range at which they are scanning and, as a result, can scan 1D barcodes at ranges from 4" to over 40 feet.

So we always want to use 1D barcodes wherever possible and only use 2D barcodes when all the information about an item must be contained in a 2D barcode. But, with the advent of the Internet, we can instantly lookup data about an item almost anywhere in the world, given its tracking number; so we don't need to put all of the data in a 2D barcode. We simply scan the 1D barcode and look-it up. This concept has been applied brilliantly by UPS and FedEx and now is

finding universal acceptance. Tomatoes are now coming with an individual barcode that can be scanned with a cell phone and their origin and other data instantly looked up over the Internet.

Inside an industrial organization, 1D barcodes are definitely what should be used for internal tracking and 2D barcodes should only be used if you have to ship to the US Department of Defense or some other customer that demands 2D barcodes on their packaging.

### **Barcode Features and Resolution**

One dimensional barcodes have special “guard-post” bars and stripes at the beginning and end of the barcode itself. These guard-post bars and stripes are unique to each barcode standard, such as Code 128 and Code 39 and in fact are different for different sub-sets of each standard. These guard-post bars and stripes are how barcode scanners are able to recognize different types of barcode and to automatically recognize a wide range of different barcode standards.

In the case of 2D barcodes, these guard-posts are replaced by feature bands along the sides of the barcode, which serve for both code recognition and image alignment before decoding.

Barcodes have a specified resolution. In the case of 1D barcodes this is the width of the smallest bar or stripe in the barcode label. Resolutions are measured in mils or thousandths of an inch. Standard tracking labels typically have a resolution of 20 mils and high resolution barcodes with a 10 mil resolution are routinely used to get more information on smaller labels. For really space constrained applications, such as putting a barcode labels on top of an integrated circuit chips, then very high resolution 5 mil resolution labels are used.

For 2D barcodes the resolution is measured in terms of the smallest feature size (dot or square) that can be resolved.

All barcodes need to have a certain amount of white space around them. In the case of one dimensional barcodes this is needed before and after the barcode. This white space, together with the guard band elements, is how a barcode scanner differentiates a barcode from all other elements. So it is essential to have enough white space, as specified for each barcode standard, before and after the guard band elements. This required white space is part of the barcode and its size is a function of the resolution of the barcode.

2D barcodes likewise need white space around the barcode for correct recognition.

## RFID and Barcode Technologies

This handbook focuses on the industrial use of barcode technology. However most of the techniques described here are equally applicable to using RFID technology.

With very few exceptions, the use of RFID technology for industrial production, process and inventory tracking has not achieved widespread acceptance. Partly this is because RFID technology is much more expensive than barcode technology. But it is also because of physical limitations of RFID technology.

The vision, sold by the popular press, was that you could press a button and have RFID technology tell you exactly where each item was on each shelf in your warehouse.

Unfortunately to do such a scan in the typical industrial warehouse, in a reasonable time frame, would require the injection of so much RF energy into the warehouse as to ionize the atmosphere within the warehouse.

A much bigger problem is that, unless you have only a small number of items with RFID tags in a controlled scanning environment (such as a physical gate with multiple sensors), the read accuracy quickly drops well below 100%, which is not acceptable in most industrial applications.

RFID technology will accurately detect the presence of an item with a single RFID tag within a few feet radius of the sensing equipment. So it can be used to track the receipt or shipment of pallets through dock doors or the transit of assemblies (such as automobiles) down an assembly line. For high volume operations willing to invest a lot of money, these can be worthwhile applications of RFID. But most of our mid supply-chain clients, who comprise the majority of industrial operations in the USA, do not have the throughput to justify the expense of such systems. Hence they rely on barcode scanning, which is the subject of this handbook.

It has been argued that a benefit of an RFID tag is that it can hold a lot of information. But the same can be said of a two dimensional barcode.

In this handbook, we focus on the use of one dimensional barcodes (such as the one shown here) because, in an industrial setting, we can easily use the tracking number in the barcode as a reference to look up much more data in a database. The use of two dimensional barcodes and the use of RFID tags to hold a lot of data only have applicability where the recipient does not have remote access to the data and so all the information about an item has to be sent along with the item. With the global spread of the Internet to the industrialized world, in general there is no need to use 2D barcodes or RFID tags for this purpose.



The exception to this is where the space available for the barcode is so small that a two dimensional barcode has to be used to hold a unique tracking number. Also in some cases, organizations such as the Department of Defense have mandated the use of two dimensional barcodes to accommodate these space-limited applications.

## Printing Barcodes

There are two ways that barcodes are used in tracking:

1. Tracking labels that are placed on shelf locations, individual items and containers such as boxes, pallets and bins.
2. Sheets of barcodes that are scanned to aid in the tracking process. These include barcoded travelers, picking sheets, and sheets of action barcodes.

Barcode labels that are attached to shelf locations, to items and containers are printed on an industrial barcode printer, such as the one shown here. These printers use a print head that contains an array of heating elements that melt “ink” from a wax or resin ribbon onto a roll of labels. These adhesive labels are pre-cut and attached to a peel-off backing, which is removed after printing and before adhering the barcode to a surface. The labels may be made of paper with a plastic coating or entirely of plastic, if high scuff resistance is required.



These barcode printers are entirely different from normal laser or ink-jet printers and require specialized training in their use and adjustment. They are much more a miniature printing press than a regular printer attached to a PC. They require special software to drive them and to prepare the format of the labels.

Because of the complexity of barcode printers, and the need for frequent maintenance, we often recommend that clients use rolls of pre-printed barcodes for shelf location identification and for identifying items and containers. These are available from a number of vendors and avoid the need to purchase or maintain barcode printers for this purpose.



Forms that contain barcodes, such as barcoded travelers and picking sheets, are printed on regular laser printers using software that knows how to generate the barcode labels as part of a form.

Please note that it is important, for industrial use, to use a laser and not ink-jet printer, otherwise the ink will run due to moisture and the barcode will become unreadable.

BellHawk Traveler		Job #: TEST2	
Part: 1000	Priority: Rush	Wanted By: Aug 4, 2000	Customer Name:
Order:	Qty To Make: 20	QOM: Each	Owens Company
Category: Padded Cover	Type: Assembly	Special Instructions:	
Operation Start Code	Department / Operation	Instructions	
	Machine Shop/Get from Inventory		
	Parts	Sheet Steel 1/2" x 48" Sheet	Qty: 2 Ea
	Machine Shop/Panel Cutting		
	Machine Shop/Pressing		
	Machine Shop/Pressing		
	Paint Shop/Finishing	Blue Paint	
	Parts	Paint Blue 1/2" Dia. Can	Qty: 1 Can
	Paint Shop/Finishing		

## Barcode Content Standards

As well as standards, such as Code 128 and Code 39, which specify how the bars and stripes in a barcode are used to represent letters and numbers there are also standards that govern the contents of a barcode. The most important of these is the Global Individual Asset Identifier standard which is maintained by the GS1, global supply chain, standards organization. This standard uses the Code 128 standard to define its bars and stripes.

This standard specifies three parts of a barcode's contents. The first is an identifier (shown in brackets) that identifies the type of barcode label (i.e. what it contains such as a product identifier or a serial number or expiration date).

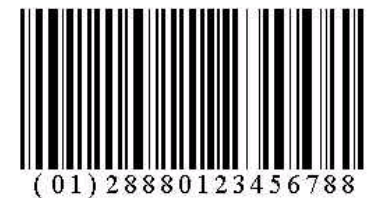
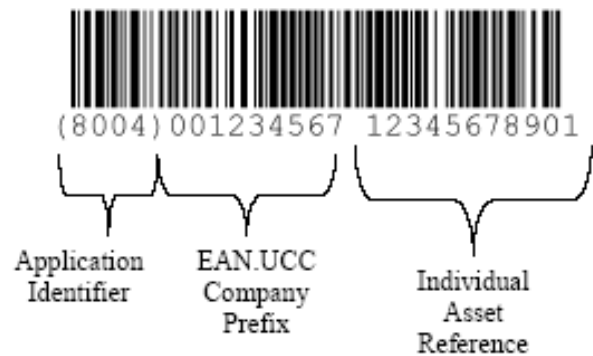
The second part is the company prefix, which uniquely identifies the issuing company. These codes are an extension of the older UPC company identifier and are issued by the GS1 standards organization.

The third part varies with the type of barcode but has a defined structure and length that depends on the Application Identifier field.

An example of a GIAI barcode is the new GTIN barcode, shown here, which is planned to replace the older UPC code.

The contents of these barcodes can also be concatenated to form a composite barcode. The example below shows the concatenation of a product identifier with a serial number to form a globally unique "license-plate" tracking barcode for the item.

### GIAI Data Structure





## Barcode Equipment

### Introduction

In this chapter we give a brief overview of some of the types of barcode equipment used for inventory, labor and order tracking in an industrial setting. There are many different models of barcode equipment available from many different vendors. The models we have selected here are typical of those that I have found to work successfully in a variety of industrial organizations.

### Tethered Scanners

Tethered or corded scanners work in conjunction with a PC. They are typically used to record operations at a bench or to record the start and stop of job steps at a shared PC.

These scanners typically have a six feet long cord that is plugged into a USB port on the PC.

The simplest, and least expensive types, such as the unit shown here, have a CCD camera element similar to the one in a cell phone. When a trigger on the scanner is pressed, a picture is taken of the barcode and the scanner decodes the barcode into a string of alphanumeric characters which are then automatically deposited into the keyboard of the PC, as if they were typed by the user.



The scanner shown in the above diagram is a Unitech model 210, which scan scan a wide variety of one dimensional barcodes. It, like most barcode scanners, can automatically recognize the type of barcode by the “guard band” bars and striper that are placed at the beginning and end of the barcode and uniquely identify the barcode as a Code 128 or Code 39, for example.

This is what is called a contact scanner. The user places the scanner over the barcode and presses the trigger. The scanner then records the barcode image and converts it into a sequence of letters and numbers. If it is able to successfully read the barcode, it emits a beep, otherwise it is silent.

This type of scanner is very beneficial when scanning barcodes from a sheet of barcodes as it eliminates ambiguity as to which barcode is being scanned. This type of scanner is also inexpensive and the model shown here sells for less than \$100 each, street price.

While contact imaging scanners are a good way of scanning employees into and out of jobs, they do not do such a great job of scanning tracking labels on individual items and containers, because it is often difficult to get the scan head in contact with the barcode. So here we use a short range tethered scanners, such as the Motorola/Symbol model LS2208 shown here.

This LS2208 unit has a short range laser scanner that has a scanning range of one to two feet. It puts out a red laser line, upon pulling the trigger, that is used to aim the scanner over the barcode. As soon as the barcode is read and loaded into the PC's



keyboard buffer, then the unit emits a beep.

A unique feature of the LS2208 is that it will work in both manually triggered mode and in auto-scan mode. When it is placed in its cradle, a magnet inside the cradle turns on a switch in the scanner such that it goes into automatic scan mode. This is useful in that it makes the unit useable in hands-free mode, such that an item with a barcode can be placed under the scan beam and automatically scanned without picking up the scanner. This can be very useful in operations such as recording the packing of barcoded items into a box on a bench.

A scanner like the LS2208 can be used to scan barcodes from a sheet of barcodes, provided that the barcodes do not appear on the same line (otherwise there will be ambiguity as to which barcode is being scanned, when both are illuminated by the laser line at the same time). But it is not as easy as using a contact scanner.

There are also imaging scanners that have scan ranges of a few feet. We do not recommend these for industrial use, in general, as it is very difficult to select a scanning barcode from a sheet of barcodes or to select a specific barcode from those on a number of items close together.

The only place where this does not apply, is where it is necessary to scan 2D barcodes. In general, this application needs special care in that the user cannot scan reliably barcodes from a sheet of barcodes and must do all selection input from a screen. Also the 2D barcodes need to be well separated from each other at time of scanning to avoid ambiguity.

We have had clients who have purchased scanners with 2D capability, just in case they needed it, only to find that these scanners were essentially unusable in the normal scanning of 1D barcodes. So this approach is not recommended.

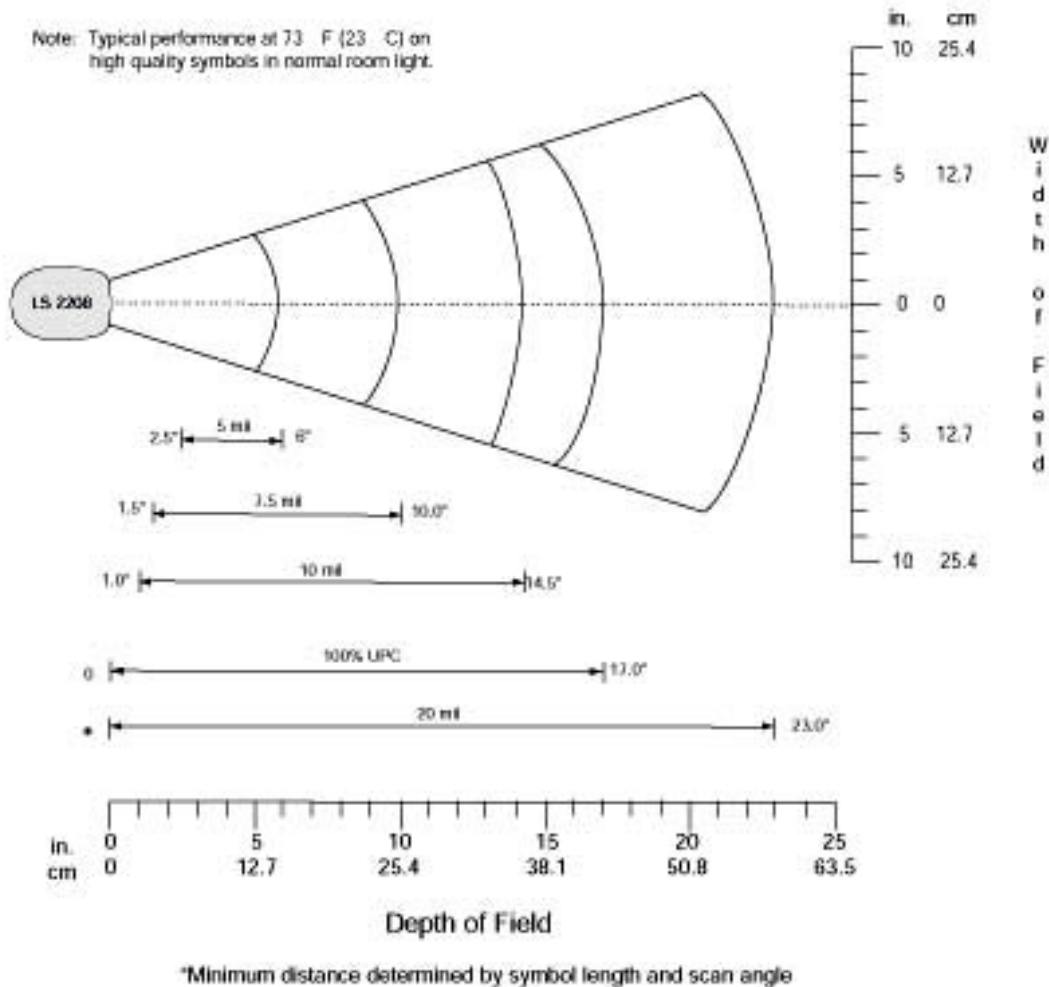
Another factor to consider is the resolving power of the scanner, typically specified in terms of mils or thousandths of an inch. This is the width of the smallest bar or stripe that the scanner can resolve at its nominal scanning distance. The smaller the physical size of the barcode you are scanning, the higher the resolution of the scanner you will need. Standard tracking barcodes used in industry have features that are 20 mils wide but the labels on sheets of scanning barcodes are often 10 mils resolution in order to contain the needed information in a limited space.

If you are placing tracking barcodes in small spaces, such as on the top of an integrated circuit, then it may be necessary to use 5 mil resolution barcodes. All laser scanners and most contact imaging scanners will scan barcodes with 10 mil resolution. When you have to scan small 5 mil resolution barcodes then you need to make sure that the scanner you are selecting has that capability.

Longer range imaging scanners may only be able to scan 1D barcodes with a resolution of 20 mils or more, which is again why they are not generally recommended for industrial use, except where 2D barcodes need to be scanned.

The minimum feature that a scanner can resolve, is actually a function of the angle subtended by the feature at the imaging element. So the barcode resolution is related to the range at which the barcode is scanned as well as resolution in pixels of the imager. It is highly recommended that you check the manufacturers specifications for the specific scanner as to what resolution of barcode it can scan at what range.

These specifications are usually published in the form of a chart such as that shown on the next page (in this case for the LS2208 model).



Most scanners can be programmed to emit a carriage return and/or a line feed character at the end of the barcode character string, when it is placed in the keyboard buffer of the PC. This can be beneficial when doing repeated scans that need to be entered into a computer program which expects the user to hit the Enter key on the keyboard after entering each data item.

This programming is typically performed by scanning special barcodes from the users manual provided by the manufacturer of the scanner. By programming the equivalent of pressing the Enter key as a postscript to the barcode contents, then the user does not have to go to the keyboard and press the Enter key after doing each scan.

## Cordless Scanners

Tethered scanners work very well for bench top applications or those applications, such as recording job labor or scanning the start and end of job, but they do not work well in those applications, such as in shipping and receiving, where there is typically a need to scan pallets and other containers that are stored on the floor.

You could extend the USB cable by about another 6 feet by using an extender cable but this is highly risky as it can cause people to trip and have accidents, which can result in the arrival of OSHA inspectors, which ..... Well let us just say that this is not a good idea.

You could use a wireless mobile computer, as described in the next section, but it is often much more convenient to lookup purchase orders, for example, on a large screen monitor attached to a PC rather than on the quarter VGA screen of a mobile computer.

The solution to this problem is to use a cordless scanner. These work just like a tethered barcode scanner except that, instead of a cable connected directly to the computer, the cordless scanner has a Bluetooth data connection (just like the one that connects a cell phone earpiece to a cell phone) to a base station. This base station then plugs into a USB port on the PC.



The result is the same in that when you scan a barcode, the contents of the barcode are automatically transmitted to the PC's keyboard buffer just as if you had typed the numbers and letters on the keyboard. As with tethered scanners you can program the unit to emit an Enter code so that you can scan tracking barcodes on a succession of items without returning to the PC.

The big difference from tethered scanners is that the scanning device can operate up to about 30 feet from its base station, so there is no need to drag a cord across the receiving dock or other place where it might cause an accident.

The unit shown here is a Honeywell/Metrologic 9535 which has a scanning unit equipped with a short range (one to two feet) 1D laser scanner. The scanner is equipped with a lithium-ion battery, which can be recharged by simply placing the scanning device into the cradle on top of the base station.

These units cost under \$500 street price including the scanner, base station, power supply and cables.

One thing to bear in mind is that all user interaction takes place through the PC to which the base station is equipped. The only feedback from the scanner itself is a beep when it successfully completes a scan. So these are not usable in stock rooms or warehouses or other situations where it would be inconvenient to walk back to the PC to complete the transactions.

Similar units are available from Manufacturers, such as Motorola/Symbol, that have a numeric data entry keypad on the scanner itself. These can be useful in those situations where quantities have to be entered interspersed with the barcode scans while the user is away from the PC.

## Wireless Mobile Data Collection Equipment

Material handlers who move around are typically equipped with wireless mobile data collection computers so as to enable them to perform scanning transactions wherever they are when they pick-up or drop-off materials in stock-rooms, warehouses or production or processing areas of a facility.



These units are essentially a PC in a ruggedized portable format. They typically have a quarter VGA color touch-sensitive screen and a numeric or alpha-numeric keyboard. They have an integral barcode scanner and a built-in wireless LAN communications card. These units are normally dust and moisture sealed and will take repeated drops onto concrete and still keep functioning.

The use of wireless connected mobile data collection computers has largely replaced the use of the older batch-mode systems where the mobile computers have to be placed in a docking cradle (attached to a PC or directly to the LAN) in order to exchange data with the main server. The use of wireless communications enables the material handlers to perform their scan transactions without frequently returning to a fixed location to upload the data that they collected.

These wireless units communicate with the main database server, in which all the transactional data is stored, over a secure wireless LAN by means of an antenna built into the mobile computer and an antenna connected to a wireless access point, which is itself connected to the same LAN as the main server computer.

There are several categories of wireless mobile computer that are used in industrial applications. These are:

1. Very rugged units with long-range scanners, suitable for use from fork-lift trucks. These typically have a “gun” configuration and are the preferred choice for use in many industrial warehouses.
2. Lighter-weight units, in a gun or brick configuration, suitable for use in a stock-room or by material handlers moving materials using hand trucks.
3. PDA configuration units that are suitable for use by QC inspectors, material managers, and other supervisory personnel that need to do scanning transactions.
4. Wearable units with finger mounted scanners that are suitable for hands-free picking operations.

For heavy duty use in warehouses and yards where fork-lift trucks are used, my current unit of choice is the Motorola MC9090G with a built-in “Lorax” self adapting barcode scanner. This scanner is capable of scanning barcoded picking sheets at a range of a few inches and is also capable of scanning large retro-reflective barcode labels hung over floor locations from the ceiling of a warehouse at ranges exceeding 40 feet. It can also scan pallet labels at a range of 10 feet or so, making it ideal for use with fork lift trucks as material handlers do not have to leave their seat to do the scanning.



These units are very rugged and can take a repeated 6 foot drop onto concrete.

