Auto ID in the Material Handling Industry
The Goals of Auto-ID

The ultimate goal of modern logistics is item level, real-time visibility of the supply chain from packaging to arrival at the destination. And automated identification (auto-ID) technology is viewed as the means to reaching this goal of total supply chain visibility. Simply stated, auto-ID involves automatically recording a product’s identity and location within the supply chain. This combined information is then used to track products throughout production and to direct specific actions to be performed on the product at the appropriate step: labeling, packaging, sortation, shipping, receiving, etc.

Bar code technology was the first step toward reaching the goal of total supply chain visibility. Today, supply chain professionals view radio frequency identification (RFID) as the ultimate tool in reaching that goal. The reality lies somewhere in the middle, and most product sortation and tracking systems use a combination of technologies, from laser and camera bar code scanners to RFID tags and readers. For supply chain professionals, the most important question is not what technology platform to adopt but which technology can make the process both manageable and profitable.

Auto-ID systems have been used in industry for over twenty years. Recently, standards and network infrastructure have been developed to provide item level identification and product information to enhance production, distribution, storage and retail processes in the supply chain. The increased use of auto-ID has reduced the price of the technology so that it is becoming feasible to consider the automated identification of everyday retail items.

The major benefit of auto-ID systems is improved product tracking, visibility and traceability. Many enhancements to existing materials handling and storage solutions have been proposed to take advantage of the increased data accuracy. One result is that real time information on product status is now available to provide a more representative indication of order status.

A typical auto-ID system consists of:

- An identity tag attached to a product – either a bar code, other product code or RFID tag. These tags store a unique identification number that is read by the appropriate device – laser scanner, camera or RFID reader.
- Networked readers and data processing system capable of collecting signals from multiple tags and of processing the data to eliminate duplications and misreads.
- One or more networked databases that store information related to the product (basic product data, tracking history, processing instructions).

The network can also include a control system that has access to the product identity information in addition to other information from the operating environment. On the basis of sensed information, the control system makes decisions and initiates actions by sending commands to actuators.

The following chapters provide an overview of the different technologies used in auto-ID systems, from bar codes to RFID. They include a basic description of the technology, its benefits and limitations, and guidelines on designing a system.
Introduction to Bar Code Scanning
Bar code symbols can be described as a series of rectangular bars and spaces that represented letters, numbers and symbols. This is still true for one-dimensional or linear symbols. But with the emergence of two-dimensional technology, bar code symbols can be defined as optically scanned graphic patterns for encoding data.

One-Dimensional (Linear) Symbol
A linear symbol is a series of bars and spaces that represent a series of characters. The pattern of bars and spaces is determined by the specific symbology. The symbol consists of four parts: bar code, quiet zone, human readable characters and guard bars (which are optional).

![Linear Bar Code Structure](image)

There are many different types of linear symbologies. The differences reflect the many applications that bar code symbols are used in. Based upon the application, each symbology has definite advantages and disadvantages over the other symbologies.

Two-Dimensional Symbols
Unlike linear bar codes, two-dimensional symbols contain data along two axes. This allows much more data to be stored in a single symbol, in some cases up to 3,000 bytes. Two-dimensional codes are gaining popularity in such major industries as electronics, automotive and package distribution. They are used when available symbol space is limited; more data needs to be encoded; a central system is in place to accommodate additional identification data; and an application requires a database on an item (useful for item tracking). The two types of 2-D symbologies are stacked (or multirow) and matrix (or imaged) codes.

Stacked codes are a set of short, closely packed linear bar codes. They can be easily read with laser technology. The most common stacked symbology is PDF 417. Matrix codes encode data in an array of squares or hexagons with "finder" and orientation structures. Each shape represents a binary bit of information. The bits are arranged through the area according to the particular symbology's algorithm. Matrix codes are read with a CCD reader that uses vision-based technology. The more common matrix symbologies are Data Matrix (or ECC 200), Maxicode, Vericode, and CP Code.

Two-dimensional codes have error correction features to reduce error rates (e.g., transposing or misinterpreting characters). The error correction methods use redundancy to compensate for
symbol degradation. Thus symbols that have been damaged by use or poor printing methods can be read correctly.

**Bar Code System Basics**

A bar code system consists of a scanner and decoder, either separate or integrated into one unit. The primary function of the scanner is to retrieve the bar and space patterns of the bar code symbol as an analog signal (raw data), convert it to digital form, and pass that information to the decoder. The decoder then translates the information into characters. An example of this process is shown below.

