Automatic Identification and Bar Coding: Promise and Pitfall

by
Kenneth L. Kimbrough
Quality Consultants, Inc.
1775 The Exchange, Suite 380
Atlanta, GA 30339

and

David Wiedman
Accuscan, Inc.
2179 Northlake Parkway, Suite 108
Tucker, GA 30084

Introduction

The implementation of automatic identification systems promises to bring significant improvement in control and productivity to American Industry. However, as with any new approach that promises to improve things, at the outset you can only be sure of one thing; change. Fortunately, data processing professionals are already experienced with how to implement systems. In other words, may of the lessons of the past can be applied to the future. One of the first lessons of any data processing implementation is learn as much as possible about the technology at the outset.

That is the purpose of this presentation; to pass on to you some of the knowledge you will need in order to successfully implement automatic identification solutions.

Any project that includes barcodes should address these five fundamental areas.

* The barcode symbology
* Printing of the barcode
* Verifying the Quality of the Barcode
* Reading the Barcode
* Collecting the Data

To put barcoding and automatic identification into perspective, it is important to know a little of its history and to briefly examine some more notable implementations.

The Supermarket

I believe it is safe to say that barcoding was born and raised in the supermarkets of America. With the advent of the concept of the self-service grocery store in 1916, the ground was laid for barcodes. When self-service grocery stores came along, the requirement to individually price items was also introduced. Before self-service, the price of items was controlled by the merchant by denying customers access to goods for the most part. Prices were not always on items and were generally stored in the owners or clerks head. The whole point of allowing customers to serve themselves in grocery stores was to reduce the cost of distribution. Indeed, from 1934 to 1974 the cost of distribution as a percent of gross sales was reduced from 24% to 20.9%.

However, as the number of items being sold, the numbers of customers being served, and the cost of labor increased, the cost of distribution began to go up again. Fortunately, the technology to address the problem was being developed.

In 1967 the first pilot barcode check out system was installed in a Kroeger market in Cincinatti, Ohio. The pilot was generally a success but one of the findings was that for the system to work, a uniform standard of barcoding products was necessary. Thus the Universal Product Code, or UPC was born. We will look more closely at UPC later in the paper.

Automatic Document Tracking - Federal Express

Federal Express is a company that has captured the lions share of the express mail business in part because of the integration of barcoding into their business. Federal Express gambled that they could gain the competitive edge in their industry through not merely adding barcoding onto their existing system, but but making it central to their business. Today, Federal Express uses the barcode to track every package they handle. And they handle a significant amount of packages. The most currant figures indicate that Federal Express processes 800,000 packages every night.

The Federal Express systems works as follows:

Every package that is mailed is accompanied by an airbill which has an 11 digit barcode symbol. When the courier picks up the airbill, the barcode is scanned using a hand held portable scanner and certain information is keyed into a portable data collection device. By the way, Fed Ex realizes an accuracy rate of 99.9999997%. Most errors are traceable to data entry errors and not scanning errors.

Once all the items being picked up at a particular site have been entered, the hand held scanner is inserted into a Radio Frequency unit in the pickup van and all the pertinent information regarding the airbill is transmitted via relay sites to the central data processing center in Memphis, Tennessee.

Each shipment of barcoded airbills is statistically sampled for scannability. Today Federal Express says that an airbill is scanned an average of 16 to 17 times from the time they pick it up until it is delivered.

LASER SCANNING OF MEDICAL SUPPLIES

The hospital of today is very concerned with accurate information with regard to the processing of laboratory work and dispensing of medications. The term that is used is "zero error". In many situations there is no margin for error!!.

More and more hospitals are turning to barcodes to provide the accuracy and timeliness necessary to meet their stringent requirements. One implementation that has emerged involves placing a barcode on each patients identification band. Each time a different service or function is provided to the patient, the barcode is read and associated with the transaction. Data about the transaction is then fed in either batch or real-time mode to a patient accounting system.

In addition, barcoding applications in medicine are found in tracking of lab work, blood (both samples and plasma for transfusion), and critical records such as X-Rays.

Inventory Control

Inventory control is another classic barcode application. The location of an item can be barcoded, as well as the item itself. Boxes of items can be barcoded, and the information can be captured with portables using contact or laser readers and transmitted in batches or even interactively through a short range radio transceiver. The application of radio transceivers is usually referred to as RF or Radio Frequency.