These units have a removable primary lithium-ion battery that is good for the duration of a shift in normal use. They also have a backup battery that will retain the state of the unit while the main battery is being charged.



The battery inside the unit can be recharged by placing the unit in a cradle for several hours. Alternately the cradle has a charging slot for a spare battery that can simply be swapped out when needed.

The cradles come equipped with a USB cable which can be plugged into a PC if it is necessary to reload the software program in the mobile computer.

For store and forward use we place a high speed (40x) one or two gigabyte SD flash memory card in these units. This flash memory is used to hold the local SQL database inside the mobile computer (as these units do not have a disk drive). The benefit of using flash memory is that the data in the database is retained even if the batteries go completely flat.

These units cost about \$3,000 each plus about \$320 for each cradle.

It is worth noting that, while some of my clients do use these for shipping and receiving, it is often less costly and more efficient to use a PC equipped with a cordless Bluetooth scanner for these functions.

For applications where extreme ruggedness and long-range scanning is not required (such as in a stock room), I recommend a unit such as the Motorola/Symbol MC3090. These units are lighter in weight and not quite as rugged but typically cost less than \$2,000 each plus \$220 for each cradle.

These units are normally ordered with a short-range (2 feet) 1D laser scanner so they can easily be used to scan barcodes from picking sheets as well as tracking barcodes on items and bins.



These units do not have a sophisticated battery backup system like the MC9090 units, so it is important that their internal battery be kept charged. But in a stock-room and similar applications, this is not an issue as these units live in their cradles when not in use.

These units are equipped with 1Gbyte or 2Gbyte SD cards for store and forward applications.



For QC inspectors, material managers, and laboratory personnel, we recommend a PDA unit such as the Motorola MC70. These still have all the functionality of an MC3090 but are not as rugged.

They do come with a built-in short range laser barcode scanner and wireless LAN communications card. They also have a slot for inserting an SD card for a local database.

These units come with a QWERTY keyboard (as opposed to the industrial alphabetic layout keyboards on the MC9090 and MC3090 units) so they are more suitable for managers and technicians.

These units cost about \$2,300 each plus about \$220 each for a charging/communications cradle.

All the above units work very well, but users do need to hold the scanner to do data entry. In some situations, such as picking, this can be a disadvantage. For these situations we recommend a unit such as the Motorola/Symbol WT4000.

These units are typically mounted on a user's wrist with a strap and then connected to a finger mount scanner by a cord. The finger mount scanner is typically worn on your index finger and triggered by pressing your thumb against the side of the scan unit. The scan unit contains a short range laser scanner, which can be aimed simply by pointing your finger at the barcode to be scanned.



A typical setup with ring scanner, arm-wearable computer, battery and cables will cost a little over \$3,000, depending on the options selected.

These units do not have an externally accessible flash memory card slot so, for store and forward use, the internal flash memory is used for the local database. This is more than adequate for most picking operations.

These units can be uncomfortable to wear and so are not recommended for general warehouse use. But where hands-free picking is required, they are the best units to use.

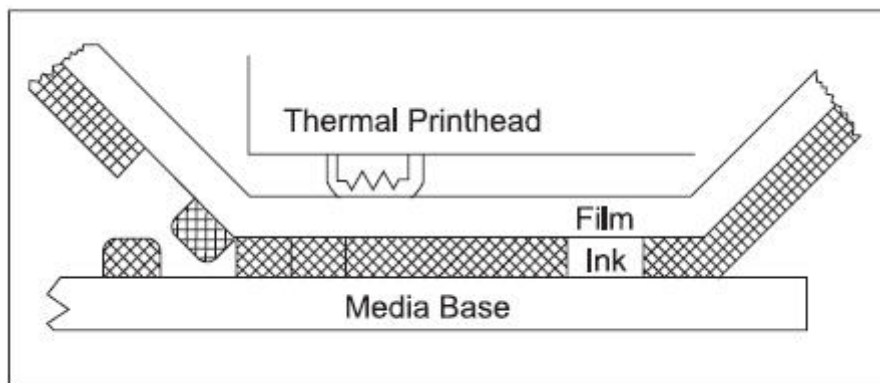
## Barcode Printers

For printing barcode labels on a roll, such as those used for tracking barcodes or shipping labels, then an industrial barcode printer, such as those available from Zebra, should be used.

These units are rugged, reliable and designed to operate consistently for a long period of time, with only periodic maintenance.



These units use a thermal transfer process, in which the ink on a wax or resin film ribbon is melted by a thermal print head onto the barcode material stock:



For details of how barcode printers work and the different types of barcode media and ribbons available for different purposes, I highly recommend the white papers and other information on Zebra's website at [www.Zebra.com](http://www.Zebra.com).

Users of these printers do need training as to how to load the rolls of barcode media and ribbon and to adjust the printer to print high quality barcodes.

These printer units come in different resolutions, measured in dots per inch, of their thermal printheads. Depending on the resolution of the barcodes you plan to print, you will need to select a printer with a high-enough number of dots per inch to print a high quality barcode. But you do not want to use too high a resolution as this can slow the printer down.

These printers can be ordered either with USB connections for direct connection to a PC or a network card for direct communication to the IP address of the printer on the LAN. These days we recommend using Network printers as they do not require tying up a PC, unless the PC is needed for a supporting function, such as receiving or shipping.

Unlike regular laser or ink-jet printers, barcode label printers need special print drivers to work efficiently. These are available from the printer manufacturers. But a better way to go is to buy a barcode label printing package, such as Bartender from SeaGull Scientific. These packages support a wide range of printers and provide a visual layout tool for barcode labels. These tools then enable barcode tracking software to automatically print labels on the barcode printer, upon demand, based on data stored in their database. This can avoid many mistakes caused by "Fat Fingering" in data to be printed out on the labels.

In receiving operations, labels are often printed out for each item to be received, at a PC, with each label having its own unique tracking barcode. These are printed out on a roll and then peeled off and attached to the received items. The tracking barcodes on each label are then scanned to complete the receiving process.

Elsewhere, such as at the end of a production line, the labels may be printed out one at a time on demand. In such a case, users may wish to consider ordering a barcode printer equipped with an automatic strip and peel fixture and a substrate rewinder so that each label can be simply pulled from the printer and attached to an item.

Labels printed on a barcode printer can each have their own unique tracking barcode plus human readable information, such as a part description, which is unique to the item to which it is being applied. This is the advantage of the use of a barcode printer over the use of pre-printed labels which simply have the tracking number.

Industrial barcode printers range in price from about \$1,500 to \$2,500 each depending on the features and resolution. Normally you should order a printer capable of printing up to four inch wide barcodes but wider printers may be needed for special applications.

## Wireless Access Points and Antennas

It is recommended that industrial wireless access points, such as the Cisco 1240 shown here, be used in warehouse and production areas. These units support two external antennas and are typically mounted up in the roof rafters close to the antennas.



In many industrial buildings, the temperature in such locations can range from below freezing to well over 100 degrees in a single day. This will cause lower cost units, such as the Linksys line from Cisco to fail due to condensation on the circuit boards. These industrial units are sealed and designed to work reliably over these temperature ranges.

Lower cost access points, such as the Linksys line will work fine in many stock room and similar applications where the same temperature extremes are not encountered.

An industrial wireless access point, such as the Cisco 1240, supports connection to two antennas, such as the MaxRad unit shown here, by means of low loss coaxial cable that can be up to 50 feet in length. This enables a single access point to be able to cover two separate locations that are many feet apart.



It is important to locate the antennas so that they are pointing down and are mounted in such a way that they are well clear of all surrounding metal, such as columns and roof joists, otherwise this metal will absorb the wireless signal.

Most wireless mobile computers use IEEE 802.11g protocols and it is important that you select access points and wireless mobile computers that can communicate with each other.



## Systems Architecture

### Introduction

This chapter discusses alternate approaches to what architectures to use for barcode tracking systems, makes some recommendations, and shows some example architectures.

### Alternate Approaches for Databases

There are two alternate approaches that are used to implement barcode tracking systems:

1. Use a separate database for the tracking system that is specific to the needs of the tracking system and then exchange data between this system and an ERP or accounting system, if this is not to be a stand-alone barcode tracking system.
2. Extend the database of an ERP or accounting system to contain the features needed for barcode tracking (such as handling the tracking of nested containers) and then interface all the data collection devices and printers to this database.

The second choice is intuitively appealing in that it results in one system that does accounting, materials resource planning and barcode tracking, all in one integrated system.

There are, however, major practical problems with this approach for industrial barcode tracking:

1. Because there are over 300 ERP and accounting systems, each with several major versions with significant user bases in the USA, it is not practical for an independent software vendor to develop and maintain a barcode tracking add-on that is tied directly into the different databases of all these systems or even a small number of them. It is only economical for the vendor of each ERP and accounting system to develop and maintain a barcode tracking add-on that is tied directly to their database.
2. Unlike retail warehouse management systems, asset management systems, and time and attendance systems, industrial barcode tracking systems almost always require customization to tailor the systems to the specific needs of a specific industrial operation. While an organization may start out with an out-of-the-box solution, most quickly find that to really get the maximum benefit from the barcode tracking system it needs to be customized to their specific needs.
3. If the barcode tracking devices tied directly to the ERP or accounting system database, this implies customizing the ERP or accounting system to fit the needs of the barcode tracking system. Then, as a result, an organization cannot upgrade its ERP or accounting system without spending more money to migrate the changes to the latest version.

In one especially egregious case, a facility that had just been acquired by a major European industrial conglomerate was charged over \$600,000 to customize their SAP ERP system to integrate barcode tracking functionality. This project took over 18 months to complete and by

that time they were several releases of SAP behind. When they inquired what it would take to bring the customizations forward to the latest release, they were quoted over \$400,000.

While this was a particularly bad case, we have known many mid-sized plants that have spent well over a \$100,000 to integrate barcode tracking equipment into their accounting or ERP systems only to have to spend a like amount whenever a version upgrade was required. As a result most of these organizations stopped upgrading their ERP or accounting systems and shortly thereafter stopped paying annual maintenance fees, which are the lifeblood of the ERP and accounting companies.

As a result of this issue, almost all of the ERP and accounting vendors withdrew from offering barcode tracking support for their products. This trend was accelerated as most of the ERP vendors were acquired post Y2K by consolidators who were much more interested in the ongoing revenue stream from product maintenance and upgrade fees than they were in making money from customizing their products for industrial applications.

This has been especially pronounced in the USA where the decline in the manufacturing base has made it uneconomical for ERP and accounting vendors serving the industrial sector to offer or maintain barcode tracking add-ons for their products. And those that had been providing barcode tracking support have largely withdrawn this product support.

As a result, the option of using a separate barcode tracking system, with its own database has emerged as the economical alternative. Such a system can be run stand-alone or can be interfaced to a wide variety of ERP and accounting system. Most importantly, each implementation can be customized to the specific needs of each operation without impeding upgrades to the ERP or accounting system to which it is interfaced.

Because they are able to interface their barcode tracking systems to a wide variety of ERP and accounting systems, vendors such as BellHawk Systems are able to offer their tracking systems software at a cost of a few tens of thousands of dollars rather than the hundred thousand dollars or more it typically costs to interface all the barcode tracking and printing devices to a specific ERP or accounting system database.

This approach of using a separate database for the barcode tracking system also frees the tracking system from being forced to be modified every time there is a change or update to the ERP or accounting system. Instead, production workers and material handlers are able to keep using a stable data collection system, even though the ERP or accounting system, to which it is interfaced, undergoes frequent changes.

As we will discuss in the section of this chapter on interfacing, the interfaces to ERP systems have proven to be remarkably stable even as the ERP systems themselves have undergone significant changes. This is primarily because the ERP data with which the tracking system interacts, such as purchase orders and sales orders, stay very stable over time. And even when the interface does need tweaking for ERP upgrades, this can be done without impacting the users of the tracking system.

In fact, we have had a number of situations where we have changed out the ERP system behind the scenes with little or no impact on the production workers and material handlers in their use of

the barcode tracking system. This would not be possible if the tracking system used the ERP system's database.

### **Alternate Approaches for Mobile Data Collection Computers**

Material handlers who move around are typically equipped with wireless mobile data collection computers so as to enable them to perform scanning transactions wherever they are when they pick-up or drop-off materials in stock-rooms, warehouses or production or processing areas of a facility.



These wireless units communicate with the main database server, in which all the transactional data is stored, over a secure wireless LAN by means of an antenna built into the mobile computer and an antenna connected to a wireless access point, which is itself connected to the same LAN as the main server computer. Communications take place in the low microwave band at around 2.4Ghz using IEEE 802.11b/g protocols.

At these frequencies, industrial wireless mobile computers can communicate with an access point when within about a 200 foot line-of-sight of its antenna. Unfortunately at these microwave frequencies, the radio waves are blocked or absorbed by conductive materials such as metal racking in warehouses, metal, liquid and food products, rebars in concrete walls, metal studs. They are blocked by people and by fork-lift trucks. They can also be interfered with by the electrical emissions from arc-welders, electric motors, contactors, switches, and other electrical equipment. This presents a challenge when implementing a wireless mobile computing system in an industrial environment.

Traditionally organizations implemented terminal-mode connections to a back-end ERP or accounting system in order to relay scan transaction data to these systems. In these systems, the mobile computer acts as a “green-screen” terminal to the ERP or accounting system.



These systems have been replaced by the use of a client-server and then thin-client web-browser based interfaces running in the mobile computers. While these have improved on the appearance of the user interface, they still rely on having a continuous wireless connection to the back-end ERP or accounting systems. As such, while these systems may work in non-industrial applications, they do not function very well in most industrial settings.

With these systems, in order to provide real-time point-of-action warnings to the users of the mobile computers, it is necessary to achieve 100% wireless coverage throughout the facility with no sources of electrical interference. This is because these methods rely on the back-end server to generate the real-time point-of-action warnings for the user. In my experience it is impossible to achieve 100% coverage with no interference in most industrial facilities. As a result, users of these systems become very frustrated because the systems do not work reliably and data has to be frequently re-entered or items moved to a location where they can be scanned.

The solution to this problem lies in using store and forward technology. In this, all the transactions are saved up in a database in the wireless mobile computer as they are scanned. Then, when the mobile computer is within line-of-site of a wireless access point antenna, the transactions are automatically uploaded to the server without user intervention.



This technology minimizes the number of access points required and ensures that there are no locations where scanning cannot take place due to coverage blind-spots. The operation is also reliable as, if communications is disrupted by electrical interference, the data in the local database is simply sent again until it is successfully received.

The mobile computer also downloads status information from the server into its local database whenever it can communicate. This enables all scan transactions to be rapidly validated against the local database rather than waiting for a response from the server.

With this store and forward technology:

1. All data input through the mobile device is extensively validated against the data in its local data database to provide real-time point-of-action warnings if the user has entered the wrong data or is about to make an operational mistake such as picking the wrong or defective material.
2. All transactional data is stored away in the local database until the unit comes within communications range of a wireless access point. The transactional data is then securely and automatically transferred to the main server without user intervention.
3. Changes to status information, such as new material picking orders and changes to the location or status of materials, which is used for real-time point-of-action validation, is uploaded to the mobile devices whenever they are within communication range. Again this is done in such a way as to ensure secure transmission even where there is intermittent communications or electrical interference from machinery.

The benefit of using this store and forward technology is that it enables operation in warehouses with a lot of metal racking containing metal parts which can cause dead-zones in communications. It is not necessary to install a costly forest of access point antennas (or to perform wireless surveys) to try to ensure continuous communications coverage. With store and forward technology all that is needed is to have antennas/access points over the loading dock and any other critical areas where material handlers travel frequently.

Store and forward technology also enables data collection in yards and off-site warehouses that have no wireless coverage. In these cases, transactional data is saved up in the database of the mobile computer while scanning is performed off-site (with full point-of-action validation) and uploaded to the main server when the unit returns within communications range.

The disadvantage to store and forward technology is that it needs a thick-client program running in the mobile computer. So special code has to be loaded and sometimes the local database has to

be reloaded when there are changes to the tracking system. As a result, the use of the store and forward technology is more difficult to set up and maintain from an IT perspective.

But, at present, the advantage of having fast, reliable and robust data collection operation for material handlers outweighs the disadvantage of the thick client architecture for the IT support staff.

In future, we may see a transition to web-based technologies, such as SilverLight, in which the thick-client application specific code is loaded dynamically into the mobile computer and to AJAX, where the web client interacts with the back-end data in a client-server mode. But we will still need the use of store and forward technologies with local databases, which are being integrated more and more into their mobile computer operating systems from suppliers such as Microsoft.

Whether these new technologies will make life easier for the IT staff remains to be seen. Certainly they substantially increase the complexity of the server-side setup as it has to be web-based. It may well be that all we are doing is moving the complexity around and simply requiring a whole new learning curve from the already over burdened IT staff at industrial organizations.

For the moment, the best approach seems to be a thick client because this code (typically written in VB.net) is much easier to customize than the corresponding thin-client web-based code.

### **Alternatives for PC Based Stations**

There are two alternatives for the PC based stations:

1. A thick-client approach with a user interface program running in the PC.
2. A thin-client approach with a web-based interface.

Here, unlike the mobile computer case, we do not have to worry about having a local database if the PC is able to connect directly to the tracking database over the facility LAN.

At BellHawk Systems we use a thick-client architecture with the PC based client written in visual basic with Access used as the development tool for implementing user screens and reports. This makes it very easy to customize the PC based code and many of our clients do these code changes themselves as they are familiar with programming in Access/VBA.

With a thin client the coding of the screens and reports is much more complex and, as a result, it would be beyond the capability of most of our clients to customize software being used in a thin-client mode. Even if they are having the code customized for them it can be twice as expensive to make changes to web-based applications as thick-client applications.

Again the trade-off is that it is more work for the IT department to maintain separate thick-client programs in each PC than it is to maintain a web server based environment (provided that the IT staff has the know how to setup and maintain web servers, including the management of related security issues).

One major benefit of the thick-client approach is that different client programs can be run in different PCs. This is highly beneficial if the code in specific PCs has to be customized to interact with specific weighing scales or test stand or process control equipment.

Thus we currently conclude that, within the four walls of a plant that the thick-client approach is currently the most beneficial.

## **Supporting Remote Users**

Mobile computers using store and forward technology will be able to communicate with the main server provided that they are both connected to the Internet. For remote facilities, this typically means establishing a VPN (Virtual Private Network) link over the Internet between the remote facility and the facility where the main server is located. This is typically done with VPN firewalls attached to the LANs in both facilities and the Internet.

As the mobile computers do not need immediate real-time access because they have their own local databases, they are able to work just-fine with relatively low bandwidth VPN links. The same cannot be said for PCs in the remote facilities directly accessing the database over a VPN link. This usually does not work very well and results in long waits for data or loss of connections due to time-outs.

The solution here is to use a technology such as Remote Desktop access to have the thick clients run on a Terminal Server processor in the main facility and then only to send keyboard, mouse and screen display commands between the PC and the terminal server, which then communicates with the database server over the main facility LAN. This retains the ease of customization of the thick-client programs with only requiring a small bandwidth for communication over the VPN links.

This Remote Desktop approach works very well and supports the use of tethered and cordless barcode scanners plugged into each remote PC for scanning purposes.

Remote network printers can either be supported as local printers on the remote desktop PCs or as network printers, accessible over the combined wide-area network formed by linking remote VPN connected facilities to the main facility.

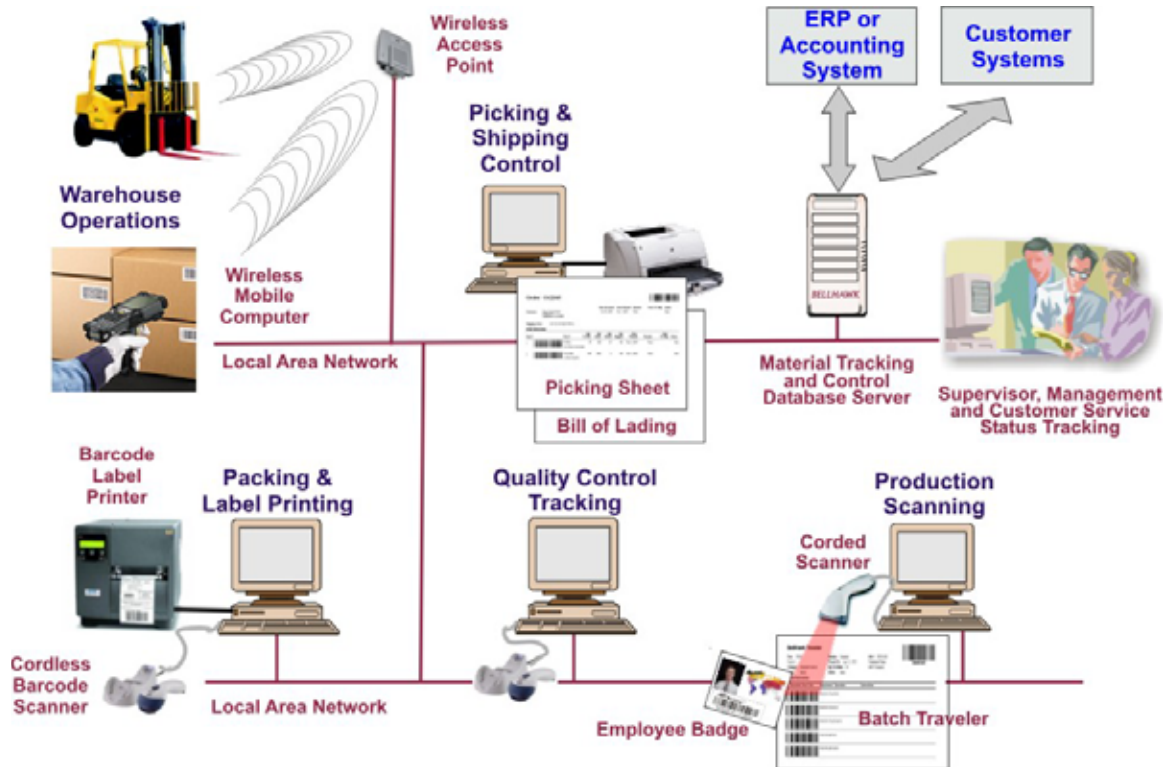
The benefit to all of this approach is that all the remote facilities can be supported when communicating to a single barcode tracking database that itself forms a single point of contact with the ERP or accounting system to which its is connected by running on the same server or being connected over the plant LAN.

