Materials Tracking and Traceability & Work-in-Process Tracking Handbook

Everything you need to know
before implementing a work-in-process
or materials tracking and traceability system

Dr. Peter Green

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Preface

It is easy to plug a barcode scanner into the USB port of a PC and scan a barcode into an Excel spreadsheet. But there is a tremendous gulf in know-how between this simple experiment and implementing a fully functional materials tracking and traceability or work-in-process tracking system.

This handbook was written to enable mangers and staff of industrial organizations to educate themselves about how to implement materials tracking and traceability systems, with a special emphasis on the needs of operations managers and IT people, who are often tasked with implementing these systems.

This handbook gives an overview of the principles, methods and technology used in tracking and tracing materials in the industrial, medical, food, and construction supply chains. It also provides an introduction to the standards that need to be followed as well as the tradeoffs involved. It is based on the know-how, about what-not-to-do, as well as what-to-do, accumulated by Dr. Peter Green in over two decades of assisting clients implement over 100 materials tracking and traceability and work-in-process tracking systems.

Author

This handbook was written by Dr. Peter Green, who currently serves as the Technical Director of KnarrTek Inc. and Milramco LLC. Dr Green obtained his BSEE and Ph.D. Degrees from Leeds University in England. Subsequently Dr. Green was a senior member of technical staff at MIT and a Professor of Computer Engineering at WPI. Dr Green is an expert in materials tracking and traceability within the industrial, medical, and construction supply chains. He is also an expert in using real-time Artificial Intelligence to assist mangers with operational decision-making in industrial organizations.

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Preliminary Edition

This handbook is being released in preliminary electronic form as a PDF for download before being published as a hard copy book and in a Kindle edition. The author is doing this because it contains a lot of useful information that the author wants to get into the hands of a number of people who are about to embark on the deployment of work-in-process or materials tracking and traceability systems.

This preliminary release is also to solicit feedback about improvements that can be made to this handbook, before it is finally published, ranging from spelling mistakes, to misstatements of fact, to areas where more material needs to be added or better explanations given. If you would like to make such comments, please send your feedback to the author at pgreen@milraco.com.

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Chapter 1 - Overview

1.1 What does "Materials Tracking and Traceability" mean?

The term "Materials Tracking and Traceability" encompasses the principles, methods and technology used in tracking and tracing materials from their origin as raw materials to the finished products delivered to the end-user.

"Materials Tracking" can include tracking:

- Mining and extraction of raw materials such as oil and iron ore.
- Harvesting food and catching fish.
- Conversion of raw materials into precursor products, such as chemicals, metals, and plastics.
- Transporting and distributing raw materials
- Making of products by converting precursor products into products that can be used by another manufacturing process or by an end-customer
- Packing, labeling, and distributing products into the retail supply chain.

Material Tracking not only includes tracking the movement of materials within manufacturing plants and warehouses but also includes tracking the transformation from raw materials, through intermediate materials, into finished products through a sequence of operations. It also includes tracking work-in-process (WIP) materials as well as tracking the shipping and receiving of materials and the movement of those materials in the supply chain.

"Materials Traceability" is the capturing and recording of materials tracking data so that we can trace-back from a finished product to all the raw and intermediate materials that went into that product, as well as the people, equipment, and processes involved in its manufacture and distribution. It also includes the ability to trace-forward from a defective raw, precursor, or intermediate materials to all the affected finished products so they can quickly be recalled.

Materials Traceability may mean different things to different people. For people within a manufacturing, food, or pharmaceutical processing plant it typically means tracking:

1. The receipt and put-away of raw materials, which may often be precursor products made by other manufacturing plants.
2. The quality control testing of those materials
3. The conversion of these materials into intermediate and then finished products, including tracking work-in-process materials.
4. The testing, packaging, and labeling of finished products.
5. The packing and shipping of products to other organizations.

Here the materials tracking and traceability is limited to what takes place within a single manufacturing plant. The same holds true for most distribution warehouses.

Other organizations, such as large retail or restaurant chains like Wal-Mart or McDonalds, are concerned with traceability throughout their entire supply chain as they are legally liable for selling defective products to their customers, irrespective of whether it was the fault of the chain or one of their supplier's suppliers.

Here there is a need to aggregate materials traceability information for all their supply chains, so that they can quickly trace-back from finished products to potential sources of defect and trace-forward from those sources of defect to all impacted products.

1.2 Why is Materials Tracking and Tracing Materials Important?

The primary reason is to minimize harm to people. The secondary reason is to minimize the economic cost to organizations resulting from defective materials or products.

The Centers for Disease Control (CDC) estimates 48 million people get sick, 128,000 are hospitalized, and 3,000 die from foodborne diseases each year in the United States. About 200 people die each year from defective tire-related automobile crashes on U.S. streets, roads, and highways.

In Fiscal Year 2018, the US Customs seized counterfeit goods valued at over $1.4 billion at U.S. borders. These counterfeit goods spanned across multiple industries including everything from apparel, accessories, music, software, medications and cigarettes, to automobile and airplane parts, consumer goods, toys and electronics. Some of these counterfeit goods cause economic harm to US Corporations. Others resulted in death or serious illness for consumers.

A small vial of the chemical Ricin, which can be easily produced from naturally growing castor beans, could kill up to 10,000 people if added to ground coffee or similar widely used products. Other bioweapons, such as laboratory modified pathogens, can be even more deadly when added to drinking water supplies or to animals slaughtered in the course of trade.

When people start to unexpectedly get ill or die, the first step is to trace-back from possibly defective or contaminated materials to identify the source of the defect. The next step is to remove all products from the supply chain, which are affected by the source of the defect, so that more people cannot be killed or injured.

This can be relatively straight forward if everyone involved has kept good traceability records in electronic format so that the source can be rapidly identified and just the affected products recalled. It becomes much more difficult and expensive when organizations do not keep good records as then a broad swath of products have to be recalled.

One manufacturer of ground beef received contaminated meat from one of their suppliers but they had no record of which batches of ground beef the contaminated meat was used in. As a result, the US Department of Agriculture ordered the beef processing plant to recall all products they had made in the past 3 years, which amounted to about 20 million pounds of beef.

The US Government agencies' reasoning, in selecting 3 years, is that most foodstuff has been used or otherwise removed from the supply chain in this time period.

The result was that the beef processing plant declared bankruptcy in 6 days, and went out of business after 60 years, as it was responsible for repaying all its customers for the recalled ground beef and for destroying millions of pounds of potentially contaminated ground beef.

The sad thing is that, if they had kept good electronic materials tracking and traceability records, the needed recall would have been limited to a few hundred pounds of ground beef and not the 20 million pounds of ground beef they had produced over the past 3 years. This would have avoided a huge wastage and unnecessary destruction of good food and the business would probably still be operating today.

A similar incident happened to a local maker of ravioli stuffed with green peppers. They received a contaminated batch of green peppers and failed to record which batch of ravioli they were used in. Some people developed food poisoning as a result of eating the ravioli at a number of local restaurants. Because the company had not kept good traceability records, the US Food and Drug Administration ordered a recall of all ravioli made by this company in their supply chain. This recall cost this small food processor over $1 Million by the time they had retrieved all the potentially defective products and reimbursed their customers for the defective product they had shipped.

Again, the cost of this recall could have been minimized if they had known which batches of ravioli were affected and just been able to recall those contaminated batches.

In both these cases, the recall could have been much quicker and simpler, thereby avoiding further people getting ill, if the companies had kept good materials tracking and traceability records. The economic impact would also have been much smaller.

These problems are not just limited to food. In 2001 Ford Motor Company had to recall 13 million tires on its Ford Explorer sports utility vehicles. Failure of these tires resulted in 250 deaths and 3,000 non-fatal injuries in roll-over accidents, over a period of about 2 years before the recall was initiated, at a total cost of over $2 Billion.

While both Ford and Bridgestone, the Firestone-brand tire manufacturer, denied responsibility, it would appear that the cause was due to an untrained employee using an improper manufacturing process to make tires on one shift for a few weeks. The result was that only a few thousand tires out of the 13 million in total that were made by the plant were defective and delaminated at high speed, causing rollover crashes. But neither Ford nor Bridgestone had kept good Materials Tracking and Traceability records as to how each tire was made, which led to significant delays in identifying the root cause of the problem, and during which many people unnecessarily died or were injured.

Of current concern is Counterfeit Pharmaceuticals. As we are learning in the current epidemic, many of the drugs that we use in the USA are made overseas, or their precursor materials are made in countries such as China that have lax and opaque reporting on the origins and manufacture of these materials. As a result, many pharmaceuticals we use may potentially be defective or contaminated.

The World Health Organization reported that Fake drugs kill more than 250,000 children a year worldwide. In order to protect the USA, the US Congress has passed to Drug Supply Chain Safety Act (DSCSA) which requires all manufacturers and distributors of pharmaceuticals in the

USA to validate that the materials they use come from reputable sources. It also requires that these organizations enable consumers to be able to check whether the pharmaceuticals they have purchased are genuine.

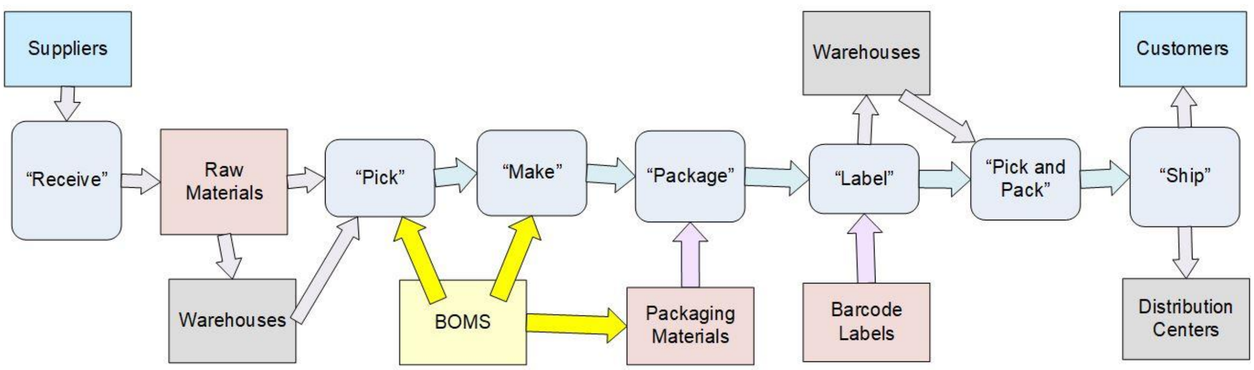
Similar requirements exist for medical devices and supplies as well as for many other products that impact the health and well-being of people and their pets and farm animals. This includes materials used in constructing buildings as well as tracking the repair and maintenance of items like jet engines and aircraft landing gear.

Minimization of harm to people, their pets, and animals requires that these organizations maintain accurate and up-to-date materials traceability records so that the source of defects can quickly be identified and the scope of the recall limited to just the affected products.

1.3 Materials Tracking and Traceability versus Inventory Tracking

One of the commonly asked questions is "I track inventory using my ERP (Enterprise Resource Planning) or WMS (Warehouse Management System); is this the same as Materials Tracking and Traceability?" The simple answer is no.

Inventory tracking, which is what ERP, WMS, and accounting systems do, are item locator systems. They track the quantity and value of materials at specific locations. This certainly could be considered a form of materials tracking but it is done for different purposes. Inventory tracking is done primarily for accounting purposes, to be able to report the value of an organization's inventory on its balance sheet. In ERP systems, it is also done for the purpose of planning the purchase, making, and future movement of materials.



Materials Tracking and Traceability, on the other hand, involves tracking the flow of materials within a supply chain. Within a manufacturing or processing plant, it involves tracking the receipt and put-away of raw materials, their transformation into work-in-process, intermediate, and finished materials, and then the picking packing and shipping of those materials to end customers and distribution centers.

Within manufacturing plants, warehouses, and distribution centers tracking the flow of materials may include operations such as repacking and relabeling products, kitting and ensuring that products are stored at the correct temperature and humidity.

Within supply chains, this may also include tracking the flow of materials through operations such as mining, harvesting, and fishing, as well as the transportation of materials between manufacturing plants, warehouses, and eventually locations where the products is delivered to the end-user.

The key here is that we are tracking the flow and transformation of materials from one form to another, such that we have the data to track back from defective products to their source and track forward from the source of defects to everywhere those materials are in the supply chain, so they can be rapidly be recalled before they cause further harm.

We may start with two different farmers harvesting lettuce and tomatoes and a manufacturer making clam-shell plastic enclosures.

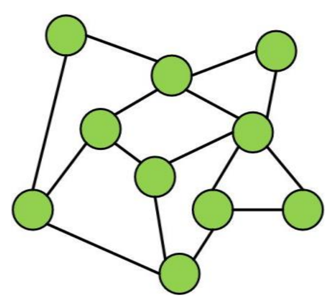
A food processor combines all three of these elements to make a prepackaged salad which can be sold in a supermarket or fast-food restaurant chain.

If people become ill after eating the salads then it is critical to be able to track back to which batch of tomatoes and lettuce from which farmers were used as well as the plastic clamshells, which themselves could be a source of contamination.

Thus, if we are the food processor, it is critically important to not only track how many pounds of lettuce and tomato we have in inventory and how many finished salads we have in our freezer, but also to be able to track and trace which raw materials went into which products.

In the supply chain, it can be critically important to track the field where the lettuce was grown in case there was contamination by fecal matter from animals, or the greenhouse where the tomatoes were grown, in case the wrong chemical was applied to kill bugs that could eat the tomatoes. It may also be critical to track who made which batch of clam-shells, from which materials, on what machine, in case there was a poisonous residue left on the plastic.

It can also be critically important to track the conditions under which the materials were transported or stored to ensure that the finished product is safely delivered to each consumer.



This supply chain traceability is made all the more complex by the use of supply networks rather than supply chains, with many alternate suppliers in use at every step along the way from farm-to-fork or from mine to finished car or airplane.

Thus, while inventory tracking and materials traceability are closely related because they both require the tracking of materials, they are different in intent and levels of complexity.

ERP systems, while they can record the receipt of materials by lot number, and the use of those materials by lot number to make products, and the picking of products by lot number, for shipment to each customer, have a number of shortcomings in their materials tracking and traceability capabilities:

- Do not have embedded trace-forward and trace-backward capabilities. As a result, tracking back to defective materials and tracing forward to defective lots has to be done manually.
- Lot number capture is at time of use in making products is optional and is usually not done accurately, or usually at all. Often this is done on paper forms and not recorded in the ERP system because of the complexity.
- Can only do traceability by the lot number. As a result, any recall will be overly broad if many potentially defective containers of material belong to the same lot.
- No tracking and traceability through Work-in-Process (WIP) materials. As a result, if the same WIP material is packaged into different products, the traceability is lost.

But probably the biggest difference is that materials tracking and traceability systems track at the container level and can therefore pin-point exactly which containers of material are defective are defective, and where they are currently located, so that they can be quickly withdrawn from use.

Users of ERP systems can only announce to the world that a certain lot number is defective and hope that someone does not use it before they are harmed in some way. These general recalls are not only expensive, because they are overly broad, but are of only limited effectiveness.

1.4 Impact of Government Regulations

In the USA, primary responsibility for ensuring health and human safety lies with US Government Agencies such as the Food and Drug Administration (FDA) and the US Department of Agriculture (USDA). Their authority to issue regulations stems from Acts of Congress, some of which we will cover here. Enforcement is often the responsibility of the States or even local cities or towns.

FDA-regulated products account for about 20 cents of every dollar of annual spending by U.S. consumers. This amounts to $2.6 Trillion dollars annually of products such as food, pharmaceuticals, beverages, medical devices, biologics, and animal food. The FDA regulates 75% of the food consumed in the USA. The other 25%, consisting of meat, poultry, and some egg products are regulated by the USDA. All of these products require detailed materials tracking and traceability in some form or other.

The primary act controlling food safety in the USA is the Food Safety Modernization Act (FSMA), which was passed by the US Congress in 2011. This places responsibility for food safety on all participants in the food supply chain including the growers, processors, distributors, retailers and restaurant chains involved in delivering food from "fork to table".

A primary requirement of the resultant regulations is the ability to be able to quickly (within 4 hours) track back from defective or contaminated products to their source and then to trace forward to all affected products so as to enable their rapid recall. The key here is the emphasis on supply chain traceability, not just on traceability within a specific processing plant or distribution center.

The FDA has handed responsibility for ensuring rapid supply chain material tracking and traceability to the major restaurant and supermarket chains by making them legally responsible for defects in the products they sell, including defects or contamination that occurs throughout their supply chains. As 96% of all food processors sell at least some of their products through these major chains, this provides a very efficient enforcement mechanism at little or no cost to the US Government.

The FDA also operates a mandatory safety program for all fish and fishery products. The FDA program includes research, inspection, compliance, enforcement, outreach, and the development of regulations and guidance. Here the primary guidance is based on the Hazard Analysis Critical Control Point (HACCP) process, which has a strong materials-tracking-and- traceability component.

The FDA regulates the safety and effectiveness of drugs sold in the United States. The FDA seeks to ensure product integrity through product and facility registration; inspections; chain-of-custody documentation; and technologies to protect against counterfeit, diverted, sub-potent, adulterated, misbranded, and expired drugs. The FDA's approval includes the drug's labeling and prohibits manufacturer promotion of uses that are not specified in the labeling.

Materials tracking and traceability has a role to play in all these activities, including:

- Tracking samples and reagents used in clinical trials
- Tracking and tracing materials used in the manufacture of drugs
- Ensuring that counterfeit products do not enter the supply chain.

The FDA also regulates the manufacture of medical devices and supplies. Here it is important to track all the materials used in manufacturing the devices and supplies, such as to be able to rapidly determined the source of defects and to be able to recall defective materials.

The FDA has long regulated manufacturing of products that could cause harm to people. It is now sponsoring a set of initiatives, such as that initiated by the Drug Supply Chain Safety Act (DSCSA), to improve tracing and traceability of materials in the supply chain. This is part of its regulatory expansion from ensuring products safety within the four walls of a manufacturing plant to ensuring product safety throughout the supply chain.

Other agencies, such as the Department of Transportation (DOT), the Federal Aviation Administration (FAA), and the Department of Defense (DoD) have their own materials tracking and traceability requirements to ensure critical parts and components, especially those used for repair, are genuine and meet required specifications.

There are also government/industry sponsored initiatives such as the Safe-Quality-Foods (SQF) initiative and the Sustainable-Forestry-Products (SFP) initiatives. These require the ability to trace ingredients materials that go into finished products so that these products can carry a seal of approval.

All of these regulations and initiatives, and related standards, have a common set of characteristics that require manufacturers and distributors to be able to:

1. Have documented procedures to ensure the safe manufacture and distribution of products.
2. Track all the materials that go into the products they make or distribute.
3. Track where products were shipped to, to enable a rapid recall of defective products.
4. Track who worked on which operations and what equipment and process parameters they used.
5. Be able to prove that they have followed documented procedures including appropriate testing and quality control.

This requires maintaining a history of all activities performed by the manufacturing plant or warehouse, including maintaining a materials traceability history. This is to enable rapid trace-back from suspect product to sources of defects and contamination and rapid trace-forward from a source of contamination and defects to finished products.

While most of the regulations have historically focused on activities within manufacturing plants or warehouses, there is now a huge emphasis on expanding these requirements to the supply chains and networks themselves.

Finally, even if there are no specific regulations that cover the products being made or distributed, following the above 5 steps will go a long-way to mitigating against law suits for shipping defective products.

Chapter 2 Tracking Materials

2.1 Introduction

In this section, we first look at traditional methods of tracking inventory, such as by using Warehouse Management Systems (WMS), and asset tracking systems. We then discuss the use of Lot Number tracking, as a means of performing materials traceability, which is often used in conjunction with WMS systems to track inventory. Finally, we look at the use of License-Plate-Number (LPN) container tracking methods which integrate the best features of these precursor systems into one cohesive model for tracking and tracing materials in the Global supply chain.

2.2 Inventory Tracking

At its simplest, inventory tracking is done by recording arriving materials into a stock room and recording when materials are removed. This recording is typically done in an accounting system, which maintains a list of Item Numbers (sometimes referred to as SKUs or Stock-Keeping Units) together with their quantity and value. At its simplest, this inventory recording is also performed using spread sheet software

Accounting systems uses this data to include the value of the inventory into the organization's balance sheet. Operationally the recorded inventory quantities are used to view how many of each item are in stock for purposes such as reordering, production, and planning shipments.

Operationally, the checking in and checking out of materials, is accompanied by periodically counting the quantity of materials in the stock room in case a materials handler has forgotten to check-in arriving materials or check-out materials when they are removed. This is typically referred to as "Taking Inventory".

Some organizations, with small quantities of slowly moving inventory, do not even bother with check-in or check-out of materials, they simply Take Inventory every few days so they know approximately how many of each item they have in stock.

This method works well when you have small quantities of items in a small space, such as a stock room, and all you are interested in is the quantity and possibly value of your inventory.

Its advantage of this method is that that it is simple to implement and there are many simple-to-use inventory tracking software systems available at low cost.

The disadvantages of this method are as follows:

1. There is no tracking of the location of each specific material within the stock room. So, if the stock room grows, with many parts stored in many different locations then it can quickly become very hard to find needed parts.

2. When you want to "Take Inventory" to count how many of each item you have in stock, then you have to stop receiving, shipping, and production operations while you do the counting.

3. There is no materials traceability as there is no relationship maintained between the materials withdrawn from the stock room and the products made and shipped to customers.

4. There is no differentiation between products having a common part number, such as by lot number, serial number, and expiration date.

5. Items arriving at different times may have different costs, making it difficult to track the value of inventory

2.3 Warehouse Management Systems

Some of the problems with simple check-in, check-out inventory tracking systems can be solved by recording the location where different items are stored. This recording is typically done using Warehouse Management Systems (WMS).

In this method, we track the quantity of a specific material at a location. This is typically done by assigning a unique number to each location and attaching a barcode containing the number to a shelf, rack, or floor location.

Often the rack barcodes are placed at eye level, as shown at right, so they can be easily scanned to record the location of the material being put-away, even though the warehouse rack may have shelves 20 feet in the air.

When pallets are placed on a warehouse floor, then typically a "traffic" post with a location barcode on its top is placed inside a yellow lined area, to indicate which floor-zone the pallets are dropped in.

Alternately a location barcode can be hung over the aisle in which the pallets were placed.

These location barcodes are also placed on bins in which materials are stored, as shown at right.

The big benefit of using a warehouse management system is that it is easy to find materials, because their location is known. It also makes it easier to do periodic checking of inventory by scanning the location barcode on the shelf, rack, bin, or floor location and counting the inventory at that location.

This knowledge of where the items in stock are located can also be used as the basis of various picking algorithms, used to direct a material handler which materials to pick from which locations for customer orders or production jobs.

To facilitate the easy put-away and retrieval of inventory from a warehouse, many warehouses have designated locations for each different part or item. This works well if the warehouse always stores the same material but can be inefficient, in terms of storage space used, if the mix of materials being stored changes over time.

The big issue with warehouse management systems is the lack of materials traceability. There is no relationship recorded between materials received, materials pulled for making or repacking, or relabeling products, and the customers to which the products are shipped. Thus, warehouse management systems, while good for tracking the quantities of materials are unable to directly record materials traceability data.

They are also unable to record data such as serial numbers, lot numbers, and expiration dates as there is no differentiation between like materials, stored at the same location except by markings on the products themselves.

2.4 Asset Tracking Systems

Another form of materials tracking is asset tracking. Here we place a serialized asset tag on items, such as tools or computers, and then scan the asset tag to record when the asset is received, issued to a person or location, moved, returned, and disposed of.

Here we have complete end-to-end materials traceability and we can find the item, based on recoding the receipt, issuance, and return of the asset. We can also assign a depreciating value to the asset so that the value of all assets can be exported to an accounting system for use in the organization's balance sheet.

The problem with asset tracking systems is that they only track serialized unit entities and we do not have the ability to track containers of material.

2.5 Lot Number Tracking

The traditional method for solving the problem of traceability through warehouses and manufacturing plants is to assign a lot number to a batch of like materials, received or produced at the same time.

When products are made and placed in a carton, a unique lot number is assigned and is printed on the outside of each carton containing like products made at the same time. If defective products need to be recalled then a recall notice is issued to all possible users and holders of the inventory to not use the defective lot number.

When lot numbered materials are used in a manufacturing operation, where materials traceability is required, then the lot number of the input materials or ingredients used to make each batch or lot of finished products are recorded. This has traditionally been done using paper forms, which are then saved in filing cabinets, with sometimes the results being transcribed onto electronic spreadsheets, such as Excel, for speedier access when required.

Some ERP and manufacturing operations management systems (MOMS) enable the capture of the lot numbers of materials input to each manufacturing operation along with the quantities used. They also track the lot numbers assigned to the finished products. These systems are, however, typically not capable of using this information to perform forward and backward traceability relating the lot numbers of raw materials to the lot numbers of the finished products made using each lot of raw materials.

In food processing and similar manufacturing operations "Julian" dates are often used as the lot number for all materials made on a specific date. These typically consist of a two-digit year code plus a three-digit day of year code, as in 20045 for the 14^{th} of February, 2020. The reason for this is that many different products are made from a common set of ingredients, such as sacks of flour, brought to the production floor at the same time. As a consequence, these manufacturers record the lot numbers of ingredients brought to the floor, on a specific day, and used, in common, to make a single "Julian" date lot numbered set of products.

This can work OK for traceability in small food processing plants, that make only a small number of products on a daily basis. But, if a contaminated container of raw materials is used, then it is hard to determine exactly which products were affected, resulting in overly broad recalls and difficult to determining the source of defective products.