The end result is that the company knows what types of products they have on hand, how many and where they are located.

Barcoded Personal Identification

The barcoding of personal identification badges is an area of growing importance and utility. The most commonly encountered applications involve the addition of barcoded student or employee numbers to a permanent badge In the case of student ID's, the barcode may be read at the cafeteria cash register to charge meals to eating plans or checking out a book from the library.

Barcoded employee badges have a variety of applications ranging from tracking time and attendance or tying a manufacturing process to a particular employee as well as the more common uses of security.
For example, a barcoded "traveller" can be created which identifies each station during a manufacturing process. As the traveller reaches a station, it and the employees barcode are read. When a step is completed, both barcodes are read again and the Shop Floor Control system is updated. The data collected can be used to arrive at more accurate forecasts of production time requirements and to pinpoint areas for improvement.

Automobile Identification

The next time you use a rental car, notice that it probably contains a barcode. The barcode is being used to keep track of such diverse activities as rental check in/out, preparation for rental, and periodic maintenance.

In addition, the three major automobile manufacturers are implementing a system to put a barcode not only on every part of the car but on the car itself and track the car with that unique serial number that is represented in a barcode format (some of the rental cars do that too).

Fixed Assets

Another major area for barcoding where significant labor savings can be realized is with conducting fixed assets inventories. In a typical barcoded implementation, each fixed asset is tagged with a barcoded/human-readable label. At physical inventory time, each item is read with a portable data collection device similar to the unit in use by Federal Express. As each organizational units inventory is completed, the data is passed to a database where a comparison is done and reconciliation reports are created.

In an organization where large numbers of items must be accounted for or deprecitation rules dictate accurate inventories, these systems will more than pay for themselves with the first inventory.

A central theme runs throughout all the applications of barcoding technology that we have seen so far. These systems deliver

productivity,
control,
competitive edge.

All of these systems provided some form of improved productivity. Manually keying in data takes time and has a much higher degree of error rates.

People can accomplish more in situations where barcoding has been properly applied. Inventories and items can be tracked faster and more accurately. This all adds up to better control.

The first year of operation of Federal Express's Customer Oriented Service and Management Operating System, $10 million was saved in billed revenue that had previously gone unbilled.

Federal Express can make the claim that they can deliver documents overnight anywhere in the U.S. and at any time tell you within an hour where your document is. That is a competive edge!!

THE BARCODE SYMBOLOGY

One of the first considerations when implementing a barcode system is the choice of symbology. This step is critical because the symbology selected will be used to represent your data throughout the system.

There are over 50 major symbologies available or in use today. Among the most commonly used barcode symbols are:

UPC
Code 3 of 9 (aka Code 39)
EAN
UPC
Codabar
Interleaved 2 of 5
Code 11
Code 128

Barcode Specifications

A barcode consists of a number of printed bars and intervening spaces. the widths of the bars and spaces, as well as the number of each, is determined by a specific convention, referred to as a specification for that symbology. A specification sets the following conditions:

* the minimum nominal width of the narrowest elements
* the ratio of the wide elements to the narrow ones
* the printing tolerances (the changes in widths of bars due to the printing process
* the structure of unique bar and space combinations to represent various characters
* the bar/space patterns that signify the beginning and end of the bar code message
* and the clear area or quiet zone, required in front and at the end of the symbol.

If these conditions are met the barcode is said to be "within spec".

The UPC Symbol

As the grandaddy and most widely known, the UPC symbol makes a good illustration of what makes up a barcode symbol. The UPC symbol is made up of a ten digit number. Twelve digits if you consider the first character and the last character. Ten digits because ten digits are represented along the bottom. What that UPC code represents is a manufacturer ID and a product ID. Price is not represented in that UPC barcode. The first character that you see which is about half-way up the barcode on the left is whats known as a system character. This represents what type of item this is in a retail environment. If it is a zero (0), it is a retail item. If it is a three (3), it is a drug item. So if you were to go into an Eckerd's or Treasury Drug and buy a box of aspirin, you would see a three (3) there. Yet if you were going to a supermarket and pick up a can of coke you would see a leading zero (0). Now, this is a UPC Version A which is ten digits. UPC works this way. Each letter is represented with two bars and two spaces. Those bars and spaces can be one of four different widths. Those series of bars make up the number then. The first five digits you see on the bottom represent the manufacturer. Lets take the Campbell soup example, the first five digits represents Campbell's soup, the second five digits might represent a can of tomato soup. No price is represented in that barcode when that scan at the point of sale that accesses the price. UPC is just one type of symbology that we talked about.