There are cases where a web-based interface is highly beneficial. Examples are:

1. To allow customers to securely see the status of their orders using a web-browser.
2. To allow customers to see the status of inventory they own.
3. To allow customers to be able to see how much material is in stock and to be able to place a shipment order in real-time for the available material.
4. To allow customers to be able to see test and process data for products they have received.
5. To allow sales people to see the status of customer orders, production schedules and available inventory from the road

In an industrial setting, the requirements are somewhat different from consumer driven web-sites because there is usually a much more trusted relationship between supplier and customer. But the technical principles are much the same. Here a web server is set up to securely handle requests from users and to get the needed information from the tracking database.

## Recommended Systems Architecture



The recommended architecture is to use a separate tracking database for the barcode tracking system. This is normally a relational database running on a server computer. This database is where all the tracking data is stored and also all the data needed for point-of-action validation is maintained. This database may be located on the same server as is used for the accounting or ERP system database.

A data-exchange interface program, which can be run on the same server, can automatically exchange data with the ERP or accounting system database. The interface program may pick up vendor purchase orders as they are entered into a front-office system and move them to the tracking database. The tracking system will use barcode equipment to record the receipt of the materials against these purchase orders and store the results of these transactions back in the database. The resultant receiving transactions will then be exported by the interface program back to ERP or accounting systems database.

PCs equipped with tethered or cordless barcode scanners run user interface programs that capture the scan actions and provide point-of-action validation of the data being captured. These user interface programs communicate directly with the tracking database over the facility LAN.

PCs are also used to control printing of documents such as barcoded picking sheets on laser printers as well as the printing of barcode labels using barcode printers.

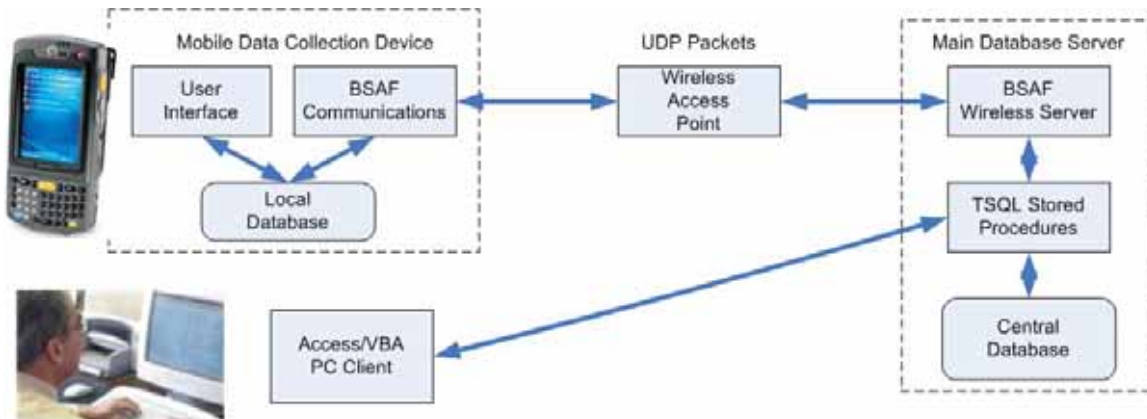
Wireless mobile computers, that use store and forward technology, have their own local databases in which to store data. All the scan transactions are validated against data stored in their local database and stored into the local databases on these units. When these units come within communications range of a wireless access point, they automatically upload the data to the main database server and download updates to their local database that they use for point-of-action validation.

Managers, supervisors and customer service people can use PCs or laptops to view the status of jobs, orders, inventory, and work-in process by running programs that use the contents of the tracking database to generate screens and reports showing operational status in real-time.

The server computer can also exchange data with customer systems, such as by sending advanced shipment notices detailing the exact contents of pallets as they are shipped to the customer.

### Example Software Architecture

Shown below is the software architecture for the BellHawk Industrial Barcode Tracking System.

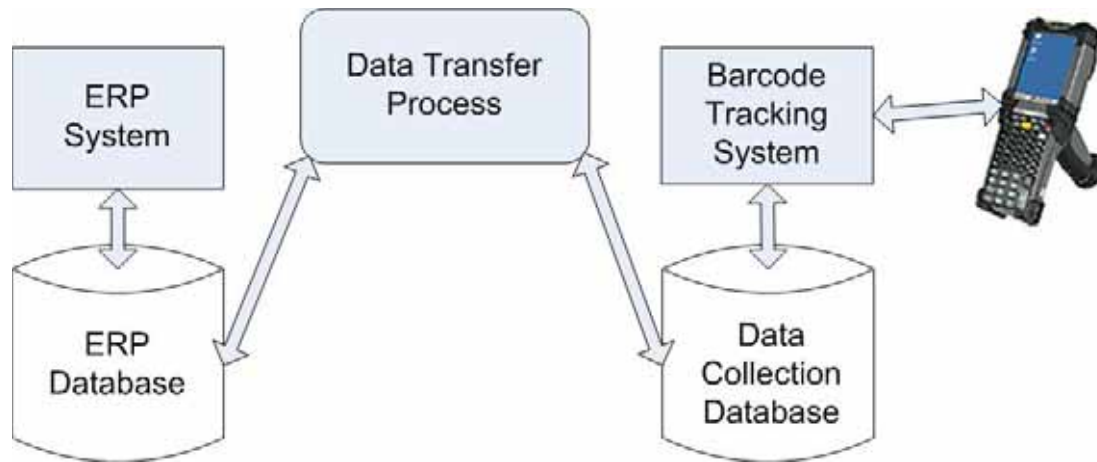


This system uses a SQL Server database running on a Windows Server computer for its primary server. The system uses Access/VBA programs running on the PCs. These access the database directly using a large number of Transact SQL stored procedures to do most of the work.

The mobile computer code is written in VB.Net and used a SQL Server compact edition database to store the local data. Communications with the main server is handled by a BellHawk Store and Forward (BSAF) communications process in each mobile device and a Wireless Server Process that typically runs in the main server. These processes exchange UDP packets using a protocol that is designed to be very reliable and robust under typical industrial conditions.

The UDP packets can be layered on top of wireless security protocols, such as WPA and LEAP, resulting in very secure and robust communications.

## Interfacing to ERP and Accounting Systems



The basic approach to building an interface between systems is to use a third computer program that does the data exchange. This avoids customizing the ERP system or the barcode tracking system to implement the interface.

This data transfer process monitors selected tables in each database and when it detects changes, it transfers the data to the other system, performing whatever data translation and mapping actions are needed in the process.

The monitoring is done on a periodic basis, typically every few minutes, so that data transfer is essentially real-time from an operational viewpoint.

Some of the data that is transferred includes:

1. Item master parts information.
2. Purchase Orders and receipt transactions.
3. Sales Orders and shipment transactions.
4. Work Orders, bills of material and routes.
5. Inventory transactions.

To make the job of writing interfaces easier, many systems provide a variety of interfaces other than directly reading and writing the databases in the tables. These include:

1. Stored procedures and interface tables in the database that enable an external application to read and write data without interacting directly with the underlying tables. This shields the data transfer application from changes to the database tables as new versions of the software are released.
2. A software developers kit (SDK) that is a library of subroutines that abstract operations on the database tables into a set of subroutine calls that act on abstractions of the data objects

and their parameters. These hide the developer of the interface from much of the underlying details of the database and make it much quicker to develop interfaces.

3. XML interfaces, often combined with SOAP messaging, to enable interfaces to be implemented with Web based applications.

The SDK approach can also be used for implementing interfaces to test stands and process control equipment.

Interfaces are usually implemented by two programmers, each of whom know the internal details of one of the systems to be integrated. These team members work jointly to code the interface between the systems based on their specific knowledge of the individual systems.

### **Interface Development Issues**

If you read, as I do, many software development articles on how to extract data from a relational database and to write data back into that same database, you would believe that a few simple lines of code, written in some dialect of SQL and the latest .Net code, will quickly implement a data exchange program. Unfortunately this is not true.

When writing a data exchange interface, we have three basic problems to confront:

1. How to extract data objects, such as purchase order line records from one database.
2. How to translate these into objects into a form that is compatible with the target database.
3. How to write the data into the target database.

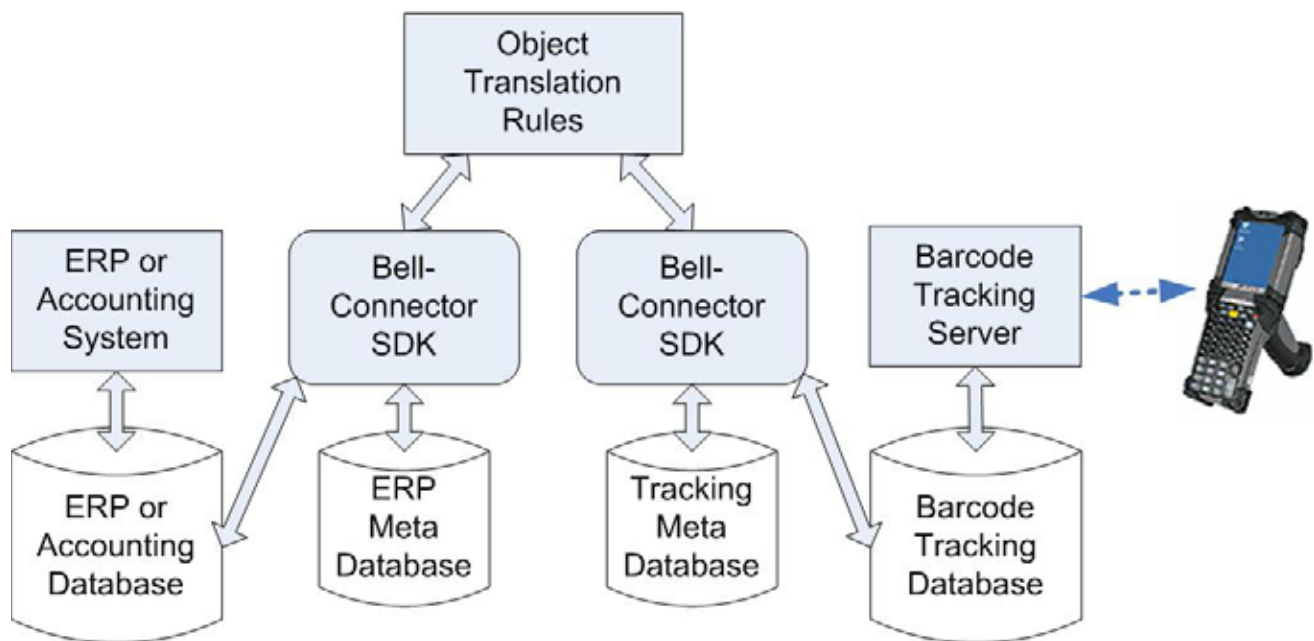
If we are fortunate enough that the barcode tracking system database and the ERP or accounting system interface are both relational databases and both exist on the same high-speed local area network, this is the simplest (but not simple) case. There are still, however, many issues that need to be resolved in reading and writing the databases. Some of these are:

1. Indirection. For efficiency, many entries in the database will use indirect references to other tables for data. For example, in the tracking database when storing a picking transaction, the person doing the picking of an item will not be represented by their name in the transaction. Instead there will be a reference to an entry in the employee table, through which we can access information about the employee, such as their name or department.
2. Sequence. When writing data to one of these databases, it is important to update tables in a coordinated order so that, for example, an item master part number referenced in a purchase-order-line record will have been exported to the target system before the PO line. This issue of precedence stems from the indirect references used in these databases and can lead to complex update sequences.
3. Update. When writing data back to a relational database, you first have to decide whether to insert a new record or update an existing one, as the insert or update statements in SQL have completely different syntax. This, combined with the sequence issues for indirect references can require the writing of many lines of difficult to read SQL code.

4. Bad Data. Any relational database that has been in service for a while accumulates bad data due to data entry errors, updates that didn't go quite right, bad data imports, and hand fixes. This includes lookup fields that have embedded non-printing control characters (due to pressing the control key instead of the shift key on keyboard entry) as well as fields that include characters such as percent, quote and comma that could interfere with SQL lookups.
5. Quantity of different data objects to be exchanged. A data exchange interface may well require the exchange of 50 or more data objects. If we simply write the data exchange in some dialect of SQL plus some supporting code then we end up with an enormous amount of code that is time consuming to write and difficult to debug or maintain.

One approach to this problem is to recognize that the indirection, sequence, update and bad data checking problem solution can all be encapsulated in a meta-data driven code layer that translates between fully resolved objects (such as PO lines records with part numbers rather than indirect references to part numbers) and the SQL code needed to select, insert or update the corresponding data into a relational database.

One such approach is the Bell-Connector, which I and my team have been working on:



Here, a software developer kit (SDK) code library abstracts the interaction with the database into a small number of actions:

1. Fetch all of a specific type of object (such as PO line or receipt transaction) from the database or fetch just the latest updates or fetch those that changed within a specific time-date range.
2. Select an object instance from the objects fetched from the database.

3. Set and get the values of fields from the current object instance
4. Store the object instance into the database.

These small set of actions are then used to automatically generate all the SQL code needed to read data from the database and to insert or update data in the database. This includes handling all the bad data detection and handling indirections and sequencing problems.

In order to do this, the Bell-Connector SDK layer needs knowledge about the structure of the tables and fields and stored procedures in the relational database with which it interacts. To do this, it relies on a meta-database, which describes the relationships between the business objects (such as employees, purchase orders and receiving transactions) and the tables, fields and stored procedures in the database.

By using a separate meta-database for the ERP system and the barcode tracking system it is able to abstract all the complexity of the interface with the ERP system into the meta-data. In the case of the Bell-Connector, this meta-data is maintained using Excel spreadsheets so that no coding is needed to implement a complex interface to an ERP, accounting or barcode tracking database.

Other benefits of this approach include:

1. Once the meta-database is defined it can be re-used to implement interfaces to other systems, without writing any additional code.
2. A meta-database for an ERP or accounting system can be defined by a person knowledgeable about the internals of that ERP or accounting system without needing any knowledge about the barcode tracking system, or vice-versa.
3. If there are changes to the structure of a database, from version to version, then this can easily be accommodated by changes in the meta-data without changing any code.

Even when the work of reading and writing objects is performed by the SDK layer, there is still much work to be done:

1. Deciding what data objects need to be exchanged
2. Mapping parameter data fields between the objects from the source system to those on the target system.
3. Validating that the parameter data is valid to exchange at a business process level and logging exceptions when they occur.

Because the mapping between data objects is controlled by a set of rules, we first tried using an Expert System to implement the rules. The benefit of Expert Systems is that the rules are declarative and thus can be quicker to implement and easier to read. This proved to be more trouble than it was worth, as most of the object-translation rules are procedural, such as converting the first name and last name of an employee on one system to a single employee name on another, rather than declarative.

We found that a procedural language, such as VB.Net, was much better for this purpose and much easier to integrate with the Bell-Connector SDK. You still end up writing a lot of code

because there are a lot of objects involved but the resultant code is easy to read and modify as it deals with objects at a business level and hides all the complexity of communicating with the databases.

One benefit of this approach is that you can have many different types of object, from multiple databases, open and active at the same time. As a result, you can construct complex “rules” that depend on different parameters of different data objects from different sources, which is often necessary in implementing business systems interfaces.

In implementing these interfaces, the rules code periodically interrogates both databases for changes to any data objects to be exchanged. It then reads the new data from the database and maps it to the target database. This enables these databases to run unattended and have data changes made to one database automatically show up in the other.

In implementing the Bell-Connector SDK, we elected to use an ODBC interface to communicate with relational databases. Most relational databases in common use support a local or remote ODBC connection to the database that understand a common dialect of SQL. This enables the Bell-Connector SDK to work with a wide range of databases including SQL Server, Oracle, MySQL and DB2 whose manufacturers support an ODBC connection. It also enables the Bell-Connector to work with systems such as QuickBooks that have third party ODBC connectors available.

This is not to imply that the Bell-Connector approach is the only way to solve these problems.

Microsoft, in its .Net framework, is working many of the same issues with a variety of abstraction mechanisms and frameworks built into their .Net development environment (some of which we use in the Bell-Connector SDK) as well as language extensions such as LINQ for making it easier to write structured queries in code. The major problem with most of these mechanisms is that they work very well with Microsoft’s SQL Server database server but support for competing database servers, such as Oracle or MySQL, are, not surprisingly, much more limited.

An alternate approach, supported in the BellHawk barcode tracking software and in a number of other ERP applications is to provide an interface through ODBC calls that an external application can make to read and write data objects without directly reading and writing the database tables used by the application.

In the case of the BellHawk DEX interface, an external application can write a BellHawk data object into an input table in the BellHawk database with a keyword for the object followed by its parameters in a specific order. The application then calls a stored procedure and DEX imports the data objects from this table. In doing this, it handles all the indirection, sequence, update and bad data checking problems that the Bell-Connector SDK does.

Similarly an external application can call a stored procedure in the BellHawk database to have DEX place the data objects into an output table, again with DEX handling the indirection, sequence, update and bad data checking.

In many ways DEX performs the same functions as the Bell-Connector SDK except that it is called from SQL instead of from a .Net language such as VB.Net or C#. But instead of storing its meta-data in an external database, DEX stores its meta-data within the BellHawk database.

DEX provides a very effective interface to the tracking database and has been used by many developers to implement interfaces to the BellHawk tracking system database. The big thing that DEX does not do is provide any support for implementing the interface to the ERP or accounting system to which the tracking system is being interfaced.

So our advice to clients who want to develop their own interface to the BellHawk tracking system has been that:

1. If you are a SQL Expert and like to write in SQL, then use DEX. You will have more fine grained control over the database access to your ERP or accounting system database.
2. If you want to have all the SQL Code generated for you automatically then use the Bell-Connector SDK.

Both approaches have been found to work very well with systems that have ODBC accessible databases and that are connected over a high-speed LAN or wide-area network. But what about other systems, such as:

1. Legacy ERP or accounting systems, often based 20 year old technology, that use proprietary databases with no ODBC or other interfaces?
2. Web-based applications that are typically hosted in the “Cloud” on a remote server, over the internet. This includes CRM systems and the newer breed of SAAS (software as a services) ERP and accounting systems?
3. Process control applications and test stands?

For older legacy system, we have found that the best approach is to export and import data using comma delimited files or Excel spreadsheets (if the target system supports these). We can then use the Bell-Connector SDK to write code that reads and writes these files and exchanges this with the tracking system database.

In many cases, the data to be exchanged is standard enough that we have been able to implement a standard import-export program that can read and write Excel or comma delimited files and exchange the data with the tracking databases. We gave users of this program the ability to specify which parameters of which objects are exchanged and in what order. This has proven very effective when the data to be exchanged is limited to purchase orders and sales orders and resultant inventory transactions. It is not as effective, however, when BOMs and routes and job tracking transactions have to be exchanged because of the complexity.

This data exchange does require a two-step manual process of first exporting the data from one system and then importing it to the other system. For some of our clients, this two step process is preferred over the automated approach. They first export the data from one system and then look at the result and make any adjustments to the source database and re-export the data until they are satisfied with the export. Then they import the data into the target system.

We have also found that the manual data transfer program is very useful for transferring setup data from one system to another when a system is first being brought on line.

Web-based applications have brought with them a whole new challenge. They do not reside on the same private, reliable, high-speed network as the barcode tracking database. Instead these

applications can only be reached over a lower bandwidth public network without guaranteed privacy and delivery.

Fortunately we now have a set of standards in place, whereby we can represent our data objects in XML and then wrap these in SOAP packets for secure delivery over the internet. So instead of reading and writing the ERP, CRM or accounting system database directly, we exchange SOAP packets with the application (or its surrogate) on the web server where it resides.

In this case, the mapping of the XML objects to and from the target database is done by the application on the remote web server. The SDK interface to the remote system uses the meta-data in its meta-database to request these data objects in the form of SOAP/XML packets from the remote server and to send data objects in this same format to the remote server. The SDK then translates these into the same interface objects as were previously used for direct database access.

In this way, we are able to reuse most of the code developed for use in a LAN/WAN environment to build interfaces to web-based applications.

Barcode tracking applications not only interface to front-office systems, they also have to interact with process control and test systems. These systems typically make extensive use of embedded PLCs and are controlled by a PC that provides the human-machine interface. In the systems we have implemented, the applications that run in these PCs typically exchange data with the tracking system by directly calling the Bell-Connector SDK library. This enables these systems to read process recipes or test parameters from the tracking system and write back the resultant test data without needing to have any knowledge of the underlying tracking system database structure.