Probably the biggest problems with lot number traceability are:

1. Overly broad recalls, which are costly and may cause significant economic damage to companies in the supply chain.
2. General recall notifications are not received or often ignored by the users of the products.
3. Difficult to rapidly determine source of defects and to recall affected products due to lack of electronic traceability history in appropriate format.
4. Difficult to enforce accurate lot recording by employees onto paper forms.

The major benefits of lot traceability are:

1. Can easily be implemented by the smallest of companies using pencil and paper.
2. No electronic supply-chain data exchange required.

2.6 License Plate Container Tracking

2.6.1 Introduction

License-Plate-Number container tracking builds upon, and integrates, all the former methods into one cohesive approach.

License-Plate-Number (LPN) container tracking is how UPS, FedEx, and Amazon track the real-time flow of materials in their supply chains. This tracking is performed by attaching a tracking barcode containing a unique alphanumeric tracking number to each container. This barcode is then scanned when materials are added to the container, the container is moved, or materials are withdrawn from the container.

This same methodology can be used to track the flow of materials within industrial plants and warehouses, as well as outdoors at building and other field sites. It can also be used to track the processing and distribution of food and pharmaceutical products.

LPN container tracking is in contrast to systems such as Warehouse Management Systems (WMS) and Enterprise Resource Planning (ERP) systems which simply track the quantity of inventory at a location. These item-locator systems lack the ability to track which specific materials were used to make which products, which is essential for applications requiring materials traceability, such as the processing of food and pharmaceutical products.

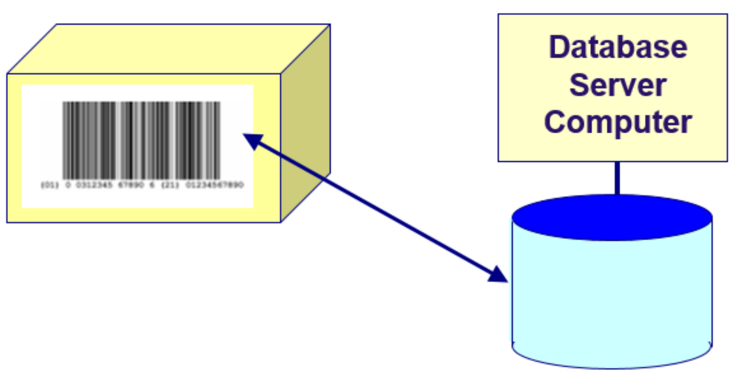
LPN container tracking systems are ideal for tracking inventory at many different locations and the flow of materials between locations, including materials in-transit on vehicles. They also work well to track assets such as tools and computers that may be issued to people as well as to locations.

2.6.2 License-Plate-Number Container Tracking

The concept behind License-Plate-Number (LPN) container tracking is that a unique tracking barcode is applied to each container and then all the information about the container is stored in a database, where it can quickly be accessed. Also data about that container, such as its location and the quantity in the container, can quickly be changed by scanning the tracking barcode on the container.

License-Plate-Number container tracking gets its name from what happens at the registry of motor vehicles when you go there to register a new car or truck. They hand you a license plate with a unique set of letters and numbers and the state of issue marked on the plate. The license plate number is unique but otherwise is just a random set of letters and numbers. All the data about your car or truck is stored in a database so that, when you get pulled over for speeding, the police officer simply reaches over to his on-board computer and types in your license plate number and is able to see all the information about your car or truck.

We use a similar principal for license-plate tracking of materials except that we put a unique tracking barcode or RFID tag on each container of materials instead of an aluminum license plate.



Note this is very different from using barcodes with data such as item number, quantity, and lot number on each container. With license-plate tracking all the data is kept in a database and the tracking barcode is simply a reference to the database record.

For containers such as boxes and pallets, which are discarded when they are empty, we typically print and apply a license-plate tracking barcode to the container of materials when it is first entered into inventory. For reusable containers, such as totes or bins, we can use permanent metal barcodes, as we do not have to change the license plate just because we changed the contents of a container (analogous to the license-plate on a car or truck).

The benefit of this is that data such as part number, location, quality control status, and quantity of materials in the container can be changed as needed without replacing the tracking barcode on the container.

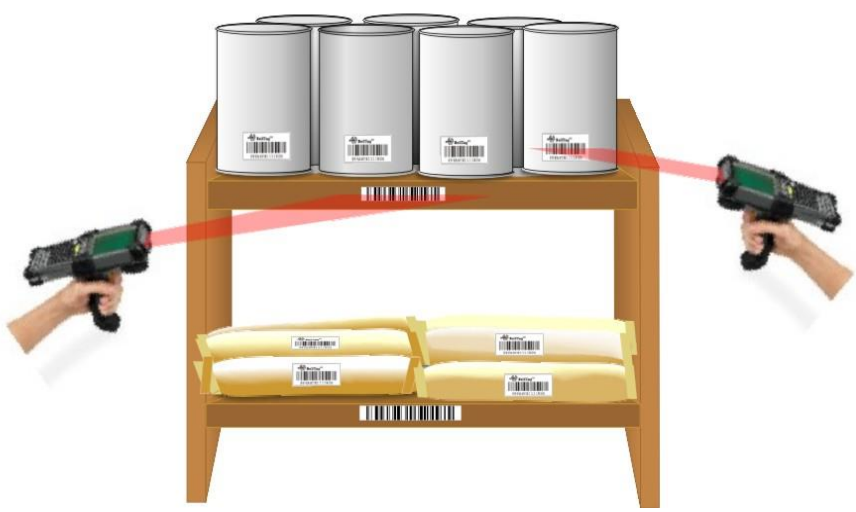
License-plate tracking is a GS1 (Global Supply Chain One) standard, where GS1 standard barcodes are used for Serialized Shipping Container Code (SSCC) barcodes which uniquely identify the containers to which they are attached on a world-wide basis. This enables a shipper to record what materials were placed in on a pallet in China and send the information related to a warehouse in the USA in the form of an ASN (Advanced Shipment Notice). When the materials are received in the USA all that is necessary is to scan the SSCC license-plate barcode to receive the materials without first breaking down the pallet and individually receiving the contents.

The license-plate tracking barcode may be as complex as a GS1 composite barcode, printed on-demand, with a GTIN, Lot Number, and Serial number, for use in the Global supply chain, or as simple as a barcode taken from a pre-printed roll of serialized barcodes, such as that shown here, for internal use within the plant. The license-plate tracking barcode may also contain an RFID chip with the same tracking number or a separate ruggedized RFID tag may be used depending on the application.

As well as being placed on containers, license plate tracking barcodes are placed on items that are not in containers. Examples include large electric motors and other electro-mechanical assemblies which may need to be tracked independent of being in an external container. These individually barcoded items may also have serial numbers which may be used as their tracking barcodes or the serial numbers may be different.

Some types of container are obvious, such as boxes, pallets, and totes. Others are not so obvious, such as reels and rolls, which contain a quantity of an item. These can be treated as a container with so many feet, for example, of material, or as individually barcoded items where dimensions such as length, width, and thickness may be treated as attributes of the individually barcoded item.

2.6.3 Tracking the Location of Materials

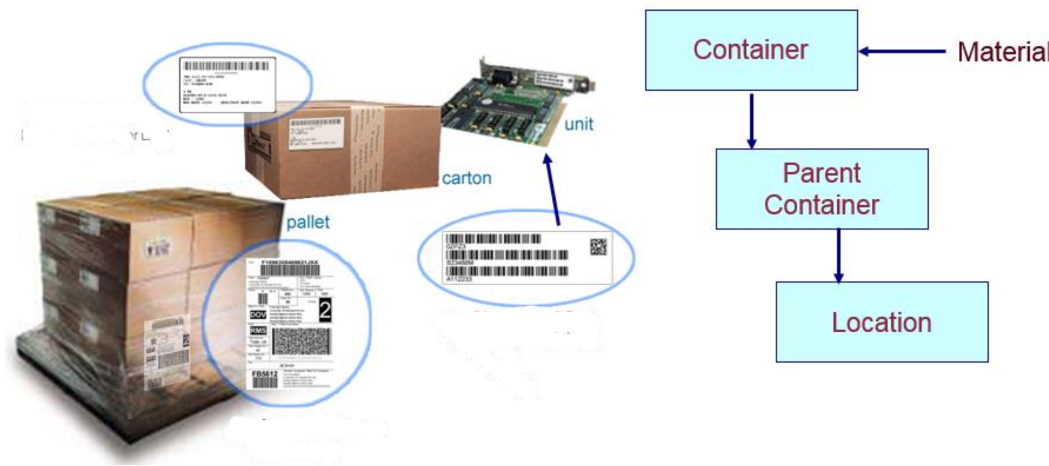


Whenever a container of materials is moved, the materials handler scans the LPN tracking barcode on the container and a location barcode on a shelf, rack, floor post, or hung overhead. These location barcodes uniquely identify each location, so that the location of each container can be tracked in real-time. These location barcodes can also be scanned when performing cycle counting or inventory auditing.

It is noteworthy that, with an LPN container tracking system like BellHawk, it is only necessary to shut down a single location, such as a shelf or rack, when taking inventory rather than needing to shut down the whole of a warehouse in order to take inventory.

2.6.4 Nested Container Tracking

One of the problems that is very hard for traditional inventory tracking systems to handle is how to track nested containers. In a nested container situation, such as the example shown here, we may have parts with serial numbers in cartons, with cartons containing many different part numbers stacked on a pallet, with multiple such pallets at an inventory location.



In a traditional ERP inventory tracking scheme, when you move a pallet to new location you have to record the withdrawal of all the parts from the old location and enter them into the new location.

LPN systems track materials, which may have their own license-plate tracking barcode, in containers, which will have their own tracking barcodes, and may have a tree of parent containers, each with their own tracking barcodes, that are at a location.

Then, when you want to record the movement of the container, you simply scan the barcode on the outer parent container (in this case the pallet) and record its new location. All the data about all the materials on the pallet is automatically associated with the new location.

The same goes for shipping the parent container, when all the materials in the parent container can be recorded as having been shipped to the customer simply by scanning the tracking barcode on the outer container.

Even better, the nested container data, which LPN systems track, can form the basis of Advanced Shipment Notice (ASN) data, that can be sent by EDI (Electronic Data Interchange) to customers so that all a customer has to do is to scan the tracking barcode on the shipping container, such as the pallet, and associate it with the ASN to receive all the materials into their inventory, with no additional data entry.

Similarly, LPN systems can also use ASN data to minimize the work needed to record the receipt of materials from your suppliers.

2.6.5 Difference of LPN Tracking from Traditional Inventory Tracking

The big difference from traditional inventory tracking is that when we want to know how much inventory we have in stock, we add up the quantity of all like materials in all the containers wherever they are located, even if they are being moved from one place to another.

Because recording a change in location is as easy as scanning the tracking barcode on the container and a location barcode on a shelf or rack, where we put it, we can use much finer grained locations for tracking. This enables us to know that a specific box of parts is on shelf A-10-6 rather than just somewhere in the warehouse.

It also makes "inventory taking" much easier in that you do not have to shut down your operations to count the inventory in the whole of your warehouse but only have to validate that the containers of material on a shelf match those those in your tracking system, one shelf at a time. As a result you can do inventory validation incrementally without shutting down or disrupting operations, in order to take inventory.

This encourages checking inventory frequently rather than waiting for a once-a-year inventory taking to discover your inventory discrepancies.

The use of LPN tracking enables tracking which containers of material were used to make which products, as well as to accurately track the actual cost of making products. This dramatically improves the traceability of materials.

ERP, WMS, and other item-locator invcentory tracking systems cannot perform LPN container tracking because they do not use a containers table as the basis of their tracking materials, whereas LPN tracking systems, such as BellHawk does.

Chapter 3 Part Numbers and Units of Measure

3.1 Introduction

In tracking materials, one of the fundamental questions is how much material is in this container, at this location. While this may seem a trivial question, it has a surprising number of nuances, from which arise three questions:

1. What is a container? The obvious answer is a box, bin, tote, barrel or some similar container that holds material. But it can also be a reel or roll of material, which hold so many feet or meters of material.
2. What type of material? This is typically characterized by a part number, SKU (stock keeping unit), or item number, which is a sequence of alphanumeric characters. But here questions arise, such as to whether we should assign a separate part number to different sizes of the same material.
3. How do we represent the quantity of materials in a container"? More formally, this is expressed as "What Unit of Measure (UOM) is used for the materials in the container"? Again, this can have a surprising number of nuances.

3.2 Containers

In a tracking system, containers can have a number of attributes:

- Can they hold just one type of material (such as a reel or bottle) or can they hold multiple different types of material (such as totes or pallets)?
- What is the "tare" weight - the empty weight of a container so that it can be weighed and the tare weight subtracted to find the weight of the materials in the container?
- Are they reusable (such as totes or pallets) or are they discarded after their contents are empty (such as cardboard boxes)?
- What materials are inside the container and how much?
- Are they an indivisible product, with a global trade identification number, or a container, with a license-plate-number tracking barcode, to which materials can be added and subtracted?
- Where are they located? Are they inside a parent container or directly placed at a location, such as in a rack or floor location in a warehouse?

Characteristics such as these, for each container, form the basis of materials tracking and traceability systems which track containers of material and their contents.

3.2 Part Numbers

One of the issues that can cause problems, when implementing a tracking system, is the assignment of part numbers. At first this can seem trivial, we simply assign a different number to each part that we purchase or make.

But what if we purchase the same 3/8" metal washer from two different suppliers? Do we give them separate part numbers, even though to all intents-and-purposes they are identical? Some organizations simply use their supplier's part number to track inventory but does this mean that we should keep each supplier's parts in a separate bin, so we can accurately count inventory, when the time comes to check-on or audit the inventory?

This quickly becomes ridiculously complicated when we purchase our washers from many different suppliers, which leads to the use of internal part numbers into which all external part numbers are converted. So we may purchase 25 washers in a box from supplier A as their part GF3456 and from supplier B as a packet of 10 washers with part number HY4523 but they simply become our internal part number W38SS with unit quantities, upon receipt.

Similarly, we may use the washers to make widgets with internal part numbers WID001, but sell them in packs of 5 or boxes of 10 with part numbers WID005 and WID010, respectively. These "selling" part numbers may also have corresponding UPC (universal products code), GTIN (global trade identification number) or NDC (national drug code) numbers, which are their external, standard, product codes.

A question arises as to whether to assign separate part numbers to different sizes of the same material? From a selling viewpoint, a 100' roll of 48" wide plastic will have a different "external" part number from a 200' roll of 24" wide plastic. But, from the manufacturing organization's viewpoint, these are the same material. In fact, they may well use a 100' roll 48" wide to make some products and return to stock 50' of 48" wide or 100' of 24" wide material, which can be use to make other material.

I have seen organizations assign a different part number for every ½" increment in width and then track the length of material on the roll. This gets hugely complex from an inventory tracking viewpoint, with thousands of variants of the same material. This also becomes very complex from an accounting point of view, when trying to assign different values to each width of material.

It is much simpler to use a common internal part number for all widths and lengths of the same material and then a value per unit weight in the accounting system, with the production tracking system tracking the weight, as well as the length and width of material on each roll. In that way the tracking system can easily report the number of pounds consumed or produced to the accounting system and production planners have enough information for deciding which roll to use for each production run.

3.3 Units of Measure

From an accounting system point of view, the answer to the UOM question is always a number, which can be associated with a cost per unit, to value the inventory. Here we see accounting systems, such as QuickBooks, with simply a table of Items in inventory with a quantity for each, and a unit value. The quantity for another may be for a count, in "eaches", for another, the length in feet, and for yet another, be measured in gallons.

From an inventory tracking viewpoint, such as we find in an ERP or WMS system, we need to carry along a unit of measure, such as EA, FT, or GALS, often with using both a "Nomenclature" such as these, and a description, such as "Each", "Feet", or "Gallons" for use in reports. This makes reporting much more meaningful than simply having a number.

Complexities come in when multiple units of measure are in play. For example, a company may buy small fasteners by the pound, package them by count (such as 25 to a box) and sell them by the box.

Early ERP systems solved this by having 3 units of measure, one for receiving, one for production, and one for shipping. This quickly evolved into allowing users of the system to define multiple units of measure for each item with conversion factors between them. These systems track the quantity in a "primary" unit of measure, such as eaches, but allow users to select a secondary unit of measure, such as ounces, in which to enter quantities, when convenient. The system can then convert the quantity entered, such as "5 ounces" into the primary quantity of "25 each" in a "count-by-measure" process, using a weighing scale.

This system, with multiple different units of measure for each part, is very flexible, in that it allows for arbitrary units of measure to be used, with arbitrary conversion factors but does require that these be setup for each of what could be thousands of different parts, which can be very time consuming.

Materials tracking systems, such as the BellHawk software, recognizes that conversion factors within a "measure type", such as count, length, and weight are universally defined by standards. Thus, the conversion between centimeters, inches, feet, meters and yards is fixed by standard and only needs to be set up once, for all parts. Similarly, weight conversions between grams, ounces, and pounds is universal. However, the unit weight of a specific item, such as a washer may vary by item number.

For many items, there is only a single measure type in use but we may want to receive this in meters, but sell or use it by the foot. In this case, universal unit of measure conversions can be used. But if we buy washers by the pound and then use them by count, we need to know what the weight of each fastener is, so we can weigh the incoming washers and compute their count.

The BellHawk materials tracking system allows the use of separate primary and secondary "measure types", such as Count and Weight and then allows the specification of how to convert between them in terms of selected unit of measures, such as eaches and ounces, , for each item. This covers almost all use cases met in practice in manufacturing and other industrial organization.

Which is better, using the setup of multiple conversion factors per item or using " universal" units of measure? For accounting and ERP purposes, the use of per-item conversions is more than adequate and, in many cases, is simpler. But for detailed materials tracking and traceability, the use of standards-based universal UOM conversions has advantages.

BellHawk, for example, carries along a primary and a secondary quantity, for each item, in each container, with its own measure type and unit of measure. These can be coupled through a standard conversion factor or treated separately. The latter is important where the conversion factor varies (as it does in practice, in most cases). For example, a box of tomatoes may have substantial variability in the unit weight of each tomato, but it may be important to know how many tomatoes as well as their weight, in each box.

Having two quantities, one primary and one secondary, may not be important when counting washers, which are very uniform in weight but can be critical with materials, such as rolled and sheet goods, which may have a variable weight per unit area. Also, high value items, such as components in gold jewelry, may have significant variability in their unit weight, making it essential to separately track the count in a container, for production use, and weight, for inventory valuation.

Understanding these unit of measure issues, also plays an important role when exchanging data between systems. A materials-tracking system may, for example track sheets of steel and their size, for production purposes, but report the total weight to an accounting system, so that the steel can be valued at its spot price per pound, at the end of each accounting period.

3.4 Receiving Issues

You order a box of 25 widgets from ABC company. The manufacturer has assigned a part number of ABC123 to the box of 25. You use these internally as part number XYZ345 with a quantity of eaches.

In your materials tracking system, you could simply receive these as 25 widgets with part number XYZ345. A few weeks later, you need more widgets and order them as a box of 10 widgets, from YKH company, with a part number, for the box of 10, of YKH786.

You could simply receive these as 10 XYZ345 widgets and toss them into the same bin as the left-over widgets from the previous box of 25. The issue is that if a problem occurs with these widgets when used to make your products, you have no way of knowing which of your suppliers were at fault. Also, because of this, you have to recall all products made with widgets irrespective of the supplier.

There are several parts to this issue:

1. We need the tracking system to know about the conversion between supplier part numbers and our internal part numbers, including unit of measure conversions, for each supplier, for each internal and external part number. For example, one of our suppliers of widgets may sell them by the pound, and expects you to pay per pound. And yet you use them individually.

2. You need to keep parts from each supplier separated. This is done by placing an individual LPN tracking barcode on each box or container, as it is received from each supplier. The quantity received is recorded in terms of the order part number and unit of measure but is tracked using the internal part number and unit of measure.

   In this way, data sent to the accounting system, about received materials, reflects the purchase order issued to the supplier. But the materials tracking system can track which manufacturer supplied the widgets used for each work order by scanning the LPN tracking barcode on each box, as the widgets are withdrawn for production.

3. Each box, from each supplier, may carry along a lot number, which can be used as part of our materials traceability record to recall products made using the same batch of parts, even though they were packed in separate boxes.

3.5 Production Issues

Most unit of measure issues, in production, relate to how to efficiently measure quantities. Most of these relate to:

1. Count-by-Weight
2. Return of Butt Rolls
3. Measuring liquids and powders added to a mix.

In production operations, parts are typically tracked using their primary units of measure. This is to make it as easy as possible for the production staff, who often must deal with thousands of different part numbers. But there are exceptions.

In count-by-weight operations, we can either use a standard conversion factor "the unit weight" or we can count out a sample set of parts and then weigh these to get an average unit weight for the batch. This is then used to compute the count of parts in a bin, for example. In this case, we typically only need to track the count of parts but this can lead to problems if there is significant variability in the unit weights.

If we always weigh the contents of a bin and estimate the parts in the bin based on sample piece-part weights, then we get a good estimate of the part count. But, if we estimate the parts count this way, when taking annual inventory, and then incrementally subtract the count of parts removed, we can end up with significant errors, especially when there are only a small number of parts left in the bin. This can result in prematurely running out of inventory.

If, however, we weigh the parts removed (often done to count the parts removed) and then also subtract this from a secondary weight for the parts in the bin, we can always accurately estimate the count of parts remaining, based on an asymptotic estimate of the average per-unit weight of the parts remaining, even when we are down to a few parts in the bin.

Another problem that arises in production is in estimating how much material left on a roll or reel of material that is returned to stock. In such operations a roll or reel is placed on a machine and then used to make products or intermediate work-in-process. Frequently not all the material is used and the left-over material is returned to stock.

The question then arises as to how much material is on the returned roll or reel. We could subtract an estimate of the material used but this can be inaccurate, especially in web-fed machines due to material wasted when setting up the machine. A better way is to weigh the material returned, subtract the tare weight of the reel or core, to estimate the quantity left.

Secondary units of measure are also useful in measuring out fluids to add to a mix. Here the formula may call for so many liters to be added. If the mix vat is mounted on a weighing platform, then the quantity to be added can be converted to an incremental weight to be added.

3.6 Shipping Issues

While we may track the making of a product by a unit count, such as a jar, we may sell these by in cartons of 10 and 25. Such packaged cartons will have their own part numbers and, if sold into the global supply chain, are required to have their own GTIN numbers or UPC codes. This can easily be handled by work-in-process tracking systems recording the packaged product carton as output from a work-order packaging operation.

The picking, packing, and shipping of these cartons can then be recorded as any other standard products. Also, their shipment, can be reported in an ASN data transmission to customers.

This can, however, have an impact on materials traceability data, as the ingredients are often recorded to make a mix in a vat, which is then packaged in a variety of products, before shipment to customers. In, this it is important to identify all the finished products into which a specific mix was packaged to enable supply chain traceability.

Most manufacturers create an item number for each product they make. But sometimes they receive orders for these products in terms of their customers part numbers, in specific packaging configurations, with the customers GTINs. Here manufacturers can add part numbers for these products to their own set of part numbers or they can track the translation between their part numbers and the customers part numbers, including quantity transformations.

The latter approach can be useful where the customer's part numbering scheme differs from that of the manufacturer or there is a possibility of conflicts with some other customer's products. It is also beneficial where the same product is being shipped to different customers under different customer part numbers.

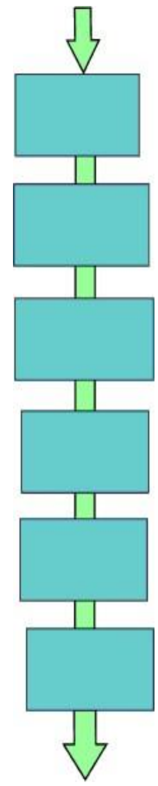
Chapter 4 Work-in-Process Tracking

4.1 Introduction

Manufacturing and other industrial organizations are faced with delivering an ever-increasing number of semi-custom products with ever decreasing delivery times.

As one plant manager told me "I used to have 6 products running in my plant for weeks on end. Now, at any one time, I have 400 different products running through 25 different work centers in my shop with an average delivery time of a few days".

Managers such as this are increasingly finding that their current methods of keeping track of their operations no longer work. Tracking progress using paper forms and Excel spreadsheets, or using manual data entry into an ERP system, used to work well when their plants were making fewer products with much longer delivery times.



But today, to ensure that customer orders get out on time, it is essential to keep track, in real-time, of many different jobs as they flow through multiple work centers.

At the same time, operations managers want to reduce their overhead cost by eliminating the need for manual keyboard data entry as well as eliminating the need for expediters and customer service people to make sure customer orders get out on time. They also want to use systems that are low cost and simple for their people to use.

Work-in-Process (WIP) tracking is an integral part of materials tracking and traceability within a manufacturing plant. At its simplest, it consists of tracking each item through a sequence of work-centers and at its most complex, consists of tracking the consumption and production of work-in-process materials by each manufacturing operation, as well as tracking containers of work-in-process materials moving between operations.

In this chapter, we look at three methods for tracking work-in-process:

1. The traditional method of tracking when work starts and stops on a work-order operation at each work center.
2. Tracking items or containers of material as they move from work-center to work-center.
3. Using a combination of work order and materials tracking to record materials consumed and consumed by each operation, as well as tracking containers of work-in-process materials. This is a combination of the first two methods.

4.2 Tracking Work Order Progress

The traditional method of tracking work-in-process is to track when each employee starts and finishes work on each operation within a work order. This used to be done using dedicated time and attendance recording stations on the factory floor. Then this was largely replaced by entering the labor time and work order status into an ERP (Enterprise Resource Planning) system, often using paper time-sheets as an intermediary step.