The "X" Dimension and Code 3 of 9

Code 39 allows you to represent alpha-numeric data in the barcode, whereas UPC is very fixed strictly numeric and strictly for the retail type environment, Code 39 is much more flexible.

The X dimension is the narrowest bar element. In any typical barcode there are two element sizes. In fact the name Code 39 is derived from the fact that any character is represented with nine elements and three of those nine elements are always Y while the remaining elements are the narrow or X element.

Having established what the X dimension, or our narrow bar element, is, we then establish a ratio called the Wide to Narrow Bar ratio. With Code 39 the Wide to Narrow Bar ration can be anywhere between 2.0 to 1, to 3.0 to 1. Or, put another way, if you have a narrow bar element that is 10 mil across and a 3 to 1 ratio, then the Wide bar would be 30 mil. Those would be your two element sizes. You can see here in these barcodes I have represented the same word from top to bottom, yet The bottom barcode is very very long. The top barcode is very short, very dense, yet they contain the same data. The reason why is because I've varied my narrow bar size, I've increased it and I've also increased my Wide to Narrow Ratio. As I affect both of those variables, I affect the density of the barcode.

PRINTING THE BARCODE

Once the symbology has been chosen, the next issue concerns printing. Printing is really the foundation of our barcode system. The printed symbol is crucial to everything that lies beyond it and that encompasses scanning, and data collection. Because so much depends on it, the symbol must be printed well. Unlike human readable text, there is much less margin for error as we shall see later. It is very critical that bars and spaces are the correct width. If those widths get out of spec in any way it will affect the read rate and accuracy of our scanner. Because the quality of the barcode is so important to a barcode system, a company should ask itself is "Are we going to take on the responsibility of printing the barcode or are we going to have another organization print for us"?

However, there are some other considerations when determining whether to print your own barcodes or not. If the information to be printed is known well in advance of the need to apply the information and the quantities to be ordered can obtain volume discounts, then outside printing is recommended. For example, in the case of Fixed Assets at HP; the asset number is a sequential number assigned to the asset as it is received. High quality, laminated, barcode labels can be ordered and distributed from a division or region office. The cost of distributing the means to print barcodes at remote locations, in the case of a sales region, is not justified. In addition, the sequential number can be tied to the items serial number and value through the Fixed Assets Database. The situation with Fixed Assets is very similar to the Grocery application. There is no need to code value (or price) on the unit itself.

However, in situation where the information to be coded is not easily known beforehand, on-site printing may be recommended. Let's take a typical manufacturing environment for example. When a finished good is produced, it may be assigned a serial number.

Typically, one of the most popular off-site methods is the offset printing. With this method, a master of the barcode (and perhaps other information) is created and a film master is created. A major advantage of this method is that the barcode or label being printed can be of the highest possible quality.
In addition, there is no need to purchase hardware or to train your staff to run a barcode printer.

Some limitations are (1) that you have to depend on someone's lead time to produce the labels and deliver them to you, (2) you may not know what information needs to be printed until the labels are needed, and (3) it may be more cost effective to control printing in-house.

An additional factor when confronting the issue of in-house versus outside printing is the availablilty of high quality, reliable printers today.

On todays marketplace there are essentially three methods for printing barcodes, dot matrix, laser, and thermal.

One of the most widely used methods of in-house barcode printing is with the dots matrix printer. With dot matrix there is a hammerbank in the printer and which contains hundreds of small hammers. The hammers are a certain dot sizes which determines the smallest dimension barcode that can be printed. When the hammers strike the paper they form the barcode from top to bottom.

Some advantages of dot matrix printers are that they are cost efficient, fast, and they can handle a wide variety of paper and label stock sizes and thicknesses. One disadvantage concerns the quality of the barcode printed by dot matrix.