## Barcode Tracking Principles

### License Plate Tracking

For many years, organizations have placed barcodes with meaning on containers. These barcodes may contain information such as part number, quantity, lot number and expiration date. These barcodes are very useful in that a material handler can scan these barcodes instead of typing in the information. But these barcodes do not uniquely identify the container, which we need to do if we are easily able to track the container.

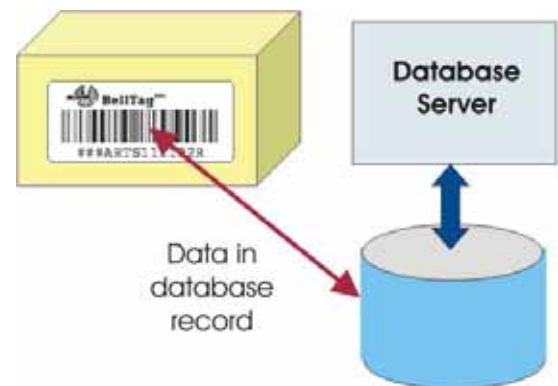


To track containers, we now use a method called “License Plate” tracking. In this method we use a single barcode for tracking each container. This barcode contains a unique tracking number and all the data about the container is kept in a database record. This method is the new international standard.

This is similar to the method used by the registry of motor vehicles which issues license plate tags for cars and trucks, which is how it gets its name. When you go to the registry they do not take out a blank aluminum license plate and hammer into it all the information about your car and truck. Instead they issue a pre-prepared license plate with a unique number that has no meaning other than to identify your vehicle. Then they enter all the information about you and your vehicle into the database. This is so that, when you are stopped by a policeman for speeding, he can enter your license plate into his on-board computer and get all the information about you and your car shown on his on-board computer.



We use a similar process to track containers of material (such as bags, barrels, bottles, test-tubes, rolls and reels) except that we use barcodes instead of aluminum license plates. Each barcode contains a unique combination of letters and numbers. The corresponding data is then written into a “containers table” in the tracking database.



Typical information stored in the database record for each container includes the part number, quantity, lot number, container type, age or expiration date, QC status, unit cost, and location. Thus when the quantity or location of the container is changed, there is no need to change the label.

We call these barcodes “license-plate tracking barcodes” or simply tracking barcodes for short. These tracking barcodes do not contain any meaningful information but all the information about a container can be accessed simply by scanning its tracking barcode.

Increasingly, RFID tags containing the same unique tracking numbers are being used in combination with tracking barcodes, so the containers can be automatically scanned by an RFID scanner as well as manually scanned using a barcode scanner.

### Nested Container Tracking

One of the big problems in material tracking is how to track materials that are nested inside containers. We might have printed circuit boards with a unique serial number and tracking barcode on each board. There may be multiple circuit cards inside each box, which has its own tracking barcode. Then there may be multiple boxes on a pallet.

When we move the pallet to a new location, we do not want to take all the circuit cards out of the boxes and scan their barcodes to record that we have moved them to a new location. Instead we simply want to scan the tracking barcode on the pallet and the location barcode for the location to which we are moving the pallet.

To facilitate this, we use the principle of nested container tracking. In this, each record in the containers table not only has information about the material inside that container plus a location code but also has a parent container, which is another entry in the same containers table.

When the parent container is moved, then the tracking system can automatically change the location of all its child containers to the new location, without the operator needing to scan all the child-container tracking barcodes. Thus a barcoded box on a barcoded pallet would have the pallet as its parent container. When the pallet is moved to a new location, only the pallet barcode need be scanned to record the new location of all the boxes on the pallet. All the boxes on the pallet and their contents will have their locations automatically updated when the parent container is moved. This avoids scanning all the boxes and their contents individually into a new location.

When a box or other container is taken from a parent container, then the parent-child relationship is broken and the box may become its own parent container or placed in another parent container.

Creating a nested description of what is in which containers is also essential for the generation of Advanced Shipment Notices (ASNs). ASNs are being used increasingly by large organizations to minimize the paperwork involved with purchasing materials. These organizations require their vendors to put barcodes and/or RFID tags on the boxes and pallets that they ship and then to send an ASN describing each pallet. This description is a nested container description with the



barcode tag tracking number for each level of container or item. When each pallet is received the pallet tag is read and matched up electronically with the ASN data, thereby avoiding any manual entry of the nested container data by the receiving organization, which is a big time and cost savings.

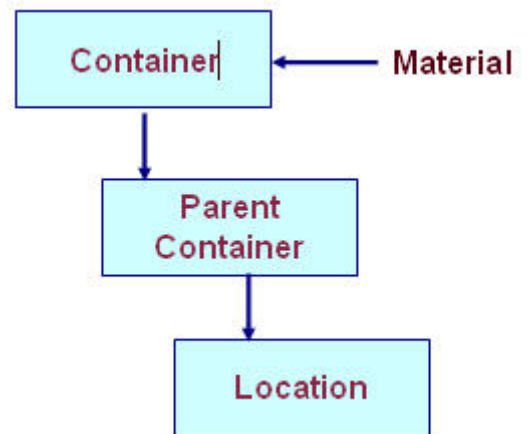
Nested containers can also be used to represent, for example, different modules mounted in a rack of electronics gear. It can also be used to represent the contents of a 96 well biological sample tray, where the 96 well-plate is the parent container and each well are its child containers, with each holding a uniquely identified sample.

At the other end of the size spectrum, an intermodal shipping container can be recorded as the parent container and all the pallets inside it as child containers, each of which has their own child containers. Nested containers can be defined to as many levels as needed to represent the contents of the outermost parent container.

### Containers Table

One major thing that distinguishes a material tracking system from a pure inventory tracking, warehouse management system or ERP system is its "containers" table. This table has an entry for each single use container and each serialized item. It also has an entry for each parent container. Each entry in the containers table has a physical location and potentially a parent container.

If there are multiple loose items in a mixed use container then these are assigned to virtual containers which will have a parent container and also a location. If multiple items are directly placed in a bin or other location then their virtual containers have no parent container.



The containers table enables us to track the location and status of every container and serialized item in our facility (or even on trucks or delivery vans). Contrast this to an inventory tracking system which typically just tracks the aggregate quantity of materials on hand by part number. The two are inter-related and changes to the containers table are often used to update the inventory status in an ERP system.

One of the benefits of the containers table is that we can scan any container or location barcode and have the system tell us in real-time what should be in a specific container or location. This enables us to perform real-time cycle counting and inventory auditing without shutting down production.

A benefit of using a containers table is that, if we track when physical containers are discarded, we can do incremental adjustments to inventory without allowing errors to accumulate. For example, we may have purchased a 50 gallon drum of coating material. It actually held 49.5 gallons. When discarded as empty it had a quarter gallon of coating material still in the drum as “washings” around the walls of the drum. Thus we had a potential  $\frac{3}{4}$  of a gallon inventory error which would accumulate if left uncorrected. By recording when the barrel is empty, this difference can be detected and the inventory corrected at the time of discard.

Empty containers, as opposed to discarded containers, can be reused without changing their tracking barcodes. They are simply like cars rented to different people but maintaining the same license plate tags and containers table entry. The same inventory adjustment benefits apply if we track when the containers become empty and are available for reuse.

The containers table is at the heart of material tracking systems. This table can be used to store all the information we need about containers and the materials inside those containers. This includes data such as part numbers, quantities, lot numbers, expiration dates, and quality-control approval status. Each record can have links to photographs of the item, process control data, test data, documents and certificates. It can also contain data such as who owns the material and the accumulated labor, material and equipment cost elements in producing that material.

This is a much richer set of data than is carried by accounting, ERP and warehouse management systems about the items in inventory.

### Applying Tracking Barcodes

When materials are received from a vendor or produced as part of a production process, they need to have a “license-plate” tracking barcode attached. Normally the materials are in a container but sometimes an individual tracking barcode needs to be attached to each item.



We refer to items with a tracking barcode as a tagged item and those without as an untagged item.

If you receive a nested container, such as a pallet with boxes with serialized items within the boxes, you have three choices:

1. Just tag the pallet and, if needed, tag the boxes when they are removed from the pallet and the serialized items when they are removed from the boxes.
2. Just tag the boxes and then tag the serialized items when they are removed from the boxes.
3. Unbox and tag everything at time of receipt.

If there are no serialized items involved and all the boxes contain the same lot number (or lot number tracking is not important for these items) then only the highest level container (such as the pallet) needs a tracking barcode.

Which choice to make will depend on the subsequent processing of the materials. It may be easier to tag all materials at time of receipt or it may be easier to incrementally tag materials as they are unpacked. This can only be determined by examining the whole process flow.

There are three primary methods of applying tracking barcodes:

1. Use pre-printed serialized barcodes.
2. Print tracking barcodes on demand.
3. Have your vendors apply barcodes before shipping materials.



The simplest way of attaching a tracking barcode is to use a pre-printed roll of barcodes. Each barcode on the roll is unique and can be peeled off and attached to the container being tracked. Each tracking barcode is then scanned and associated with the materials in the container.

If material tracking is only to be performed inside your plant, then the barcode label contents can be of the form #012345, #012346, #012347 etc., with each label being incremented by one. We do recommend using a prefix, such as a #, to make mistake prevention easier. If the materials are to be tracked in a plant of another company, then we recommend that you follow the GIAA standards for uniquely identifying a container on a global basis.

Sometimes the same tracking barcode needs to be placed on a serialized item and the box, in which it came. In this case, we recommend the use of rolls of side-by-side barcodes with each pair having the same barcode. One of these barcodes is attached to the unit and one to its box. Then the box barcode can be scanned until the box is discarded when the unit barcode is scanned.

This assumes that the box or other container can be opened. If not then a tracking barcode is attached to the box and the item(s) inside the box are simply recorded as untagged material until the container is discarded. This often applies to rolled material wrapped in plastic. The tracking barcode is applied to the wrapping until the material is used. Then a barcode is typically applied to the core as the material is returned to stock. But it may equally apply to instruments inside a sealed box.

Labels should be printed on high-quality plastic-coated stock with a backing adhesive appropriate to the surface to which they will be attached. They should be printed using a thermal offset process which bonds the barcode label printing to the plastic surface. This is so that the labels will stand up to industrial handling. Do not use office labels for this purpose as they will fall off and be easily defaced.

The rolls of pre-printed barcodes can be produced by printing these on an industrial thermal offset barcode printer, using label printing software. Alternately, these can usually be ordered pre-printed at modest cost from your local barcode label supplier. The benefit of purchasing pre-printed labels is that there is no need to purchase an industrial barcode printer, or software, or train someone to use and maintain the printer.

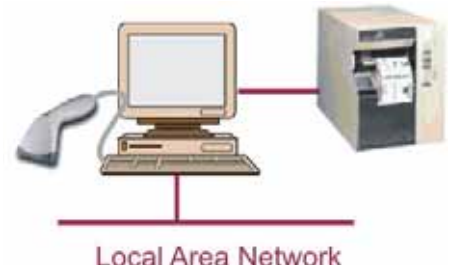
Applying a label with a tracking barcode to an item from a pre-printed roll is simple and requires little operator training. Rolls can be carried around (such as on a fork-lift truck) or placed in strategic locations. This is not possible with a print-on-demand solution that requires an expensive industrial barcode printer at each location.

The disadvantage of the pre-printed barcode labels is that they rely on other labels already on the packaging to provide needed human readable information, such as part number and description. If the containers do not have this information or information, such as hazardous materials labeling, needs to be added then it will be necessary to print the labels on demand.

On-demand printing is typically done using a barcode printer attached to a PC and barcode labeling software, which provides the specialized interface needed for the barcode printer (which is very different from an office printer – as it is an offset printing-press in a box).

The labeling software will typically be driven by the tracking software and get its data from the tracking software's database to save keyboarding in the data (with the possibility of mistakes).

Normally, the labels are printed out as a group and then attached to the containers, rather than printing out the labels one at a time. The exception to this is when a print-and-apply system is used on a production line.



Typically the labels are printed out for received materials by selecting a vendor PO number and line item on the PC screen and then entering other data such as lot number, quantity and expiration date as well as the number of containers. Each label so generated has a unique tracking barcode plus the necessary human readable information. These can often be directly applied to the containers with no further scanning, as all the information about the container is known at time of label generation.

Sometimes, however, quantities, lot number and expiration dates are different for each container in the batch. In this case the tracking barcode is attached and then scanned and then the additional data is recorded.

At the end of a production line, a set of labels is typically pre-prepared for a batch run and placed in a label dispenser, where they can easily be retrieved and attached to containers coming off the end of the line. As more labels may be produced than are needed, it is important that the tracking software delays “activating” the labels until they are scanned as the finished materials are scanned at put-away time.

One good way of applying labels to boxes coming off a production line is to pre-prepare a roll of tracking barcode labels with human readable information and place these into an automated application system, which is much less expensive than a print-and-apply system.

One way of avoiding the need to print labels on materials you receive is to have your vendors apply tracking labels before shipping these to you. These should have tracking barcodes that will be unique from any that you use within your plant, such as following the GIAA standards.

These labels may also have other barcodes, such as part number and quantity, which can be scanned at time of receipt to associate this data with the tracking barcode (without typing them into a mobile computer keyboard). A better way to proceed, however, is to have your vendor send you the information about each container and its tracking barcode in the form of an advanced shipment notice (ASN) so all that you have to do is scan the tracking barcode upon receipt and have the tracking system software associate the unique barcode tag with all the information about the contents of the container.



Thus we might, as per our previous example, have a pallet with boxes of printed circuit boards. We would have our vendor apply tracking barcodes to each circuit board and box and then send

us all this information about the nested container representation in the form of an ASN. Upon receipt, all that is necessary is for our receiving person is to scan the barcode on each pallet and the materials are all automatically received. This eliminates the need for any paperwork on the receiving dock and makes receiving a job for a fork-lift truck-driver and not a more expensive receiving clerk.

This does require that you trust your vendor and do periodic quality control checks but it does work very well with vendors who supply you with a large amount of raw materials on a regular basis.

There are, however, exceptions to this process:

1. Small vendors, with limited technical ability to supply pre-barcode materials. If these supply you with material on a regular basis then you might want to think about sending them the tracking barcode labels along with the order, so that they can pre-apply the labels.
2. Vendors who only occasionally supply you with materials. These one-off purchases are never going to be barcoded according to your needs. Here, the best way to proceed is to apply your own tracking barcodes.
3. Really large vendors, for whom you are a small customer. They will not change their barcoding scheme for you. You can adapt your tracking system to recognize their barcodes or you simply apply your own tracking barcodes.

One of the questions I frequently get asked, is “Why cannot we simply use the vendor applied barcodes that come with the packaging, rather than applying my own tracking barcodes?”

There are many reasons for this:

1. Often there is no unique tracking barcode on the container. There are barcodes for part number, quantity, lot number etc. but no unique identifier.
2. Even if there is a tracking barcode, it is not guaranteed to be unique amongst all your vendors (unless it obeys GIAA standards). The easiest road to total confusion is to have the same tracking number on two containers of different materials.
3. It is very hard to train material handlers to recognize and scan many different formats of tracking barcode and very easy for them to make a mistake. These days containers have many different barcodes in many different locations. For this reason many organizations elect to apply their own tracking barcodes so they can make them visibly unique (such as by using a colored label stock and/or printing the company name and logo on the label). They also prevent mistakes by prefixing the tracking barcodes with several unique characters (such as #) that are not otherwise commonly used.

In summary:

1. Use pre-printed “license-plate” barcode labels from a roll for simplicity.
2. Pre-print and then apply labels for received and made-here materials with human readable information.

3. Have your vendors pre-apply labels (where feasible) and send data in advanced shipment notice format.

### Location Barcodes

Location barcodes are used to identify locations in a facility. These locations may be bins, shelves, racks or floor locations. Location barcodes are linear one-dimensional barcodes that typically have meaning, such as “A32C” for “Aisle A, Row 32, Shelf C”. This is so that material handlers can easily recognize and remember location codes.

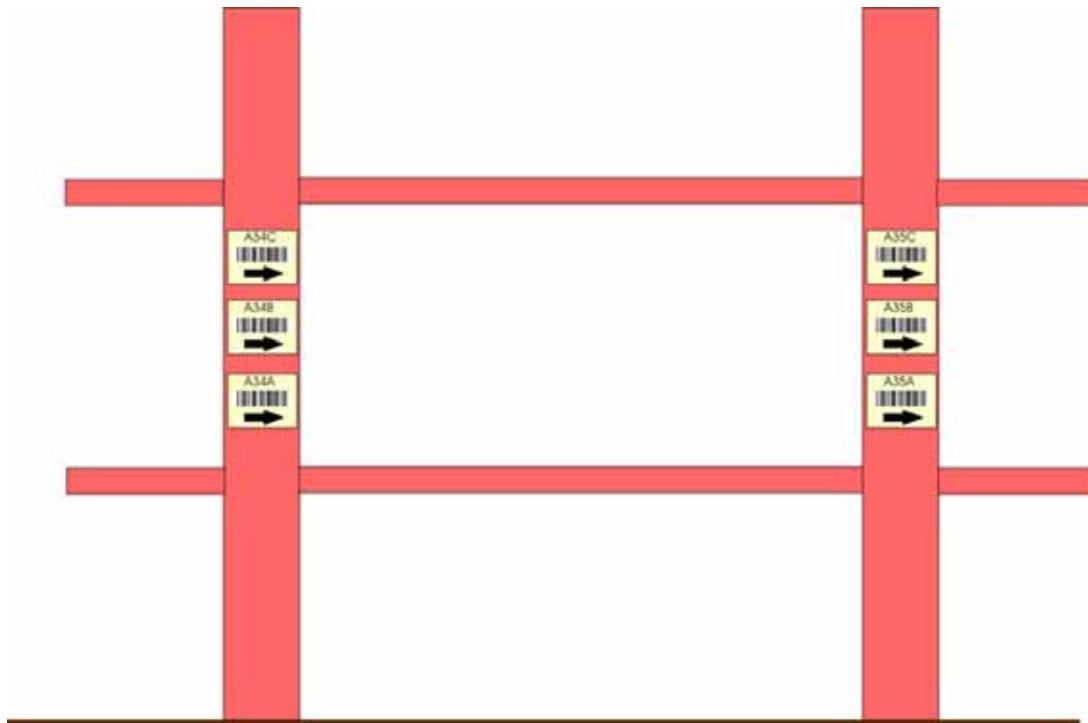
We do not recommend codes of the form 234.127.987.345 as these have no meaning to material handlers.

Codes need to be kept short, usually less than 10 characters, so that location barcodes can be printed big enough to scan at a distance.

Location barcodes used in stock rooms are typically at least 2 inches wide with at least a quarter inch of white space each side. They should be printed at 15 mil resolution for ease of scanning. These barcodes are typically placed in the middle of each shelf.

If bins are used within a stockroom then these can be given individual location barcodes. Most organizations, however, prefer to put part number barcodes on the bins and then to have these represented as multiple part bins on a shelf location.

The barcodes used for shelf locations in warehouses should be at least 3 inches wide with three eighths of an inch of white space either side and have 20 mil resolution barcodes so they are easy to scan from a distance. They should be placed on the uprights of racking one above the other at about eye level, as shown below:



Do not attempt to place the barcodes on the warehouse shelves (as you would in a stock room) as they can be very hard to scan if they are 20 feet in the air. Material handlers are able to easily associate barcodes with shelves when placed as shown. Also place the barcodes in a "picket fence" orientation as shown above. If placed in a "ladder" orientation with the stripes running horizontally, the barcodes are ergonomically difficult to scan as they require twisting the scanner through a 90 degree angle.

For floor locations (such as where pallets are placed), barcodes are typically hung over the floor locations. These are typically hung at the 20 foot level to allow pallets to be stacked. They are printed on a retro-reflective material and are typically 12 inches wide with a 100 mil resolution barcode. The material handlers need to be equipped with mobile computers that have scanners which are capable of scanning these barcodes at a range of at least 35 feet due to the angle at which these are scanned. These barcodes are typically placed on a plastic backing so they hang at about a 30 degree angle from the vertical, thus making them easier to scan.



Retro-reflective barcodes are also used to identify dock doors. These are typically hung over the dock door so they can easily be scanned as pallets are loaded onto a trailer at the dock.

In yards, location barcodes can be placed on posts with heavy bases or on fiberglass whips (such as used for snow plow markers) such that they will not get damaged when the fork-lift truck drivers run into them. In this case, barcodes about the same size as used on warehouse racks work well. They do however need to be printed on a plastic base with a UV resistant resin ribbon if they are to survive for a long time outdoors.

Location barcodes need to be unique. If the organization is using a combined tracking database for all its facilities, then the location codes need to include a facility prefix to ensure uniqueness.

Location barcodes should be printed on an industrial barcode printer using a thermal-offset process to ensure longevity. Do not use office labels as these will quickly become damaged and fall off. Ideally the location barcodes should be printed on a plastic coated or plastic substrate with a resin ribbon to ensure that the barcodes will not get defaced when banged. If the location barcodes are to be used outdoors then ultra-violet resistant resins and substrates should be used for the labels.

The barcode label preparation process usually starts by preparing an Excel spread sheet with the location codes and descriptions. This is then used as input to the barcode labeling program that will be used to print out the location barcodes.

Organizations with their own barcode printers can print out their own location barcodes. But it is usually more economical to have the location barcodes printed (and possibly applied) by an organization that specializes in producing these labels.