![Elements to Results Diagram](image)

Two key criteria for bar code reading equipment are:
- **Autodistinguishing** – The ability of the scanner to recognize a number of selected symbologies and process their data.
- **Autodiscrimination** – The ability of the decoder to recognize and correctly translate (decode) more than one symbology.

**How a Scanner Works**

A bar code scanner works on the simple principle that dark bars absorb light and light spaces reflect light. Increasing the contrast between dark and light makes it easier for the scanner to pick up video information from the bar code symbol.
Bar Code Scanner

The scanner uses a light source to illuminate the symbol. Typically it is a solid-state visible laser diode (VLD). Other light sources include LEDs, helium-neon (He-Ne) laser tubes, and infrared lasers. A photodetector collects a small portion of the reflected light from the bar code symbol, which passes an optical interference filter. The filter blocks ambient light and allows only the laser light carrying the absorption and reflection information from the bar code to pass to the photodiode. The photodiode converts the light energy into an electrical signal that the photodetector circuit amplifies. The analog signal then passes through the signal conditioner, which "cleans-up" the analog signal and digitizes it into a pattern of ones and zeros. This digital data is then sent to the decoder.

How a Decoder Works
The decoder/microprocessor receives the digital signal from the scanner and compares the pattern of ones and zeros to the particular bar code symbology standard of ones and zeros. If there is a match then a good read is achieved, and the ones and zeros are converted into a series of data characters that reflect the information encoded in the bar code symbol. If the decoder cannot match the pattern of ones and zeros then a no-read has occurred and a no-read message is generated.

Decoder Diagram

The interface sends the data to the host device for further processing. If capable, it can also control local I/O points based on the data decoded. An example of this would be energizing a conveyor diverter for a sort application. Other capabilities of a decoder include counting items,
matching incoming codes against a predefined list (match table), and reformatting bar code data to the host device (host replacement).

**Moving Beam Scanning**
Most moving beam scanners use a visible laser diode (VLD) as the light source. The VLD can be mounted to a thermal electric (TE) cooler, which conducts heat away from the diode and allows the scanner to operate in higher temperatures. The light exits the diode (VLD) and passes through an aperture that shapes the laser spot size. The laser spot then travels through a fixed or adjustable focusing lens.

**Shaping and Focusing the Laser Spot**

Accu-Sort's AdaptaScan™ reader is an adjustable lens scanner that sets the lens to the optimum position (focus) based on the symbol dimension (narrow bar width) and distance from the scanner's front window. An advantage of adjustable lens scanners is that they incorporate multiple read ranges and can be reset (refocused) if necessary to accommodate changes to symbol dimension or distance. Some scanners dynamically move the adjustable lens for each label read. A fixed lens scanner has an LED aperture or focusing lens specifically designed for a symbol's narrow bar width and distance from the scanner. Fixed lens scanners cover only a specific read range. The scanner lens must be modified by the manufacturer if symbol dimension or distance changes.

A mirror element is used to move the laser spot across the bar code symbol. All mirrors in the scanner are front surface mirrors, meaning that the reflective coating is on the top of the glass or plastic substrate. This is done to maximize usage of the available laser light energy and to minimize signal distortion. Typically, systems include a transmit mirror to transmit the light and a receive mirror to receive the return video signal for processing into digital form. Accu-Sort’s AdaptaScan reader uses a patented compound mirror for both functions called the Arc-Raster mirror. The transmit mirror is the center flat portion and the receive mirror is the concave portion. The mirror is either fixed position for linear scanning or oscillates for raster scanning.

Mirrors can be attached to a rotating polygon, and the spinning action of the polygon produces a scan line that moves in one direction. The advantage of this type of scan line generation is that non-linear reads can be made with a single line scanner using Accu-Sort’s patented DRX software package. The disadvantage is that moving parts (i.e., motor bearings) wear over the life of the unit, affecting scan accuracy.

A mirror attached to an oscillator is another method of generating the scan line. It produces two directions of travel on a single scan line. A disadvantage of this method is that it restricts label placement. This type of scan pattern also does not allow the use of DRX software. The
advantage is much reduced physical wear on the moving part (resonant scanner device). This is also a more costly option and requires more calibration at assembly for best operation of the unit.