Today this data collection is performed by systems such as BellHawk, which use barcode scanning to record when work starts and ends into database servers located at a remote data center, using a web-browser on a wide-variety of mobile devices.

The process starts with the creation of a work order to process an individual item or batch of material.

This work order has a unique work-order-number and a route of operations. Once the work order is created then a barcoded traveler, such as is shown at right, can be printed out on an office laser printer.

This traveler has a barcode for the work order at top right and barcodes for each operation needed to be performed in the work order down the left-hand side.


Work Order

WO00000101

Importance: Standard
Date Wanted: 12/22/2015
Sales Order #:
Customer: CDE Furniture Manufacturers
Instructions: Make Stainless Steel Knobs

Step #: 1
Operation: Production: Lathe
Step Instructions: Lathe

Step #: 2
Operation: Production: Drill and Tap
Step Instructions: Drill and Tap

Step #: 3
Operation: Production: Polish and Inspect
Step Instructions: Polish and Inspect

How this is used is illustrated below using screens from the BellHawk Materials Tracking and Traceability and Work-in-Process tracking system. Screens from other systems that do work order tracking function in a similar way.

To record starting work on an operation, the user selects a Start Work button from the screen of their device, which brings up the Start Work screen, shown at right.

The user then scans a barcode on their badge (identifying the employee) followed by scanning the work order and step barcodes from the barcoded traveler sheet.

The user then selects the [Submit] button to record that they have started work on that operation on that work order.

When they stop work on the operation, the user selects a Stop Work button on the screen of their device, which brings up the Stop Work screen, shown at right, and then scans a barcode on their employee badge followed by scanning the work order and step barcodes. They can then, optionally, enter a "piece work" quantity processed or made.

If work on the operation is complete then the user checks that the operation is complete and selects the [Submit] button to indicate they have stopped work and the operation is complete.

If the user is just going on break, then they leave the check-box unchecked, and the system records that they have stopped work on the operation but the operation is not completed.

When they come back from break the user records another Start Work operation, followed by another Stop Work, when they have stopped work.

In this way, the tracking system is able to track when each operation on each work order starts and ends, who worked on it, and the amount of labor required for each operation.

This, however, gives us no information about the materials consumed on each work-order operation or the ability to track work-in-process materials, or to report how much product was made and how it was packed and shipped to the customer. As a result, this traditional method of WIP tracking does not capture any information that is useful in materials tracking and traceability.

4.3 Using License-Plate-Number Container Tracking

In license-plate-number (LPN) container tracking we place a unique tracking barcode on each item or container of items we wish to track through our manufacturing, repair, or other industrial operation.

When an item or container of materials is first entered into the tracking system, it can be associated with a customer, job, or work order and other data about the item or parts captured.

Then, as the material moves from operation to operation barcode scanning can be used to record the movement of the item or container to each operation by scanning its license-plate tracking barcode and selecting or scanning the new location/operation.

Finally, the barcode can be scanned to record the shipment of the item or container of material to the customer, again by scanning its license-plate tracking barcode.

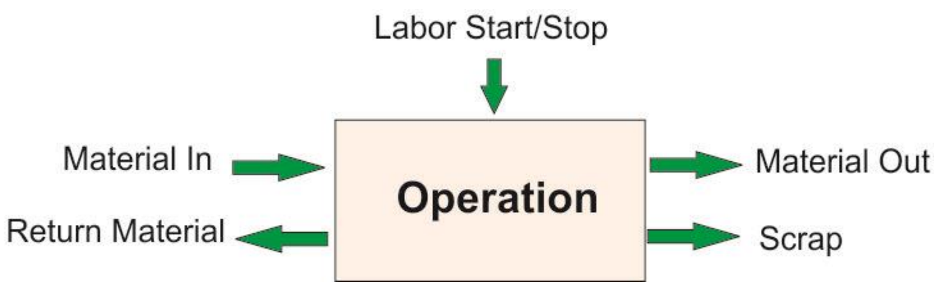
This is typically used to track the assembly, repair, and testing of serial numbered items, each of which has a unique license-plate tracking barcode attached to it. But it can also be used to track batches of material.

If the user is able to associate a specific barcode scanning device with a work center, then only a single scan, using that device, is required to record the movement of the item or container of parts to that work-center.

From a barcode scanning viewpoint, this is the simplest method to use, because it only requires one scan per work-center. But, as a trade-off, this method only provides real-time information as to where materials are, and does not provide any additional information such as materials or labor consumed on each operation.

By setting up locations for the staging areas in each of the work centers, as well as locations for each work center, a tracking system can record when an item enters and leaves a staging area. This enables tracking of how long each item or batch was waiting to be processed as well as how long it took to process the item or batch in each work center.

4.4 Tracking Materials and Work Order Status



Here we use the same barcoded traveler as in the prior example as the starting point and can record the start and stop of operations on work orders, as described in the prior section.

In addition, we can use license-plate-number tracking to record materials consumed on an operation. Here the operator scans a barcode on their badge followed by scanning the work order and operation from the work order. Then the license-plate tracking barcodes on containers of input material are scanned and the quantity consumed recorded.

With a system like BellHawk, a BOM can be setup for the work order operation and this can be used by to check that the correct that the correct materials are being used and to warn the operator if they are about to make a mistake by using the wrong material.

Material can be recorded out of operations as containers of material by scanning license-plate tracking barcodes on the containers into which they are placed and recording the quantity placed in each container. Alternately assemblies, repair items, and the like with their own license-plate tracking barcodes can be recorded into and out of operations.

The big benefit of this method is that the work-in-process can be placed in separate containers destined for separate operations, such as having some parts destined for a rework operation and some destined for the next scheduled operation on the parts.

4.5 WIP Tracking Issues

If we are tracking a repair part through a sequence of operations then we can simply attach a unique LPN tracking barcode to the part and track its movement through a sequence of work centers by scanning its LPN barcode when it arrives at each work center. Alternately we can assign a work order to that repair job and track the repair part through a sequence of operations.

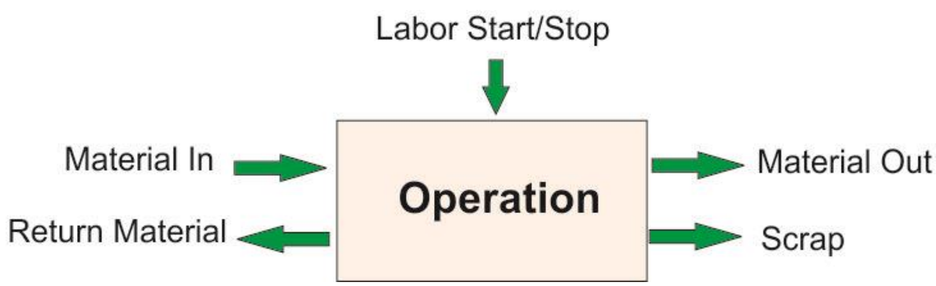
In neither case is there an issue with part numbers, as the part being repaired already has a part number.

But what if we are making a batch of products, that go through a series of operations. If we are tracking the WIP parts in and out of each operation, we need to have a part number for these WIP parts. We could create separate part numbers for each variant of WIP material as it flows between each job step or we could use a generic part number.

Creating separate WIP part numbers for each stage of making many different products, quickly becomes an overwhelming task for most manufacturing operations. Equally, just using a generic part number, does not enable easy tracking of the location of WIP materials, especially if many totes or carts are in use, with WIP products in many different stages of production.

An alternate approach, used by systems such as BellHawk, is to use the same part number as the finished product for the WIP materials, but to use a WIP flag on each container to distinguish them from finished products until they have completed the last operation on the route. In that way WIP materials are distinguished from finished materials inventory but can still be tracked as WIP moves from operation to operation without creating special part numbers for each different stage of transforming raw materials into finished products.

4.6 Test, Repair, and Assembly Operations



When using a combination of work order and LPN materials tracking, the standard paradigm is that materials get consumed when they are recorded into a work order operation and get produced when they are recorded out. With test, assembly, and repair operations, the unit being tested, assembled, or repaired does not get consumed when recorded into an operation.

Units being tested assembled, or repaired, typically have their own LPN tracking barcode. When they are recorded into an operation, they are simply recorded as being worked on. When the units are recorded out of an operation, they are simply recorded as being no longer worked on.

Materials may be consumed on the test, repair or assembly operation but they do not change the part number or LPN tracking barcode on the unit being tested, assembled or repaired.

In repair operations, parts may be replaced with new parts, and the removed parts recorded as materials-out or scrap, as appropriate.

4.7 Comparison of Methods

1. If all that is required is to track where serial numbered items or batches of items are in their assembly, repair, or test process, then scanning an LPN tracking barcode on each part as it moves from work-center to work-center provides a very simple way of getting real-time visibility into the status of each customer order. This method can also provide an easy way of tracking how long it took to process each item or batch in each work center.

2. If the primary goals are to be able to see the status of batches of material or individual items and to capture the labor required in their manufacture, repair, or testing then work order tracking should be used. If, however, split batches could occur, such as for rework, then a combined work order and LPN materials tracking system should be used.

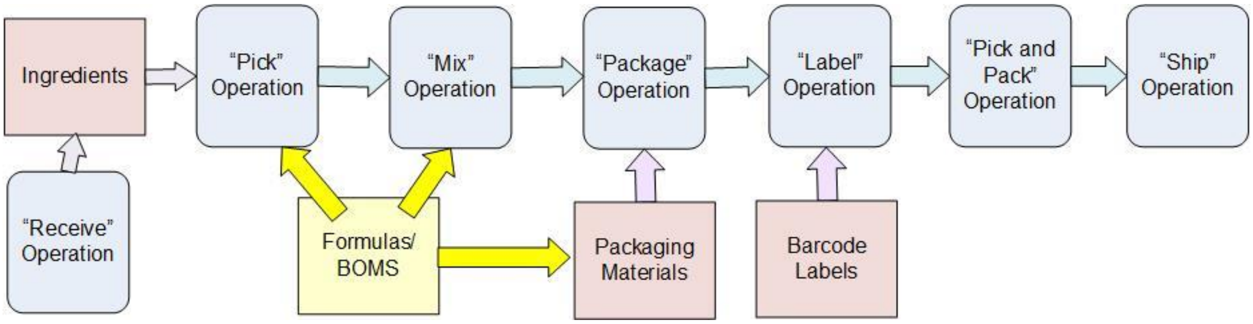
3. If the primary goal is to prevent the use of wrong materials on a job then a combined work order and LPN materials tracking system should be used to track the consumption of materials on each work order operation and compare this with a stored BOM for each work order operation.

4. If the primary goal is to accurately capture labor and materials cost data then tracking labor and materials is required a combined work order and materials tracking system should be used. This can be augmented by capturing the setup, run, and down times of the equipment or machines used to get an overall job cost.

5. If the primary goal is to capture a materials traceability history so that this can be used to track back from defective finished products to the raw materials used and to track forward from defective ingredients to the products in which these ingredients were used, then tracking work orders and materials is necessary and WIP tracking should be used.

In general, a system that combines work-order tracking with LPN materials tracking provides accurate tracking of the status of customer orders as well as capturing materials traceability and job costing data. But, in some simple cases, LPN barcode tracking or work-order tracking on their own can reduce the amount of scanning required and may provide the tracking information required.

Chapter 5 Tracking the Transformation of Materials



5.1 Introduction

A key element in materials tracking and traceability is tracking the transformation of materials.

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 tested and repaired.
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.

Tracking these transformations enables us to trace-back from defective products to the materials and processes used in the manufacture, test, or repair of products, and the people involved, to find the probable source of the defects. It also enables us to trace-forward from defective materials or processes to the location of all the affected products.

5.2 Operations and Routes

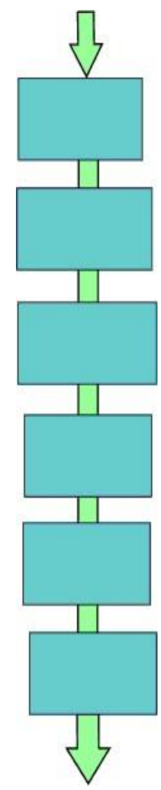
The transformation of materials typically involves multiple steps in transforming raw materials into work-in-process and then to intermediate products, which are typically used in a variety of products. In materials tracking and traceability, these steps are represented as "Operations" in which materials, labor, and equipment time are consumed, and one or more materials are produced.

Some types of operation are:

- Process operations in which materials are irreversibly transformed into new materials, such as by mixing, molding, welding, cutting, soldering, and gluing. The output material has a different part number from the input material(s).

- Assembly operations where parts are assembled together into an assembly or sub-assembly but the parts or sub-assemblies can be removed, if needed. The output assembly has the same part number as the input assembly.
- Test operations where there are no changes to the parts being tested but test parameters may be collected and the quality control status may be set to passed or failed or needing more inspection. Each output part or assembly has the same part number as the input part or assembly.
- Repair operation, in which parts are replaced in an assembly but the basic assembly does not change. Each output part or assembly has the same part number as the input part or assembly.
- Repack/kitting operations. Here the input materials are the same as the output materials but the packaging and its labeling change. The output material has a different part number from the input material(s).

Operations to make a specific product may be organized into Routes, which consist of a sequence of operations. This enables the creation of Work Orders (sometimes also called Manufacturing Orders or Jobs) to make a batch of products with a specific route. Typically, in such a case, a barcoded Traveler, as shown below, is produced for the Work Order, with barcodes for the Work Order number and Operations, which can be scanned to facilitate data collection.




Work Order

WO00000101

Importance: Standard
Date Wanted: 12/22/2015
Sales Order #:
Customer: CDE Furniture Manufacturers
Instructions: Make Stainless Steel Knobs

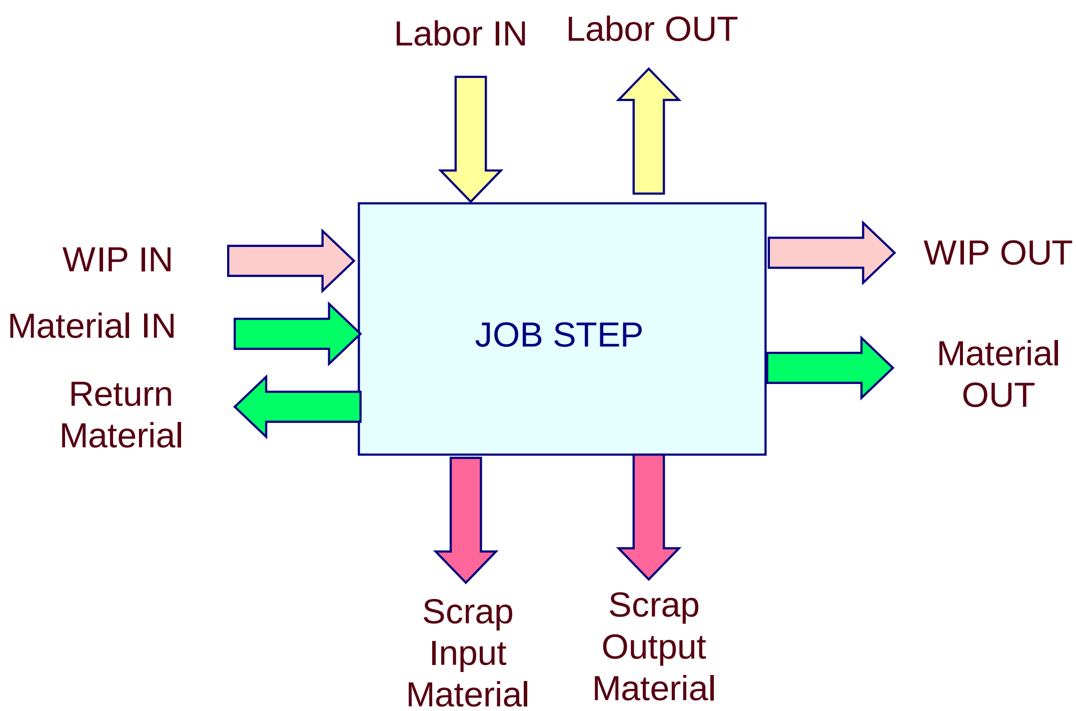
Step # : 1
Operation: Production: Lathe
Step Instructions: Lathe

Step # : 2
Operation: Production: Drill and Tap
Step Instructions: Drill and Tap

Step # : 3
Operation: Production: Polish and Inspect
Step Instructions: Polish and Inspect

For materials tracking and traceability, there is no requirement for a pre-established route. Also, barcodes for operations which are not on the route, such as for rework, can be scanned for tracking purposes.

5.3 Recording Resources Consumed and Produced



Operations can consume and produce "Resources". These resources include:

1. "Raw" Material consumed
2. Finished product Out
3. Work-in-Process Out to the next operation
4. Work-in-Process In from a prior operation
5. Scrap of input or output materials
6. Labor time of operators who run machines or equipment
7. Equipment or machine time.

Normally we record the part number and quantity of the materials as they are consumed and produced by an operation. Sometimes it is not possible to determine a priori, the quantity consumed, such as when a roll of material is loaded onto a machine from which multiple output items are produced. In this case, we normally record the whole roll as being consumed by the operation, when it is loaded onto the machine, and then weight the unused part of the roll when it is returned, to enable the materials tracking system to determine the quantity used and the quantity returned to stock.

When recording the material-in to an operation, we have three choices:

1. Simply record the part number and quantity consumed. Useful for tracking inventory but not very useful for materials traceability.
2. Record the part number, quantity, and lot number of the material consumed. This gives useful materials traceability information but, as we explained previously, can lead to difficulty pin-pointing the cause of problems and can lead to overly broad recalls.
3. Record the container from which the material was taken by scanning its LPN barcode and enter the quantity input. The part number, lot number, serial number, and possibly other information, previously associated with the LPN tracking barcode are then automatically associated with the materials traceability history.

When recording labor and equipment time resources consumed, we often need to break these down into phases corresponding to setup, run, and cleanup, for the equipment. The same or different operators may be involved in the different phases, and these may all need to be recorded along with how long each phase took. It is usually important, also, to record when the machine or piece of equipment stops running and needs repair or maintenance and why. It is also typically important to record how long it is down, and who fixed the machine.

5.4 Comparison with ERP Systems

ERP (Enterprise Resource Planning) systems, at their core, consist of an accounting system plus a Materials Requirement Planning (MRP) system.

Work Orders are often exported from ERP systems into materials tracking systems as the starting point for performing materials tracking and traceability. As such, it is worthwhile making a few comments, by way of comparison.

Work Orders (or Manufacturing Orders or Jobs), generated by an ERP system, have a finished product part number and a quantity to be made just like their corresponding materials tracking and traceability systems. They also have a route of operations to be performed plus a bill-of-materials (BOM) of the "raw" materials to be consumed to make the desired quantity of the finished products.

The BOMs for making parts are used by the MRP sub-system to plan the creation of work orders to meet projected sales goals, as well as the raw materials that need to be purchased, and to schedule when the work orders need to executed. Sometimes this planning is performed across multiple linked manufacturing plants in the enterprise, hence the term ERP.

Most ERP systems do not have a concept of the materials to be consumed and produced by each Work Order operation. This can cause issues when their work orders are used as the input to a materials tracking and traceability system because, in this case, the only reasonable assumption is that all the materials are consumed in the first operation of the route, which may or may not be a reasonable approximation to the truth.

This works well for work orders with a single operation or a single process operation followed by a test operation. But if there are a sequence of processing or assembly operations, each consuming their own materials, spread out over an extended time period then this can cause operational problems relative to actual and planned materials consumed.

ERP systems will typically use the bill of materials (BOM) for each product, along with the actual labor and machine times, as input to their cost accounting tracking functionality. They will not, however, record the materials actually consumed on each operation, when it occurs, to adjust their inventory until the finished products are shipped, when the inventory is "back-flushed" based on the product BOMs.

This can result in major errors in their inventory quantities but avoids the problem of accounting for the value of inventory consumed in making the products a significant time ahead of realizing the gain from the sale of the products which the raw materials were used to make.

Some ERP systems will not only record the quantity of materials consumed on each work order but will also record the lot numbers consumed. This does give some measure of materials traceability but not with the precision of LPN container tracking.

5.5 Quality Control

An important aspect of materials tracking and traceability is recording when materials are inspected and the results recorded. This may be as a result of a simple go/no-go inspection of the materials or as a result of a separate test operation.

It is important to record when materials are inspected, to ensure that a planned quality assurance plan is being followed, and to make sure that materials, which have not passed inspection, are not used in a production operation or shipped to a customer by accident.

This is easy to do with LPN tracking methods, as an LPN materials tracking system can track the Quality Control (QC) status of each container or serialized item and record when they are inspected, and the outcome, including the reason codes for failing to pass QC inspection. These LPN tracking systems can also prevent the use of containers or serialized items, which failed inspection, as the container barcodes are scanned to record them as material-in to an operation.

This is much harder to do with lot tracking systems, as the only recourse to the failure of a member of the lot is to fail the whole lot until it is reinspected.

Materials tracking and traceability systems may have the ability to capture test results and to add these to their materials tracking and traceability history. These results may be manually entered or captured directly from automated test stands.

5.6 Scrap and Wastage

Scrap takes a number of forms:

1. Defective raw material discovered when an attempt is made to use them on work order operation.
2. Defective WIP produced by a job step.

3. Defective finished product.

Wastage is part of the normal manufacturing process, such as scrap metal left over when parts are flame-cut from a sheet of steel. It is normally accounted for by adding a certain percentage to the planned input materials quantities needed for a desired production quantity.

For materials traceability, it is important to record scrap, as this is unexpected, and may be an important element in discovering he source of defects but wastage is a normal by-product of the manufacturing process.

The scrap or wastage material may simply be discarded or may be given a new part number, such as for scrap steel that is then tracked separately from the products being made.

Parts that did not pass tests to become a desired product may be recorded as output from an operation as another part number with a lower grade. Sometimes parts may be deliberately graded into different part numbers, depending on test results.

Tracking of scrap is straight forward with LPN container tracking systems, as it is easy to record quantities of scrap as added to scrap bins (such as by weight) when they occur. It is much more difficult with ERP systems that do not have a concept of intermediate materials or their being scrapped as part of a manufacturing process.

5.7 Work in Progress (WIP) Traceability

Work-in-Process (WIP) is not counted as inventory, with value, unless it is a true intermediate material with its own part number.

WIP materials are, however, an important part of materials tracking and traceability, as the output of a container of WIP material from one operation becomes the input to another operation. If this container of material is defective, or becomes contaminated while waiting to be processed by the next operation, then we need to record this.

In its simplest form, we can simply record the quantity of WIP out of a job step as it occurs and assume that this is the WIP input to the next transaction in the route. But this can cause problems if the WIP materials for one work order is used for another similar work order.

It can also cause problems if a batch is split and some of the output goes into containers destined for rework operations while other progress to the next operation in the route. Here the use of LPN container enables tracking of each container of WIP materials as it goes through its own sequence of operations.

The simple recording of quantities transferred 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 or simply are part of a split batch. One way of handling this issue is to give part numbers to all WIP materials and to use one-step/operation 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 process can be solved by the use of LPN container tracking, which uses barcoded totes or other containers in which to place the WIP. The WIP material is given the same part number as the finished product but is flagged as work-in-process and not part of the finished goods inventory. Also the container of WIP material carries along the work order number and operation as part of its identification to avoid confusion.

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 same item in and out of job steps.

WIP material tracking is not used in systems that simply track lot numbers as a way of doing materials traceability as its effective use depends on using LPN barcodes or RFID tags on totes and similar containers of intermediate materials.

5.8 Tracking Intermediate and Finished Goods

In materials tracking and traceability systems, all materials produced by manufacturing processes are typically placed in containers with LPN 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.

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.

5.9 Summary

Performing materials traceability within a manufacturing, food and pharmaceutical processing, construction, repair and many other industrial facilities requires tracking the transformation of raw materials into intermediate and then finished products. This can be done using lot number tracking alone but can be done much more comprehensively using License-Plate-Number (LPN) container tracking methods.

LPN tracking is essential if WIP materials are to be tracked, especially if split batches happen or similar WIP materials can be used on multiple work orders.

LPN container tracking has many similarities to the inventory tracking performed in ERP systems but ERP systems are only capable of doing lot number tracking, which make it difficult to determine the source of defects and to minimize recalls resulting from using problematic materials or processes.

Chapter 6 Tracking the Manufacture of Complex Make-to-Order Assemblies

61. Introduction

Even the manufacture of a chair requires the making of many parts, their assembly into sub-assemblies, and then their final assembly into a chair, which needs to go through a sequence of finishing operation, before shipment to a customer.