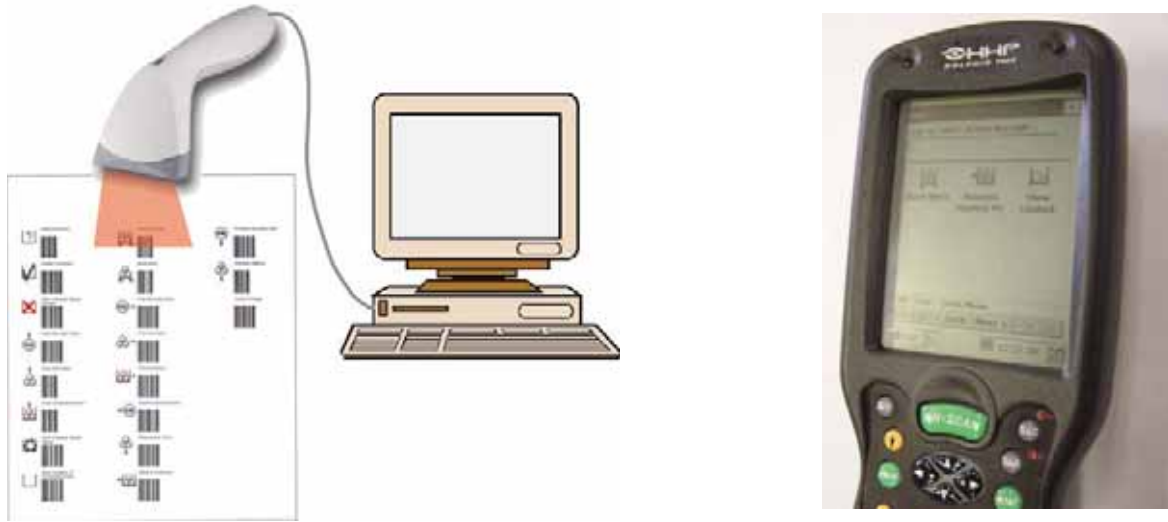
Overhead retro-reflective barcodes need to be ordered from suppliers who specialize in making these labels as they cannot be produced using a standard industrial barcode printer.



## Barcode Tracking Methods

### Transactions

Material tracking transactions, such as entering materials into inventory or withdrawing material from inventory are either performed on PCs or on mobile computers.



Scan transactions on a PC can be initiated by scanning an action barcode from a sheet of transaction barcodes that are generated by the tracking system. These barcodes are usually placed on the table or wall in the vicinity of the PC. Thereafter the user is requested to scan or enter one data item at a time. After each data item is entered it is validated extensively and the user is warned if they made a mistake. Then the user can re-enter the correct data immediately with no delay. The same principal is used on the mobile computers except that scan transactions are started by selecting an item with the stylus on the touch sensitive screen.

The transactions sequences are dynamically organized to minimize the amount of data entry required. This also enables a relatively small set of icons to cover a large number of possible actions. Thus an action such as "Move Material" can cover moving material from a container or a location to a container or location. The branching occurs naturally and avoids the material handler having to remember a large number of options.

As each input is requested an icon pops up to identify the type of data to be entered. Also there are audible confirmations of a successful scan and visual warnings of mistakes made.

All transactions require the identification of the person performing the transaction. This is normally performed by requesting an operator to scan a barcode on their badge. For FDA CFR 23 Part 11 and other similar tracking applications, this is supplemented by the



request of an operator's password to form a unique two part electronic signature. When a mobile computer is being used by only one person then the badge scan is only requested if a transaction has not recently taken place recently.

## Inventory Tracking

Once we have placed “location” barcodes on racks and shelves and placed “license-plate” tracking barcodes on our containers of material, we can now record where they are put-away. In doing this we scan the location barcode and then scan the license-plate tracking barcodes on all of the containers we are placing in that location. This location is stored as part of each container’s record in the tracking database.



Whenever we move a container, we scan the new location barcode and then scan the license plate tracking barcode on the container. In this way we know the real-time location of each container.

When we first enter material into inventory, we record the quantity of material in each container and store this as part of the container’s record in the tracking database. When we remove material then we scan the tracking barcode and record the quantity removed. We use the same principle when we add contents to a container. In this way we know, in real-time, the quantity of material in each container.

We can put tracking barcodes on individual items such as computers, amplifiers, motors and then use the same principles to track their locations.

When dealing with small items, such as electrical connectors or nuts, bolts and washers, it is not practical to put a barcode on each item. So we put a tracking barcode on the bin and then record the quantity added or subtracted from the bin.

In putting a barcode on the bin, there are several choices:

1. The bin barcode can be a location barcode
2. The bin barcode can be a container barcode
3. The bin barcode can be a part number barcode.



In the first case, we simply add or subtract material from the location. The disadvantage is that we can end up with a large number of locations. In the second case, we record the location of the bin (which can be moved) and then record materials added and subtracted from the bin. In the third case, we treat all materials on a shelf location as a mix of parts and then scan the part number barcode to differentiate between them.

Generally method 2 is the preferred method as then treatment is uniform between loose items kept in a storage bin and a box of the same items on a shelf.

## Inventory Validation

We can “take” inventory in a several ways:

1. We can print out a list of the inventory at each location and manually record the discrepancies and then enter these adjustments into our inventory tracking system. This is a traditional way of verifying inventory.
2. We can scan a location and have a mobile computer present the inventory that should be at that location on its screen. Then we can enter any discrepancies between the materials actually there and the data contained in the tracking database for that location.
3. We can attach colored tags to each item or bin as we manually record the quantities on the tags. Then we can collect all the tags and enter them into a computer where the quantities are compared with the quantities in the inventory tracking system. This is the traditional way of validating inventory.
4. We can do “blind” validation in which the location barcode is scanned using mobile computers. Then the tracking barcode on each container or bin is scanned and the quantity in the container is recorded.

The big problem with inventory verification or validation is that we have to “freeze” all activity at a location between the time that the data is captured and when it is compared with the current status of the material in the tracking database at that location. With traditional pencil and paper methods, there can be a long delay between the data capture and the data entry, which can result in shutting down operations while inventory is being taken. This is why many companies pay expensive overtime to employees to take inventory over holidays and plant-shutdown periods.

With mobile computers (or using Laptop computers on carts), we only need to “freeze” activity at a location for the duration of taking data at that location, which is typically a few minutes at most. This data can then be automatically compared with the contents of the tracking database at that time and the discrepancies recorded. This means that operations do not have to be shut down while inventory verification or validation is in progress.

It is for this reason, that it is important to divide a warehouse or stock room into small locations, such as a shelf or a floor location that will only hold a limited number of different items. It is also much easier to resolve discrepancies at a shelf level rather than trying to chase down materials that are missing from the whole of a stock room or a major section of a warehouse.

Inventory verification, by visually comparing what is at a location with what is presented on the computer screen, is beneficial for frequent checks on inventory to pickup any mistakes made by material handlers. This can be combined with a “Cycle Counting” process to verify the most rapidly moving items more frequently. But, as verification using mobile computers is quick and easy, cycle counting is often replaced with a warehouse or stock-room inventory verification schedule in which one section is verified each day.

Inventory validation is important when it comes to proving-out the value of inventory in stock for accounting audit purposes. It is also important when using employees to take inventory who have no vested interest in inventory accuracy. Here, it is important to use a “blind” method

whereby the inventory at each location is entered by scanning the location and container barcodes and then recording quantities without knowing what should be there.

It is generally not a good idea to automatically update the tracking database based on the inputs from inventory verification or validation. This is because people taking inventory make mistakes by forgetting to scan containers and entering wrong quantities. Rather, a report should be printed out of all discrepancies for a materials manager to investigate.

Often pallets and other containers “walk” across the warehouse as they are “temporarily” moved (without scanning) to a new location and then never moved back. So they show up as missing in one location and as an excess in another location. These discrepancies can be automatically adjusted and the containers recorded in their new locations automatically.

Missing containers and erroneous quantities, however, need human judgment as to the action to take. If the materials manager finds a small quantity discrepancy reported in a bin of washers, he will simply correct the inventory in that bin without further action. If a container of valuable or hazardous material is missing then this requires rapid and in-depth personal investigation as to what happened.

In reporting inventory discrepancies, it is important to highlight defective materials or materials awaiting inspection that are not in suitable quarantine areas, as this indicates operational problems.

In summary, the use of mobile computers, combined with appropriate inventory verification and validation tracking software, can significantly reduce the time and cost of taking inventory and can avoid shutting down operations while inventory is being taken. One of our clients was able to reduce the time to take physical inventory from 14 days (over the Christmas and New Years’ holidays) to less than 12 hours, during normal operations, using these methods.

## **Cycle Counting**

To ensure the accuracy of inventory, it is necessary to periodically verify the quantity of physical inventory against the computer record. The classical way of doing this is to stop production, as well as warehouse operations, shipping, and receiving, and to physically count the inventory. At the same time, the computer records are updated from any paper records that have not yet been entered. At the end, the physical count is compared with the computer record and any discrepancies investigated and adjusted.

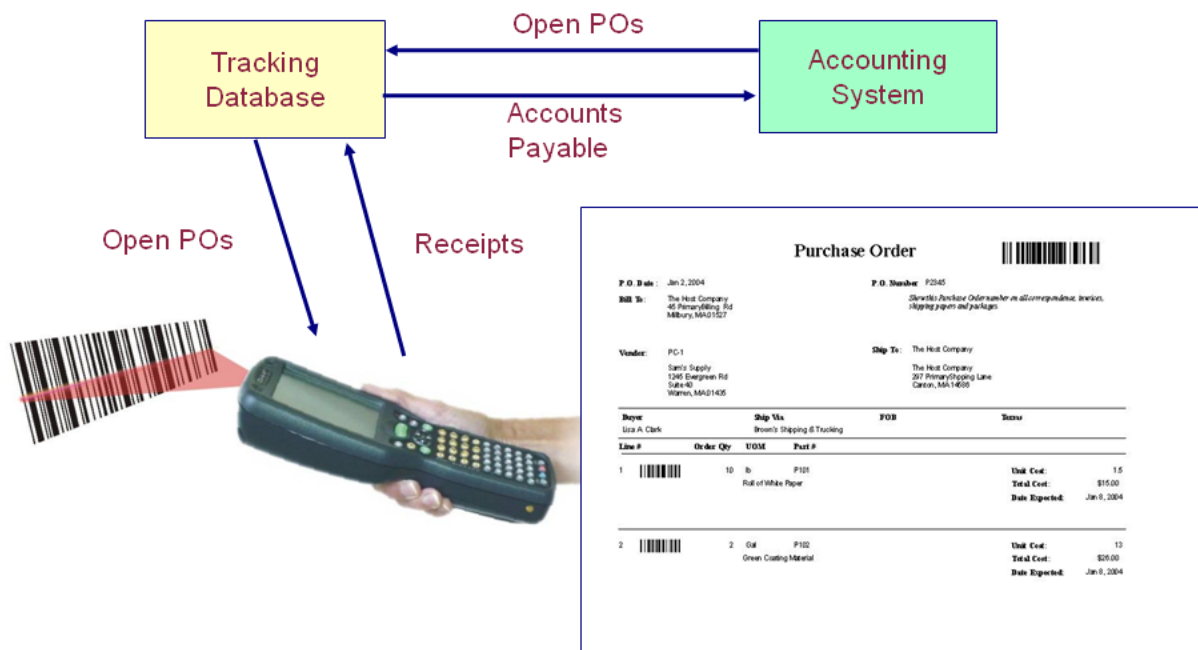
This is a very inefficient way of auditing inventory as it requires ceasing operations and is frequently done on weekends resulting in poor worker and staff morale. As this is a painful process it is done as infrequently as possible, resulting in poor inventory accuracy.

With a barcode tracking system the inventory records are synchronized in real-time with the physical movement and usage of materials. As a result, a materials manager can walk up to any bin or shelf and scan the location barcode. They will be presented with a record of what the system understands to be in that location at that instant of time. They can also scan any container and be presented with the contents of that container. The materials manager can then enter an adjustment at that time, if needed.

With this technique, there is no need to shut down operations to audit inventory. Cycle counting can take place in real-time as production and distribution proceeds. It is recommended that 20 or so locations be audited every day to find and correct any mistakes in inventory. Because of the techniques used in barcode tracking systems, a high level of inventory accuracy is maintained. Most of the errors that are found by cycle-counting result from failing to record the movement of pallets that are moved to gain access to other pallets and not put back.

One client found that these perpetual real-time inventory and cycle counting methods enabled them to reduce their annual inventory taking from a two week to a one day process. A number of clients have found that they are able to achieve inventory accuracies in the high ninetieth percentile with minimal materials management effort.

## Receiving Materials



The receiving process typically starts with the entry of a vendor purchase order (PO) into the accounting or ERP system. This is then transferred to the tracking database as an open PO. If mobile computers are being used for receiving, then the POs are transferred to the local database in each mobile computer.

When materials arrive, the receiving person has a two choices. They can print out a barcoded receiving document (which corresponds to the copy of the purchase order sent to receiving in a manual system). Then they can scan the barcodes corresponding to the purchase order and purchase order line from this receiving document.

Alternately they can select the purchase order and purchase order-line from drop-down boxes on the screen of the mobile computer or PC, thereby avoiding printing out the paper form.

A license-plate tracking barcode is then placed on each container that receiver wish to track individually and this barcode is scanned. Then the receiver enters the quantity received in that container and, if required, the lot number and expiration date.

Once each container has been received then the location is recorded for put-away and the material is recorded in the tracking system as an entity to be tracked. The receipt transaction is also relayed back to the accounting or ERP system where it adds to the inventory being tracked for financial purposes and also becomes an account payable to the vendor.

One issue that always arises is whether to put tracking barcodes on a container and if so, at what level of granularity. For example, we may receive a pallet with 12 boxes on it, with each box containing 20 brackets.

There are several ways of treating this receipt:

1. We could simply record this as the receipt of 240 brackets as loose material and record the location in which this material is placed, when no tracking barcodes (except for the put-away location barcode) are required. Then the materials will be pulled from this location bracket by bracket.
2. We could put a tracking barcode on the pallet and record the floor location of the pallet. Then we can pull individual brackets or boxes of 20 brackets of loose material from the pallet. The advantage to this is that we can record the movement of the pallet.
3. We could put a tracking barcode on each box and on the pallet. Then we can record the pulling of boxes or of brackets from boxes. This has the benefit of being easier to withdraw whole boxes and to count inventory. It also enables boxes from different lots to be mixed in one location as each box carries with it, its lot number and expiration date.
4. Finally, we could open the box and put a tracking barcode on each bracket, so it can be individually tracked. This may be supplemented by putting tracking barcodes on the boxes and the pallet. This is usually only done for individually serialized items that need to be tracked individually.

At its simplest, the tracking barcodes can come from a pre-printed roll of license-plate barcodes. This is the simplest way of labeling incoming materials as multiple rolls can be in use without conflict as the association with the tracking number is done at time of receipt.



This works well for pallets and boxes (or other containers) with visible markings on them, so there is no confusion as the contents of a container.

In other cases, the containers may not be clearly marked as to their contents or other human readable information, such as their expiration date or hazardous material classification. In this case, it is usually beneficial to print out special labels for each container. This is typically done at a PC with the user selecting the PO and PO line and then entering other information before printing out a set of labels.

These labels are then adhered to the incoming material and the license plate tracking barcode on each label scanned to record the receipt of the material into inventory.

If we have a lot of individually barcoded items or even many boxes, this labeling process can become a major chore in receiving. For those cases, it is then beneficial to request the vendor to place tracking barcode labels on the pallets, boxes and items (if needed) and then to send details of each nested container and item that is shipped. This is normally sent in the form of an Advanced Shipment Notice (ASN) and includes details of each container, its tracking barcode, its contents, quantities, lot numbers and expiration dates.

If this is done correctly, then the receiving process can be reduced to simply scanning the barcode on each pallet and having this information related to all the data in the advanced shipment notice. This, of course, requires close collaboration between vendor and customer and also requires that both have industrial strength barcode tracking systems in place.

### **Quality Control Tracking of Materials**

It is important that certain materials are not used or shipped to customers unless they have been subject to quality assurance. Some raw materials may come from qualified vendors and may be used without further inspection. Some may be inspected by the receiving clerk and others may need to be inspected by the quality control department before they may be used.



To track the quality control status of materials we carry a set of flags on each container record that designate whether the container needs QC and whether it has passed QC. When we enter a container into inventory, we look into the item master to see if the part needs inspecting and, if so, what type of inspection needs to be performed:

- No inspection needed –automatically approved
- Needs QC inspection
- Lot sampled inspection by QC with every N<sup>th</sup> item or container to be inspected.

Locations can be designated as QC quarantine areas. Materials that have not passed quality control can only be moved into quarantine areas. An attempt to move an item that has not passed QC into an area that is not marked as quarantine will result in a warning.

Employees can be designated to have Quality Control authority by a flag on their employee record. These people can scan a tracking barcode on a container or serialized item and designate the container or item as having passed or failed QC inspection. This can be done using a PC or mobile computer. If it has passed, then the container can then be moved to a non-quarantine area.

Containers or serialized items that are part of a statistically controlled lot are designated to not need inspection unless they are automatically selected for inspection. If a QC person designates a container or serialized items, that is part of a lot, to have failed QC, then all containers in the lot may be marked as "needing inspection" or failed.

## Tracking Material Movement

The movement of materials can cover a range of activities:

- Movement of loose material from one location or container to another.
- Movement of a barcoded container into or out of another barcoded container or location.
- Movement of serialized items into or out of locations or barcoded containers.
- Extraction of non–barcoded containers from a barcoded container with placement of a tracking barcode on the extracted containers and their placement into a location or into/onto a barcoded container (For example extracting boxes from one pallet, barcoding them, and putting them on a mixed use pallet).



These can all be reduced to two basic forms of a move transaction:

- Move loose material
- Move containers

The flow of the transactions depends on the barcodes that are scanned as the transaction proceeds and whether they are known or unknown tracking barcodes.

When a move to a pallet or other such parent container is required, and the container does not have a barcode, then it is first entered into the system with a "create container" transaction that records the pallet type, its initial location and tracking barcode.

Material move transactions are typically performed using wireless mobile computers but can be performed using PC equipped with corded or cordless scanners.

When materials are withdrawn from a container, the system automatically tracks the quantity left in a container. If a container becomes empty as a result of material movement then it is recorded as "empty" (with zero quantity) and ready for reuse or "discarded" (and marked as deleted in the containers table). In either case, any residual material quantity carried by the system is then zeroed out and an adjustment in the inventory recorded and possibly sent to the ERP system. This incremental adjustment is a very powerful technique to prevent the accumulation of quantity errors.

When a container becomes empty it is treated as being reusable or discarded depending on a setting in the container type. Thus cardboard boxes may be marked as being discarded but plastic totes may be marked as being reusable.

## Stock Room Operations

Materials may be entered into a stock room as a result of one of the variants on the "enter–into–inventory" transaction such as when materials are received or are produced by a job. Materials can be withdrawn by a "withdraw from inventory" transaction or withdrawn for use on a job or picked for a customer order. These transactions may be performed using PCs equipped with

cordless scanners in smaller stock rooms or using wireless mobile computers in larger stock rooms.

Stock rooms are typically organized into shelf locations and bins, all of which are given tracking barcodes. Serialized items and barcoded containers that will be handled as integral entities are scanned onto shelf locations. Loose materials are scanned into and out of bins.

Bins are typically designated as picking locations. Any single-use containers placed in these picking locations are treated as loose material. Thus we might have a bin for a certain size of bolts. If we place a container with 25 bolts in this location then they are simply treated as 25 bolts and the container loses its identity.

## **Warehouse Operations**

Warehouse operations are similar to stock-room operations except that the size and scale are much larger. Materials are typically put-away using fork-lift trucks. We place location barcodes on racks and bins and also we hang large reflective barcodes over floor locations.

To make operations easier, we use mobile computers with long range laser scanners, so that fork-lift truck operators do not have to leave the seats of their fork lift trucks to do scanning.

Materials put away in the warehouse are typically palletized and the pallet barcode and the location barcode are scanned to record the put away location. As the location where the materials are put-away is recorded in the database, this enables materials to be placed where there is space not just in designated locations. They can then be retrieved from the racks or bins by looking up their locations in the database.

As with a stock room, certain locations can be designated as picking locations. Containers of materials moved to these locations will be considered simply as loose material, ready for picking by scanning the bin or shelf location rather than the container barcode.

Materials can be withdrawn from a warehouse using a "withdraw-from-inventory", or a "pick", or a "pack" or a "ship transaction" or they can be moved to another location using a "move" transaction.

## **Tracking Material Transformation**

Material transformation occurs in a number of ways:

1. Traditional manufacturing where raw materials are converted to a finished product in a series of operations.
2. Food and drug processing, where raw materials are mixed, processed and then packaged to become finished products.
3. Repair operations, where broken items are repaired and rested.
4. When secondary operations, such as kitting, assembly, packing and labeling, are performed in a distribution warehouse.
5. In laboratories, test and engineering organizations where the end products are documents.

In each case we represent what happens as a route consisting of a sequence of operations and the materials, labor and other resources consumed in each operation.