**Illumination**
Scanners use light to scan bar codes. Most scanners provide some means of illumination (light source) to illuminate the symbol and some method of light detection (photodetector) to capture a fraction of the light reflected from the symbol. The illumination used in a scanner can be either focused illumination or floodlight illumination.

Focused illumination projects a spot of light onto the bar code symbol and attempts to capture a fraction of the reflected light from the symbol. Focusing can be used to concentrate the signal onto a photodetector.

Floodlight illumination illuminates a large area of the symbol so a small aperture (or slit) in front of the photodetector can collect a small portion of the reflected light. The size of the aperture determines the scanner resolution. Charged Coupled Device scanners usually use floodlight illumination.

**Light Sources**
The light source used to illuminate the bar code symbol is typically a visible laser diode (VLD), LED (light emitting diode), infrared laser diode (ILD), or helium-neon (He-Ne) laser tube. In selecting a scanning device, the first decision is whether to use a visible or infrared light source.

A visible light source is compatible with most printing inks, dyes, and thermal printing because the inks and dyes that appear dark to the human eye absorb visible red light. In some cases, the same inks and dyes cannot be read with infrared light sources. Some printing inks use organic dyes that absorb light in the visible spectrum but not in the infrared range. Some thermal paper also absorbs red light but not infrared light. Therefore, bar codes printed with organic ink or on certain types of thermal paper cannot be read by an infrared scanner.

**Visible Laser Diodes** generate visible red light at wavelengths between 660 and 700 nm. The light source (laser) is a constantly moving, concentrated spot. For the most part, VLD scanners have replaced Helium-Neon (He-Ne) scanners in almost all applications because they are smaller and consume much less power than a He-Ne laser tube.

**Infrared Laser Diodes** generate light at wavelengths greater than 780 nm. Although infrared light cannot be seen by the naked eye, it is visible to photodiodes and other photo-optic sensing devices. Infrared scanners work well on symbols printed with carbon based inks, photographic labels, laminated labels, laser etched codes on metal and some metallic based pigmented dyes.

The main advantage of infrared is that it can read through oil, grease, grime and visibly opaque coverings. Visibly opaque coverings are best described as being visible to the naked eye (and visible light sources) but invisible to an infrared scanner. The disadvantage is that infrared requires true black and white bar codes printed with carbon-based ink. Usually, the ink must have at least 20% carbon content for use with infrared scanners.

**Charged Couple Devices (CCDs)** use a cluster of LEDs to flood a bar code with light. The bar code image is transferred to an array of very small photodetectors. The LEDs have limited light output power, so most CCD scanners require close contact with the bar code, typically 1 to 2 in. (2.54 to 5.08 cm) maximum. However, some new high-speed sortation scanners using CCD
cameras to read 2D array codes use high intensity flood lamps to overcome the distance limitation.

**Light Detection**
The photodetector used in a scanner can be a photodiode, photointegrated circuit (Photo IC), phototransistor, or CCD. The first three detectors are single-element types that detect light as the beam passes across the bars and spaces. Higher signal levels result from focusing the returned light onto the detector.

CCDs are composed of arrays of microscopic photodetectors that, in essence, take a still picture of the symbol. Due to their complexity, CCDs are more expensive than other photodetectors. However, handheld CCD scanners can have a lower overall cost because they eliminate various moving mirror components.

**Bar Code System Design Considerations**
For simplicity, the items discussed in this section relate to using a one-dimensional (linear) bar code system. A large number of factors govern the type of bar code system selected, including:

- Application
- Line speed
- Scan rate
- Scanning distance
- Optical throw
- Bar code symbol density
- Bar code symbol height, length, and orientation
- Decode speed

**Application** – Important questions to answer before selecting and designing a bar code system are:

- How will the bar code data be used?
- Will items be matched or simply scanned for identification?

Some decoders allow the use Match Codes to sort items.

**Line Speed** – The speed at which an item moves on an assembly line determines how long the symbol is in view of the scanner. A faster moving item requires a scanner with a faster scan rate.

**Scan Rate vs. Line Speed** – Scan rate is only one item of significance in an automated system; line speed must also be considered. For example, consider a one-inch tall bar code symbol affixed in the ladder position to a 6 in. (15.24 cm) long box. The box is traveling at a rate of 180 fpm (1 inch in approximately 36 milliseconds).
Scan Rate vs. Line Speed

For maximum system reliability, the label should be scanned multiple times to compensate for any possible printing imperfections. A common rule of thumb for any application is that the scanner should make at least five scan attempts of the bar code symbol. In this example, if the scanner scans at a rate of 200 scans per second (1 scan every 5 milliseconds), the bar code will be scanned five to six times.