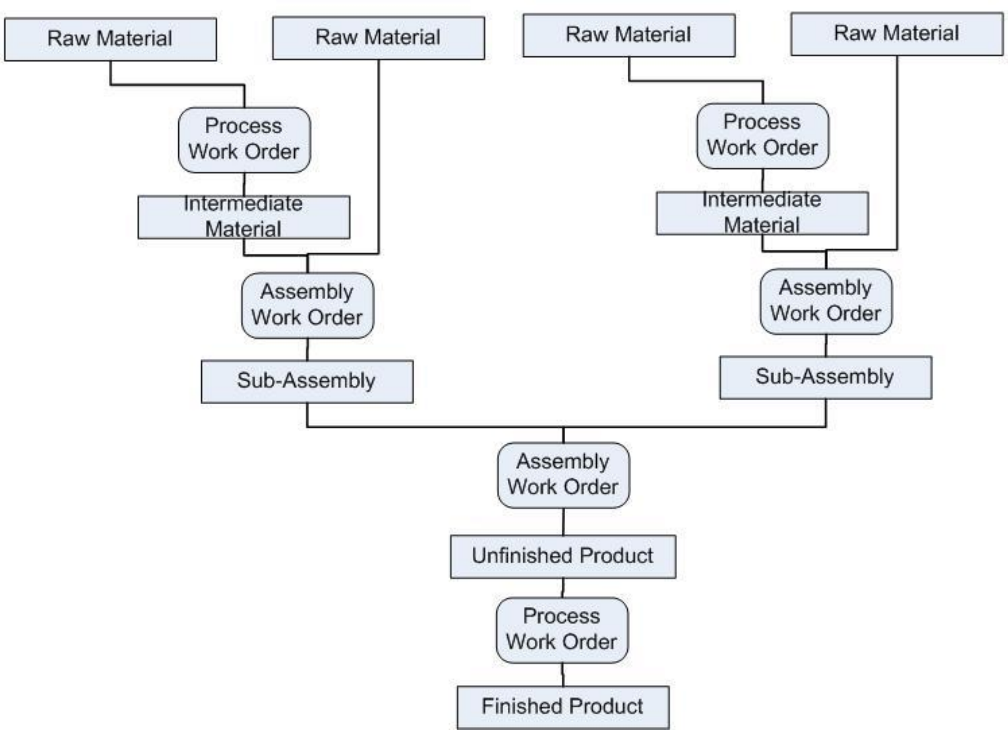
We see even more complexity in the manufacture of kitchen cabinets and curtain-wall windows for skyscrapers. Here the manufacturer is not only making one assembly but is making sets of assemblies, which sometime have to be delivered to a building site and installed in a sequence of releases.

Today, these types of projects are typically made-to-order based on raw and intermediate materials, which often are semi-custom sub-assemblies.

Often these projects require engineering design, using CAD (computer aided design) systems, as an integral part of the manufacturing process. They also involve ordering materials needed for each specific project and scheduling the making of the many required parts and sub-assemblies, so they all come together when needed for shipment to the customer or installation at the customer's site.

6.2 Modeling the Process

In order to manage a make-to-order process, such as those described above, we first need to model the process. One way of modeling this process is using a Material Flow model, as shown below:



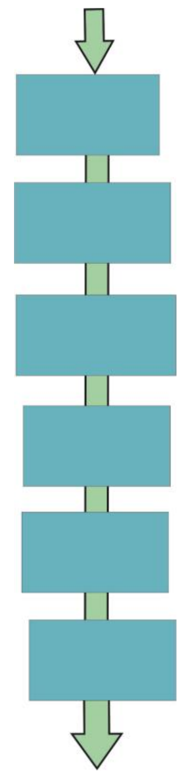
In this model, raw materials flow into the manufacturing process and are converted into intermediate parts; these intermediate parts are then sometimes assembled into sub-assemblies; sub-assemblies and parts are then assembled into products; these products are then finished, packed and shipped to customers.

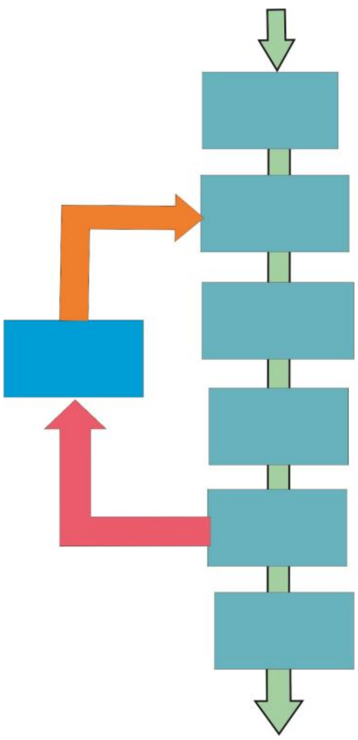
In between the conversion of materials is a work order, which may consist of one or more operations in one or more work centers.

At any one time there may be hundreds of different materials waiting for processing or being processed within hundreds of work orders. Because each customer order is different, this flow changes dynamically with different materials flowing through different operations depending on each specific customer order.

This material flow process looks like a river estuary with raw materials flowing in at the top and streaming into intermediate products which join to become finished product flowing out at the bottom.

Note that this is very different from the classical "ERP" manufacturing model in which the manufacturing process is simply modeled as a fixed route of steps or operations through which batches of material flow, as shown at right.





Each of the work orders within the material flow model may have one or more route steps, with work-in-process materials flowing between the route steps.

In a make-to-order operation though, work orders are much more likely to encompass operations, such as rework operations, which are not on the route, as shown at left and to consume materials at different steps along the work-order route rather than just having a BOM (bill of materials) for the whole work order.

The biggest issue, however, is that just tracking the status of each work orders, independent of its context for the overall customer job or project, is like looking at one leg of an elephant through a magnifying glass and trying to determine the status of the elephant.

For each customer order there may be hundreds of intermediate parts being worked on in multiple work centers based on dozens of work orders active at any one time. Multiply this by a few hundred customer orders and ensuring that each customer order gets shipped on time becomes a very complex problem.

6.3 Tracking Materials in Complex Projects

The basis of tracking projects as complex as these is to place an LPN tracking barcode on each item of raw material purchased for a project, on each intermediate part or sub-assembly made, and on each final assembly. These are then used to track the existence and location of each of these including possibly on a construction site, or in-transit to a construction site. They may, alternately be placed in shipping containers, each with its own LPN tracking barcode for delivery to a customer.

Each part, whether it is a container (which could be a roll, reel, sheet, or length) of raw material, a sub-assembly, or a final assembly, is associated with a project, by associating the LPN container barcode with a project. The exception to this is common-stock objects, such as nuts, bolts, and washers, which only become associated with a project when picked for that project.

Many sub-assemblies and assemblies are designed using a CAD system. Most of these CAD systems have the ability to generate Bills of Material (BOMs) for each sub-assembly and assembly. This data can then be imported into a materials-tracking system to create work orders to make each assembly or sub-assembly. These work orders, will each have a sequence of route steps, the first of which will be to collect or kit the parts needed for the assembly or sub-assembly.

From these work orders, we can generate:

1. Purchase Orders, to purchase the needed materials for the project, including purchase orders to add-to common stock so we have enough on hand for this project, as well as for other projects.

2. Pick orders to pick the kits of materials needed for the work orders and bring them to the appropriate work-centers, ready for making the parts, sub-assemblies, or assemblies, as appropriate.

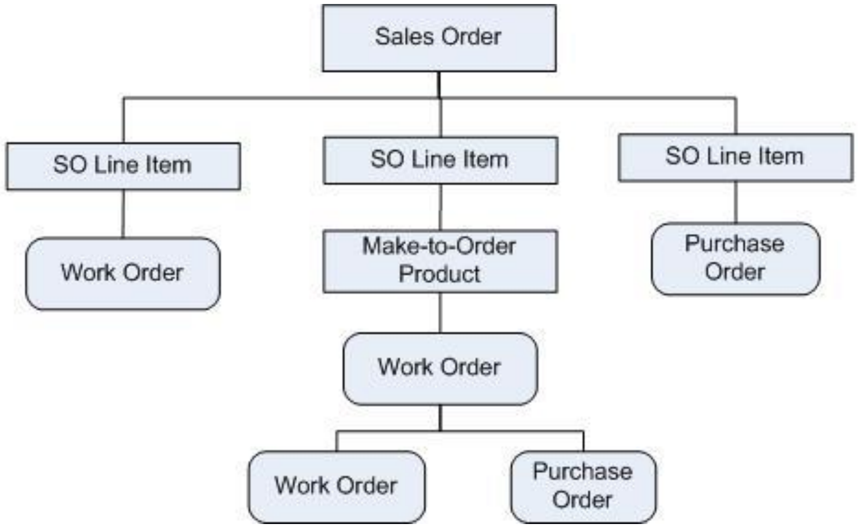
Each multi-step work order may have work-in-process tracking materials in totes, on carts, and on pallets. There may be hundreds of these containers in use at any one time for many different projects, flowing through a busy make-to-order shop. To keep track of these, we attach an LPN tracking barcode (usually permanently attached to totes and carts) and associate each of these containers with the WIP material in them and the project they belong to.

Finally, as each assembly is finished, we can attach an LPN tracking barcode to the assembly and use this to track the picking, packing and shipping of the customer order. Alternately we can scan the LPN barcode on each assembly, or component, to record its loading onto a truck/trailer for shipment to the site where it will be installed.

This not only enables us to see the status of all the materials for each project in real-time, but forms the basis on which we can schedule work-orders to make sure that customer orders are shipped on time.

6.4Tracking the Status of Make-to-Order Customer Orders

To do this we need to tie our work orders and materials to sales order lines:



A customer order may consist of multiple line items for:

1. Work to be performed on a work order, such as engineering or design services
2. Stock items to be shipped with the order
3. Make-to-Order Products

The make-to-order products will require the issuance of work orders to make, assemble, or otherwise produce the custom item. This may require the issuance of subsidiary work orders to make sub-assemblies or intermediate items or to purchase special raw materials or pre-built sub-assemblies or intermediate parts from suppliers.

If we link all the work orders and purchase orders to the customer sales order line that they are required for, then we can produce a report showing the status of these orders. If we add to that report, the status of all the intermediate, work-in-process and finished products related to that sales order, then we can get a report that shows the real-time status of all the of a customer order.

This then enables us to see the status of each order individually separate from the all the customer orders flowing simultaneously through our production operation.

It is certainly more efficient to be able to look at a computer screen and tell a customer the status of their order rather than sending an expediter to the shop floor to find out the status of all of the parts of their order. But this is not enough to efficiently manage our make-to-order operation.

For this we need to use a system like BellHawk, which will automate the process of generating the needed work-orders and purchase orders. We also need a system, again like BellHawk, which will dynamically schedule work orders such that they get worked on in the right sequence to make sure customer orders are shipped or installed on-time.

Chapter 7 Data Collection Issues

7.1 Introduction

The simplest way to track inventory is to write down, on a paper form, whenever materials are checked into a stock room or out from a stock room. These additions and subtractions can then be entered onto an Excel spreadsheet and a list of parts in the stockroom maintained in the spreadsheet, along with the quantities in stock.

For materials traceability, you can use paper forms to record the lot numbers of materials that go into making each batch of materials, along with the lot number of the batch of products being made from the recorded raw materials. This data is usually filed in a filing cabinet, to be ignored until something goes wrong with a product or you are notified that one of your raw materials is defective or contaminated.

Sometimes this data is entered into an Excel spreadsheet, so it can be more readily retrieved in the event of a recall.

This method of tracking and tracing materials is inexpensive and affordable to even the smallest organization. So, what can go wrong?

In this chapter we first examine the issues with simple manual data entry methods and then explore various technologies that can be used to automate the collection of data.

7.2 Problems with Paper Forms

There is nothing as inexpensive or as flexible as a number 2 pencil and a paper form, which is why many organizations continue to use them. Then they manually key the data written on the paper forms into Excel spreadsheets, or their ERP or accounting system, or simply put the paper form in a filing cabinet, in case something goes wrong.

Unfortunately, there are also a number of problems with this approach:

1. You can write anything on the sheet of paper. There is no feedback. The sheet of paper does not tell you if you have transposed two digits in that 12 digit part number. It also does not tell you if you are using the wrong part for a job or if the part you are picking has failed inspection.
2. As a result, many data capture errors mistakes occur that are not detected. These can be costly for valuable managers and IT staff to find and correct, especially if they are subsequently entered into an ERP or accounting system.

3. Operations mistakes, such as picking a wrong or defective or contaminated part, can be very costly. They can lead to the need to scrap or recall products and have led to millions of dollars of losses and even the bankruptcy of companies.

4. Even when this paper-forms data is subsequently entered into a computer, the data is typically entered a day or more later. As a result, managers are trying to run their operations with out of date information about customer orders, inventory and jobs, which dramatically reduces their efficiency.

5. There is no rapid recall capability when something goes wrong. All you have is a row of filing cabinets full of paper forms that may or may not be correctly filled out. This is a recipe for disaster if you are suspected of producing a defective product that may cause people to be harmed.

6. It takes a long time to write data down and then subsequently key all this data into a computer. In aggregate, many companies are wasting the time of multiple full-time equivalent people who can be better deployed elsewhere.

7.3 Barcode Tracking to the Rescue

Using paper forms and manual keyboard data entry to collect operational data wastes a lot of people's valuable time and can result in many data collection and operational mistakes. These can be prevented though the use of barcode scanning and mobile data collection technology.

With the use of barcode scanning:

1. Data collection is point-and-shoot. There is nothing to write down and can be used by people with limited computer literacy. This is much quicker that writing down data on a paper form and manually keying it into a computer. Usually the cost savings from this alone can pay for the cost of implementing a barcode tracking system in under a year.

2. Users have immediate feedback when data is captured correctly. The scanner beeps when you have accurately captured and rejects all barcodes it cannot read.

3. Because it is in electronic form, the barcode tracking software can immediately validate that the correct data has been entered. It can validate that the user has scanned a valid location barcode on a bin from which they are picking material rather than a UPC code on the candy bar that they brought for a snack.

4. Even more importantly, the barcode tracking software can validate that the correct part has been picked and that it has passed QC inspection. As a result many potentially very expensive mistakes can be prevented by immediately warning the user before they make the mistake.

5. Because the data is captured in real-time and quickly transferred to a central database, managers, supervisors, customer service people and everyone else in the organization can immediately see the status of customer orders, work orders, and inventory.

6. A permanent record of what materials were used to make which products and who they were shipped to is immediately captured. This data can be used to rapidly produce reports that enable detection of the source of defects and the tracking down of all defective material that resulted from a specific defect or source of contamination.

7.4 What about RFID?

There has always been the fallacy that you could attach an RFID tag to each item in your warehouse and then press a button and have the system instantaneously detect what was in inventory and where it is located. Unfortunately, the amount of energy you would need to interrogate all the tags simultaneously would ionize the air in the warehouse and kill everyone in the warehouse.

When used for tracking the movement of materials, RFID uses the same License-Plate-Number (LPN) container tracking methods as are used with barcodes, except that the RFID tag contains the license-plate number, rather than it being encoded in a barcode.

Frequently, in LPN tracking, both RFID tags and barcode labels are used on the same container, often with the same LPN tracking number. In this way barcode tracking can be used for initially identifying a container and its contents and then RFID can be used to track the motion of the container, as it moves from place to place, as described in the Chapter on RFID Tracking Technology.

Realistically RFID is good for tracking the movement of big things, such as pallets or carts, each with their own RFID tags. It is very inaccurate at tracking the movement of many small things, each with their own RFID tag. Barcode tracking on the other hand, is very accurate, providing that someone does the scanning.

Thus, we find RFID scanning being used for recording the loading and unloading of pallets to and from trailers and tracking the movement of carts and totes in a production environment.

RFID is not very accurate in detecting location or movement of pallets or carts. The beam-width of the interrogating antenna is typically many square feet in area. All we know is that the RFID tag is in the beam or not, whereas with barcode scanning, we can record the location of materials down to very small bins.

The other problem is that, with RFID, there is no sense of directionality. We only know the tag was "seen" in the interrogating beam and not which direction it was traveling through the beam. This can be problematic in determining whether the cart left a room or entered a room. This then requires the system to remember the last location for the cart, and to have knowledge about plant layout, in order to resolve this issue.

One place that it has found a major application is in work-in-process tracking, especially on assembly lines. An RFID tag is attached to the assembly, such as a car or truck, at the beginning of the line. The progress of the assembly down the line is then read automatically using the RFID tag. This can then be used to trigger automated equipment, such as robots, to carry out a specific operation.

In this application, the use of RFID is superior to using barcodes, which would have to be read by fixed station barcode scanners, which may fail due to the barcodes being obscured or damaged.

In summary, RFID has a limited role to play in materials tracking and traceability due to accuracy issues. But it can be used to good effect in recording the loading and offloading of trucks/trailers and on assembly lines. It can also be used as an assist in finding carts and trolleys of work-in-process within a manufacturing plant, especially those with multiple shops spread over a large area.

7.5 Commentary

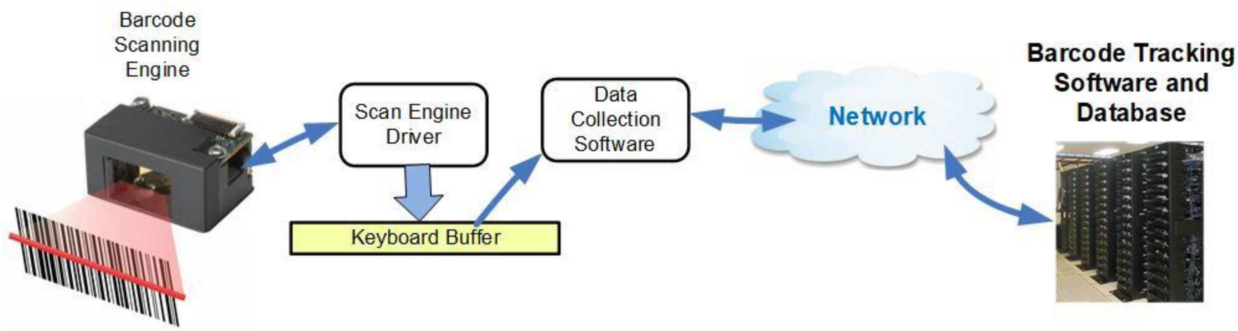
For most industrial applications, the use of barcode technology to track materials has become standard, due to its low cost and ease of deployment. As such, the following chapters will focus on the use of barcode technology, except for a final technology chapter about how RFID works. This is for those readers who are interested in RFID or who may have special applications where RFID is applicable and can be cost justified.

Chapter 8 Information Technology Architectures

8.1 Introduction

In this chapter, we examine some alternatives for information technology architectures for data collection. We focus on the use of barcode technology, which is predominantly used for electronic data capture in materials tracking and traceability systems, as well as in work-in-process tracking systems. In a subsequent chapter, we look at the use of RFID technologies, which have much more limited use in these applications.

8.2 Elements of a Barcode Data Capture System



A barcode scanner acts just like a keyboard. It uses an optical or laser scanner to scan a barcode and to decode the bars and stripes of different widths into a stream of alpha-numeric characters that are placed into the keyboard buffer of whatever device the barcode scanner is connected to.

It is then Data Collection Software in a device, such as a PC, tablet, or mobile computer, to which the barcode scanner is attached, that interprets the alpha-numeric string of characters and sends the result to barcode tracking software, which typically runs on a server computer. It is this server software, usually along with an associated database, that is responsible for performing inventory and operation tracking, as well as materials traceability.

The software used normally consists of two parts, one within the device to which the scanner is attached and the other runs on a server computer to which many barcode scanning computers can be attached and which holds the central tracking database.

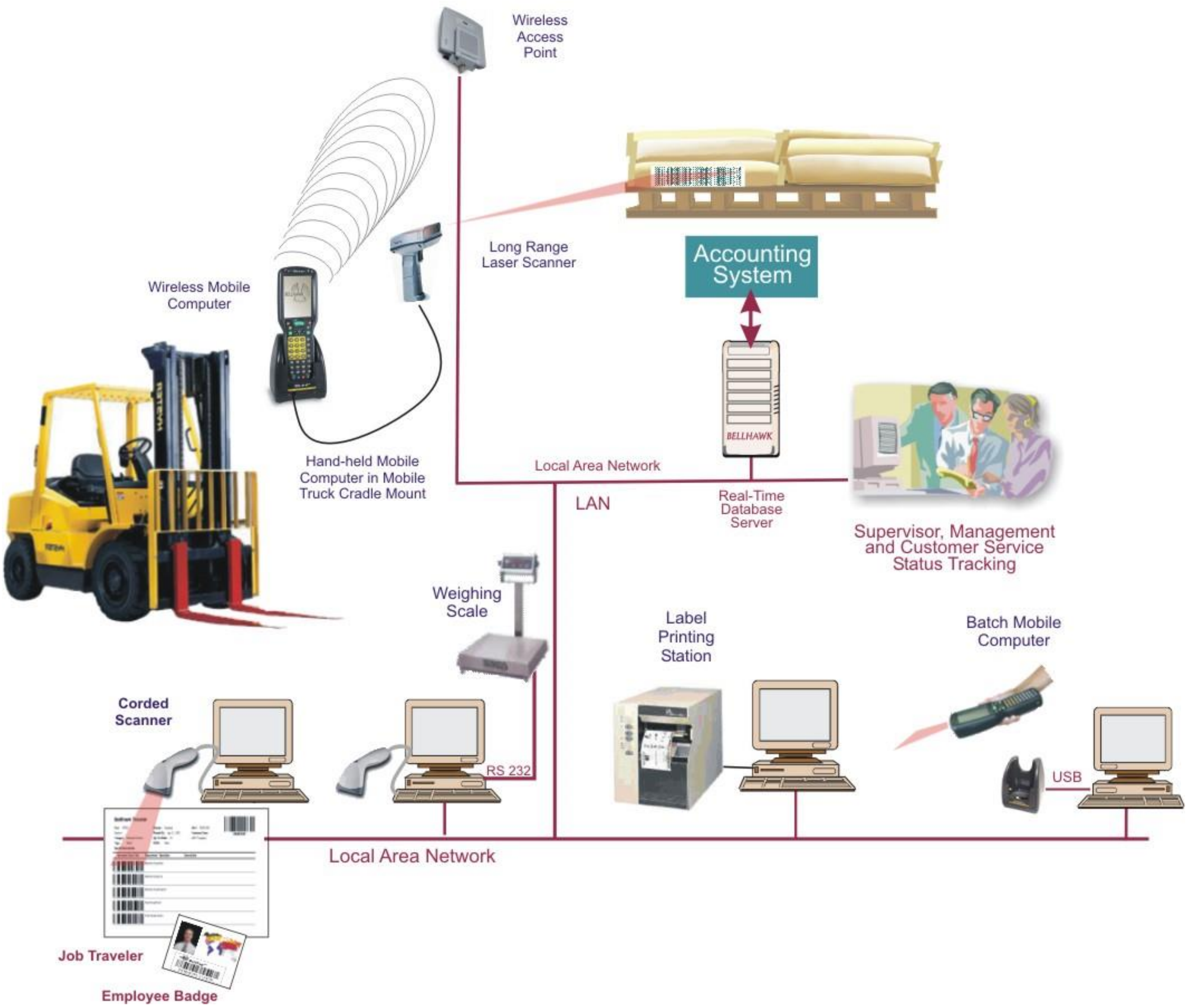
Sometimes simple barcode inventory and asset tracking systems consist of a single desktop computer or mobile computer application, with an attached or integral barcode scanner. In these systems the tracking software and a database are all contained within the device. They are simple and easy to use, and certainly a step-up from using paper forms or Excel spreadsheets for data capture.

The big drawbacks to these single computer/device systems, however, are:

1. Only one person can be using the data collection/data viewing device at a time.
2. There is no separate database that can be automatically backed-up
3. There is no separate database used for generating reports.
4. If the one device gets broken, all inventory tracking is stopped.

In general, for industrial use, it is essential to use multiple data collection devices connected to a central computer which contains the inventory and operations tracking software. This enables multiple people to be capturing data and looking at data at the same time. It also enables the tracking database to be integrated into an organization's IT (Information Technology) infrastructure for backup/recovery and security purposes.

8.3 Client-Server Systems



Client Server systems were the primary systems in use for inventory and production tracking in the first decade of the 21st century but have subsequently been replaced, in most materials and operations tracking applications, with Web-Server based systems, starting around 2007, when Microsoft and other major software houses started their migration to the Cloud.

As shown above, these systems had a database server, typically with a SQL database, connected to the local area network within the manufacturing plant or warehouse. Most data entry was performed using PCs equipped with external corded barcode scanners and data viewing and reporting was also performed using PCs. The code for the "thick client" computer programs in the PCs was typically written in Access VBA (Visual Basic for Applications), This code communicated over the Local Area Network (LAN) to the database in the Server Computer, which was typically a Windows Server computer. A typical low-cost server could support a dozen or more PC workstations.

These systems could also support barcode label printing and collection of data from weighing scales, again using thick-client programs running in the PCs.

These systems supported a variety of methods to enable mobile computers to collect data and communicate with the server database. Some of these include:

1. Batch mode. Here data was collected by simply scanning a sequence of barcodes into the memory of the mobile computer with little or no error checking on the data being collected. The data was then retrieved by a PC when the mobile computer was placed in a cradle attached to the PC and used to update the database. The biggest problems, with this mode were:

    a. Mistakes in data collection were not discovered until the transfer to the database (and sometimes not even then), often requiring a significant amount of time to find and correct the errors.

    b. Inventory updating was often not performed until the end of a shift, resulting in unexpected stock outs or the need to carry excess inventory to avoid this problem.

    c. If something went wrong with the mobile computer during its data collection, all the data could be lost, often irretrievably.

2. Terminal-Server mode. Here the mobile computer ran a thick-client program that emulated a desktop PC over a wireless link to the server computer. This worked reasonably well providing that there was continuous wireless connectivity to the server, which could often be a problem with the wireless access points in use at that time. There were also issues with the low resolution and small sizes of screen available with the available wireless mobile computers, which meant that emulating the PCs required having a complete alternate thick-client front end program which worked with the low-resolution screens available.

3. Store and Forward mode. Here each mobile computer has its own local database, in solid state memory, and its own thick-client data capture program. The local database is a subset of the main server database and is updated whenever the mobile computer is in wireless contact with the server, over the wireless network. All collected data is verified against the local database so that the user can be warned if they are making a data collection or operational mistake. Data so collected is then relayed to the server by the code in the mobile computer whenever it is in wireless communication with the server.

4. Hybrid batch and store-and-forward mode. Here the mobile computer runs in store and forward mode but its local database is synchronized with the main server when it is placed in a cradle attached to a PC. This enables the user to be warned whenever they are about to make a mistake but does not require the use of wireless communications, which was expensive and considered a security risk back in the early 2000's.