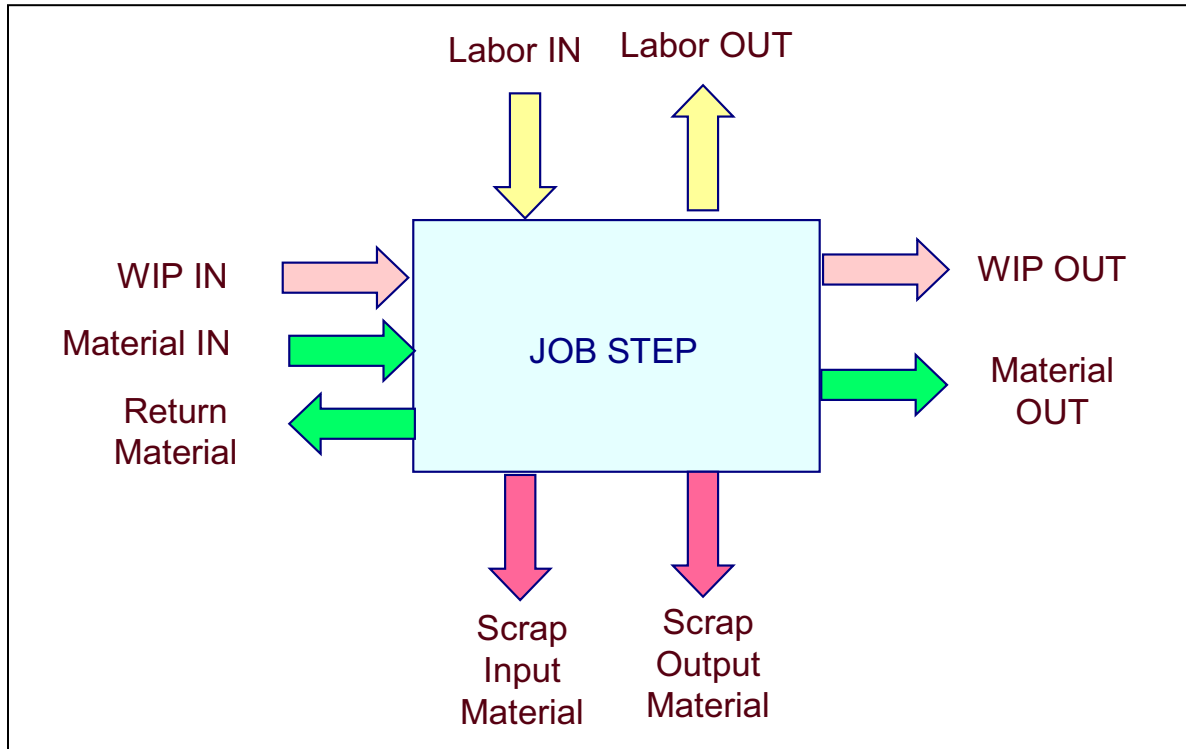
ERP systems normally represent this as a Route, consisting of a sequence of operation steps, and a Bill-of-Materials (BOM) that are consumed in the process. Industrial barcode tracking systems, such as BellHawk, take into account the fact that materials, labor and other resources may be consumed at different steps in the route.

Whether this information originates in an ERP or MRP system or is entered directly in the barcode tracking system, it is used to produce a barcoded traveler, which has a form similar to that shown below:

BellHawk Traveler			
Part : P0002	Priority : Rush	Job # : TEST2	TEST2
Bracket	Wanted By : Aug 4, 2001	Customer Name :	
Category : Finished Goods	Qty To Make : 30	Genen Company	
Type : Assembly	UOM : Each		
Special Instructions :			
Operation Start Code	Department / Operation	Instructions	
	Machine Shop/Get from Inventory		
	 P0001	Sheet Steel 18G 48 Sheet Qty: 2 Ea	
	Machine Shop/Panel Cutting		
	Machine Shop/Welding		
	Machine Shop/Inspecting		
	Paint Shop/Painting	Blue Paint	
	 P0003	Paint Blue 1Gallon Can Qty: 1 Gals	
	Paint Shop/Inspection		

The traveler has a barcode at its top right hand corner for the job or batch or work order. It then has barcodes down the left hand side for each of the operations or steps to be performed in the material transformation process. Underneath these step barcodes there are indented barcodes, one for each material to be scanned into that job step.

This traveler is then scanned to record the use of materials, labor and other resources on the job and the production or return of materials from the job, as described below. It is also used to record the transfer of work in process (WIP) from one job step to another.



### Recording Labor used on a Job Step

An employee will start by selecting the transaction from a screen or scanning the transaction barcode, from a sheet of action barcodes. Then the employee will scan his badge, followed by the job and step barcodes from the traveler for the job. This records the employee as starting work on the job step.

When the employee finishes work on a job step, a similar process is followed except that the employee selects a scan-out transaction instead of a scan-in transaction.

The system then records the amount of labor used on each job step and makes this available for viewing by a supervisor. Also this data can be exported to an ERP or accounting system as part of the job costing information.

Some systems, such as BellHawk, support the ability to record people as being part of teams, such that the team leader only has to scan-in and out to record the labor for the whole team.

### Tracking Use of Materials on a Job

To record materials used on a job/batch step, an operator enters or scans a job/batch number (from a traveler or a barcode attached to a worksheet) and operation (from a page of operation barcodes) or job step (from the traveler). If a traveler is being used, then the operator scans the indented barcode for the line item. The operator then scans a container or location barcode and records the quantity used. The material is then recorded as having been consumed by the job step. If the material has not passed QC or is the wrong part number then the operator is warned not to use the material when they scan the container or location barcode.

In some tracking systems, such as BellHawk, material can also automatically be back-flushed from a floor stock location when a unit is recorded as WIP out of the job step. This is convenient for small items, such as nuts and bolts, and allows these items to be automatically withdrawn from inventory without scanning them.

If material is returned from a job step, then the operator scans a “return material” transaction, followed by scanning the batch and step barcodes and then the indented barcode for the material from the traveler. The operator then scans the barcode on a container and enters the quantity returned in the container. The container may be a new or existing container. Typically it is a partially full box of material left over from the job step. The quantity of material consumed by the job step is recorded as the difference between the materials scanned into the job step and the materials returned.

It is recommended to measure the quantity of material returned, using a weighing scale, to maintain inventory accuracy. The scale may be used to weigh material after subtracting the tare weight of the container or it may be used to estimate piece part count based on stored or measured unit weights. Translating weights to counts or weights to other measures requires storing multiple units of measure for each container. Systems such as BellHawk have this capability as well as the capability to interface with weighing scales and to automatically translate between the units of measure, so as to avoid human error.

As materials are consumed on jobs and returned from jobs, raw materials inventory is automatically adjusted. Note that this is much more accurate and timely than back flushing raw materials inventory (based on the BOM for the part being made) at the end of the job as it measures actual rather than theoretical material consumption.

Sometimes materials are moved from a stock room to a job as a kit. In this case, the first job/batch step on the traveler contains indented barcodes for all the materials in the kit . Materials are moved into a tote, scanning the barcodes on the traveler to record the transfer of materials to the job. When the kit has been picked, the traveler is placed in the tote. The material in the kit is assumed to have been consumed by the job until it is returned.

If a group of jobs is run together through the same operation on the same equipment, then they can be formed into a run-group, and the group treated as a batch job. In this case material can be scanned into to the run-group and returned from the run-group. The actual material usage can then be allocated over the jobs according to their relative BOM quantities for the material in question.

## **Scrap and Wastage**

Scrap takes a number of forms:

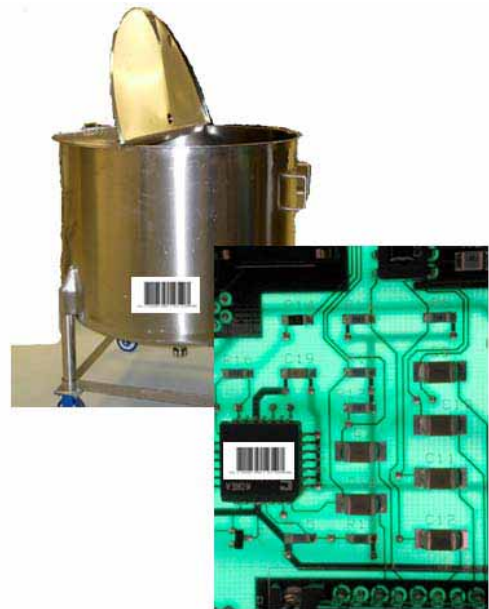
1. Defective raw material into a job.
2. Defective WIP produced by a job step.
3. Defective finished product.

These are all scanned as separate transactions, so the source of the defect can be recorded.

## Work in Progress (WIP)

In its simplest form, we can simply record the quantity of WIP out of a job step as it occurs and the quantities of WIP into the next job step using a WIP transfer transaction. This can be used to record the quantity out and in of job/batch steps in a batch mode or in a flow operation, where materials are flowing through multiple job steps simultaneously. WIP materials do not have part number but typically have generic descriptions set up to guide operator input, such as "sheets", "rolls" etc.

The simple recording of quantities works well unless WIP materials do not go straight from one job step to another but really are treated as inventory that may be used on multiple jobs. One way of handling this issue is to give part numbers to all WIP and to use one-step jobs. This requires inventing a large number of part numbers and is also inconvenient if the normal production flow is really a multi-step process.



This can be solved by the tracking of barcoded WIP which uses barcoded totes or other containers in which to place the WIP. When a set of WIP is complete at a step, then a barcoded WIP out transaction is scanned, followed by the job/batch barcode, the job step, and then the barcode on the tote. The quantity in the tote is recorded and the resultant material is designated by the part-number/operation. The container barcode can be used to identify the material in the tote when the material is scanned back into the next job step using a barcoded WIP-in transaction.

This same method is used in the case of items going through a repair process or the incremental assembly of large items. In this case, a tracking barcode is placed on the item at the beginning of the process and used to track the item in and out of job steps.

## Tracking Intermediate and Finished Goods

All materials produced by manufacturing processes should be placed in containers with “license plate” tracking barcodes. For intermediate materials, these tracking barcodes may be placed on totes or other carriers as well as on rolls, reels, and other such containers. For finished goods these are typically placed on “first-level” packaging such as cardboard boxes or wrappers.

License plate tracking barcodes on containers enable intermediate materials to be tracked into jobs to make finished goods. They also enable finished goods to be tracked into the warehouse and to be tracked as they are picked, packed, and shipped to customers.

Material out from a job/batch is recorded using a material out transaction. This is followed by scanning the job/batch barcode and then scanning tracking barcode on each container and recording the quantity in the container, if appropriate. The tracking barcodes can be pre-printed license-plate tags or they can be printed specifically for each container or item.

In this way we form a traceability path from each job/batch to the containers of material or the serialized items produced as a result of that production batch. If a job/batch produces barcoded containers of intermediate material, then these materials are scanned into the job/batch to make the finished goods, thus maintaining traceability from raw materials, through intermediate materials, to finished goods.

## Recording Other Data




The barcoded traveler can also be used to record the equipment or machinery used in a manufacturing process. At its simplest this consists of recording when a machine started running and when it stopped running on a job. It may also involve recording the setup and clean up time for the machine or other resource as well as any down time for repairs.

This data is then made available to an ERP or accounting system for job costing purposes. It is also recorded as part of the tracking and traceability record for manufacturing or processing materials used to make a finished product.

As part of this process, test data and process control data can be captured by the barcode tracking system. This can be done by simply having the operator capture the data on a PC or mobile computer as part of a special job step scanning transaction. Alternately it may involve interfacing the process control system and test stands to the barcode tracking system so their data can be captured automatically as part of the tracking and traceability record.

## Picking and Packing Customer Orders

Customer Orders are typically entered into an accounting, ERP or CRM system and then exported to the barcode tracking system. These customer orders are then used to generate barcoded picking tickets for the items to be picked.

Order O4786										
Customer :		Date Received	Date Wanted	Priority	Date To Ship	Status				
Cinon Technologies 5 Rivera St Cablestown, NJ 08456		Jan 3, 2004	Jan 14, 2004	Standard	Jan 12, 2004	Open				
Shipping Notes :										
Order Instructions:										
Line #	Part #	Qty To Pick	Qty Order	Qty Picked	Qty Shipped	Date Wanted	Priority	Date To Ship	Status	
1	 P101 Roll of White Paper	10	10	0	0	Jan 14, 2004	Standard	Jan 12, 2004	New	
2	 RM Raw Material	1	1	0	0	Jan 14, 2004	Standard	Jan 12, 2004	New	

For customer orders with multiple line items convenient to use a barcoded picking sheet:

This picking sheet has the customer order barcode at the top right and line item barcodes down the left hand side. The picking line barcodes can be organized in an optimal picking sequence.

These picking sheets can be produced manually by the shipping supervisor or automatically from the sales orders as they arrive. In either case they need to take account of the inventory in stock and available for picking.

The material handler goes around the warehouse and picks materials. They can select a "pick container" transaction and then scan the order number, then the line item, and then the barcodes on the pallets or containers, if they are picking whole containers, or serialized items. If they are picking material from a container, such as non-barcoded bags from a pallet, or loose material from a bin, they will use a "pick material" transaction and go through the same sequence, except they will record the quantity of material, such as the number of bags, picked against the line item. The orders can be picked to barcoded shipping containers, which can be pallets, shipping boxes, or totes or they can be picked directly to a location, such as a staging area.

As the order is being picked, the system checks to ensure that the items being picked match the line item and also that the items have passed QC inspection, if this option is in effect. The system will display the quantity to be picked and also warn the user if they attempt to pick too much for the line item.

Materials that have been picked can be shipped with a "ship picked" transaction in which the material handler scans the picking sheet number barcode. This records the material that has been picked on this pick order as having been shipped and relieves it from inventory. It may also cause the shipment data to be exported to an ERP system.

The materials being picked can be recorded as being placed in a container ready for shipment. Then a shipping label can be created for any shipping container by selecting the shipping container from a drop-down list on a PC screen and printing out a shipping label in a designated format. Finally the container is recorded as having been shipped in a "ship" transaction.

As an alternative to creating a picking sheet, a container can be simply shipped in a ship transaction, with the customer, order number and optional price being recorded at that time. This is simpler for large items which are shipped individually.

After materials have been picked and packed for the shipment, a packing slip can be printed out for each container or for the whole shipment.

If needed, the tracking system can be integrated with a UPS or other common carrier shipping system to automate the printing of the shipping labels and to capture the shipment tracking number for feeding back to an ERP, accounting or CRM system.

## **Shipping Dock Tracking**

The previously described "ship-picked" transaction works well for smaller volumes of shipments. But it does not address the problem of ensuring that the correct pallet or other container gets on the correct truck. This problem is especially prevalent in high volume operations that have many dock doors active at the same time.

This set of transactions starts by the shipping supervisor assigning a set of customer orders to a shipment that will be loaded onto a truck or trailer at a specific time and date.



When the truck pulls up to the loading dock, BellHawk records information about the shipper, such as the common carrier name and truck number, as well as the dock number. A bill of lading can also be printed at this time so the driver can check off the items as they are loaded on his truck.

As orders are loaded onto a truck, the shipping (tracking) barcodes on each pallet or other shipping container are scanned in a "load" operation with a barcode on the dock door as the destination location.

If the material handler makes a mistake and attempts to load the material on the wrong truck or trailer, then they will be immediately warned. This prevents a potentially expensive mistake with its resultant loss of materials or late delivery penalties.

The shipping supervisor can see each container as it is loaded onto the truck along with the status of loading each order. In this way the supervisor can make sure all the materials are loaded on the truck before closing the dock door.

When the loading is complete, a final bill of lading is printed out on a PC for the truck driver and a manifest is generated in a file so that it can be sent to each customer.

The tracking system can also generate an Advanced Shipment Notice (ASN) to be sent to the customer once the shipment has left the dock.

### **Traceability**

As a result of all the previously described scanning transactions, the tracking system stores the data that forms a link between materials received from vendors, through the consumption and production of materials on jobs, to the materials shipped to customers on customer orders. This traceability capability enables the tracking system to trace back through the job steps used to make a product and the people and machines involved, as well as the vendor materials used.

The resultant one-step backward traceability tree can then be used to help identify the cause of the problem. Once the cause of the problem is identified, then the container or lot number of the defective material can be entered and the tracking system will produce a trace-forward tree detailing all the jobs on which the problem material was used and all the suspect containers of finished goods materials. These can then be traced to the end-customers to which they were shipped, if the picking, packing, and shipping options were used. This enables a limited and effective recall to be rapidly implemented potentially staving off expensive litigation.

These traceability capabilities of a barcode tracking system enable clients to comply with tracking and traceability regulations of agencies such as the FDA and USDA.



## Project Management

### Implementing a Barcode Tracking System is Easy, Isn't it?

Plugging a barcode scanner into the USB port of a computer and having the scanned barcode data “magically” appear in the keyboard buffer, as if you had typed it in, makes the development of barcode data collection systems seem trivially easy. And yet, over the past decade, many organizations have spent hundreds of thousands and sometimes millions of dollars on tracking systems that have failed. These systems have sometimes failed technically but more often they have failed because the resultant systems failed to meet the many diverse operational needs of different users within the implementing organizations.



In this chapter we will focus on the project management and people issues facing organizations such as manufacturers, food processors, and industrial distributors who face the issues of not only tracking materials but also of tracking work-in-process. Tracking the location of materials, such as in a pure inventory tracking system, is reasonably straight forward; but as soon as we have to also track the transformation of those materials, these projects get really complex as they involve a lot of people within the organization.

While most of us think in terms of classic manufacturing, materials transformation also occurs in food and drug processing, reagent and DNA sample tracking, document and repair tracking, as well as in packing and labeling products. So many non-manufacturing organizations are also faced with the same complexities when they come to implement tracking systems.

In this chapter we will look at the people issues that need to be addressed as well as the multiple disciplines that need to be integrated into an implementation team in order to successfully implement a tracking solution.

### Driving Forces

I have led a team that has implemented over 70 barcode and RFID tracking solutions over the past decade. I always feel that we are in the “burglar alarm” business, in that almost nobody decides to implement a tracking solution until something goes wrong; just like the burglar alarm sales people never sell anything until after someone has broken into a home or office.

We have lots of conversations with prospective clients about ROI (return on investment) and how many barcode tracking systems will pay for themselves in less than 6 months due to efficiency savings. The results of these conversations usually appear in justification documents to senior management but no-one, in my experience, ever committed the funds to implement a tracking system based on ROI. Even where there were spare capital funds for a tracking system,

we have lost out to other worthy causes such as a new BMW for the company President or a paint reclamation system for the production people.

Sometimes the driving event is very personal, such a materials manager deciding that they are never going to spend another Christmas away from their family to take inventory again. Sometimes it is major, such as the FDA threatening to put you out of business by ordering a major recall. And sometimes it is just “the straw that broke the camel’s back” such as another large chargeback penalty from a customer or bill for expedited shipping charges because some employee made a silly mistake.



While there may be one event that causes an organization to implement a new tracking solution, it is important to recognize that there will be many users of the resultant system, with different and sometimes conflicting needs. The event that causes the decision to implement a tracking system may be a major mistake by an employee, an old system ceasing to function, or a demand by a key customer to provide electronic tracking data to them. But as soon as the decision is made to even think about implementing a system, all the pent-up needs of other factions will quickly come to the fore.

Some of the driving motivations we have seen are:

1. Company President or division manager – improve competitive position by having better capabilities than the competition (visionary)
2. Sales – deliver customer orders on-time with correct materials, labeling and packaging (increase personal compensation by selling more)
3. Operations – keep track of customer orders in real-time and prevent mistakes (make my life easier)
4. Inventory manager – track materials and work-in-process accurately (no more nights and weekends)
5. Quality Control manager – prevent mistakes and capture traceability data (prevent mistakes for which I get blamed)
6. Information Technology (IT) manager – replace old technology with new technology (career enhancement)

Noticeably absent from this list is “to make life easier for employees”. Implementing a tracking system will not make life easier for your employees and will certainly increase their anxiety in the beginning. All the benefits accrue to the senior management team and the stakeholders in the success of the organization. Employees will have to learn new skills and will have to do more work in that they now have to do barcode scanning and other data entry tasks. Barcode scanning may replace some paper and pencil data entry tasks but I can guarantee that the people who actually do the barcode scanning will have a large amount of fear, uncertainty and doubt about the new system (the FUD factor).

Even worse, many workers suspect (rightly so) that management will be tracking their activities much more closely and many fear that they lose their jobs as a result. This leads to a lot of push-

back, especially from long-term employees who have been “coasting” at their jobs. It is a truism of operations management that the performance of most non-management employees quickly sinks to equal the performance of the least productive worker (who can get away with it) in the group. By gathering accurate and timely performance data, managers can start to weed out under performing employees and more highly reward those who perform at a higher level.

So between the FUD factor and the rational fear by under-performing employees, the internal management team can expect a lot of push-back. Many tracking projects have been scuttled before they got started because management did not want to handle these human resources issues (or had lost effective management control of their organizations). So I advise managers never to tell employees that this will make their job easier. Tell them instead that data collection will now be an integral part of their jobs. Also tell them that you expect a certain percentage of employees will not be able to, or want to, master these new skills and will need to find employment elsewhere.

### **Pre-Implementation Planning and Budgeting**

Implementing a barcode tracking solution to solve a business problem is not just a matter of buying some packaged software, plugging in a CD-ROM and running it. It is critically important to realize that the successful implementation of a tracking solution is a serious project that requires an interdisciplinary team with many skills.