Optical Throw vs. Depth of Field – Optical throw is the distance from the scanner’s window to the minimum depth of field. Depth of field is the area where the scanner’s lenses focus the light source. The center of the depth of field is the point where the beam is actually the narrowest.

Spot Size – In most cases, spot size must be 0.7 and 1.4 times the size of the smallest element. The exception is Case Code symbols. If the scanner is placed incorrectly, spot size may be too small or too large. This incorrect spot size will misread poor quality labels. For more information, refer to Symbol Density.

Distance – The distance between the symbol and scanner is important because all scanners have defined read ranges.

Symbol Density – Symbol density determines the minimum scanner resolution. The symbol’s resolution and distance between it and the scanner determine the scanner’s required depth of field. To read narrow bars, spot size must be proportionately smaller. Therefore, to read a symbol whose smallest bar is 0.010 in. (10 mil), the scanner must be positioned close enough to the symbol to produce a 7-14 mil spot size.

Symbol Height – Symbol height has a great influence on scanner and decoder speed, particularly when the symbol is positioned in the ladder orientation. A tall symbol remains in the
scanner’s beam for a longer time than the same symbol in a picket fence orientation. This will allow for a longer scan rate or allow more scan attempts. The orientation of the symbol also influences the amount of time it spends in the scanner’s field of view. There are some obvious exceptions, such as a symbol that is as tall as it is wide (1x1 or 2x2), or a symbol whose bars are taller than its length [3 in. (7.62 cm) tall bars and a 1 in. (2.54 cm) long symbol].

Symbol Length – A long symbol in a picket fence orientation will be entirely in the scanner’s view for less time than a shorter symbol. The longer symbol requires a faster scan/decode rate, fewer attempts, a wider sweep of the beam, or a slower rate of travel. Ideally, the scanner’s field of view should be twice the symbol length. This allows users to compensate for faster line speeds and slower scan speeds.

Orientation – Variations in orientation are categorized as skew, tilt, and pitch:

- **Skew** reduces the number of scan attempts in the ladder orientation by reducing the relative width of the symbol. Compensating for skew requires an increased depth of field.
• **Tilt** reduces the number of scans that cross the symbol due to its tilted position. Depending on the degree of tilt, the beam has less chance of covering the entire symbol at once.

• **Pitch** has a number of different effects. In the ladder position, it increases the scanner's required depth of field. In the picket fence position, the scanner's beam may not cross the entire symbol at once because the symbol seems to be smaller in height. Pitch also reduces the effective narrow bar and space width.

### Skew, Tilt and Pitch

![Skew, Tilt and Pitch Diagram](image)

**Decode Speed** – The number of decode attempts required to ensure a good read depends on both scan rate and decoder processor speed. Most decoders operate slower than the attached scanner. Therefore, only a percentage of scans will be decoded or they will be stored in a buffer and processed later. Under normal conditions, the decoder requires only 2 to 5 decode attempts as the object passes by. Under less than ideal conditions, such as poor quality labels, the number of decode attempts should be increased.

**Bar Code System Performance**

Bar code system performance is rated by the system's substitution error rate and first read rate. These two factors rely on system the hardware and software.

**Substitution Error Rate (SER)** – Substitution error occurs when the data interpreted by the scanner differs from that actually encoded on the bar code label. Substitution error usually results from label printing defects. Substitution error is extremely difficult to determine and usually is not discovered until the data has been processed and an obvious data error is noticed.

**First Read Rate (FRR)** – First read rate is the percentage of time that a symbol is scanned on the first try. Bar code symbols should have a first read rate of at least 90%. A first read rate of less than 90% usually means that either the bar code symbols or scanning device need some type of adjustment or modification. This does not mean that a first read rate of less than 90% is unacceptable.

**Scanning Accuracy** – The characteristics that influence the performance of a scanner are:

- Symbol density
- Spot size
- Bar width
- Print quality
• Print contrast

*Symbol Density:* Bar code symbol density is defined by the width of the symbol's narrowest bars and spaces. The narrower the bars, the smaller the overall symbol size. If a symbol's smallest element is 0.0075 in. (0.019 cm) wide, it is called a 7.5 mil label.