Store and forward could work really well, as it did not require 100% wireless coverage in a warehouse and was not subject to transmission losses due to electrical interference, which often plagued terminal server mode wireless computer setups.

The biggest problems with store and forward mode data collection were:

1. Delays between updating the local databases in the mobile computers and making corresponding changes to the central database. This could cause the mobile devices to become seriously out-of-sync with the main database making data checking on the mobile computers, such as for available inventory, increasingly inaccurate with time.

2. Certain device and communications failures could cause the local and main databases to become seriously out-of-sync. This would require intervention by an IT person who had to decide which parts of which database were correct and to appropriately update both databases.

3. Because the data synchronization was automatic, users forgot about synchronization and left their mobile computers in locations where they were out of communications range. As a result, important data collected by the mobile computer could be delayed by days before it was used to update the main database, which caused all manner of operational problems.

Back in the early 2000's wireless access points were expensive, insecure, and had limited range. Today they are inexpensive, secure, and, with mesh access points, able to be installed to give 100% coverage, in warehouses and outdoors, such as in yards.

Back in the early 2000's store and forward mobile computers enabled mobile inventory and operations tracking despite lack of wireless communications coverage, especially outdoors in yards and the like.

Today, with our ubiquitous communications coverage, this technology is quickly being replaced with mobile computers that can communicate directly with web-servers in the Cloud over the Internet, a company's own Intranet, or the mobile-phone data network.

There are still, however, still a significant number of these legacy client-server systems in use. Most of them now use Terminal Services, which was pioneered by Citrix, to enable PCs to communicate with servers over the Internet, as if they were communicating over a local area network. This same mechanism is used by legacy terminal-server based mobile computer systems, communicating over their local wireless network and then the Internet to the server.

The use of terminal-services is, however, being phased out due to security concerns. This is because a "hacker" can emulate a PC and gain access to the organization's local area network and all its servers, using Terminal Services. This situation is even more of an issue for mobile computers, where terminal services communications flow over the wireless network and are easy to intercept.

8.4 Web-Server Based Systems

At the core of these systems is a website linked to a SQL database. All user interaction is performed using web-browser based devices. There is no need to install "thick-client" software programs on each device as all interaction with the system is performed using a standard web-browser running on the device.

Such software can be installed “in the Cloud” at a remote data center or installed on a Windows Server within the facility within which it will be used. Typically all data exchange between the devices and the server use multi-layer encrypted data transmission for security.

Data collection can be performed using a wide variety of devices such as PCs or Android tablets that have external corded or cordless barcode scanners which are used for data capture. These devices can also include ruggedized PDAs with integral barcode scanners as well gun-style units equipped with long-range scanners, which are suitable for scanning from the seat of a fork-lift truck. Data viewing can be done using these same devices as well as using smart phones and tablets.

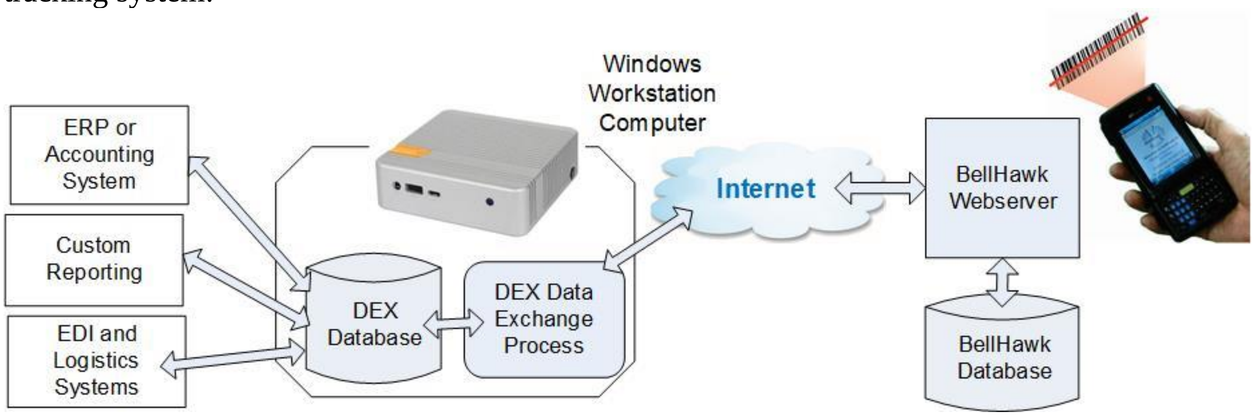
This data collection and viewing can take place over a local area network, over a wired Internet connection, or over a mobile phone data network, anywhere there is an Internet connection to the server computer. This enables data collection and viewing at multiple geographically separated facilities as well as field service sites, building sites, and other outdoor locations, which is a major improvement over client-server systems which were limited to tracking inventory and production in a single facility.

There are always trade-offs. Web-Server based software can be installed at a remote secure data center, with full IT support for activities such as backup and restore, as well as backup power, and excellent Cyber security support. But the database in which all the tracking data is stored is no longer accessible for running reports, printing barcode labels or other such purposes.

Instead, industrial computers are used in each facility enable communications between barcode label printers, weighing scales, and other systems and devices in each local manufacturing plant or warehouse with the web-server software to be run in the Cloud or at a remote corporate data center.

Instead of directly communicating with the database, these industrial computers communicate over the Internet, typically with the web-services interface of the website, to fetch and store data in the main database. These devices can then communicate at high speed with the devices, such as barcode label printers and weighing scales, with which they communicate over the local area network in the facility in which they are installed.

This same web-services interface can be used by external systems, such as ERP systems, to exchange data with the barcode tracking software. Alternately the server database can be "mirrored" in a local industrial computer so that data can be easily exchanged with the barcode tracking system:



Typically, the main database in these web-server applications is designed for rapid data collection using a number of devices equipped with barcode scanners. This requires structuring this database with many levels of indirection and cross-object references which makes it very unfriendly for reporting and interfacing purposes.

The solution to this is to make the "mirrored" data exchange interface very simple in structure, with tables similar to an Access database. Data written into the data exchange database tables is automatically relayed to the main database. Also, any data captured in the main database is automatically relayed to tables in the local data exchange database.

This makes it easy for users to generate custom reports and systems integrators to implement interfaces to a wide-variety of systems within a manufacturing plant or warehouse.

The big advantage of web-server based systems over client-server systems is their simplicity of deployment, at multiple geographically dispersed facilities, if needed. There is no special software to load on the barcode data collection devices and users can view the data in real-time anywhere there is an Internet connection, using a web-browser.

The big disadvantages is that you cannot simply change some VBA code in a PC to customize the software. You now have to be an expert in .Net ASP code development to do this, which requires a much higher level of software development skill.

However, with the use of local industrial computers, which communicate with the main web-server and database, much of that simplicity is returned by providing simple mirrored databases for reporting and interface development.

One complaint that we have heard is that web-browser interfaces are somewhat "clunky" compared with those of thick client programs running in the devices. There is no doubt that a custom App, tailored to the specific mobile device, can have a much "flashier" interface than can be provided by the one-size fits all devices web-browser interface.

To this end some people have developed custom "thick client" Apps that run in specific barcode mobile computers to capture and display data. These devices then typically communicate with the website through its web-services interface.

Such an approach can result in a more engaging user experience but comes at the expense of installing and maintaining thick-client software on each mobile device. What can make this approach problematic, beside the cost of software development, is the rapid evolution of internet security protocols along with rapid evolution of screen resolution and other device characteristics. This either results in the system becoming frozen in time or the need to continually update the software to support changes in devices and communications protocols.

Using a thick-client "App" can be required in those cases where the data collection software needs to access special devices on the device, such as an RFID reader, it's compass, or its 3 Axis accelerometers. But for most barcode data collection applications this is not required.

8.5 Commentary

Today Client-Server systems have mostly been replaced by Web-Server based systems because they can be installed in a remote data center and securely accessed from anywhere there is an Internet connection. The maintenance of these systems can then be performed by IT specialists without need for IT support within a manufacturing plant or warehouse.

Chapter 9 About Barcode Labels

9.1 Introduction

Barcodes, as we know them today, were originally invented to be Universal Product Code (UPC) to be attached to grocery items, so that the product codes could be automatically scanned at checkout time. The initial version was a circular bulls-eye pattern with varying widths of circles to encode a product code. This was found to be unreliable to print and read with the available technology in the 1970's and was replaced with a set of variable width bars and stripes, which were easier to print and scan.

These have evolved to become the modern UPC codes, which are ubiquitous on all products sold at retail. They consist of a set of bars and stripes that are scanned by a linear or one-dimension (1D) barcode scanner. In a UPC barcode the bars and stripes have different widths and 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.

Since their inception, these UPC codes have spawned a whole family of different barcodes for use in industrial and other applications. In this chapter, we will discuss the different types of barcode in use for materials tracking and traceability, how to print them, and the different ways they are used.

9.2 Different Types of Barcode

Two of the most commonly used types of barcode for materials tracking and traceability are linear or one dimensional (1D) barcodes and two dimensional (2D) barcodes.

9.2.1 One Dimensional Barcodes

Linear or One Dimensional (1D) barcodes are used for product and material tracking and data entry throughout factories and warehouses. These barcodes encode characters by using different widths and counts of bars and stipes arranged in a "picket fence".

Linear Code 128

Starting from the UPC code, which just encodes a specific set of numbers, different organizations developed different ways of representing not just capital letters and numbers (such as in code 39) to being able to represent all the ASCII characters on a keyboard (code 128) by using different sets of bars and stripes.

For materials tracking and traceability, we use barcodes that can contain a variable number of alpha-numeric characters. These barcodes have "guard" bands of different widths of bars and stripes, at their beginning and end, which uniquely identify the barcode "code" being used and also serve to delimit the beginning and end of the barcode.

It is essential that there is "white space" at the beginning and end of the barcode, at least twice as big as the width of the guard bands, so that barcode scan engines can recognize clearly identify the start and end of the barcode. One of the big mistakes that we see industrially is that users do not leave enough white space on either side of their barcodes, resulting in barcodes that cannot be read reliably.

In between the guard bands, different encoding schemes are used. Basically, these fall into two categories: those, such as used by older code 39 barcodes, use two widths, whereas more modern encoding schemes, such as code 128, use multiple widths, which are multiples (1, 2, 3, and 4) times the width of the narrowest bar or stripe. These different encoding schemes reflect the resolution of the barcode scanning engines at the time they were invented.

One thing to recognize is that the decoding of these codes is independent of the optical "magnification" used, as it is the relative size and count of the bars and stripes that determines the encoding not their absolute size. This enables decoding at different ranges, providing that the scanner has the ability to resolve the different widths.

Early optical scanners, which used a CCD (charge-coupled-device) imager, had a limited number of pixels they could resolve, which is why codes such as code 39, which only uses two widths, came into common use. It was why laser scanners, were (and in some cases, still are) preferred for their high resolution, especially in long-range scanning applications.

Today, we have high-resolution CCD elements, which were developed for digital camera use, applied to reading barcodes. These can easily resolve variable width codes, such as code 128, at ranges of many feet, which has led to the adoption of code 128 as the basis for international barcode content standards, such as those of the GS1 (Global Standards One) standards organization.

The two most common barcodes in use within industrial organizations are Code 39 and Code 128. Code 39 was adopted in the 1980's as the basis for many logistics standards and may still be required today. But, today, it has largely been replaced by Code 128 barcodes and this encoding scheme has been adopted as an ISO (International Standards Organizations) standard, so it can be used world-wide.

A 2"x1" label, encoded in Code 128, can hold about 16 alpha-numeric characters. This makes it ideal for license-plate-number (LPN) tracking barcodes for internal use within an organization. This also makes it ideal for location barcodes, which are placed on racks, shelves, bins and other locations in stock-rooms and warehouses.

But, complex contents for the barcodes, such as those required by the GS1 standards, require labels at least 4" wide to hold all the required characters and so are only used for logistics purposes. And, when we need to encode data such as the part number, lot number, serial number, and expiration date in the barcode, as is required by tracking standards for pharmaceuticals, then we simply cannot encode this data in any reasonable width linear barcode.

9.2.2 Two Dimensional Barcodes

Two dimensional barcodes are used for encoding larger amounts of data. A typical 2D barcode can hold over 1000

Two Dimensional

ASCII characters in a 2x1 barcode but requires a high- resolution imaging scanner to read the barcode.

Instead of encoding characters as bars and stripes, 2D barcodes encode character: as groups of black pixel squares known as "glyphs". These barcodes also have features that enable recognition of the type of barcode, such as the guard bars shown in the PDF417 encoded 2D barcode, above right.

These 2D barcodes were extensively used in the 1980's to carry along data about the contents of containers, as embodied in specifications such as the DoD (Department of Defense) Military Standards 129 and 130, as shown below:

With the advent of the Internet and the transition to License-Plate-Number (LPN) tracking methods, the need to carry along all the information about the contents of a container has greatly diminished. All that is necessary is to use an LPN container barcode and then to send the LPN for each container, along with all the information about the contents of the container, possibly including materials certifications and test results, to the recipient over the Internet.

But where Internet communications may be limited, such as in a war zone, other methods still very-much have their uses. As a result, we still see the use of PDF417 2D barcodes, in combination with Code 39 1D barcodes still used extensively for DoD logistics applications.

For pharmaceutical tracking and traceability applications, the FDA now requires each dispensing unit to carry along the following information in human readable format and in the form of a 2D Data Matrix barcode (as shown at right):

- National Drug Code (Typically Encoded as a GS1 GTIN)
- Lot Number
- Serial Number
- Expiration Date

(01) 00614141 9000 08
(21)66781
(10)1803149
(17)190316

This uses a composite GS1 standard sequence for its contents (see section on GS1 barcodes), which would not fit onto a 1D barcode, especially if the barcode is placed on a pill bottle or vial.

It is interesting that this 2D barcode is unique to each dispensing unit and thus can be used as an LPN tracking barcode for each dispensing unit. This barcode can then be scanned into a web-site of a repository (more on this in the Chapter on Supply Chain Integration) to determine whether the drug is genuine or is a fake. This is to aid the medical community in the USA to prevent the use of fake pharmaceuticals from third world countries, which can kill people.

Another application of 2D barcodes is the use of QR codes, such as that shown at right, to contain information that can be used as part of advertising, such as the URL of a website. These can be scanned using a mobile phone camera to take the user directly to the website, using a web-browser on the device.

QR codes are typically not used industrially because other barcode formats, such as Data Matrix and PDF417 have much more redundancy in their encoding and thus can be still be read when damaged. A Data Matrix barcode, for example can still be accurately read with over 30% of its pixels damaged. This is not true with a QR code. But then QR codes on printed advertising material are much less likely to be damaged than 2D barcodes in industrial use. Also, if there is an error made in looking up a website URL, this is far less potentially damaging than returning erroneous information about a vial containing a cancer drug.

One other application of 2D barcodes is to place license-plate tracking barcodes into really small spaces, such as onto the top of integrated circuits in PC boards. High resolution (5 Mil) 2D barcodes are much smaller than their 1D equivalents and thus find their application in tracking really small serialized items, on which space to place a barcode is at a premium.

Finally, 2D barcodes, such as the Data Matrix can be embossed onto metal which enables their application in environments where heat, chemicals, or ruggedness would preclude the use of regular, sick-on-barcodes. These can be read with regular 2D barcode imagers, whereas this would not be possible with linear 1D barcodes.

9.2.3 2D Versus 1D Barcodes

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

A 1D barcode can hold an identifier, such as a “license–plate-number” 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), shown at right,

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) shown below.

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. It is noteworthy, however, 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.

At time of writing, a simple imaging barcode scanner that plugs into a PC and can read a 1D barcode can be purchased for under $60 and a short range (up to 2 feet) 1D laser scanner (puts out a red scanning line) can be purchased for under $150. A short–range 2D imaging scanner of equivalent performance costs about $250.

Another issue is range. A laser scanner provides its own illumination in the form of a narrow laser beam and measures the reflected light in a limited spectrum. A 2D imager is like a camera and has no control over the illumination of the target barcode. At short range, in good light, where the barcode occupies a large part of the image, they work really well.

At long range, a location barcode may be hung in the rafters of a warehouse, where it is poorly lit, and the barcode may only occupy a small part of the image. The image may also include ceiling lights, which may "blind" the imager in the scanner by forcing it to adjust the image pixels recorded (which have limited resolution) to the brightest lights in its field of view (just like in a camera). Although high resolution imaging scanners can read barcodes at long ranges, this issue can severely limit the application of 2D imaging scanners in practical long-range scanning applications.

Another limitation of 2D imaging scanners is that their field of view may include a number of barcodes, especially at longer ranges. This can result in the wrong barcode data being output from the scan engine. While the ability to read a number of barcodes at the same time has been touted as an advantage, in most cases it causes great difficulties, as many of the "spurious" barcodes on cartons and boxes are non-standard barcodes from third parties and only serve to confuse the barcode tracking systems.

Laser scanners, in contrast, are very precise about what they are scanning and only scan the one barcode at a time, which is illuminated by the laser beam. Also, some 1D laser barcode scanners can modify the arc they scan, to the range at which they are scanning and, as a result, can scan 1D barcodes at ranges from 4” to over 40 feet. This is made possible by using the laser beam as a range-finder whereas, by cob an imager has no sense of range, as all it gets to decode are a set of pixels.

As a result, we always want to use 1D barcodes wherever possible and only use 2D barcodes when large amounts of data must be contained in the barcode. With the use of the Internet, we can instantly lookup data about an item almost anywhere in the world, given its tracking number. As a result, we don’t need to put all of the data in a 2D barcode. We simply scan the 1D LPN tracking barcode and look–it up over the Internet.

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, for simplicity and low-cost, and 2D barcodes should only be used if you have to ship to the US Department of Defense, or have to follow FDA labeling requirements, or have some other customer that demands 2D barcodes on their packaging.

Increasingly both 2D and 1D barcodes are being used in supply chain logistics, as appropriate to their intended use.

In the above example, we see dispensing units, such as pharmaceuticals, with 2D barcodes of each dispensing unit. These are contained in boxes that have 10 mil resolution GS1 1D SSCC (serialized shipping container code) barcodes, that uniquely identify each box. The boxes are stacked on a pallet that has a 20 mil SSCC barcode (typically on the outside of the shrink wrap) so that the pallet LPN tracking barcode can be scanned from the seat of a fork-lift truck.

9.2.4 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 10 mils and high-resolution barcodes with a 5 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 high resolution 5 mil resolution labels are used.

Rack and Floor Post labels for use in a warehouse typically have a resolution of 20 Mils so they can be scanned at a range of 10 feet from a form-lift truck seat. Overhead, aisle markers may use a resolution of 100 mils to ensure they can be scanned at a range of 40 feet or more.

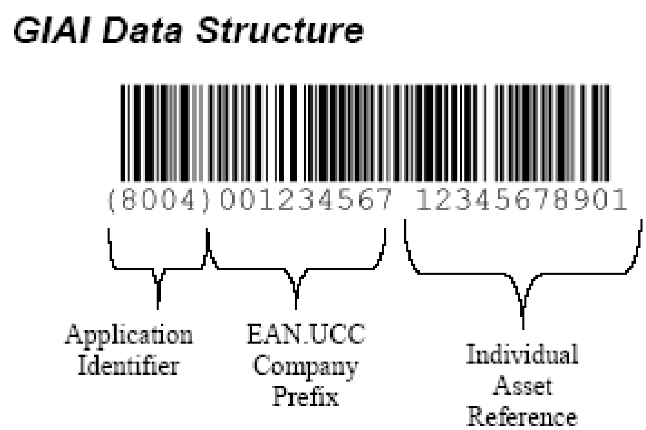
For 2D barcodes the resolution is measured in terms of the smallest feature size (dot or square) that can be resolved.

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 white 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.

9.3 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 One, standards organization. This standard uses the Code 128 standard for 1D barcodes and the Data Matrix standard for 2D barcodes to define the meaning of the contents of the barcode.



This standard specifies three parts of a barcode's contents. The first is an Application Identifier (AI), which is 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 replacing the older UPC code as the standard for encoding products, at least for industrial use.

(01)28880123456788

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

The most commonly used 1D barcode is a Serialized Shipping Container Code (SSCC) barcode, shown below right. This barcode is attached to pallets, boxes, and other containers of material to uniquely identify each one. The contents of an SSCC barcode are as follows:

- Application Identifier (00)
- Extension Digit - Typically used to enable multiple points of shipment to have their own container sequence
- An 8 Digit Company Prefix - a Globally Unique Identifier for the Organization creating the label. This prefix is issued by GS1 and, for companies with older UPC company prefixes, consists of on their UPC prefix with a leading zero.
- A 9 Digit Serial Container Reference, which along with the Company Prefix and the Extension Digit must forma unique License-Plate-Number (LPN) tracking barcode.
- A 1 Digit Checksum for error checking.

This SSCC barcode is used to uniquely identify a container anywhere in the global supply chain. It can be scanned just like any other LPN barcode to record the movement of each container.

With an LPN nested container tracking system, like BellHawk, each box can have its own SSCC barcode as can the pallet on which the boxes were packed. Details about the contents of each box can then be sent as an Advanced Shipment Notice (ASN) along with the SSCC codes of each box and that of the pallet. This enables one-scan receiving of the pallet by simply scanning the pallet SSCC barcode, as the ASN provides all the information about the contents of each nested container along with its SSCC LPN tracking barcode.

GS1 composite 2D barcodes are often used where more data than just a simple LPN identifier is required. A good example of this the barcodes now required by the Drug Supply Chain Safety Act (DSCSA). For pharmaceutical tracking and traceability applications, the FDA, which is responsible for implementing the DSCSA, now requires each dispensing unit to carry along the following a composite 2D Data Matrix barcode with the following contents:

- (01) National Drug Code (Encoded as a GS1 GTIN)
- (10) Lot Number
- (21) Serial Number
- (17) Expiration Date

(01) 00614141 9000 08
(21)66781
(10)1803149
(17)190316

This does, however, also illustrate problems with the GS1 composite format that users need to be aware of. The GS1 composite format is simply a sequence of letters and numbers with no pre-defined separators between the component entries. Certain fields, such as the GTIN and the expiration date have a pre-defined length, so they can easily be decoded but the lot number and serial number are variable length fields.

If there were only one variable length field, the standard way of handling this is to make the lot number the last field in the sequence and thus was easy to identify after decoding all the fixed length fields that preceded it. But when there are two variable length fields, this becomes much more difficult.

One way of solving this is to terminate the serial number with an ASCII non-printing group separator GS1 character when forming the composite string to write into the 2D barcode. This can then be used to recognize the end of each variable length string by the barcode scanning software that is decoding the composite barcode string. This software then strips out the GS1 before using the lot and serial number.

The 2D Data Matrix specification also included the ability to write a group-separator "Glyph" (image pattern) in the 2D barcode, to separate fields. This can be used to separate the fields in a GS1 composite barcode, within the Data Matrix barcode. Unfortunately, most 2D barcode scanners do not have the ability to decode the presence of this Glyph into a GS1 ASCII group separator character when outputting the ASCII contents of the 2D barcode into the keyboard buffer of the device to which they are attached.

The good news is that, however it is formed, with or without separators, the resultant contents when scanned forms an essentially unique LPN container tracking barcode. This can then be scanned to track the packing of these serialized barcodes into boxes with SSCC barcodes, which are then packed onto pallets with SSCC barcodes. In this way a system like BellHawk can be used to construct the ASN data needed by the recipient organization.

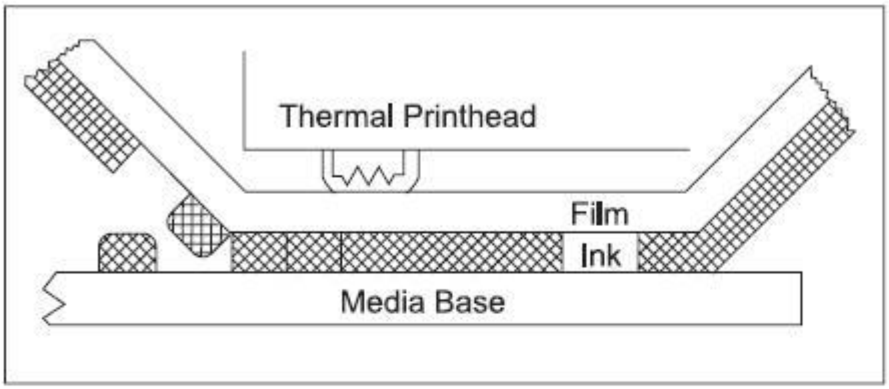
This LPN barcode can also be scanned into a website that is the on-line repository for all valid DSCSA barcodes for pharmaceutical dispensing units. This enables rapid detection of fake pharmaceuticals, which are potentially harmful.

9.4 Printing Barcode Labels

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 or Honeywell, 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.

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. 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.

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.

For lower volume applications, with simpler loading and setup requirements, many organizations will use a clam-shell printer such as that shown at right.

These printers are lower cost and typically plugged into the USB port of a PC. They are not designed for high-volume printing but work-well for applications where intermittent printing of labels in low-volume are required.

Barcode label printers are also available as wearable units, as show at left. These units communicate through the wireless LAN and enable the user to print out labels on demand based on requests entered though their mobile device.

Many barcode label printers will also work with thermal media, in direct thermal mode. The thermal paper barcode labels used in this method change color from white to black where heated by the printhead to print the barcode and text on the label. The benefit of this is that wax or resin film ribbons are not required. The major disadvantage is that these barcode labels fade with time and not rugged, unlike even the lowest-cost labels produced by melting the ink from the ribbon onto the label. As such direct thermal printing is not recommended to printing barcode labels for industrial use.