Before starting implementation, it is essential to accurately define the objectives of any barcode tracking project and to plan and budget for its implementation. Some of the steps in this process are detailed here:

1. Appointment of an internal organization project manager and champion. While collaboration is important, it is even more important to have someone in charge of the project on a day-to-day basis. Barcode tracking systems projects cannot be managed by a committee. You need a strong internal project manager who works collaboratively with a team of internal and external people to get the system implemented. This project manager may be from operations, IT or manufacturing engineering. The most important skill here is that of project management. Also an in-depth knowledge of company politics and the competing aspirations of different departments and their managers is essential.
2. Documentation of problems to be solved. These problem description(s) usually come from the operating department(s) of the facility that is having the problems. Not infrequently the presenting problem (“I want to track inventory better”) masks an underlying personal goal (“I am fed up with working nights and weekends to sort out this inventory mess”). It is important that the problems get documented along with the anticipated outcomes, both operational and financial of implementing a tracking solution. It is the internal project manager’s responsibility to make sure that the problems and the anticipated solution outcomes get clearly documented. It is also critical to get inputs from all the relevant parties to an internal decision.
3. Prioritization of the problem solutions. There is never enough money to solve everyone’s problems. So problems and their solutions need to be prioritized. Even if money is no object,

it is critical to tackle problems one at a time so the team does not get overwhelmed. Usually the priority of fixing a problem is directly correlated to the cost of fixing the problem. If the organization has a big problem that can be fixed for relatively little money then this tends to have high priority. On the other hand, we have seen situations where the “stove-pipe” needs of a department, while very genuine, are of lower priority than fixing a strategic marketing problem for the company. Here an external consultant with lots of experience in implementing similar tracking systems can give quick “back-of-the-envelope” problem solution cost estimates that can help guide the prioritization process.

4. Preliminary systems design and cost estimating. In this step of the process, the operational problem(s) to be solved are mapped to a preliminary systems design. This preliminary systems design usually involves selection of the software and hardware components of the system. These are then used to develop a cost estimate based on the cost of the software, equipment and professional services needed to implement the proposed system. This requires a systems architect who is knowledgeable about both the operational and technological aspects of tracking solutions. Most mid-sized industrial organizations will not have a systems architect with the appropriate cross disciplinary skills on their staff, so they will need to be guided by an external consultant.
5. Budgetary approval by senior management or board of directors. It is critically important to get this approval before proceeding with the project as the necessary funds may not be available (and everyone would waste their time). The cost of departmental tracking systems starts at ten thousand dollars and up and the cost of a company wide system, operating at multiple facilities, can cost several hundred thousand dollars. In most organizations the funding of these systems is part of the capital budgeting process (which may be very informal or very formal). This approval requires the preparation of a preliminary proposal and budget plus a cost justification. The preliminary proposal is typically prepared by the external organization that will lead the external team assisting their client to implement a tracking system.
6. Selection of the internal team. A single internal project manager cannot do it all. The team should have representatives from operations management, materials management, IT and manufacturing engineering (or equivalent). The CFO or division comptroller should also be part of this team but may not attend all of the team meetings. The company President or division manager will take more or less interest depending on how well (or badly) the project is progressing.
7. Once the project is approved, at least in principle, the next step is to do process mapping. This involves a number of steps:
  - a. Determine what real-time information screens and reports will need to be produced by the tracking system, including details of the data fields. This will help identify the data to be collected.
  - b. Identify data to be transferred from the tracking system to external systems. Document frequency of transfer and data fields to be transferred as well as mechanisms to be used.

- c. Determine all the places where data collection will take place and the most appropriate equipment to use (PCs with barcode scanners, mobile computers, weighing scales, tie in to process control equipment, barcode printers, etc.).
- d. Document and identify equipment to be used. This may be conditioned on the capabilities of the software it is proposed to use. Get quotes for equipment to be used.
- e. Document the data entry sequences to be used. Note that the choices here may be conditioned by what is available as standard in the software it is proposed to use.
- f. Identify data to be transferred into the tracking system from external systems to avoid duplicate data entry. Document data records and fields and data transfer mechanisms.

This is usually done by an external consultant who has interdisciplinary knowledgeable and many years of experience about operational data collection processes, tracking software, barcode, RFID and wireless mobile computing. This consultant will work with the internal team to do the process mapping. Frequently, this requires a visit to the client's facility but may be performed remotely for simpler applications.

- 8. Selection of the tracking software to be used. This is usually done by the internal team in collaboration with the consultant who assisted with the development of the process mapping document. There are a number of alternatives for the acquisition of the tracking software:

- a. Develop a custom tracking solution “from scratch”.

Unless the tracking application is trivial (such as scanning barcode labels into an Excel spreadsheet) this is the most expensive and highest risk way to go. It is not uncommon for companies to spend in excess of \$300,000 on programmer salaries or on consultants in developing a custom production and inventory tracking application. Even then, the resultant system has a high probability of not being used operationally because it takes so long to deliver that the requirements change in the mean-time. More importantly, the software development team often does not have the knowledge of how to do material and work-in-process tracking from an operational viewpoint (especially if an off-shore team is used) and so produces software that is not useable in practice.



- b. Customize an existing ERP (Enterprise Resource Planning System). These systems know about inventory, jobs and work-in-process. They often have manufacturing and warehouse management modules. Sometimes they have rudimentary barcode tracking capability. It is tempting to think that it will be easy to extend these systems to add needed capabilities such as license plate and nested container tracking.

Many companies have expended well over \$100,000 on consultants to modify their ERP systems to add the needed barcode tracking and real-time data capture capabilities. Provided the consultants are knowledgeable about both the internals of the ERP system and are also knowledgeable about production and inventory tracking (read expensive labor rates) then these conversions seem to work fine.

The big problem with this approach is that, once the ERP system has been customized, then it is impossible to upgrade the ERP system without paying the same expensive consultants about 60% of the original customization cost to move the software changes to the next version. As new versions of most ERP systems come out every 6 months, this can get very expensive. The alternative is to not upgrade, which is why we see so many organizations with customized ERP systems of Y2K vintage. As the underlying operating systems go off-support because of security issues, these are becoming increasingly problematic.

- c. Add point-solutions, such as production tracking, warehouse management or asset tracking software to an existing ERP or accounting system. This can be an economical way to go, if a single point solution will meet the needs of an organization and the software product has a pre-built interface to your version of your accounting or ERP system.

Some point solution software products are available for as little as \$1,000. But, being packaged software products, they are not customizable; so the internal team has to carefully study the capabilities of the proposed system to make sure it really does meet their needs. Some more expensive point-solutions can be customized but it is not unusual for organizations to spend tens of thousands of dollars or even more on this approach.

The biggest problem with this approach comes when more than one point solution is required, such as tracking both inventory and production. Now you have to integrate two different point solutions with your ERP or accounting system and make them all work together. The real-time interface and data exchange problems cause many of these projects to fail operationally or to cost hundreds of thousands of dollars.

- d. Purchase a new ERP system that purports to have all the capabilities the organization needs in one system. While this may benefit the commissions of ERP sales people, inevitably the new system does not meet the tracking needs of the organization and in most cases the purchasing organization finds themselves back in the situation described in (b) above.

That is not to say that an organization does not need to also upgrade their accounting or ERP system; but such an upgrade will inevitably not solve their tracking problems. It may, however, be beneficial to coordinate the purchase of a new accounting or ERP system with the purchase of a tracking system to avoid duplication of function.

The author has seen many cases where organizations have purchased expensive ERP systems with many modules they never used when they could have achieved the same result with purchasing a simple, inexpensive accounting system combined with a tracking system that meets their needs.

Most organizations never use the planning capabilities of their ERP systems because they are too complex for many mid-sized organizations to use. Instead they use their ERP systems as glorified accounting systems. This is OK if only the accounting modules are purchased but not OK if the organization is sold many expensive modules they will never use.

While newer ERP systems do support barcode scanning capability (usually very limited unless you are paying over \$100,000 for the ERP software) they do not support the wireless mobile computer technologies, such as store-and-forward, that are essential for reliable operation in most industrial environments, except as expensive point-solution add-ons.

The other problem with this approach is all the retraining that will be needed for the people who use the existing accounting functionality. This is very expensive and in many cases unnecessary as all that is needed is to interface a tracking system to the existing accounting functionality.

- e. Purchase a modular tracking system, such as BellHawk, that provides the middleware layer between the barcode and wireless mobile equipment and the front-office accounting, ERP and CRM systems. This software typically costs in the range of \$5,000 to \$25,000 depending on the modules selected plus the cost of software and interface customization.

The benefit here is that the software modules normally provide over 95% of the needed lines of code working out-of-the-box, thereby substantially reducing the time and cost of implementation. As the modules are designed for customization and rapid systems integration, this can be usually completed quickly and cost effectively.

Another benefit is that the existing front-office accounting and sales order entry functions can be left undisturbed when implementing the tracking solution.

- 9. Selection of the Wireless Mobile Computer methodology to be used. This is only applicable if you are planning to use wireless mobile computers with integral barcode scanners for data collection. This is generally determined by the organization's IT staff working in collaboration with the software and equipment vendors. It may have a major effect on the selection of the software to be used.



There are two critical issues that impact this decision:

- a. The need to do point-of-action validation of the data captured and to warn users if they are about to make an operational mistake.
- b. The environment in which the wireless mobile computers will be used. Most industrial environments and warehouses have lots of metal racking and equipment that block and absorb the radio waves. They also have lots of liquids and solids that can block and absorb these same radio waves as well as electrical machinery and industrial process equipment that can interfere with the transmission of data between the mobile computers and the wireless access points.

The choices of wireless communications methodology are:

- a. Terminal server, web server or client server. Here the database against which the point-of-action validation is performed is on the main tracking database server. This

then requires 100% wireless coverage with no blind-spots and no interference from electrical machinery or industrial processes.

- b. Store and forward. Here all the data validation is performed against a local database in the mobile computer. This provides rapid response and warnings to users irrespective of whether they are in communications or not at the time of data entry. Data is stored in the local database, in non-volatile memory, as it is captured. Then this local database is synchronized with the main server whenever it can access the main database.

The benefits of the store and forward approach are:

- a. Data is transferred to the main server in essentially real-time when the mobile computer is in communications range of an access point.
- b. The unit automatically switches to “batch” data collection mode, with local error checking against a subset of the main database, when the unit is out of range.
- c. Data is saved in local non-volatile memory until it can be successfully transferred to the server. The mobile computer keeps retrying, without user intervention, until it receives an acknowledgement that the data has been successfully stored away on the disk of the main server.
- d. Each mobile computer has a large subset of the data from the main server in its local database so the mobile computer is able to make complex decisions about whether to issue warnings to the user. This data synchronization takes place without user intervention.
- e. Considerable cost savings is achieved by minimizing the number of wireless access points, antennas and wiring needed. Instead of needing a wireless survey followed by the installation of many expensive antennas and access points, it is sufficient to make sure that mobile computer users have frequent line-of-sight visibility to an antenna as they move around the facility. It is often possible to cover a complete plant and large warehouse with two or three access points.
- f. Store and forward technology enables scanning and data entry to take place in yards, off-site storage locations and in the field where there is no data communications. It can also be used over Internet communications links from remote facilities and over the cell phone data network.

10. Selection of the external implementation support team. Here there are choices:

- a. Use one external organization that has all the skills needed in-house to complete the project. This is usually the most expensive option. It is mostly chosen by “Fortune 1000” companies who will hire a major contractor such as IBM or CSC and spend millions of dollars on their project.
- b. Have your project manager act as the general contractor for the project. This works well, and is the least expensive, especially if you have an experienced IT or

manufacturing engineer project manager. Here the project manager will separately purchase the software, equipment and services from a team of vendors.

- c. Have an external organization act as the prime contractor for the project. Here the external organization provides a project manager who will work with the internal project manager to coordinate a team of subcontractors, who will supply the various components for the system.

The choice of which way to go will depend on the available budget as well as the skills and time available of the internal project manager.

11. Document in detail and cost-estimate the software customizations to be performed. This is usually performed by the organization that will do the customizations. This may be the supplier of the tracking software or it may be an internal software development group providing that they have access to the source code. In the latter case, the cost estimate should include the cost of training in the internals of the tracking software. Sometimes the reports are customized by the client organization and the scan sequence customizations are customized by the supplier of the software.
12. Document in detail and cost estimate the implementation of interfaces between systems. This should include choosing interface development toolsets and documenting how they will be used. This is usually done as a team effort between specialists in the tracking system interfaces and experts in the interfaces to the accounting, ERP or CRM systems being interfaced to.
13. Develop and cost-estimate a training and go-live support plan. This may be as simple as training the project manager, who will train and support everyone else. It may involve external training and support consultants who are familiar with the operational application of the tracking software.
14. Develop a detailed budget and schedule for the project and get senior management approval. This will include schedules of payments to vendors and project milestones upon which the payments are based. Once approved, then implementation can proceed.

It is important to recognize that most industrial organizations do not have the needed interdisciplinary skills to carry out the above processes by themselves. They will need to hire consultants with the appropriate skills to assist them. They will also need to engage vendors of software, equipment, as well as training and support services in dialog and to get needed quotations. In some cases, such as detailing software customizations, these organizations will expect to get paid for the engineering services they provide.

## Implementation Process

It is critically important to realize that the successful implementation of a tracking solution requires an interdisciplinary team with many skills. This section describes some of the tasks that need to be undertaken and the skills required.



1. Let contracts for the supply of the software, equipment and needed professional services. This is a purchasing function but the internal project manager will need to be heavily involved in this process to make sure mistakes do not occur. Normally these contracts call for scheduled delivery of the software and hardware (which often require substantial prepayments) and incremental payment for services.
2. Perform the needed software customizations. This may be done by the tracking software vendor or the IT staff of the client or a mix. These customizations may be delivered incrementally, as needed, to support incremental training and deployment schedules.
3. Setup the database server. This is typically performed by the internal IT staff or the organization providing IT support to the organization. The server may be an existing server or a new server may be purchased for the tracking system. The database, such as SQL Server, will need to be installed and configured as will the security access privileges to the server. This is followed by the installation of the server-side components of the tracking system. Again this can be performed by the client's IT staff by simply following the installation directions.
4. Setup a training-room pilot installation. This will be used for training of managers, supervisors and employees who will do the actual scanning. This training room pilot will initially have a PC equipped with a barcode scanner and a laser printer. As training progresses a barcode printer and a wireless mobile computer may be added to the training room pilot. This installation and setup can be done by the IT department.
5. Train the project manager and internal team members in how to use the software. Today, this is often done on a remote basis using PC based video conferencing. We have found that an hour or so each day of remote hands-on training for a week is much more effective than a concentrated day of classroom time. This training is typically provided by the vendor of the tracking software.
6. Implement the interface from the tracking system to the other systems. This is usually done by a combination of consultants who are specialists in the external systems interfaces and experts in the tracking system interface.

Once the data elements to be exchanged between the systems are defined then much of the interface development work can be automated using available software tools. Mostly these tools require the entry of table and field data definitions and automatically then they generate the needed interface code. The needed expertise is in the data to be exchanged and the foibles of the target system relative to what data it will and will not accept.

The implementation of interfaces is usually started immediately after the database server and training room pilot are setup. Interface implementation may be done in parallel with training the inside team unless the interface is a critically important part of the user experience. Very often data such as purchase and sales orders can initially be entered directly into the tracking system and then later imported from accounting and sales order management systems.

Usually that part of the interface needed to get setup data into the tracking system is implemented first and then exports are implemented later. In many cases, organizations elect to run their tracking systems stand alone until they are operating successfully in this mode and then they implement automated interfaces.

In many cases organizations start out using manual data transfers, using comma delimited files to get setup data and even operational data into the tracking system.

Thorough testing of interfaces is essential. It used to be essential for developers of interfaces to go onto the client site to do this testing. Now that developers can have secure access to a server over the internet, this is no longer required unless the security policies of the organization preclude this.

7. Setup the data needed by the tracking system such as units of measure, item master parts lists, employee access privileges, work centers and operations. This data may be entered directly or, where appropriate, it can be imported from another system and then edited or additional information added where needed.

This is a major project all by itself and can take an organization weeks or months to complete. This work is performed by the inside team, usually augmented by lead people who are familiar with the data items being set up. These people will need training in how to do the data setups. Also IT may be involved in transferring data from other systems to the tracking system.

The most important thing to note is that there are many possible ways of using a tracking system. These differences are reflected in the setup data. Many of the high level decisions will have been made in the process mapping step but there are a thousand and one details that can trip an inexperienced user up.

Some typical issues that confuse people are:

- a. Do we use the same part number for the same material when it appears in different configurations?
- b. Do I use separate operation codes for the same operation performed in different work centers?
- c. What is a work center and how does it differ from an inventory location?

At this stage, if the inside team does not have the needed experience, it is recommended that an outside consultant, who has been through this before, be used to guide and advise the inside team in this process. This is usually done on a remote basis.

I also advise the inside team to only put in a limited amount of data, enough for testing out the most common operational scenarios but not more. The reason is that, inevitably,

decisions made about setup data turn out to be wrong once everyone gets to try out using the system in a training room environment.

In trying out the system in a training room environment, a tremendous amount of organizational learning takes place leading, usually, to a decision to wipe out the contents of the pilot database and start again before the system goes live. Sometimes it takes two or three attempts to get a data representation for what goes on in the facility that everyone is happy with. So keeping the amount of training data small saves a lot of data entry and setup time and encourages experimentation.

8. Introduce barcode printers into the training room pilot. These require the installation of a barcode label generation program that provides the interface to the printer and is compatible with the tracking software. The installation of the equipment and the software is usually performed by the vendor of the equipment. The vendor will also be able to provide needed supplies such as labels and ribbons.

Note that it is recommended that, initially, people using the training room pilot use pre-printed rolls of “license-plate” tracking barcodes for training as these do not require any training in the use of barcode printers. Some organizations keep using these license-plate tracking barcodes forever as they are simple and can be ordered at modest cost from a variety of suppliers. But other organizations need to have labels that have human readable and hazardous materials information printed on their labels along with the tracking barcodes. These organizations then need to master the complexities of barcode printers.



Barcode printers that are capable of printing labels that will stand up to the abuse of industrial environments typically use a thermal-offset process that melts a wax or resin ribbon onto a plastic substrate. These are much more complex to setup, use and maintain than your office laser printer. It is essential that users be trained in how to use and maintain these printers. It is also important that a field technician from the vendor periodically services the printer.

Once the printer is installed and up and running, then one or more people at the using organization need to be trained in how to use the label software. Usually this training has two parts:

- a. Training in how to use the label generation software to create new label formats. This is usually done through a mix of on-line training provided by the developer of the label generation software and training provided by the supplier of the barcode equipment and software.
- b. Training in how to setup the field name relationships in the label software so they will be automatically recognized by the tracking software. This is usually provided by the vendor of the tracking software to the IT department.

If barcode labels with embedded RFID tags are to be used, then a more complex printer is needed and more training needs to be provided in the use of the printer and the setup of

the label in the label generation software. Expert advice is also needed in the types of RFID tags to use for specific applications.

9. Adding mobile computers to the training room pilot. Here there are several parts to the process:
  - a. Loading the tracking software onto the mobile computers and on the main server. This is typically done by the IT department but the mobile computers may also come with the software pre-loaded by the mobile computer vendors.

- b. Installing and wiring wireless access points and antennas. A simple office desktop access point may initially be used for the training room pilot but we highly recommend installing industrial access points before system's deployment.

Please note that the access point(s) and the main server need to be connected to a router to enable return path routing back from the main server to each individual mobile computer.

- c. Setting up the wireless access points and their security parameters to enable the wireless mobile computers to communicate with the server. Also setting up the security parameters in the wireless mobile computers to enable them to communicate with the access points.
  - d. Testing that the wireless mobile computers are collecting data correctly and are relaying this correctly to the main server.

Installing the access points and antennas and related wiring may be done by the suppliers of this equipment or by the organization's own maintenance department. But, if an organization is using its own electricians, please make sure that they closely follow guidelines for antenna mounting and placement and cable run limitations.

Setting up the security parameters for the access points and the mobile computers will typically be performed by the organization's IT staff assisted by the equipment vendors, as needed.

10. Preparing to train users in how to perform data collection tasks. Here it is important to realize that data collection takes a small amount of a lot of people's time. The task of data collection should be segregated into actions that need to be performed by individual people or small groups of people. Material handlers doing picking, packing and shipping do not normally need to scan work-in-process between jobs so they do not need to learn these data entry actions.

For each role, it is important to prepare a sequenced list of the steps to be taken in each type of data entry that a person in that role is responsible for. These lists typically have the barcode label or a picture of the icon to be selected to initiate the scan action.

These instruction sheets are used as the basis of training users. They should be in language that the users are familiar with in their everyday usage at the plant or facility.

11. Train the users in how to perform data collection, using the training room pilot. It is beneficial to do this on a functional area by functional area, such as by starting in receiving

and then moving to stock room operations. Sometimes it is useful to start with supervisors and lead people and then progress to material handlers and production workers.

This training can be done by the project manager and members of the inside team, if they have time. If not, then an external training organization can be used.