*Spot Size:* For the scanner to accurately detect the width of the bars and spaces, spot size should be between 0.7 and 1.4 times the narrowest element. If spot size is too small, some spots and voids in the label may be read and sent to the decoder. If spot is too large, the scanner will try to read a bar and space at the same time. The results will be a less than desirable signal sent to the decoder, which will reduce the percentage of good, reads.

![Spot Size](image)

An adjustable focus scanner, such as AdaptaScan, can automatically adjust the spot to optimal size for a given depth of field. It calculates this size based on parameters such as symbol narrow bar width, symbol position, and scanner distance. Depth of field optimization increases symbol readability while enhancing overall system performance.

![Spot Size Read Results](image)

*Bar Width:* The narrowest bar width that the scanner can read depends on optic quality, spot size, amplifier and conditioning circuitry and distance to the label.

*Label Print Quality:* A variety of printing imperfections can cause an invalid or incorrect reading of a bar code symbol.

  • **Ink Coverage:** Too much, too little, smeared or nonuniform ink can cause invalid reads, or no-reads. Too much ink results in spreading, resulting wider bars and narrower spaces.
Wider Bars and Narrower Margins

Too little ink results in narrower bars and wider spaces. If a bar does not have enough ink coverage, it may not be recognized by the scanner as a bar.

Narrower Bars and Wider Margins

Smearing could result in wider bars or invalid reads, depending on how badly the symbol is smeared.

Smeared Bar Codes

Nonuniform coverage could result in narrower bars or no bars at all which could also result in invalid reads or no-reads.

Nonuniform Coverage

- Edge Roughness: The edges of the bars in a bar code symbol must be smooth. If they are not, the scanner may misinterpret the width of the bars and spaces. Edge roughness is usually more noticeable in symbols produced by a dot matrix printer.
• Spots and Voids: Spots and voids are common in most dot matrix printing processes. Spots are small areas that have ink where no ink should be present. Voids are small areas that have no ink where ink should be present.

• Print Contrast: Print contrast is the ratio of reflectivity between the bars and spaces in a bar code symbol. Print contrast ratio is usually expressed as a percentage. For reliable first time reads of a bar code symbol, the symbol should have a print contrast of at least 75%.
Introduction to Camera Technology

Laser-based bar code reading systems are reliable, but their accuracy is affected by a number of conditions, including label quality, label size, label location and transport speed. In addition, laser bar code scanners have difficulty reading two-dimensional codes omni-directionally. These symbols can store up to 3000 bytes of data, and they are widely used in such major industries as electronics, pharmaceuticals, automotive and package distribution. The second major limitation with laser scanners is scan speed. Typical scanning speed is 500 to 1000 scans per second, which means that either conveyor speed must be limited to 560 fpm or labels size must be increased. Either option results in lower throughput and additional non-value-added costs.

CCD (Charge Coupled Device) camera-based scanners were developed in order to overcome these problems. Compared to laser readers, camera-based systems provide highly reliable and accurate reading. They can read bar codes from any angle from 45 to 90 degrees from the surface as well as bar codes placed up to several meters from the camera. Using camera images and sophisticated vision algorithms, the system can reliably read bar codes omni-directionally and under difficult conditions including blurred, partially occluded or damaged, and “noisy” barcodes due to surface material. The camera sends imaging data to a decoding device which then transfers the data to a host controller. Camera-based systems also provide multiside inspection and optical character recognition (OCR) in addition to basic bar code scanning.

Camera Basics

Camera scanners differ from laser scanners in a number of ways. Laser scanners move a laser beam over a barcode, and all white areas are reflected while black area are absorbed. This returns an analog representation of the bar code that is then digitized and sent to a decoder for processing. Most laser products have a scan rate of 500 to 1000 scans per second.

Camera systems can be classified as either linear CCD arrays or CCD/CMOS area arrays. Linear arrays work similarly to laser scanners except they use gray scale imaging at scan rates as high as 18,000 sps. Also, linear imaging systems need to be mounted so that the bar code to be read has to be in constant movement through the imaging area. The image is built through consecutive scans of the linear CCD sensor of the moving bar code.

Area arrays take an image similar to that of a digital camera. They capture entire frames or images of a bar code at rates of up to 60 frames per second.