Barcode label printing 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.

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.

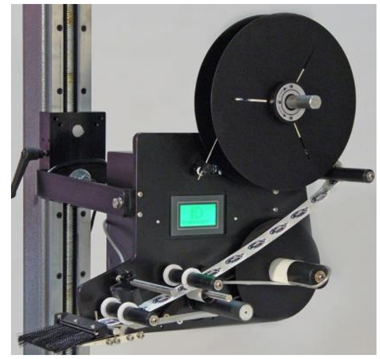
Labels printed on a barcode printer can each have their own unique tracking barcode plus human readable information, such as a part description, which is unique to the item to which it is being applied. This is the advantage of the use of a barcode printer over the use of pre-printed labels which simply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

9.5 Using Preprinted Rolls of Barcode Labels

An alternative to using a barcode label printer to print out barcode labels on demand, for the purpose of license-plate-number (LPN) container tracking is to use rolls of pre-printed barcode labels, such are shown here. Each label has a unique tracking barcode number but have no human readable information, beyond the license-plate number itself.

These labels can be simply peeled off and attached to anything you want to track. Then the labels are scanned and the relevant information is entered into a tracking system. These are ideal for many internal tracking applications as they do not require users to print them out, when needed. Instead these can be purchased as pre-printed rolls or printed ahead of time using available barcode printers, such as in the shipping department.

9.6 Automated Barcode Label Applicators and in-Line Printers



While most barcode labels are printed on demand, and then applied manually to products and their packaging materials, this can take a significant amount of time and slow down production when a high volume of products or their packaging have to have their own unique barcodes.

One solution to this is to pre-print a sequence of labels and then place them into an applicator that automatically applies the labels to each product or its packaging as it comes down an automated production line. This works well until the applicator jams due to labels wrapping themselves around its spindle or labels fails to be automatically applied.

For this reason, typically, more labels are printed than are needed, and an automated fixed station scanner is placed at the end of the production line to make sure the labels are readable and correctly positioned on each unit. When there is a failure, the line is halted, and badly labeled products have to be discarded or reworked before being relabeled.

The problem with this is that, if labels were serialized, then there will be "holes" in the serial number sequence of the finished units. This may not be a problem, if the serial numbers of the "good" units are recorded at the end of the line. But, in other applications, such as validated pharmaceutical applications, this may not be acceptable.

To solve this problem, an in-line barcode label printer and applicator is used. Such a system, when used in conjunction with an industrial PC, which is tied to a barcode tracking system, such as BellHawk, can generate serialized LPN labels and apply them, all at one station.

Such a station is able to detect when a jam or similar problem occurs, stop printing, and turn on the ANDAN light to alert operators that attention is needed. After fixing the problem, printing can then be resumed at the last good serial number, without leaving "holes" in the serial number sequence.

9.7 Barcode Label Printing Media

The most common barcode label "media", used in barcode label printers, come in the form of rolls of peel-off labels, with a "wax" paper backing. The labels are made of paper and are die-cut to the size needed for the labels.

Common sizes for labels are 1", 2", 3" and 4" wide with lengths (along the roll) of ½", 1", 2", 3", and 6".

These labels are designed for thermal transfer printing with a ribbon that is loaded into the barcode label printer at the same time. The most commonly used ribbons are "wax" ribbons, which have the ink embedded into a wax coating on a plastic substrate. The barcode printer's print-head, which consists of a row of dots, melts the wax onto the paper as it passes under the print head, forming a durable image on the barcode label.

Paper labels not very durable when subjected to impacts from hard objects. To overcome this problem, paper labels are also available with a thin plastic coating which improves their durability.

These coated paper labels, however, are still not waterproof and are also subject to fading in sunlight, due to UV irradiation. To overcome this problem, more expensive labels are available in polypropylene plastic. These labels need to be used with "resin" ribbons, which have the ink embedded in a resin coating. These ribbons require a higher temperature to melt the ribbon, but result in a water and UV proof label that is very rugged.

There are specialty labels, such as those made from substances such as Kevlar, for special purposes. There are also "piggy-back" labels with multiple layers of label, such that a large primary label can be printed and then smaller labels subsequently peeled off the larger label. These piggy-back labels are typically used for situations, where a barcode label needs to be initially to a larger container, and then a related barcode label need to be applied to a subset of its contents, such as a QC sample.

Barcode labels are available with a wide-range of specialty adhesives. The common paper labels come with an adhesive that is good for their attachment to cardboard but specialty adhesives are available for adhesion to plastic and metal surfaces. Most labels are not intended to be removed, once adhered, but special "low-tack" adhesives are available to permit easy removal of the barcode label, if needed.

There are also specialty barcode labels, with special adhesives, designed to work in moist, freezer, or relatively high temperature applications. Although, for really high-temperatures, we have to rely on laser-engraved or embossed metal barcodes.

9.8 Embossed and Laser Marked Barcodes

For those applications where a separate barcode label cannot be applied to metal or plastic parts, due to heat, abrasion, or fit, and yet a barcode label is required. A laser beam can be used to etch a 1D or 2D barcode directly into the surface. On most surfaces these barcodes can be read using a high-resolution barcode scanner, with appropriate lighting.

An alternative to laser marking, are machines that emboss a barcode into a metal tag, which can be riveted or screwed to whatever it is desired to track. These barcodes are very rugged and can be read by standard barcode scanners. They are most suitable for 2D barcodes, such as the Data Matrix shown here, with the square pixels of the printed barcode replaced by raised portions of the metal tag.

These tags, along with corresponding barcode tags made using laser engraving are often used on reusable totes, carts, pallets, and vats, which are used to hold intermediate materials. These rugged labels enable to same barcode to be reused over and over again to identify the material in the reusable container without the need to replace the barcode.

Where chemicals are used, which could destroy the surface of a laser etched tag, then the tag can be encapsulated in clear ceramic (like glass - but tougher) to protect the label.

9.9 Location Barcodes

9.9.1 What are Location Barcodes?

A location barcode specifies a location at which materials may be stored. A typical location barcode that might be attached to a shelf is shown at right.

It consists of a one dimensional barcode, which contains the code for the location with the same code in human readable form. It may also contain arrows and other indicators to enable the selection of the correct barcode to scan for a shelf.

These barcodes are typically printed on a plastic substrate with the use of resin ribbons (for thermal transfer printing) or other durable inks (if colored) to make them as scuff and damage resistant as possible.

These barcode labels come with an adhesive backing that is suitable for attachment to metal shelves and have a peel-off paper backing. If these are to be attached to wood shelves, plastic surfaces, or used within refrigerated environments then labels with special adhesives may need to be ordered.

The horizontal width of the barcode depends on the number of characters to be encoded in the barcode plus start and stop bars and stripes plus white space that is required before and after the beginning and end of the barcode. It also depends on the width of the bars and stripes used to encode the characters in the barcode.

The width of the narrowest bar or stripe in the barcode sets the distance at which the barcode can be scanned because of the limitations of the angular resolution of the barcode scanning engine in the scanning device. This width is measured in thousandths of an inch or "mils". For shelf barcodes this width typically needs to be at least 20 mils for scanning at a range of about two to three feet. To scan at ranges of 8 feet of so, such as from the seat of a fork-lift truck, then the barcode should be typically 40 mil resolution.

These distances will be dependent on the angular resolution of the scanning device and its type (active laser or passive imager) and are provided here for general guidance. Please contact your equipment supplier for guidance as to the barcode widths and resolutions to use with specific barcode scanning devices in specific operational cases.

The reason that we use one dimensional barcode labels rather than two dimensional barcodes for locations is that they can be read at longer ranges, especially by active laser scanners. Laser scanners are traditionally preferred for materials handling applications because it is easier to select the correct barcode when one barcode has to be selected from among many other barcodes nearby using the red illuminating line of the scanning laser. Because they actively illuminate the target barcode laser scanners are also less susceptible to optical interference than passive imaging scanners, which are needed to scan two dimensional barcodes.

Of recent years, passive imaging scanners have improved dramatically in their resolution and are now starting to be used in materials handling applications as they are inherently more rugged and can be lower in cost. This may, in future, lead to a change to the use of two dimensional barcodes for location barcodes as they can be read more reliably by imaging scanners. But for now, we recommend using one dimensional location barcodes, except in special applications.

9.9.2 Types of Location Barcode

A location barcode attached to a shelf can be used to record when containers of material with tracking barcodes or loose items are moved to a shelf.

They can also be used for bins, which hold large items, such as shown below:

However, when tracking small items, such as fasteners, medical supplies, or tools then tracking, and especially picking, is made easier by attaching a "license-plate" container tracking barcode to the bin, as shown at right. The location of the bin can then be changed, if needed, by scanning the bin barcode and the new location barcode for the shelf on which it is placed. This provides flexible use of stock-room space as the product mix changes without replacing the barcodes that are permanently attached to the shelves.

These location and bin barcodes can then be scanned to record the movement of materials into and out of the bins or locations. They can also be scanned during "cycle counting" and inventory auditing to checking the amount of inventory present, in case someone has made a mistake in not recording the movement of inventory or has made an error in specifying the quantity moved or withdrawn.

Shelf barcodes work well when the shelves are at, or close to, eye level. But when warehouse racking is used, it becomes impossible to quickly and accurately scan barcodes placed on the high shelves. For this reason, we use a set of rack barcodes placed at eye level, on the rack verticals, as shown at right.

These rack barcodes:

- Are color coded as to the shelf level - to avoid mistakes. It helps if the shelf edges are colored (with tape or paint) to be the same color as the color used on the eye level barcodes.
- If fork-lift trucks are being used, have a barcode with large enough bars and stripes so they can be scanned by the driver without leaving his seat.
- Have an indicator arrow showing which set of shelves the barcodes belong to.

Many organizations also store materials on pallets in floor locations. Here there are three choices. Our preference is to use "traffic" cones with location barcodes attached to the top of these traffic cones, as shown at right. These are then placed inside a yellow lined floor area and the location barcode on the cone is scanned to record the location of any pallet placed within the floor area so marked.

The barcode on these location markers is located about 4 feet from the floor, and is large (typically 10"x6"), making it easy to scan by fork-lift truck drivers without leaving the seat of their truck. We recommend attaching the barcode (which is attached to a plastic board) to the cone by means of Velcro. In this way, when the fork-lift truck driver hits the cone with his truck, the cones can easily be stood up again and the barcode quickly reattached when it comes loose.

One alternative to these is to use overhead location barcodes hung over warehouse aisles, as shown here. The problem is that, in most industrial warehouses, these need to be hung at least 25' in the air, making them difficult to scan, even with expensive, long-range barcode scanners.

Another alternative is to use ceramic coated location barcodes epoxied to the warehouse floor. In our experience, these can easily become damaged in industrial use and are difficult to scan from the seat of a fork-lift truck.

The big advantage of the traffic cones is that they are inexpensive and that the warehouse floor locations can easily be changed, as needed, as different projects and products, need different amounts of floor space over time.

Note that the barcodes should always be placed so that the bars and stripes are vertical, in a "picket-fence" arrangement. This is because all the handheld barcode scanning devices are ergonomically designed to be used with barcodes in this configuration. Also the height of the barcode should be chosen so as to allow for normal variability from horizontal in scanning.

Also note that barcodes should not be placed next to one another, horizontally, as this can lead to errors in selecting the correct barcode to scan. They can be placed together vertically, as in eye level rack barcodes, because it is easy to select the barcode to scan using a red aiming line from a one-dimensional barcode scanner. But this can still lead to problems when using two-dimensional imaging scanners, where a wider vertical separation is also required.

9.9.3 Choosing a Location Numbering Scheme

For location barcodes, we recommend using 6 to 8 characters. This gives enough characters for the barcode decoding algorithm inside the scanner to quickly and accurately decode the contents of the barcode. It also enables the use of wide-enough bars and stripes to make the barcode able to be scanned at a reasonable distance. If too few characters are used then the scan engine may not be able to accurately decode the contents of the barcode. If too many characters are used then the barcode becomes longer (approximately in proportion to the number of characters encoded) and the width of the bars and stripes in the barcode have to be made narrower to fit within the available space (such as the width of a warehouse rack) thereby reducing the range at which they can be scanned.

For warehouse racks, we recommend using a letter for each aisle or zone, followed by a number, for the rack bay, followed by a letter for the shelf height, such as is shown at right. These are much easier for material handlers to remember and use than some thing like "`23.12.5`".

Note that in the scheme shown at right, we use the full width of the vertical rack for the barcode (plus needed white space on either side) to maximize the size of the barcode and thus the distance at which it can be scanned.

9.10 Printing Picking Sheets and Work Orders with Barcodes

While not essential, from an operational viewpoint, it is often convenient to print out sheets of paper with barcodes, such as for picking or work orders.

Pick Order P000033

Employee :

Ship Date : 12/11/2006

Ship Time : 10:30:00

Customer Name : XYZ Builders

Contract Number : C000030

Ship Order Number : S000043

Pick Line Barcode	Part #	Qty To Pick	Qty Picked	Status
	T101 Red Roofing Tile	100	0	Released
	T102 Grey Roofing Tile	50	0	Released

These are not printed on a barcode label printer but instead are printed on an office printer, using special software that automatically embeds the barcode images into the documents.

Such forms are typically printed on office laser printers or on ink-jet printers with waterproof inks. This is to avoid the barcodes becoming unreadable due to running and smudging.

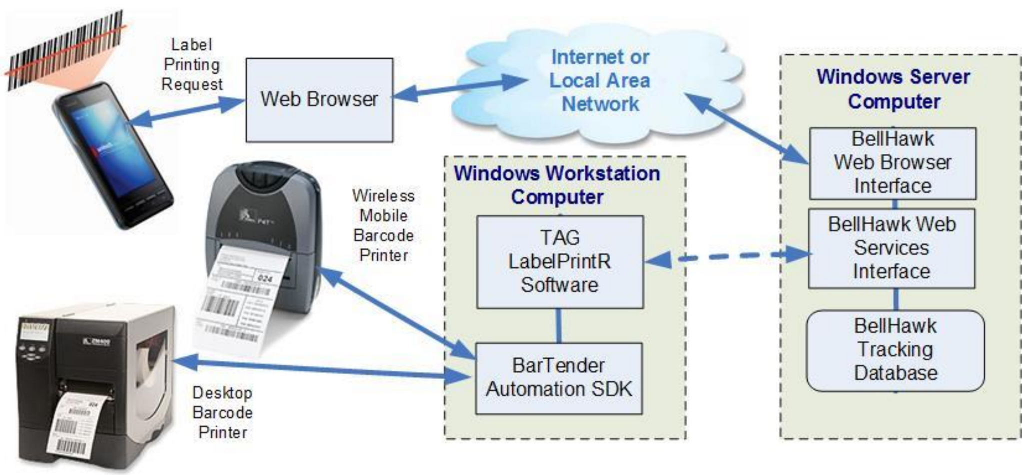
9.11 Color Barcode Printers

Color barcode label printers are a hybrid between inkjet printers and thermal transfer barcode label printers. Instead of melting ink embedded in wax onto the label, using a print-head with a row of heating elements, these printers use a linear array of ink jets. This enables them to print barcode labels, human readable information, and graphics onto the label in a wide variety of colors. As the ink they use is waterproof, these labels are nearly as durable as paper labels printed with a thermal transfer barcode label printer.

This overcomes the limitation of a thermal transfer printer, which can only print in black. Color can be added to the label by printing this onto the label stock ahead of time, but this cannot accommodate the case where each label may have a different color.

These printers have specific operational uses, such as printing out a red border onto the LPN tracking barcode, if the unit fails initial inspection, and printing this in green, if it passes. But in general, they have found their primary use in short-run printing of product labels.

9.12 Issues with Remote Label Printing



One of the issues with having a barcode tracking and labeling system running in the Cloud at a remote data center is that the barcode label printers are in one or more local plants. These printers often need to download several megabits of data to describe the data to be printed on each label. If unique labels, such as with different LPN tracking barcodes, need to be printed at high speed, it can be difficult to get enough network bandwidth over the Internet to achieve this.

Also, pushing data directly to the printer over the Internet requires opening up a "hole" in the network firewall so that the barcode printing system can write directly to the printer, via the organization's internal network. This can present a major security risk.

A better way to solve this problem is used by systems such as BellHawk. How this works is, when a user requests the printing of a label, such as from their mobile computer, the code behind the web-browser gathers up the variable data that needs to be placed on the label and writes it to a print queue on the server. This is typically only a few bytes of data.

Software running in a computer in the remote plant or warehouse then long-polls the server over the Internet such that the server returns the contents of the print queue record, to the remote computer within a fraction of a second, even over limited bandwidth internet connections.

The remote computer, which has the label format (fixed data) stored on its hard-drive merges this fixed data with the variable data from the print queue, and outputs the resultant much larger data stream to the barcode printer over the high-speed local area network.

As the local computer is only reading from the main tracking system, it behaves just like any PC accessing the Internet, thereby avoiding a major security issue. Also the request in the print queue can be for many similar labels, such as with incrementing LPN tracking barcodes. Such singular requests can then be expanded into the printing of many unique labels by the remote computer.

This system is also amenable to simultaneous high-speed printing in multiple, geographically distributed warehouses and manufacturing plants, as the computers handling the printing in each plant only fetch a limited amount of data but expand this into the large amount of data needed for printing in each plant.

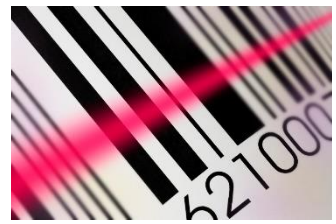
Chapter 10 Barcode Scanning Equipment

10.1 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 types of equipment that I have included here are typical of those that I have found to work successfully in a variety of industrial organizations.

10.2 Advantages of using Barcode Scanners for Data Collection

The advantages of using barcode scanners 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 makes 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.

10.3 Laser versus CCD based Scanners

Barcode scanners are of two types, a laser scanner, whereby the barcode is scanned with a laser beam, and a CCD imager, which essentially takes a picture of the barcode and then decodes the image.

Early barcode scanners, all used laser scanners, with a visible reading beam, as CCD imagers did not have the needed resolution to successfully decode barcodes.

Laser scanners were typically used with one dimensional (1D) barcodes, which consist of bars and stripes, as it was easy to scan the barcode with an oscillating laser light and to decode the reflected signal. There were some laser scanners where the laser beam was mechanically moved in a two-dimensional raster pattern to enable them to scan a two-dimensional (2D) barcode. These have, however, been replaced with CCD imaging scanners.

Today CCD imagers are inexpensive and have high resolution, and are increasingly taking over from laser scanners. The one area of hold-out, for a long time, was in the area of long-range scanning, such as for scanning an overhead barcode used to mark a floor area. Here a range of 40' is required, which was beyond the effective range of CCD scanners because of their limited pixel resolution.

CCD scanners have now improved to the point that are now being used for long range scanners. But this has brought with it the issue of which barcode to decode when multiple barcodes appear within the image captured by what is essentially a digital camera.

For 1D scanners this is usually solved by having an aiming spot, or a red-line (like a laser beam) projected onto the barcode, so the imager knows which barcode to select. This gets to be more of a problem with long-range scanners, which are much harder to aim correctly at a distance of 40 feet than a barcode scanned at a range of a few inches.

Some manufacturers have touted the ability to scan multiple barcodes at the same time as a useful feature. But, when it comes to scanning license-plate-number tracking barcodes or rack locations, for materials tracking and traceability purposes, this is much more of a hindrance than a help. This is because a significant level of Artificial Intelligence (AI) can be needed to sort out which barcode(s) are useful and which were randomly present in the image, such as being left over from prior uses of the container being scanned.

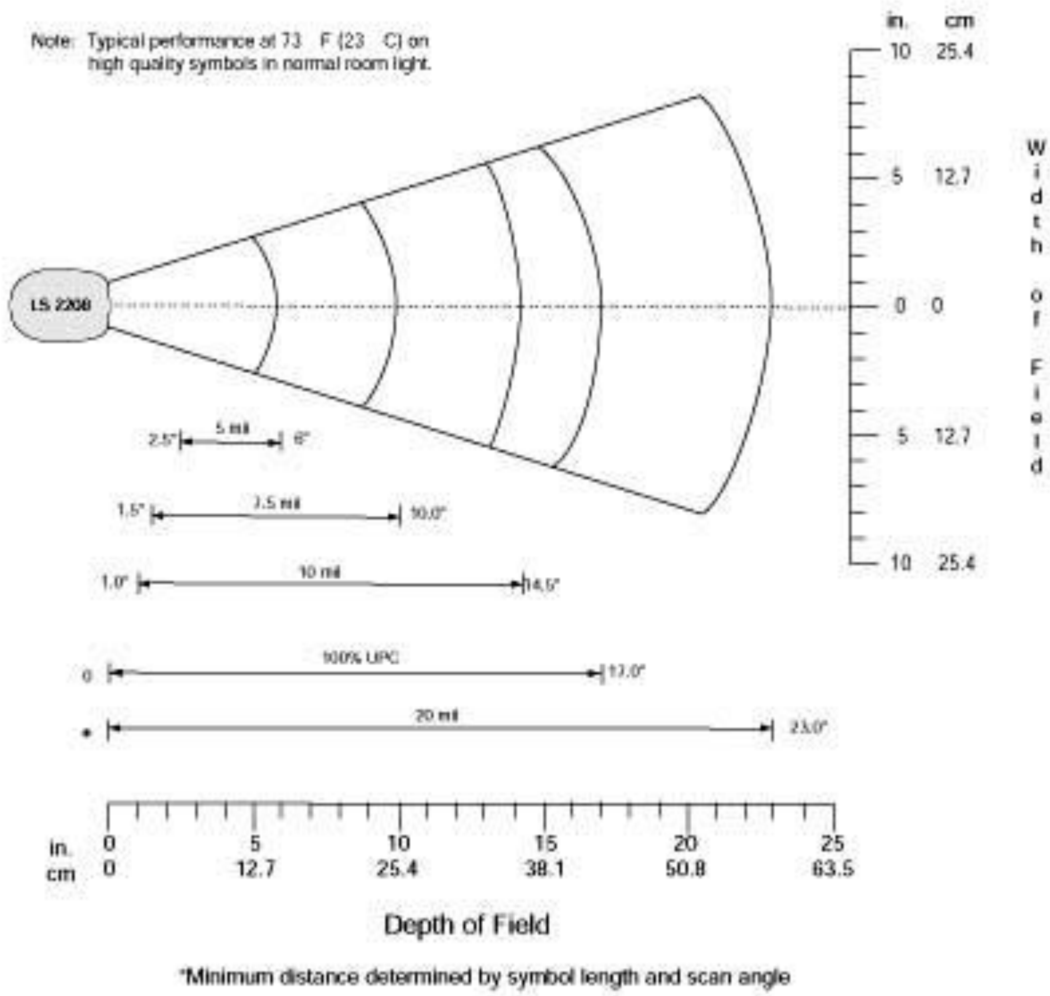
10.4 Scanner Resolution

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 for 1D barcodes or feature for 2D barcodes, 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 warehouse or pallet tracking barcodes, used in industry, have features that are 20 mils wide but the labels on sheets of scanning barcodes, such as picking sheets, are often 10 mils resolution in order to contain the needed information in a limited space.

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 sepcifications 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 here:



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.

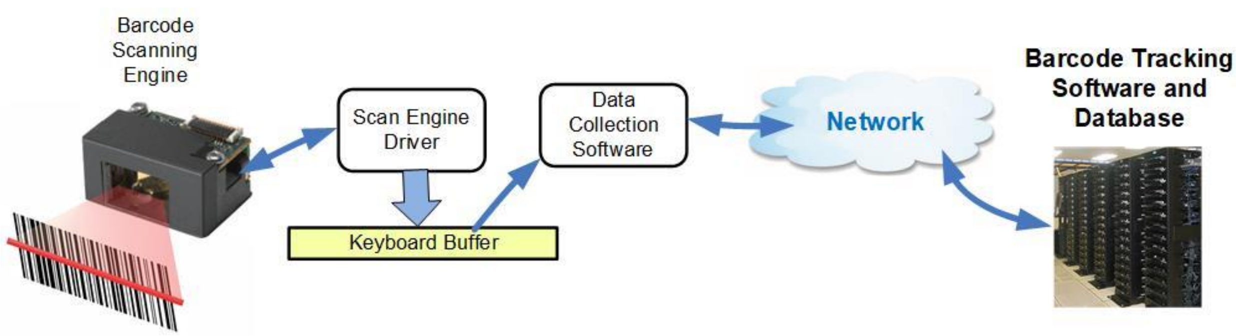
Medium range scanners, with ranges of several feet may well require barcodes with a minimum feature size of 20 mils and long-range scanners may require barcodes with a minimum feature size of 100 Mils.

Because they have simpler structure, 1D barcodes are easier to scan at longer range, which is why they are used on warehouse racks and on floor location markers. Because of their more complex structure, scanning of 2D barcodes is usually limited to short range.

Scanning barcodes at ranges beyond 10 feet require special long-range scanners. CCD based long-range scanners have special optics that enable them to focus on a target at these long distances. But this usually requires that the barcode be well lighted and of high contrast. This also precludes these scanners being used to scan high resolution barcodes at short ranges, without refocussing their optics (just like a camera).

This is why laser scanners are still often preferred for long-range scanning in warehouses as they provide their own illumination in the form of a laser beam and can be used with barcodes that have reflective "white space" to enhance distance. Some of these laser scanners are also able to scan high resolution barcodes at short distances, because their resolution is set by the low-dispersion width of their scanning laser beam rather than by the optics associated with the CCD imager.