Because there is a physical slap of a hammer on the paper, the dot itself can be distorted. In addition, since the hammer is round, a close examination of even a high quality dot matrix barcode will reveal a wavy pattern.
If the printer is not regularly serviced, chances are that the barcode will eventually go out of spec. Once the barcode is out of spec, the bar code read failure rate is going to increase. In other words, the barcodes being printed will be come useless. The purpose here is not to discourage you from considering dot matrix printers. Rather, you simply must be aware that you are using a mechanical device that will require more frequent periodic maintenance that you might expect from a the ordinary system printer.

The Thermal Process

Another commonly encountered printing process is the thermal printing. There are two types of thermal printing; thermal and thermal transfer. Both processes produce a very high quality image, very fast and are cost effective. Both thermal and thermal transfer involve the heating of a print head. They differ in that thermal printing the heated print head is pressed against chemically reactive stock. Whereas, with thermal transfer the heated print head is pressed against a film stock. The portion of the film stock representing the characters is transferred to ordinary paper/label stock.
With either thermal process a very high quality image is produced.

The major drawback to thermal printing is environmental. Because thermal printing uses a heat sensitive paper stock, it can be easily discolored if stored or used in hot environments. If thermal stock is stored in a very hot truck, there is the potential for the entire label to discolor. Retailers will use this type label very often because they work in a controlled environment.

Two other issues need to be considered when using either thermal process; speed and label size. Typically, thermal printers will not handle stock over 8 inches wide. Printing speeds for thermal printers are usually in the range of 2 - 3 inches per second.

Laser Printing

The past few years have seen the emergence of relatively low cost laser printers. Because of some inherent technical difficulties, however, laser printers have not yet had a significant impact on the printing of barcodes. Given the growing demand for barcodes and the advances in technology this picture will likely change in the next decade.

To understand why laser printed barcodes have not been more pervasive, a brief explanation of how laser printers work is in order. Laser printing uses the same basic technology found in photo copying machines. Thus the correct name for laser printing is Electrophotographical Printing, or EPG. In a typical EPG printer, employs a Helium-Neon laser to "draw" the characters on the paper/label stock. The laser causes an electrostatic image consisting of charged and uncharged areas to be formed on the surface of an cylindrical drum. A toner consisting of small, black, electrically charged particles is brought near the surface of the drum, and the toner particles adhere to the paper.
The importance of understanding this process is that two conditions exist which can affect your application. First, high speed laser printers (40 pages per minute and up) use several drums and can run quite hot. Special consideration must be made when evaluating the gummed-label stock to be run through the printer. As you can imagine using the incorrect stock can result in frequent jams and unreadable output. Second, because laser printing causes toner to be electrostatically adhered to the print stock, there is no absorption of the printed image into the paper. If the barcode is to be read using a contact reader, special care must be taken to ensure that the barcodes don't smear. Paper stock is available that will prevent smearing but you must look for it.

SYMBOL VERIFICATION

Having established the method for printing an often overlooked aspect of barcoding must be addressed; symbol verification. The entire purpose of verification is to ensure that the barcodes you are printing can be read. If the symbols are unreadable, you have defeated the purpose of the system. Simply reading the barcode with a standard scanner is usually insufficient; all you have proven is that your reader will read that particular symbol. To ensure that the printed symbols are in spec they must be read by a verification device.

A verification device evaluates the "X" and "Y" dimensions of each symbol. Some devices also calculate the wide to narrow ratio and checks that the correct print contrast is maintained.

Print verification readers range in cost and sophistication from the type used by an offsite printer in the $10,000 range to devices in the
$1,500 or $2,000 range that merely check the barcode and tell you if it is in spec.

SCANNING

Now that you have printed a readable, verified barcode symbol, it has to be scanned to be of use. Before looking at scanning devices, a few words are in order about the physical act of scanning.

With any type of scanner that you use, the symbol must be scanned completely. The scanner must move all the way through the barcode symbol. You can't stop in the middle, lift up and go back down and go from there. Also, it doesn't matter if the symbol is read from left to right or right to left. Barcodes are always omni directional. Every properly printed barcode has a start and stop character in the barcode which identifies which direction it is being scanning from. The important thing is that a full pass must be made through the barcode symbol.

What the barcode scanner is looking for when it passes over the barcode symbol, is a pattern. What the dot of light is trying to encounter is a pattern of dark and light bars and spaces. When the light encounters a space, more light is reflected back. When the light encounters a bar, there is very little reflectance.