Several points to note here for the trainer(s):

- a. Pay special attention to feedback from the trainees about how the system will be used. They may well spot issues that have not been thought about and could cause operational problems if not fixed. These can sometimes require additional customization of the software to handle special cases. These conversations often begin in the form “What about the special shipment we make to XYZ Company once a quarter?” and lead to some very interesting conversations amongst managers who were not even aware of the transactions that will cause trouble if not handled..
  - b. Pay attention to suggestions by trainees about how the data collection process can be improved and especially suggestions about how overall operational flow can be improved as a result of implementing the new tracking system. These are “Kaizen” events that can lead to some significant grass-roots reengineering activity.
  - c. Tell employees that the intent is not to make any major changes to operations (unless major changes are planned) but simply to capture data about jobs and materials. This is to minimize the pushback due to the FUD (fear, uncertainty and doubt) factor. We have found that implementing a new tracking system can facilitate major changes and improvements in the ways that an organization does its business. But we do it in such a way that people don’t feel threatened by all the negative connotations of process re-engineering (job loss or other negative personal impact of major changes). Instead we enable them to make the changes, all under the guise of collecting data.
  - d. Train the users to do their data collection tasks on at least three separate occasions and, even then, they will make mistakes when the system goes live.
  - e. Encourage trainees to bring examples from their regular work-flow so that they are working on real-data. This may need some preparation by the trainers but is well worth while to ensure familiarity.
12. If the system is to be deployed in a warehouse or stockroom then all the shelves, bins and racks and floor locations need a tracking barcode. Locations should be given a rational code that is meaningful, such as “E24C” for aisle E, bay 24, shelf C, so that these are easy to identify and recognize by material handlers. The location barcodes can be printed internally, if an appropriate barcode printer is available, or outsourced to label printing organization. Large retro-reflective barcodes, suitable for hanging over floor locations, will be to be ordered from the providers of these specialty labels.



This activity can be handled entirely by the internal team although it may be beneficial to subcontract the whole time-consuming job to an organization that specializes in labeling warehouses and stock rooms.

13. Preparing for deployment. The keyword here is incremental. Do not attempt to go live with your tracking system in all departments and functions at once. This is a recipe for disaster. Start in receiving or shipping or somewhere in the middle and get the data collection for that function working and then move onto the next.

The reason for incremental deployment is that, despite all the training, people will make a lot of mistakes and have a lot of questions. You will need to have one or more people dedicated to helping these new users in each department during the first few days of using the system. If you try to go live in multiple departments at once, you simply cannot get enough knowledgeable people on-site at once to help these people.

The demand for assistance during go-live in a department is a large time commitment for the project manager and the departmental supervisor(s) and/or manager(s). It may be well to have additional support from external organizations to assist in this process.

Be prepared to have to fix mistakes by making edits to the database. There are mechanisms in most tracking systems for correcting the occasional mistake but the volume of mistakes during the early go-live period often it easier to make the corrections directly in the database. This can be done by the IT manager or by the support organization for the tracking software. It is important to make sure that people with the appropriate technical skills are available to fix problems during these go-live activities.

In addition to this, you have to do the obvious tasks of making sure that the needed equipment is deployed and working in each department prior to going live. Also make sure that users are entered into the system with appropriate access privileges.

14. Deployment, the big event or hopefully non-event, if everyone has done their job properly as part the implementation team.
15. Post-Deployment. After the system starts running and managers and supervisors can see the information they need in real-time, two things happen:
  - a. They quickly become dependent on the tracking system and complain bitterly when anything goes wrong (even if it is due to a data entry mistake by their own people). This requires a quick response, usually by the IT department, assisted by the vendors who supplied the software and equipment to resolve issues. This implies that the organization needs to have support contracts in place, before and not after problems arise.
  - b. They want lots of different custom reports. Most tracking systems come with a set of standard reports but everyone wants their own reports with the available data presented in their way. This leads to requests for many custom reports. These can be developed by the IT organization or subcontracted, typically to the supplier of the tracking software.

Over time, responsibility for the system migrates from the project manager and the internal team to the IT manager as the tracking system becomes just another system for the IT department to manage.

Operational managers also discover some human resources challenges, such as:

- a. Employees who don't have the ability to do accurate data capture. A feature of many tracking systems is the ability for managers and supervisors to correct employee mistakes. If this happens too often then managers need to take corrective action.
- b. The data from the system shows that certain people are not working efficiently or that certain processes need improvement. This is all to the good but presents its own unique challenges.

15. Additional Phases. Usually these systems implementations are divided into phases, with each phase having its operational objectives. Once the initial phase has proved its worth then there is usually a time lag of a number of months, while the impact of the new system is assessed. Then it becomes apparent that the capabilities of the tracking system can be expanded at modest cost to meet new objectives and a truncated implementation process starts again for the new objectives.

### **Costs and Benefits**

The external cost of implementing a barcode tracking solution, using a middleware software approach, typically ranges from about \$10,000 for a simple PC based departmental system to about \$120,000 for a wireless mobile computer system that will serve the production and inventory tracking needs of a facility. Organizations typically initially spend around \$60,000, of which one third is for software licenses, one third for barcode and wireless mobile computer equipment and one third for professional services. This is usually expended during the 3 to 6 months it takes to implement a tracking solution.

Additionally, organizations should expect to spend between 10% and 20% of this amount for consulting and pre-deployment engineering support services.

Over the following two years, most organizations typically spend the same amount again, primarily on support services, custom reports and software customizations to add capabilities to their tracking solutions.

The average payback time in improved efficiencies and reduction in labor costs for a barcode tracking solution is typically less than 6 months. Some pay for themselves in a few weeks and some take as long as a year. The average life of these systems is estimated at 5 to 7 years although they can be kept running much longer with upgrades to computer hardware and wireless mobile computer technology. So the ROI (return on investment) is very good, providing the system implementation is successful.

### **Conclusions**

It is apparent from the above description that successfully implementing a barcode tracking solution is a non-trivial process. The pay-off both in terms of operational efficiencies and preventing major business problems due to employee mistakes can be very high. But these are only achieved if the system is successfully deployed.

Implementing a barcode tracking solution requires a multi-disciplinary team with team members who are experienced in addressing the myriad of problems that will inevitably arise during systems implementation.

It is essential to have the following skills available:

1. An internal project manager who has good project management skills. This person may be supplemented by an external project manager.
2. A consultant/systems architect who has extensive knowledge of industrial production and inventory tracking practices as well extensive knowledge about tracking system software, barcode equipment, wireless mobile computing, information technology and human factors.
3. A knowledgeable vendor who can provide barcode and wireless mobile computer equipment as well as providing on-site equipment support and repair services.
4. A knowledgeable IT support organization that can provide support during the implementation phase and then take responsibility for on-going support of the system after it has gone live.
5. An organization that can provide most of the needed software pre-built and can provide needed customization services at cost-effective prices.
6. Technical staff members who are knowledgeable about the interfaces available for the tracking system and the ERP, accounting and CRM systems with which it will exchange data.
7. Training and support staff who are experienced in industrial operations and can assist employees during the transition to using a barcode tracking solution.
8. Senior management that is committed to seeing the system implemented and working with the implementation team to overcome the inevitable problems that will occur.



## Pre-Deployment Testing

### Introduction

A critical part of any barcode systems implementation is the pre-deployment testing of the system by the client's team to make sure that it works correctly. This chapter describes in detail the recommended steps in that process.

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Implementing a barcode tracking system can dramatically improve an organization's efficiency and customer service. In some cases our clients have saved millions of dollars and quadrupled their sales as a result of having implemented a barcode tracking system.

But there have been other cases where the tracking systems have failed to go live. The primary reason for this is a failure of the client organization to take ownership of the system and to thoroughly test the system before deployment. This chapter gives a recommended process for testing the system as it is implemented and deployed in a number of phases:

1. Equipment and software installation and check out
2. Preliminary operational testing
3. Evaluation of need for customizations
4. Systems integration testing
5. Operational testing
6. Running in Parallel
7. Go-Live



I have chosen to open this chapter with the Chinese symbol for Crisis, which consists of two parts: Danger and Opportunity. If you are the project manager in charge of deploying a barcode tracking system, it will often feel like you are in crisis during this period of time, with many conflicting demands on your time and many multi-disciplinary project problems to solve. There is great opportunity for a successful installation to become the basis for great cost-savings and sales growth for your organization, which will make you a hero. But there is also danger in that failure to successfully deploy the system can significantly damage your career (at least with your present employer).

I hope that the following guidelines will help you avoid the pitfalls in this process.

Happy dragon slaying!

## Phase 1: Equipment and Software Installation and Check Out

The first phase of this is typically performed by the client's IT department or an external IT consulting organization. This phase typically involves the following steps:

1. Installation of needed PCs and a database server computer, including the installation of appropriate database server software on the database server computer.
2. Installation of LAN networking components to link the PCs to the database server and verification that the PCs can remotely access the database server.
3. Installation of barcode scanners attached to any PCs that will be used to perform barcode scanning and the verification that the scanned data is correctly entered into the keyboard buffer of the PC, including the automated generation of return and line feed characters.
4. Installation of an empty tracking database on the database server. The installed database will contain all the necessary tables and stored procedures as well as required initialization data.
5. Installation of user interface software on the PCs, including establishing and verifying communications between the PC based front-end applications and the back-end tracking database.
6. Installation and setup of needed wireless access points and antennas, including verification that the wireless access points are able to communicate with the server.
7. Testing the wireless mobile data collection devices to ensure that they are able to communicate with the server computer through the wireless access points.
8. Installation and setup of the data collection software on the mobile data collection devices and ensuring that the mobile devices can communicate with the tracking database.
9. Installation and setup of any required barcode label printers. This includes loading label and ribbon stock and ensuring that the printers are network accessible.
10. Installation and setup of barcode labeling software including verification that labels can be printed on demand on the label printers.



Please note that, at this stage in the project, only one model of each mobile computer and barcode scanner and printer that the organization is planning to use for the project should be purchased and installed and tested.

As systems testing progresses and end users are exposed to the issues of using this equipment on a day-in day-out basis, clients often make changes to equipment selected for tracking in specific operational functions. Barcode equipment is like automobiles, once purchased its value declines rapidly and is often hard to return, even in new unused still-boxed condition, after 30 days. So only purchase the minimum equipment you need for testing purposes at each phase in systems testing and check out.

## Phase 2: Training Room Pilot

The next phase is testing the operation of the software and is typically performed by operations managers and supervisors whose people will enter data into the system.

Typically this preliminary operational testing is performed in a training room pilot environment on an un-customized version of the tracking software (unless customizations are required for specific basic operations to take place). This testing is often performed with the assistance of a trainer who is familiar with the operation of the tracking system.



Initially the project manager and the managers and supervisors using the barcode tracking system for the first time may feel overwhelmed by the complexity of the system (which is often more complex than the ERP or accounting system to which it is attached). But with the help of user manuals and training videos, supplemented by web-based and on-site training sessions, they will become familiar with how the system work in a few days (typically spread out over several weeks, with a few hours per day).

This learning process typically takes place as part of the initial operational testing of the system.

Initial testing is done with a limited set of data on a stand alone system and follows the following set of procedures:

1. Enter basic initialization data such as company, unit of measure, facility, department, and work center information.
2. Enter a small number of employee's who will be test users of the system
3. Enter a small set of representative item master parts.
4. Enter a small set of inventory locations.
5. Practice entering and withdrawing materials from inventory, viewing the resultant changes to inventory.
6. Practice entering vendor POs and receiving materials against those POs using PC based scan transactions. View resultant changes to inventory.
7. Practice putting away received materials and putting the materials away in a simulated stock room or warehouse. View resultant changes to inventory.
8. If job tracking is being used, then practice creating routes and bills of materials for items to be produced.
9. Practice creating jobs and printing out barcoded travelers.
10. Practice recording the consumption of materials on jobs using a PC based scan station and viewing the resultant changes in inventory.

11. Practice scanning people in and out of job steps using PCs and viewing the resultant labor records.
12. Practice recording work-in-process transfers between job steps using a PC based scan station.
13. Practice recording finished goods out of job steps using a PC based scan station.
14. Practice simulating the putting away of finished goods in the warehouse using a PC based scan station.
15. Practice entering customer sales orders into the system and generating barcoded picking sheets.
16. Practice “picking” finished goods for a customer order using a PC based scan station, as well as recording the shipment of finished goods.
17. Print out and examine the various tracking reports produced by the tracking system.

Once the users are familiar with performing the scan actions using PCs they should then repeat the testing using mobile computers so as to familiarize themselves with the differences imposed by the smaller ergonomic form factor of the mobile devices.

Supervisors and managers may also want to test out special functions, such as quality control tracking and the printing of barcode labels on a barcode printer.

In all the above testing, it is important for clients to generate written test plans with specific test cases and expected test results so as to ensure that the system is tested in a manner that is consistent with its expected use.

### **Phase 3: Customizations**

As a result of the preliminary operational testing, the supervisors and managers may well come up with a list of changes that they would like to have made to the system in order to make it work better for their specific application. Such changes may include:

1. Changes to reports and screens displaying status information to provide different data or the same data in a different format.
2. Changes to scan data collection sequences to eliminate steps that are not needed in this specific application.
3. Changes to scan data collection sequences to capture additional data.
4. Changes to standard forms, such a job travelers, picking sheets and packing lists.
5. Changes to generate special barcode labels at specified points in the process.
6. Additional data verification and real-time warnings to be given to scan device users.
7. Email alerts to be sent to supervisors when certain events occur

Vendors of barcode tracking systems will typically provide such customizations on a fixed-price basis after receiving detailed written specifications for the changes requested.

To enable the programmers of the tracking system software to properly test the customizations they make, it is a good idea if the client generates a set of test data and then sends a backup of the test database to the tracking system vendor to be used in testing the customizations prior to shipment to the client.

Once the customizations have been made then the client's managers and supervisors need to retest the system to make sure that it performs as specified.

#### **Phase 4: Systems Integration Testing**

Often the barcode tracking system needs to be integrated with the other systems, such as ERP, accounting, CRM and process control systems and test equipment, with which it will exchange data. These interfaces are implemented by teams of programmers who are knowledgeable about the internals of the databases and systems that need to exchange data.

These teams will do their own functional testing but it is important for the client's own team to do operational testing to make sure that the interfaces work as specified. Typically the testing of an interface with an ERP or accounting system goes as follows:



1. Enter a vendor purchase order in the accounting system or ERP system. Make sure that it gets transferred correctly to the tracking system.
2. Perform a receive transaction against the PO using the tracking system. Make sure that the appropriate inventory and PO changes are reflected in the ERP or accounting system.
3. Enter a job into the ERP system, with route and BOM, and make sure that the job gets correctly transferred to the tracking system.
4. Print out a barcoded traveler in the tracking system and perform transactions against the job using the tracking system. Make sure that the appropriate changes to the inventory are reflected in the ERP system and that appropriate labor and materials charges to the job occur.
5. Enter a sales order in the ERP, accounting or CRM system and make sure that this is correctly transferred to the tracking system.
6. Generate a barcoded picking sheet in the tracking system and pick, pack and ship a customer order. Make sure that the appropriate inventory changes are reflected in the ERP or accounting system and that shipment/invoice data is correctly generated in the ERP, accounting and CRM system.

This testing should first be performed using PC transactions and then using mobile computer transactions, for a complete, end-to-end zig-zag test.

Data exchanges with an ERP, accounting or CRM should be tested using a test database containing realistic data (normally a copy of a live ERP, accounting or CRM database). This is so that problems with exports from the tracking system do not have a negative effect on live operations. Also it is much easier to repeat tests with a test ERP/accounting database that can be restored to a prior state as often as necessary.

Testing of interfaces to process control systems and test equipment is generally more situation specific but follows the same principal of ensuring that the correct data is captured in response to specific events.

### **Phase 5: Operational Testing**

Once the system and its interfaces have been tested with limited data and all bugs fixed and issued resolved, then it is time for the client's team to start operational testing.

This typically starts with setting up all the inventory locations and making sure that all these locations have location barcode labels and that these are correctly entered or imported into the tracking system database.



Then bulk data such as the item master parts lists, employees, work centers, operations are imported from the ERP or accounting system. Then the data imported into the tracking system is carefully inspected to ensure that the data was all imported correctly.

This is followed by importing all available purchase orders, jobs and sales orders into the barcode tracking system and making sure that the imports all were correct.

The next step is the initial training of material handlers and production workers who will be responsible for capturing data using the barcode scanning devices. This training should be specific to the job function to be performed by the employee and should be repeated in several short (less than one hour) training sessions in a small group setting using realistic test data imported from the test ERP or accounting system database.

This initial training may result in operational issues being raised that need to be addressed by further customization to the software or by changes to operational procedures. It also may raise issues about the suitable choice of barcode scanning and printing equipment for a specific application area.

Once these issues are resolved, all the equipment needed for going live should be purchased, setup, loaded with software and checked out that it works.

A written test plan should then be prepared to test the barcode tracking system in conjunction with a test ERP or accounting system database, with which it exchanges data. This test plan should include several examples of each of the cases that the system is expected to handle in regular operation. It is often beneficial to collect these test examples as part of the initial end-user training that is performed as part of this phase.

Each of these tests should then be run individually according to the test plan and the results carefully evaluated test by test. If there appear to be discrepancies then screen shots of the discrepant data should be immediately taken along with backups of the tracking system database and the ERP or accounting system database (if the problem involves a data transfer). Electronic copies of the screen shots, plus the database backups, plus copies of log-files and other relevant data should then be placed in a separate folder on an FTP site where it is accessible to the software developers.

Then a detailed description of the problem (cause and effect) should be prepared in writing and forwarded to the software development team for their evaluation.

Please note that it is critical that database backups be taken immediately after the test has been completed and before the next test is run otherwise it may be impossible to determine the cause and effect relationship that caused the problem.

Most software vendors will charge for setting up and evaluating problems that are not obviously bugs. So submitting an error report that essentially says “this number in this report looks odd” can result in setup and investigation charges for many hours of labor to find out whether the reason was a data entry error or a user’s misunderstanding of how the software should work or a genuine bug in the software. So submitting precise cause and effect error reports is important for avoiding these charges.

It is important to closely evaluate the apparent problem with the software against the data being used and the functions as described in the Users Manual for the system or the specifications for any customizations. This is because, in my experience, well over 90% of the reported problems are due to data entry errors or misunderstanding with how the software is supposed to work. Those that are due to genuine bugs are usually easy to spot as they usually result in system level error messages from the software itself or the underlying operating system software.

It is important to distinguish between bugs in the software and the fact that the out-of-the-box software does not do exactly what you want. In general, pre-packaged software is provided on an as-is basis. That is, the software is warranted to perform the functions as specified in its documentation but nothing more. To have the software perform differently, or to have different legends on screens and reports, you need to order specific customizations from its vendor.

Also, just because you find a bug in the tracking software, it does not mean that the vendor of the software will rush to fix it. Obviously if it is a problem that makes the software fail to run and generates an internal system error, then the vendor will perform an emergency fix. But these cases are very rare. In most cases, the problems are not “show-stoppers” and fixes for these are typically incorporated in the next release of the software.

## **Phase 6: Parallel Operation**

After the operational testing is complete and all issues resolved, it is then recommended that the tracking system be operated in parallel with existing systems. In this phase, the tracking system is configured to receive live feeds from the operational ERP, accounting and other systems but does not export data to these systems.



In this phase, is recommended that the tracking system then be incrementally deployed, in a side-by-side mode with existing tracking systems on an operation by operation basis. For example an organization may start out with deploying the tracking system in receiving and put-away and then proceed to production and then finally to picking, packing and shipping.

The reason for this is that the employees doing the data collection will need a lot of hand holding during the first few days that they go-live and it is impossible to provide enough personnel to do

all the hand-holding needed if all the operations in the plant go-live at the same time. It is much easier to go-live incrementally, in parallel with legacy data capture, than to attempt to switch the whole plant from a legacy (often manual) system to a new automated barcode tracking system all at once. In my experience the probability of failure in attempting to switch over on a whole-plant at once basis is very high and should not be attempted.

The parallel go-live in each operational area should be immediately preceded with refresher training where needed for the employees who will do the data collection. Then trainers should be on hand to provide support as each operational area goes live to resolve issues as they arise. This includes showing material handlers and production workers how to handle specific data entry situations and also assisting supervisors and managers with correcting any mistakes that have been made.

With the incremental parallel approach, clients can always call halt to the deployment process if issues arise that need to be dealt with before proceeding, without unduly impeding on-going operations.

### **Phase 7: Go-Live**

This really should be a non-event for the people using the tracking system if all the previous testing and training has been completed correctly.

Once data capture using the barcode tracking system is running smoothly then the legacy data capture system can be switched off or stopped and the transactions recorded by the barcode tracking system used as a live-feed to the attached ERP, accounting or CRM system.

During the parallel operation phase, and initially after going live, the data generated by the tracking system should be closely monitored to ensure that it is correct and also that employees are not making data entry errors.

Then that should be it. The tracking system is running smoothly. You are the hero who slayed the dragon.

But of course that is not the way it works out. As soon as people find out all the things that their new barcode tracking system can do to make their lives easier, they will want to add more functionality to the system. And so the saga continues.....





## Author Biography

This Handbook was written by Dr. Peter Green, who is the Chief Technology Officer of BellHawk Systems Corporation. Dr. Green is an APICS member who is a recognized expert in the use of barcode, RFID and wireless mobile computer technology to capture tracking and traceability data. He frequently gives talks on this subject to professional groups.

Dr. Green was educated at Leeds University in England where he received his BSEE and Ph.D. in electronics and computer science degrees. Dr. Green was previously a Professor at WPI and a member of the research staff at MIT. He and his team at BellHawk Systems have implemented over 70 tracking and traceability systems over the past decade for a wide variety of industrial, commercial and Government clients.



Dr. Green consults with organizations during the planning phase of their barcode tracking systems. He also provides advice and counsel to senior management in how to handle issues that inevitably arise in the deployment of these systems.

Dr. Green is also very actively involved in continuously improving BellHawk Systems' software technology and in the development of interfaces to external systems.

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**For more information, please contact David Holliday at Winco ID at 1-800-325-5260 x 237.**



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