Regardless of the type of array used, camera systems recognize bar codes by translating the bar code symbol into a gray scale image. Gray scale image data ranges from 0 to 255, with 0 being black and 255 being absolute white. This data is sent to a processor which first processes the data to determine a region of interest (ROI), an area where possible bar code data might be located. This part of the process represents the highest overhead in the processor. Once an ROI has been determined, that portion of the image data is then processed to determine if bar code data is present. Any bar data present is decoded by proprietary software.

Camera systems have improved greatly in recent years. The first camera system contained a 4k linear sensor mounted in a large, bulky enclosure. It required costly high-power integrated sodium lighting for illumination. The focusing mechanism was crude and slow, so these systems did not represent a significant improvement over laser sensors.

Second generation systems included up to 6k sensors with separate imaging and decoding. Just like today’s camera systems, image data was sent to the decoder via a gray scale...
interface. However, these systems still required large, bulky enclosures and sodium lighting for illumination.

Today’s camera systems include up to an 8k sensor with less costly LED illumination. The illumination source can be mounted in the same plane as the camera, providing a compact installation. Image data is sent to the decoder via a “camera link” interface using a LVDS (Low Voltage Differential Signal) RS-644. Fiber optic interfaces are also available.

**Cameras vs. Lasers**

Camera-based systems are cost-effective in the fastest and most challenging inspection applications such as postal sorting. These systems consist of high-speed cameras, powerful image processing, high-power lighting and optical systems that can focus and read in as little as 30 milliseconds. Applications are fast; therefore, system demands are high.

The main advantage of camera bar code scanners is speed – both barcode resolving and object transport. They typically can read bar codes on packages traveling at 600 fpm and spaced as little as 2 inches apart. Camera systems can accommodate box dimensions from 1 to 36 inches on a side and can read bar codes on any or all six sides of the package. Typical read rates are 99.7%.

<table>
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<tr>
<th></th>
<th>Laser Scanners</th>
<th>Camera Scanners</th>
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<tbody>
<tr>
<td><strong>1D Readability</strong></td>
<td>Good read rate</td>
<td>Excellent read rate</td>
</tr>
<tr>
<td><strong>2D Readability</strong></td>
<td>PDF-417 (linear only)</td>
<td>All</td>
</tr>
<tr>
<td><strong>Dimensioning</strong></td>
<td>No, separate product needed</td>
<td>Yes</td>
</tr>
<tr>
<td><strong>Side by Side Detect</strong></td>
<td>No, separate product needed</td>
<td>Yes</td>
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<tr>
<td><strong>OCR</strong></td>
<td>No</td>
<td>Yes</td>
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<tr>
<td><strong>Video Coding</strong></td>
<td>No</td>
<td>Yes</td>
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<tr>
<td><strong>Throughput Improvement</strong></td>
<td>Minimal</td>
<td>Yes</td>
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In many high-speed applications, the challenge is to find bar codes in any orientation on multisided packages. Here, scanner read points are set up so that all sides of a six-sided parcel can be read. A camera is placed on each side of the cube. The transport medium then moves the parcel through the tunnel created by the scanner points. The application requires large fields of view and high transport speeds. Therefore, these systems are typically linear array cameras rather than area arrays. In these applications, cameras provide higher read rates than laser scanners. Cameras also can read bar codes regardless of whether the packages are right-side up, upside down or rotated.

Another advantage of camera readers is the ability to decode low aspect ratio codes, allowing for the use of smaller labels. This translates into savings in label paper.

Also, as noted above, cameras are better able to read two-dimensional (See sidebar: Types of Two-Dimensional Bar Codes) and damaged codes because of their more sophisticated image capture diagnostics. This results in fewer no reads and less operator intervention to complete the sortation process.
The main disadvantage of cameras is cost. Camera systems can cost two to three times more than laser systems. In addition, camera systems require lighting and focusing, which can add to the cost.

As sorting systems add functionality, image-processing requirements increase, as do sensor speed and lighting requirements. At higher speeds, the sensor has less time to acquire an image. This typically means that more light has to be used for the camera to produce quality images. Many sorting applications have used high-pressure sodium lamps because of their high output, but LEDs are finding increased use because newer versions have sufficient power for high-speed, high-resolution sorting applications. Combined with Fresnel lenses, LED lights produce a strip of light instead of lighting an area. By placing the LED stripe coplanar to the linear CCD array, the light is directed exactly where it needs to be.