Types of Scanners

There are only two types of scanners available on the market; contact and non-contact. The best known example of a non-contact is the slot scanner found in supermarkets and some retail stores. With non-contact scanners the operator does not have to make contact with the barcode. To achieve this objective, the supermarket slot scanner is actually over a hundred different light beams. In order for the barcode to be read, at least one of the beams must make a complete pass over the barcode. Because of the sophistication required to make this type of reader function properly, it is quite expensive. An alternative device that is usually more affordable, is the light pen.

Light Pens

Initially, nearly all barcode reading was done with a contact reader known as a light pen. Light pens are alot less expensive, more in the $150.00 to $200.00 price range.) What they allow the operator to do, is make a pass across a barcode and look at that symbol one time. A consideration when evaluating contact versus non-contact is the reading surface. If the label is affixed to a variable surface, it is going to be much more difficult to read than if the label is affixed to a smooth, flat surface.

Laser Scanners

In contrast, a non-contact scanner may cost 6 to 7 times as much as a light pen but it has certain advantages over the light pen. A laser scanner works by producing a dot of light using a mirror mechanism that rotates inside. Like the light pen, it also produces a dot of light. However, the dot of light is moving back and forth at forty scans per second. To the human eye the beam looks like a line. In reality, the line is the same dot being bounced off a mirror very swiftly. Because the dot is being scanned forty times a second,

there is a much higher probability that the barcode symbol will be read by the scanner that by a wand. Therefore, you will see or hear the term "aggressive" used to describe a laser scanner. Two other advantages to laser scanning are that items can be read from several inches to as much as 7 feet away and laser scanners have a much higher success rate with reading irregular surfaces.

Fixed Mount Scanning

Occasionally, the situation arises where fixed mount scanners are called for. These are always non-contact readers. They are best utilized where it is either very easy for the operator to manipulate the object to be scanned or if the movement of the scanned object can be tightly controlled. Two common examples involve fixed scanners for reading symbols in library check out and scanners reading labels off of boxes on an assembly line.

DATA COLLECTION

Two major methods of data collection are employed today. The first is fixed terminal/station. The second involves the use of portable data collection devices. In both cases, contact and non-contact readers can be used.

Fixed Station

Typically, a fixed station has the following components:

* a barcode reader
* a digitizer (aka "wedge")
* a personal computer/work station or terminal

We have already discussed the barcode reader and most are familiar with the personal computer/workstation or terminal configurations. Which leaves the "wedge". The purpose of the wedge is actually quite simple. The data reader by the data collection device is in analog form and must be translated into digital form before it can be used by a digital computer. The wedge is the translator. As technology progresses, the wedge will probably disappear. For example, within the last year Hewlett Packard has introduced a wand with the wedge built into it. The need for digitizing hasn't gone away. On the contrary, only HP has simple miniaturized the wedge and put it where it belonged, into the wand.

Portable Scanning

Portable scanning encompasses the use of any device not physically attached to the "data analysis" computer. The most commonly encountered methods are portable data collection terminals, such as the hand held unit used by Federal Express, and RF transmitters. RF systems differ from all other applications in that once data is collected by either laser or light pen, it is transmitted to the host computer via Radio Frequency. Thus, the individual doing the dat collection can be a mile or more from the "host" and each barcode that is read is immediately recorded without the need to upload at a later time.

Another form of RF data collection involves the use of "RF ID Tags" attached to items. In a recent application, RF tags are attached to the chassis of

automobiles at the beginning of a production line. As the chassis travels through the manufacturing process, remote sensors read the information on the tag and keep the Shop Floor Control data base updated with the current location of the chassis.

CONCLUSION

At this point, most of the major issues involved in the implementation of a barcode system have been addressed. The last issue concerns the integration into your data processing system of the data you are collecting.

The most basic principal of data processing especially to barcoding. Garbage In Garbage Out!! Make sure that you are collecting the right information and that the data is good. Verify the barcodes!! How will I or my users use the information we are now collecting. Remember, you may now be collecting data in quantities you never dreamed of before. Be prepared!!

I began by saying that the lessons you've learned in years of implementing data processing systems can be applied to barcodes and that the first thing you had to do was to learn about the technology. Hopefully, this overview of barcoding technologies has given you some food for thought. For those of you just starting out, you have just completed your first lesson. There will be no test today!