10.5 Decoding Speed and Accuracy



Barcode scanning is done by a scan engine that scans the barcode using a laser scanner or uses a CCD (charge-coupled-device) to capture an image of the barcode as an array of pixels. The scan engine then decodes these into a set of alphanumeric characters, which are then typically placed into the keyboard buffer of the device to which the scan-engine is attached.

1D barcode scanners can automatically recognize the type of barcode by the “guard band” bars and stripes that are placed at the beginning and end of the barcode and unqiuely identify the barcode as a Code 128, Code 39. The 2D scanners recognize the type of barcode by the features in the 2D barcode that are unique to the 2D barcode being scanned. They can also scan 1D barcodes but without the benefit of the red aiming line.

One of the most critical human factors in using barcode scanners is their speed in recognizing and decoding a barcode. In an industrial setting, users get unhappy if there is more than a second or two between when they press a scan trigger on their device to when they see a response on the screen of the device to which the scanner is attached.

This means that the scan- engine and its driver have to be able to recognize and decode the barcode and place it into the keyboard buffer in about 100 milliseconds. This requires the use of special hardware and software inside the scan engine as the engine may have to attempt to decode the image or laser scan against dozens of different barcode formats to see which fits the best.

One of the key-features can be the ability to decode damaged or dirty barcodes. This is done by "fuzzy logic" to find the statistical best match, not only to the barcode label format, but also to a set of alphanumeric characters that match the capabilities of the barcode being scanned. This is sometimes accompanied by adaptive adjustment of the optics or laser scanning to get a meaningful decode by adjusting the optical focus or modulating the scan angle of the laser beam.

A useful feature is the ability to "program" the scan engine to emit a cariage return and/or 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, such as a web-browser, which otherwise would expect 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.

This same programmability can be used limit the scan engine to just recognize certain barcodes so as to improve decoding speed and accuracy.

Usually this is all taken for granted, as today's barcode scanners just work, for the most part. But it is important to select a scanner with the right scan engine for the job. Also speed and accuracy can be improved by programming the scanner to just look for types of barcodes that you are using.

It is important to make sure that the scanner, or the device to which it is attached, emits an audible beep or flashes a light, or both, when a barcode is successfully scanned. This is to provide feedback to the user which, if absent, makes the scanner hard to use as a user may be attempting to scan a barcode at a range (too near or far) and resolution that is beyond the capabilities of the scan engine to successfully decode and not know it.

Being able to retry scanning, at shorter or longer distances, until a beep is emitted is very useful feedback but sometimes, in high noise environments, this is not enough and needs to be supplemented by visual feedback.

Barcode scan engines are a miracle of modern engineering. They are lightweight, yet very rugged, and amazingly inexpensive considering what goes into them. They also have working lifetimes of many years without significant degradation.

Finally, one question I often get asked, is "Can I use the camera attached to my mobile phone as a barcode scanner"? The answer is yes, you can get third-party software that will use your camera to take a picture of a barcode, decode it, and place the resultant code into the keyboard buffer on your mobile phone. But a mobile-phone makes a very poor industrial barcode scanner for the following reasons:

1. Slow- It typically takes several seconds to manually aim the camera at the barcode and then to press the button to capture the image.
2. Accuracy -The decoding software running on your mobile phone's processor is no match for the specialized firmware in a scan engine for decode speed or accuracy.
3. Ruggedness - most industrial barcode scanners can take repeated several feet drops onto concrete but most mobile phones cannot.

There are specialized cases where mobile phone camera's may be useful, such as scanning QR codes to look up information on a website but, for industrial use, ruggedized mobile computers, with integral barcode scanners and mobile-phone capabilities, work much better and are not much more expensive than a mobile phone alone.

10.6 Tethered or Corded 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 scanning range of a few inches. They use 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.

These are available as 1D and 2D barcode scanners. The 1D units typically have a red aiming line similar to a laser scanner and the 2D units typically have an aiming spot. These scanners can recognize the type of barcode being scanned and automatically decode it.

The lowest cost tethered scanners are not dust and moisture sealed and are suitable for light industrial use with desktop PCs. More rugged, dust and moisture sealed tethered units are available at higher cost for use with industrial PCs. Also units with longer range scanning capabilities are available for applications such as plugging into industrial computers mounted on fork-lift trucks.

Tethered laser barcode scanners still have their uses, especially when hands-free scanning of 1D barcodes is required. An example of this is the unit shown at right, which acts as a tethered handheld 1D laser scanner, when removed from its cradle but will go into automated scan mode when placed in its cradle and a switch inside the scanner is triggered by a magnet on the cradle.

When a barcode is passed through the laser beam, the scanner decodes it and outputs the barcode contents, which is placed into the keyboard buffer of the PC, to which the scanner is attached. The scan engine can be programmed to emit an [Enter] sequence after scanning, causing automatic submittal of each barcode, as it is scanned, to the barcode scanning system software.

There are a number of different configurations for similar devices but all are able to switch between scanning manually and being used in a hands-free mode. This can enable their use as hands-free scanner to automatically scan the tracking barcodes on a sequence of boxes.

There are 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 to ensure that the 2D barcodes need to be well separated from each other at time of scanning to avoid ambiguity.

I 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 because of their close proximity. In general, if you only need to scan 1D barcodes then purchase a 1D scanner and only purchase a 2D scanner, if really needed.

10.7 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 smaller screen of a mobile computer.

A 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 wireless data connection to a base station , which also serves as a charging station for the scanner. This base station then plugs into a USB port on the PC just like a tethered scanner.

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.

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. As a result, 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.

Some of these scanner units connect to the base station using Bluetooth wireless communications (just like the method that connects a cell phone earpiece to a cell phone). Others use standard wireless communications, sharing the same bands as are used by wireless mobile communications, and using much of the same technology. Wireless communications have the potential advantage of quicker communications and better security but may also conflict with other devices using the same wireless frequencies. Bluetooth is a short-range wireless communications technology that is designed for shared communications. Because of its short range, it can be inherently secure. Also, it does not suffer from the potential communications conflicts of standard wireless communications.

An alternate form of cordless scanner is shown at righ These small, lightweight, hand-held units are typically used in conjunction with Laptops, Tablets, and sometimes Mobile Phones. They are available with 1D and 2D CCD scan engines and communicate with a mobile device using Bluetooth protocols.

These units have limited battery life and are not suitable for applications requiring continuous barcode scanning because of the limited battery life. Lower cost units are not dust or moisture sealed but will typically survive a four-foot drop onto concrete (which the tablet, laptop or mobile phone to which they are attached will not).

These units are, however, ideal for field or mobile applications where a small portable barcode scanner is needed for occasional use. This includes adding "proper" barcode scanning to mobile phones.

10.8 Hands Free Scanners

Closely related to the cradle-mounted scanners are finger mounted scanners, like the one shown at right. These scanners typically communicate with Android tablets using Bluetooth communications.

The big benefit of these units is that they leave both hands free for materials handling without the need to pick up a scanner, every time the user needs to scan a tracking or location barcode.

These scanning units are available with 1D laser and imaging scan engines and 2D imaging scan engines. They are able to communicate with a tablet out to a range of 10 to 15 feet. But, please bear in mind that all user interaction takes place through the tablet.

Scanning is initiated by pressing a button on the side of the unit with a thumb. The resultant alphanumeric string is placed in the keyboard buffer of the tablet. As will other scan engines, the scan engine can be programmed to emit an [Enter] sequence following the scan, so as to automatically submit the scan to the barcode tracking software.

These scanners have a scan-range of a few inches, so the user needs to be close to the barcode being scanned. They are typically able to scan 10 mil and 20 mil barcodes.

The biggest limitation with these units is battery life. A unit, such as the one shown above, will run for a few hours, depending on frequency of scanning, and then need to be recharged through a micros-USB port on the scanner. As a result, most organizations will need to have spare units, which can be recharged while other units are in use.

Units with longer battery life are available are available, such as the one shown at right, but these typically need to be work across two fingers to comfortably support the additional battery weight.

Sometimes these units are also used with mobile phones, to add barcode scanning capabilities, without the limitations of the built-in camera in the mobile phone.

10.9 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 an Android tablet in a ruggedized portable format. They typically have a 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 (as shown at right) 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 industrial warehouses and yards, and for recording the movement of pallets of material on the factory floor, where fork-lift trucks are used, my current units of choice are typified by the Zebra 9000 series mobile computers, as shown at right.

These Android-based devices have a built-in “Lorax” self-adapting laser barcode scanning engine. 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 repeated 6-foot drops onto concrete and still keep working. They 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.

Competitive units with CCD based scanners are available from companies such as Honeywell. These scan engines have the benefits and disadvantages described in a previous section of this chapter.

In industrial warehouses, the use of these ruggedized gun-style mobile computers has largely replaced the use of a tethered long-range barcode scanner attached to a mobile computer, which is permanently mounted on fork-lift truck. This is because the gun-style mobile computers are very flexible. They can be used with fork-lift trucks but also can be used with pallet-jacks to move materials and can be taken with the materials handler wherever they go.

In large scale distribution warehouses, where there are dedicated fork-lift truck drivers, who do nothing else, then the fixed mount units have the benefit of larger screens. They are also powered directly by the fork-lift truck battery and so do not need charging.

For applications where extreme ruggedness and long-range scanning is not required (such as in a stock room), then there are a wide variety of units available at lower cost. These units typically have a short-range 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, 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.

As an alternative to the gun-style units, PDA (personal digital assistant) units are also very popular, because they are relatively inexpensive. These ruggedized units have a built-in short-range scan-engine, a wireless LAN card, and a processor that runs the Android operating system. These are available with laser or CCD scan engines, are typically dust and moisture sealed, and can take a several foot drop onto concrete. Some have physical keyboards and some rely on on-screen keyboards.

Many of these units are also available with mobile-phone data network communications capability, which enables these units to be used anywhere there is Internet connectivity available over the mobile phone data network.

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 wearable unit, such as the one shown here.

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

These units can be uncomfortable to wear for prolonged periods and so are not recommended for general warehouse use. But where hands-free picking is required, these are an excellent choice.

10.10 Fixed Station Scanners

Fixed station barcode scanners are mounted in a fixed location and used to scan barcode labels as they come within the view of the barcode scanner. They are typically used to read barcodes on products or product packaging as they pass down a conveyer belt or roller-rack.

These units are available with both laser and CCD scanners and often come with inputs that enable the scanner to be triggered when a unit to be scanned passes through an optical beam.

These units may come with an RS232 or RS422 wired connection for direct connection to the serial port of an industrial PC or PLC. They may also have an Ethernet connection available to that they can be connected to an industrial PC over a local area network.

In a materials tracking application, the scanner reads the unique LPN tracking barcode from the container being tracked and then the PC to which it is attached translates this as a move of the container to a new location (where the scanner is located) and updates the main tracking server as to the new location of the container.

Chapter 11 RFID Technology

11.1 Introduction

In this chapter, we will be discussing the use of Radio Frequency Identification (RFID) technology to track the movement of containers of material in warehouses and manufacturing plants. RFID has much broader use, in general to such applications as tracking vehicles and for use in access security control, which we will not be discussing here.

11.2 How RFID is Used

A disadvantage of barcode tracking is that users have to scan the barcode every time a container moves or materials are added to a container or withdrawn from the container. The exception to this is when barcodes are scanned by a fixed station scanner, as the containers or parts move down a conveyer belt.

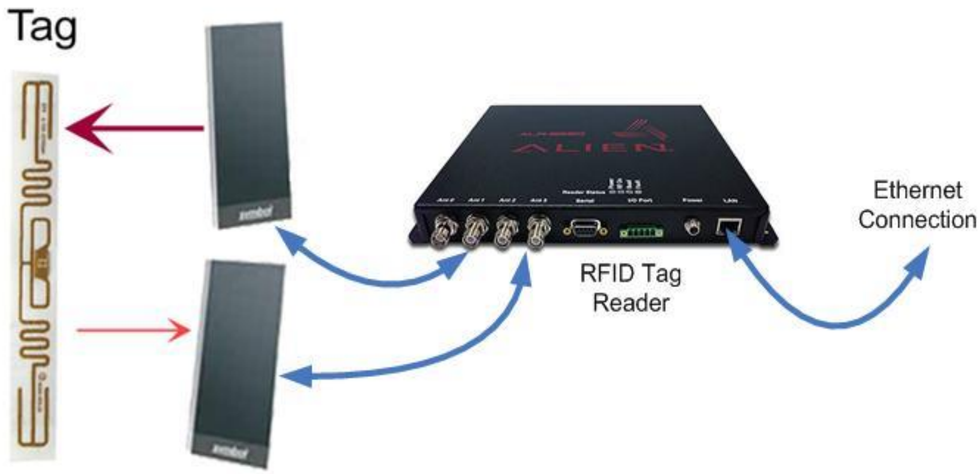
RFID is used to automatically record the movement of materials from place to place by automatically detecting the presence of an RFID tag placed on a carton or pallet containing the materials. It is not typically used when other data entry has to be performed, such as by using a mobile computer, as the additional time to scan the tracking barcode on the container is minimal. But where we simply need to record the movement of containers, from one location to another, RFID has a role to play in avoiding the need for people to record their movement.

It is especially advantageous in:

1. Recording the receipt of pallets into a facility.
2. Recording the movement of totes, carts, and pallets of intermediate and WIP materials within a manufacturing plant.

3. Recording the loading of pallets on trucks/trailers.

11.3 How RFID Works



RFID works by using Tags that contain a transponder and an antenna attached to each pallet or other container of material. The RFID tag reader electronics periodically sends out an interrogating signal. If the transponder within the RFID tag receives the signal, it responds with its unique identification (ID) number and possibly other data encoded in the tag memory. This signal is picked up by another antenna and then decoded by the RFID electronics.

The TAG ID number and possibly data stored in the RFID tag is then decoded from the returned signal and sent to software that interprets this data along with the identification of the antenna that recorded the data.

The software then decodes this into the movement of a specific container, to which the RFID tag was attached, by relating it to the location of the antenna detecting the tag.

11.4 Using Barcodes in Conjunction with RFID

In a materials traceability application, we typically attach both an LPN container tracking barcode and an RFID tag. Both typically have the same ID number. In this way, when a container of material, such as a pallet, is loaded with materials, the pallet can be identified by scanning the LPN barcode. But when the pallet is loaded onto a truck, for example its RFID tag can be scanned by a dock-door portal to identify that pallet being placed on the truck.

Because they have the same LPN ID number, the barcode and the RFID tag can be scanned interchangeably, using the appropriate technology.

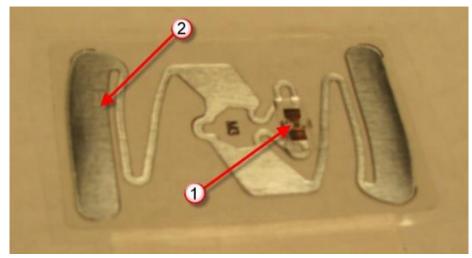
To facilitate this, barcode labels are available with both an RFID tag (1) and a surface (2) on which a barcode label can be printed. These can be printed and encoded at the same time, using special barcode label printers, with an RFID attachment. This ensures that the ID on both labels and RFID tags are the same.

One common use of RFID tags is to track the movement of carts and trolleys holding work-in-process materials. Here we typically use ruggedized RFID tags which can be screwed to the cart or tote. These tags can be ordered with an external barcode that contains the ID number of the RFID tag.

This enables the use of barcode scanning to record the loading of parts onto the tote or cart. But then RFID can be used to automatically record their movement within the plant. This solves a major problem in finding work-in-process, which may have been "parked" in many different locations.

Ruggedized combination RFID and barcode tags are also used in special applications, such as military transportation, where ther may be air-dropped. Here the tags are attached to each pallet and barcode scanning used to record the loading of different cargo onto each pallet. But then RFID is used to record the loading and off-loading of the pallets.

11.5 RFID Tags and their Limitations



RFID tags come in two categories, active and passive. Active tags contain batteries to power their electronics whereas the passive tags extract energy from the incoming radio wave and use this to power the transmitter that sends back the tag ID and other information.

Passive tags are primarily used in materials tracking and traceability applications because they are smaller and lower cost than active tags. They also have an unlimited life, whereas active tag life is limited by its batteries. As a result, passive tags can be embedded in barcode labels and more easily integrated into tags that are permanently attached to finished products.

These passive tags, as shown here, consist of a tiny electronics package (1) and antenna elements (2). Almost all RFID tags used in the supply chain operate in the 860 to 930 MHz frequency range as this enables physically small antenna elements to be used within the tag.

Because they use the energy of the incoming radio wave to broadcast the ID, passive RFID tags only broadcast a very low-level signal, which results in a short detection range, which is typically 6 feet or less from the main receiving antenna. This is also limited by the power of the interrogation radio wave, which is limited to a few hundred milliwatts for worker health reasons.

The interrogation antenna typically has a beam-width of 30 degrees or so to enable interrogation of multiple RFID tags within its beam. But, if these tags all responded at the same time, their transmitted ID signals would interfere with each other. As such, the tags delay the time at which they broadcast their ID by a random amount of time, so that the decoding electronics box can read each tag individually.

Even so, some tags broadcast at overlapping times. As a result, the tags will keep broadcasting their ID's at random times as long as they are "illuminated" by the main sending antenna.

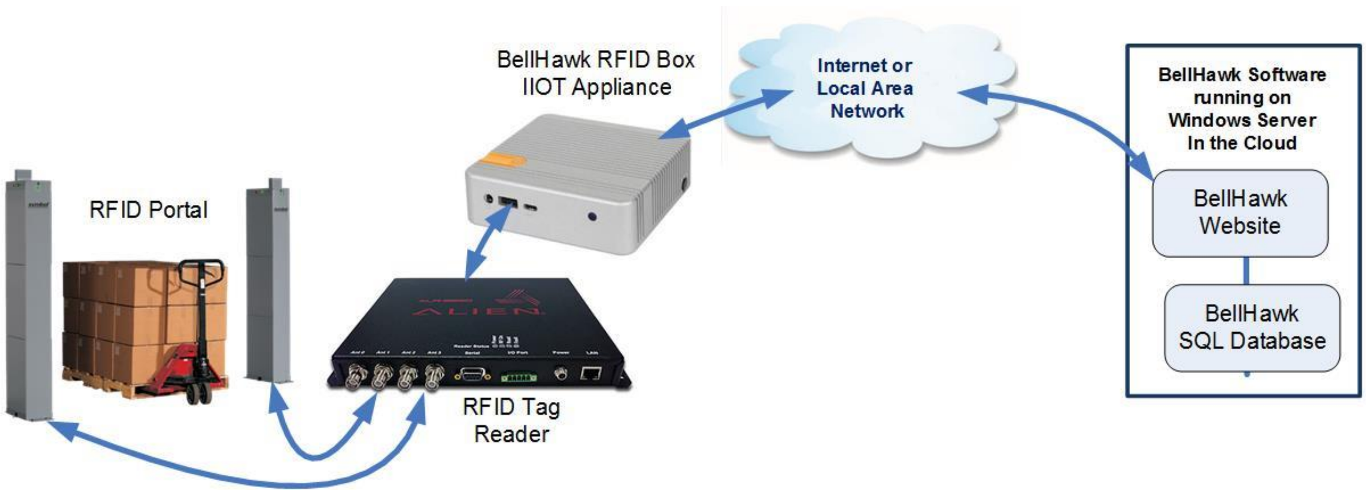
This has two effects:

1. The more tags that are being illuminated, the slower their transit through the beam has to be in order for them to be read. Conversely, at a constant speed (such as on a fork-lift-truck) the more tags there are on a pallet, the less of them that will be read during transit through the interrogating beam, resulting in inventory errors.

2. A common sending and receiving antenna can be used to interrogate the tags, by repeatedly switching from transmit to receive. This is less effective in making sure all the tags are read but is less expensive.

The big take-away with passive tags is that it is easy to detect the movement of a single RFID tag through an interrogating beam but when there are multiple tags, then inventory accuracy declines rapidly. In one experiment the author performed, read accuracy fell below 90% when a pallet with more than 6 tags on it was moved at fork-lift trailer loading speed through a portal with separate interrogation and receiving antennas at each side of the portal.

11.6 Equipment Considerations

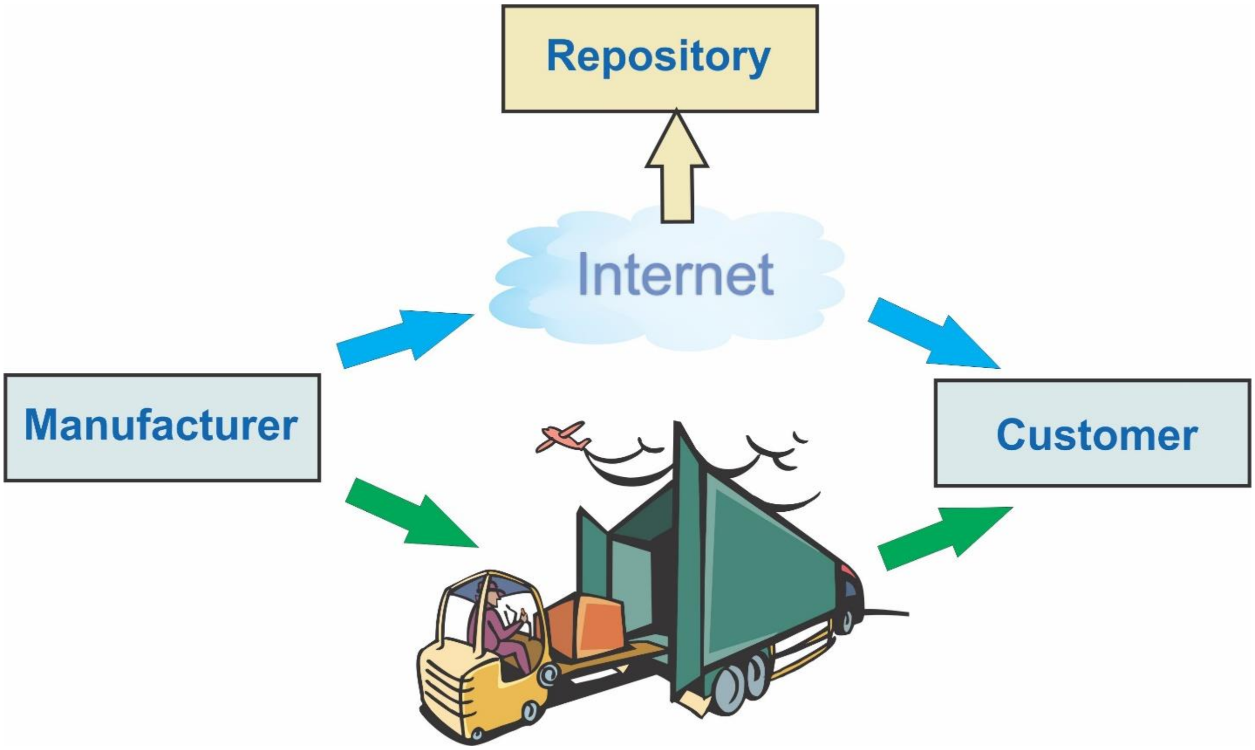


Antennas to detect the movement of pallets of material off or onto trailers are typically mounted in RFID portals, which are mounted on either side of each dock door. Detection of the location of carts and totes on a shop floor are better done with ceiling mounted antennas that project a cone shaped beam through which the RFID tags pass.

These antennas are connected to an RFID reader box, which performs the interrogation of the RFID tags and can typically support up to 8 antennas. These boxes typically keep a "pool" of RFID tags they can "see" and send events, such as new tags arriving or leaving each antenna zone to an attached computer using an RS232 or LAN connection.

It is then the function of the local computer to update the materials tracking software with the new location of the pallet or cart, every time a new tag arrives or leaves an antenna zone. In this way, movement of materials can be automatically recorded without need for a person to do barcode scanning.

Chapter 12 Supply Chain Integration



12.1 Introduction

This is an area that is still rapidly changing in its requirements and thus this chapter is likely to change with each new edition of this handbook.

Today, it is not sufficient for the systems that industrial organizations use to simply focus on what is happening within the four walls of their organization, it is also important that those systems be able to exchange data with upstream and downstream supply chain partners.

The reasons for this are:

1. To enable rapid materials traceability throughout the supply chain, such that a defect in a raw material at the start of the supply chain can be quickly traced to all the recipients of the resultant products, no matter how many processing plants and warehouses the raw, intermediate, and finished products have traveled through.

2. To make the process of receiving materials more efficient and less error prone. A pallet of materials sent from one facility to another, many contain many separate parts. It can take a long-time for a receiving clerk to unpack all the items and enter them into their accounting, warehouse management, or ERP system as received goods.

   By placing an LPN tracking barcode on that pallet and sending Advanced Shipment Notice (ASN) data about the nested-container contents of the pallet, the sender can reduce the receiving clerk's work to a single scan of the LPN tracking barcode. Even better, an RFID tag on each pallet can be scanned, as the pallet is unloaded to automatically receive the pallet.

3. To eliminate duplicate quality control testing. We often see the situation where the manufacturers of intermediate products or sub-assemblies performs a set of final inspection tests before shipping a product and then these same tests are performed by the QC (Quality Control) department of the recipient organization. By having the sending organization send information about the testing of the products to the recipient, these tests do not have to be duplicated.

4. To be able to detect counterfeit materials in the supply chain. By having the sender uniquely identify each part or container of materials with the maker, the part number, the lot number, the serial number, and the expiration date, and then send this information to a Cloud-based repository, any recipient of that part or container can check whether these materials are genuine or fake.

5. To be able to gain operational visibility as to what materials are available at what locations in the supply chain. This can then be used as the basis for making or ordering more materials, as needed for customer orders. Good supply chain visibility enables just-in-time manufacturing and lean inventories, with the ability to respond rapidly to supply chain shocks through the use of alternate suppliers.

In this chapter we will look at some of the mechanisms and initiatives being used and proposed for supply chain integration, to achieve these objectives.

12.2 GS1 and Materials Identification in the Supply Chain

UPC or Universal Products Codes are what drove the use of barcodes in the supply chain. These contain a 6-digit company prefix, followed by a 5 digit product identifier (within the company) and a checksum digit to detect errors in scanning.

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These are used throughout the world in retail stores to enable rapid identification of products at time of checkout simply by scanning the UPC code.

Originally this was used in the USA with a US based organization issuing the company codes. But as their use expanded globally, 6 digits were not enough for all the companies making products and an international registration body was needed.

The GS1 or Global Standards One standards organization now issues company codes, which can be between 6 and 10 digits in length for products sold at retail.

For industrial products, GTIN (Global Trade Identification Number) barcodes are increasingly being used. Like the UPC codes they incorporate a company code (issued by GS1) and a product code (issued by the company).

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GTINs fit in with the overall GS1 standard for barcode contents, with an application identifier of (01), for a code 128 format GTIN barcode. These can have up to a 12 digit combination of company and product code. Also they can be combined with other barcode formats to form a composite barcode containg fields such as lot and serial number and expiration date.

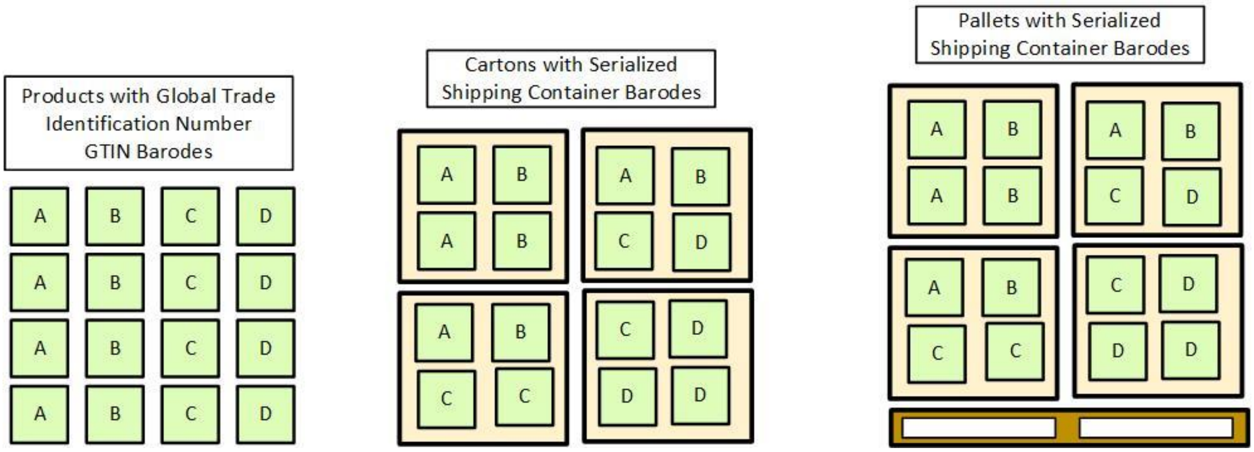
GTIN barcodes are used to identify products but when these products are packed into boxes and then stacked on pallets, we typically use SSCC (Serialized Shipping Container Code) barcodes on boxes and pallets to identify each packing layer.

The SSCC is a regular GS1 barcode with an application identifier of (01). This is followed by a combination of the GS1 company prefix and a unique serial number that the company assigns to the box or pallet.

If the contents of each box and pallet is sent to the recipent when the box or pallet is shipped, in the form of an Advanced Shipment Notice, then the contents can be received without further data entry simply by scanning the SSCC barcode on the outside of the box or pallet.

12.3 Advanced Shipment Notices

Advanced Shipment Notices consist of information sent from a manufacturer or distributor to their customer. This information consists of a nested container description of products packed into boxes, onto pallets, or packed inside a shipping container.



At the innermost layer we have individual products, or boxes containing multiple of the same product. In the supply chain, these have a GTIN barcode to identify the products, in a similar manner to UPC codes. The ASN records for these may include the lot and serial number and expiration date

Each of these records contains the SSCC barcode for its parent, thus identifying which carton the individual product was packed in.

The ASN records for each carton include its SSCC barcode and may also include information about the weight and packing material of the carton but do not include any information about the products packed into the case or carton.

In a typical ASN there are also records for pallets. In this case, each carton record contains the SSCC barcode for the pallet onto which it was packed.

Normally the ASN record for the pallet does not contain a parent SSCC barcode, as the pallets are then recorded as being loaded into a truck/trailer by scanning their SSCC barcodes.

It is noteworthy that the ASN records mirror the nested container representations used by systems such as BellHawk for tracking materials within warehouses and manufacturing plants. This facilitates the easy transfer of information between manufacturers and their customers.

When a shipment is made, the ASN data for the shipment is sent to the receiving customer or DC (Distribution Center) and this is stored in the recipient's materials tracking system as a pending receipt. When a pallet is received, all that is necessary is for the material handler to scan the SSCC barcode on the pallet, for the recipient's material tracking system to receive the pallet.

The recipient's materials tracking system can then match up the SSCC barcode on the pallet with the previously received ASN data to be able to immediately receive all the materials into inventory without the need to break-down the pallet and record every carton by hand into a warehouse management or ERP system. This can result in greater accuracy and a very substantial savings in labor time and cost.

The materials tracking system can then automatically notify the accounting system so that an appropriate set of pending accounts payable records are recorded.

It is noteworthy that the SSCC barcode can be supplemented by a corresponding GS1 format RFID tag. If the dock-door is equipped with an RFID reader then the RFID tag can be automatically read, matched against the pallet TAG number sent in the ASN, and the pallet automatically sent.

These RFID tags can also be used to automatically record which pallets got loaded onto which trucks at time of shipment and this can be used as part of the ASN. When the pallets are received, high volume DCs can then use this information to direct the pallets to be loaded onto specific trucks/trailers as part of a cross-docking operation.

While ASNs were originally introduced as a means of improving efficiencies in the supply chain, they are now increasingly being used to transmit information that can be used in materials traceability. To support this, ASNs are also sent to organizations that maintain repositories of the movement of materials. This is to facilitate the rapid recall of products in the supply chain in the event of defective or contaminated products.

The weakness here is that the ASN contains no information about the transformation of raw materials into products, which is critical in areas such as the food and pharmaceutical supply chains. For this we need to add information about the "pedigree" of products.

12.4 Pedigree Information

The main limitation of ASNs is that they do not:

1. Include any information about the results of testing of products before shipment to customers.
2. Do not specify what materials went into each product, so as to enable traceability from defective ingredients or components to the affected products.

There is a cost saving to be had by not having customers replicate tests that have already been performed by the manufacturer of the intermediate products they are potentially using in their products. This is always assuming that the customer trusts their supplier or only does limited statistical testing to keep their suppliers honest.

Currently this test data is sent to customers from their suppliers in terms of paper forms or PDF files of a printed certificate attesting to the quality of the products, which sometimes includes the actual test data.

Pedigree information attempts to address the question of which materials went into which product. Most manufacturers of products that could result in harm to people or animals track the manufacturer and lot number of the ingredients or raw materials that went into their products. Usually these are recorded on paper forms or Excel spread sheets, at the manufacturer's facility.

While this data may be useful in helping the manufacturer determine which batches of which products could be affected by a batch of defective raw materials, it does not enable the rapid recall throughout the supply chain, especially if there were several manufacturers involved in various stages of making the final product.

To this end there have been a number of initiatives to establish repositories, some based around Blockchain architectures, to which participants can submit ASN and pedigree data in electronic format. Participants can then interrogate the supply chain data to assist in end-to-end materials traceability activities, such as determining the source of possible defects and minimizing recalls.

12.5 Transmitting Supply Chain Data

The electronic transmission of supply chain data origination with the Electronic Data Interchange (EDI) value added networks or VANs, which were servers established to exchange data over landlines between major corporations, such as General Motors, and its suppliers. This has morphed, over time, into a series of XML (Extended Markup Language) data format specifications, such as EDI 856, which has become the X12 standard for the transmission of ASN data.

This data is typically sent as a secure Multipurpose Internet Mail Extensions (MIME) message over the Internet to special servers which know how to handle EDI messages and are the direct descendants of the early VANS.

While EDI is extensively used by larger corporations for exchanging supply chain data such as Purchase Orders and Advanced Shipment Notices, they do not incorporate Pedigree information or certification data.

Currently much of this is handled by the transmission of enhanced ASN data in the form of comma delimited files, which is exchanged with the recipient organizations as well as repositories. This data transmission typically is done by secure FTP (file transfer protocol).

GS1 is spearheading the development of EPCIS (Electronic Product Code Information Services) dada exchange standard. EPCIS is a global GS1 Standard for creating and sharing visibility event data, both within and across enterprises. Basically it enables the sharing of events such as receiving, transforming, packing, and shipping of materials with organizations within a supply chain, as well as with repositories.

EPCIS data, like EDI, is transferred in the form of XML. The EPCIS standard, uses XML metadata to define the contents of this data transfer. This format has so far gone through two major revisions and is still evolving. It is based on the use of GS1 standard barcode formats, such as GTIN and SSCC.

This has led to conflicts with the Pharmaceutical community, who need to exchange similar data to support the Drug Supply Chain Safety Act (DSCSA). Members of this community want to continue to use their traditional NDC (National Drug Code) numbers instead of switching to the use of GTINs. The basic problem is the NDC is assigned irrespective of the manufacturer whereas GTINs are based on the manufacturers code. Attempts to reconcile this, such as by setting aside special GTIN codes that incorporate the NDC do not appear to have succeeded.

As a result, the major Pharmacy Benefit Managers have now developed their own supply chain data exchange standards based on the use of NDC codes and the use of a Blockchain based repository.

There is also movement to extend the use of the EDI X12 format to incorporate the materials transformation data needed for food supply chain traceability. This is being promoted by major fast-food restaurant chains who already make extensive use of EDI and whose suppliers are, for the most part, already using EDI. Large corporations, such as IBM are also promoting their Blockchains as the answer to traceability in the food and other related supply chains.

What we have in practice, at the time of writing this chapter, is the use of many different data exchange formats for exchanging supply chain traceability data. Some of these, such as EPCIS, are vying to become the one standard used by everyone. But it is not clear that any one will emerge as the clear winner and, it may be that some merger between the EDI and EPCIS standards ends up being the de-facto standard.

One issue that arises is with external to internal part number confusion. If ABC company sends a report to a repository that it has shipped one ABC123 box of widgets to XYZ company and XYZ reports that it has received 25 XYZ345 widgets, there is the possibility of much confusion, as the ship and receive reports do not match up.

A solution to this is to have XYZ company report the receipt of one ABC123 box from ABC company and separately report its conversion into 25 XYZ345 widgets, which can then be traced internally and reported to the repository as they are consumed to make products.

Chapter 13 Implementing Barcode Tracking Systems

13.1 Introduction

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.

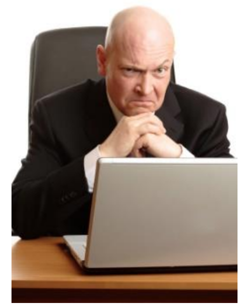
In this chapter we will look at the people issues that need to be addressed as well as the multiple disciplines that need to be integrated into an implementation team in order to successfully implement a tracking solution.

Here 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.

13.2 Driving Forces

I have led a team that has implemented over 100 barcode and RFID materials and work-in-process tracking solutions over the past decade or so. 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 annual 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 dumb 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 materials tracking 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. 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. 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). As a result, 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.

13.3 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, downloading and installing it, and then 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. As a result, 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 technical 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 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 (interface to external system API, ODBC connection to database, flat file).

c. Determine all the places where data collection will take place and the most appropriate equipment to use (PCs with barcode scanners, mobile computers, RFID portals, 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 high risk way to go. It is not uncommon for companies to spend in excess of $300,000 on programmer salaries 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 aging customized ERP systems. As the underlying operating systems go off-support because of security issues, these are becoming increasingly problematic.

c. Add limited point-solutions, such as job-shop tracking, warehouse management or asset tracking software to an existing ERP or accounting system. This can be an economical way to go, if a limited 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 materials traceability, which is becoming increasingly important for participation in the global supply chain..

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. Use a modular tracking system, such as BellHawk, that provides the middleware layer between the barcode, RFID and wireless mobile equipment and the front-office accounting, ERP and CRM systems. This software typically costs in the range of $500/month to $1,500/month 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 (or RFID 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 technology are discussed in Chapter 8.

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 own 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 or external 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.

13.4 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. If needed, 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 of itself and can take an organization weeks or months to complete. This work is performed by the inside team, usually augmented by consultants 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 and possibly RFID tag encoders 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. If needed, 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. This is not needed with systems, such as BellHawk, that use a web-browser user-interface

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 many different 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 properly.

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, or barcoded floor marker-posts, 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 date 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.

13.5 Costs and Benefits

The non-recurring equipment and services cost of implementing a barcode tracking solution, using software such as BellHawk, typically ranges from about $5,000 for a simple PC based system to about $60,000 per facility for a wireless mobile computer system that will serve the production and inventory tracking needs of each facility. In addition, organizations can expect to spend between $500/month to $1,500/month for software subscription or rental fees. The non-recurring costs usually expended during the 3 to 6 months, per phase, it takes to implement a tracking solution.

Additionally, organizations should expect to spend between about 20% of the non-recurring costs for consulting and pre-deployment engineering support services.

Over the following two years, most organizations typically spend the same amount again of non-recurring costs, 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's implementation is successful.

13.6 Commentary about Implementation

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.

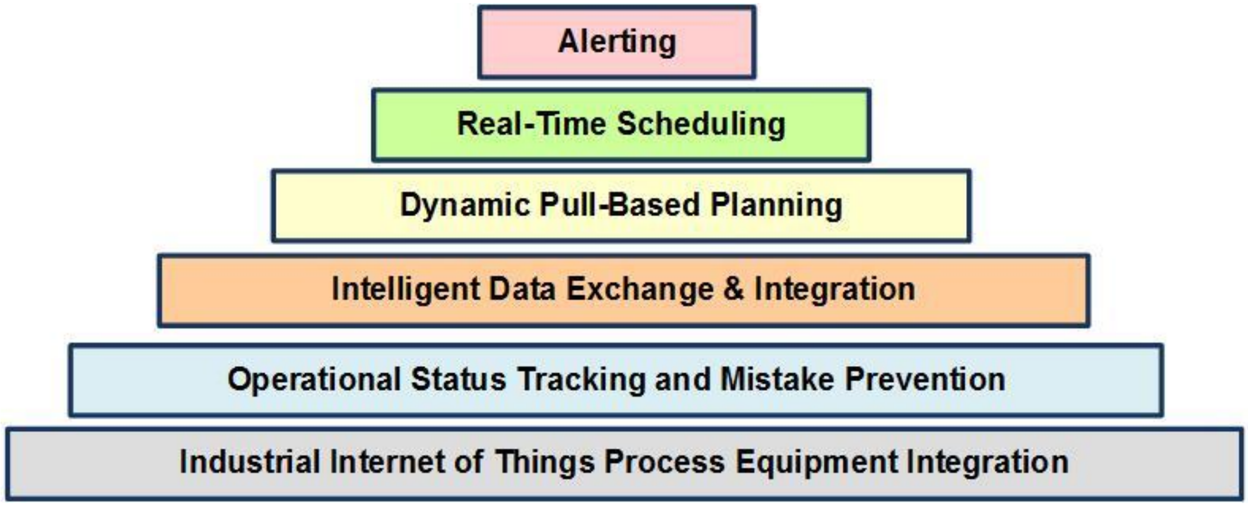
It is essential to have the following skills available:

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.

The team with these skills typically consists of participants from:

- The operations and IT departments supporting the plant(s) and/or warehouse(s) in which the system is being installed.
- An external consulting organization that is managing the overall project, including systems design, implementation, training and support. This organization will typically provide or manage training and go-live support.
- A software organization that is providing the software and necessary support, as well as performing customizations, where needed, and assisting with any needed integrations.
- Experts in systems with which the tracking software will exchange information
- Suppliers and installers of the needed barcode scanners, printers, mobile computers, and wireless infrastructure.

Chapter 14 Artificial Intelligence and the Future



A study about 6 years ago by what is now the mobile barcode scanning device division of Zebra Technologies found that 80% of the 60,000 or so mid-sized manufacturing companies in the United States were still using manual recording onto paper forms and then keying this data into Excel spreadsheets to track their materials and their work-in-process in their manufacturing operations. Unfortunately, the situation has not improved much in the mean-time.

Some organizations have been forced to automate their data collection because of materials tracking and traceability requirements from their customers, such as requiring ASN and/or Pedigree data to be sent in electronic form to some type of repository. But many have not, automated their data collection despite the potential cost savings and probable increased sales due to improvements in customer satisfaction.

I believe that there are several reasons for this:

1. Implementing these systems is complex and requires a high-level of technical know-how, which most organizations do not possess. They require a lot of setup and a significant amount of user training.

2. These tracking systems have a high "FUD" (Fear Uncertainty and Doubt) factor for employees about their work being tracked and for managers about the possibility of not achieving the expected results.

3. Preventing data collection and operational mistakes requires integrating a significant level of artificial intelligence, which is specific to each organization, in order to warn employees when they are about to make a mistake.

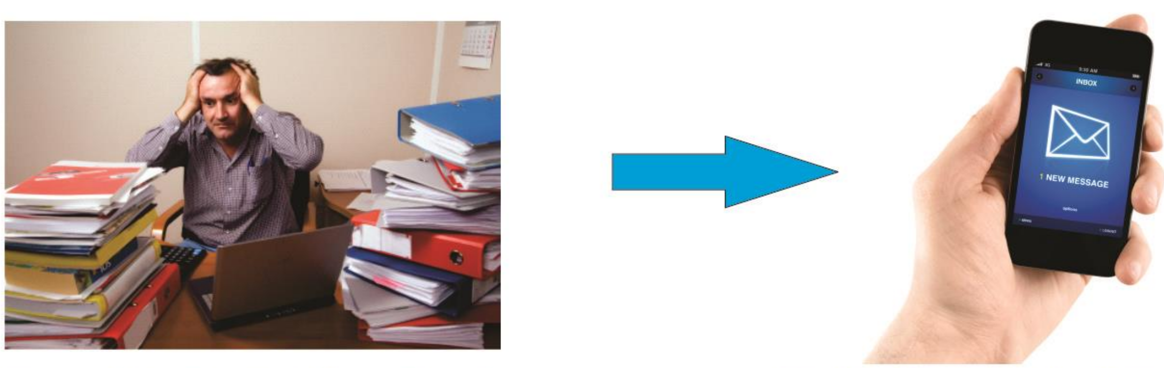
4. The complexity of integrating a tracking system with other systems the organization uses to avoid duplicate data entry and prevent mistakes.

5. While our current technology does an excellent job of collecting data it does not do a very good job of making sure that the right people get the right information, which they need to do their jobs, when they need that information.

To address these one at a time:

1. It is important to work with a team of people who have implemented these systems before. There are many tradeoffs to be made and pitfalls to be avoided. If your people has not previously implemented materials tracking and traceability or work-in-process tracking systems, the best way to ensure success is to work with people who have.
2. Much of the Fear, Uncertainty, and Doubt can be avoided by starting with a tracking system, such as BellHawk, which typically provides over 90% of the needed features, as standard. This can then be tried out by managers and employees alike to make sure that it meets most of their needs, before customizing the system to meet the specific needs of the organization.
3. Tracking systems like BellHawk are based on the use of rules-based expert systems. This enables the system to be configured for each organization by setting the parameters for its rules. Even then, customizations to data collection screens and real-time warnings often need to be further customized for the needs of each organization. It is important to use a software platform, such as BellHawk, which is designed for ease of customization.
4. It is important to use a software platform, such as BellHawk, which has well documented interfaces through which to exchange data with other systems. This enables experts in ERP, accounting, CAD, and process control systems to integrate their systems with the tracking system.
5. While systems, such as BellHawk, do a good job at collecting data, and provide good mechanisms for users to generate custom reports, to meet their own individual needs, users still have to look at screens and reports to see what is happening and what problems are arising that they need to pay attention to.

To solve this problem, we need to use an AI (Artificial Intelligence) system such as MilramX



From: After-the-Fact Reporting of Errors and Mistakes

To: Real-Time Alerts when Problems are About to Occur

MilramX examines data captured by the tracking system, along with data about planned materials receipts, production, or shipments, and uses this to alert people when events are about to occur that they may need to pay attention to.

Some examples of these events (or non-events) include:

1. Altering material handlers when shop-floor Kan-Ban bins of materials need to be replenished.
2. Alerting materials managers when they need to reorder materials or automatically alerting suppliers when they need to ship more materials, under a blanket purchase order.
3. Alerting materials and production managers and when materials for a high importance customer order have arrived, or have failed to arrive when due.
4. Alerting production managers, when work orders need to be released to the floor, or automatically generating work orders to make needed parts.
5. Alerting production managers, if an operation on a work order is taking too long or the scrap level is too high, or there are too many units failing in test.
6. Alerting sales people and customers, when products are ready for shipment. Also sending alerts to production and shipping schedulers if a shipment is behind schedule.
7. Alerting production managers if set-up or tear-down of a machine is taking too long. Also alerting maintenance people when a piece of equipment goes down and needs fixing.

These and many more events can enable managers and employees to work much more efficiently, without the need to "walk-the-floor" to spot when problems occur or to sit "glued-to-a-screen" to see if anything went wrong. By using a rules-based expert system, such as MilramX, managers and employees can rely on the system to alert them by text-message or Email, when issues have arisen that need their attention.

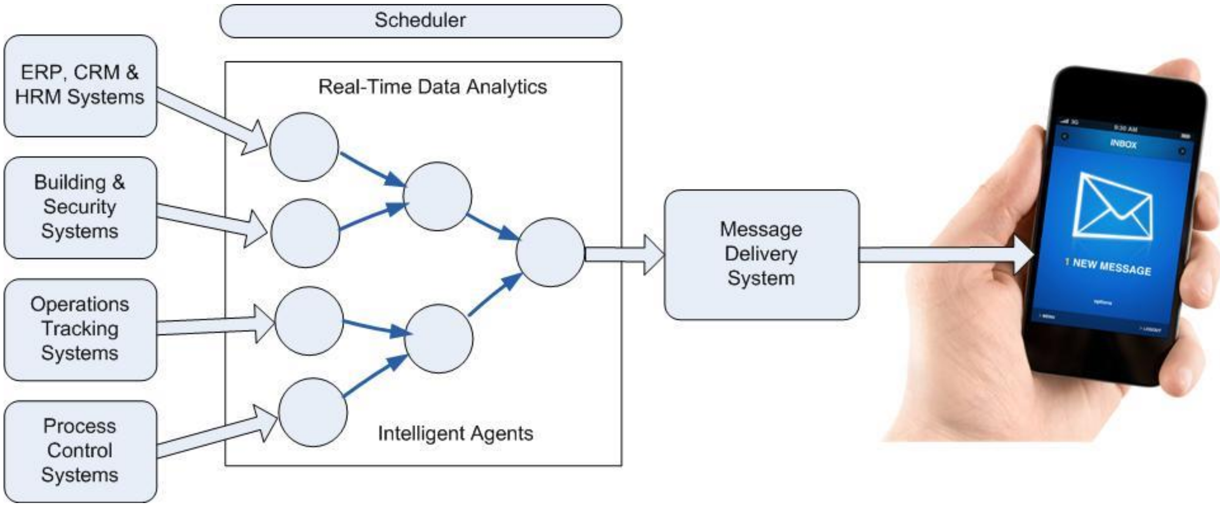
Sometimes the alert itself contains enough information to take action, such as "Bin D45 needs replenishing with fifty " brackets". At other times, managers are required to look at screens or reports, or to go to a production location to get all the details. The important time saver, and problem preventer, is that people do not need to be concerned with the issue until they receive an alert. This is much more efficient as, in a well-run operation, most activities go as planned. But managers, especially, do need to quickly pay attention before, and not after, problems have arisen when things do not go as planned.

In my experience, the rules that need to be implemented to generate alerts are idiosyncratic to each manufacturing operation but the underlying methods and algorithms are applicable across a wide-array of applications. For this reason, it is important to use a software platform, such as MilramX, to provide over 90% of the needed code, so that full attention can be focused on implementing the needed alerting rules without wasting time and money on implementing the underlying infrastructure.

Systems like MilramX are different from classical AI systems, which use deep reasoning algorithms to try to deduce meaning from large amounts of data. MilramX belongs to a class of AI systems, known as real-time AI systems, which include systems such as self-driving cars.

These real-time AI systems examine data in real-time, as it is captured, and interpret that data in such a way as to make decision and recommendations in near real-time. They need to quickly come to a good decision rather than take a long-time to come to a "perfect" decision, too late.

MilramX uses the paradigm of Intelligent Agents that can monitor data from many systems and then collaborate in making decisions and delivering alerts.



While a real-time AI platform, such as MilramX, can make it easier to implement systems that make the work-lives of managers and employees much easier, it is important to work with a team of people who have experience in implementing these applications.

A system, such as BellHawk, also uses AI methods to assist managers in materials planning or scheduling their manufacturing operations. BellHawk then relies on MilramX for intelligent information exchange with other systems and people, including with customers and suppliers. This again improves the efficiency with which people are able to work.

It is my hope that, by not only collecting data, but also using AI to provide managers and employees with the right information at the right-time, we will provide sufficient impetus for many more manufacturing and other industrial organizations to automate their materials tracking and traceability and their work-in-process data collection.

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