**Camera System Design Considerations**

Factors to consider when designing a camera bar code scanning system include:

- Bar code/label size
- Transport speed
- Transport width
- Package size
- Package spacing

**Bar code/label size** – The overall size of the barcode is usually not important in camera systems but the width of the bar code’s narrow element is. A certain DPI (dots/pixels per inch) needs to be maintained to decode a bar code. A certain number of pixels are needed per narrow element to properly resolve the bar code so it can be decoded. The cameras mounting distance is adjusted to produce the correct DPI. Camera mounting distance affects other application parameters including transport width. To gain DPI, the camera must be mounted closer to the transport, but this will limit coverage.

**Transport Speed** – Transport speed affects the selection of the sensor for the application. A 6k sensor has a higher scan frequency, or clock rate, than an 8k sensor, but the smaller sensor also limits transport coverage.

**Transport Width** – To meet the transport width requirement, a combination of lens and sensors size needs to be made. Different lenses are used for different sensors.
Package Size and Spacing – Package spacing depends on several factors:

- Whether the application is front read or back read
- Transport speed

In a front or back read application, package spacing should be as large as the tallest box to avoid shadowing. Therefore, if the largest box is 20 inches, package spacing should be 20 inches. There is a fixed time associated with focusing the camera to read the barcode so package spacing cannot be less than the minimum focus time.

Beyond Barcodes – The Future of Camera Systems

Until recently, camera-based sorting systems were used only in high-end, high-speed sorting applications where increased read rates justified the extra cost quickly. Now, mid-range applications are moving to machine vision because of the need to read 2D codes or because of other features that are beyond the capabilities of laser scanning systems. New CMOS technology offers the potential for lower cost cameras with faster read times.

Today, camera systems are moving into a number of applications where their unique characteristics offer advantages, including:

- Optical Character Recognition (OCR)
- Optical Character Verification (OCV)
- Dimensioning
- Video Coding
- Machine Vision

Optical Character Recognition (OCR) is finding increased use in applications where a barcode is not available. For instance, OCR software can be used to actually “read” the address block of a package or envelope label. Presently this technology is being used primarily in postal applications.
Dimensioning – Camera systems provide the ability to determine package dimensions, which can be used to determine the optimum loading of a truck or to charge customers for oversize
packages. In operation, a light curtain first determines box height. Then, length and width are determined by the pixel size of the box.

**Video Coding** is used in applications where the barcode cannot be read and the image can be sent to an operator who manually enters the correct data. Video coding can be used in any application but it is used most often in parcel and postal applications. In operation, the region of interest is selected, and the camera zooms in on this area. The operator then enters the pertinent data (ZIP code for example) via a keypad. The data is sent to a processor for use in sortation or other operations.

**Machine Vision** systems are used for parts inspection. Here, they can be used to determine:

- Part Rotation
- Part Size
- Part Identification
- Print Quality
- Part Overlap
- Direct Parts Marking Verification
- Pattern Matching
- Color Matching
- Contaminates
Sidebar:

**Types of Two-Dimensional Bar Codes**
The 2D Data Matrix code was developed in the late 1980s by RVSi Acuity and Ci Matrix. Data Matrix codes were designed for marking small parts and are used today for small electrical parts, by the pharmaceutical industry for unit dose packaging, by the automotive industry and by NASA. The Data Matrix 2D bar code can store about 2000 characters and provides a fixed level of error correction capability. However the Data Matrix code needs imaging system to decode and is limited in high-speed applications.

![2D Data Matrix Code](image)

In 1991 Symbol Technologies introduced the PDF-417. A single PDF417 symbol carries up to 1.1 kilobytes of machine-readable data. Also, the code can be accurately scanned and read even if up to 50% of the symbol is destroyed. Special rastering laser scanners were used to read this bar code until CCD (Charge Coupled Device) and other imaging systems were developed. One limitation of this barcode is that it cannot be used in high-speed applications.

![PDF-417](image)

In the early 1990s, high-speed bar code imaging was developed to fill a need in the parcel industry. One high-speed code, MaxiCode, was developed in 1992. It can carry 93 alphanumeric characters of data, is 15% denser than square dot codes, and can be read even if 25% of the code is damaged. MaxiCode can be read by either CCD or laser scanners and has built-in error correction.
Several other 2D Bar Codes are also used in industry as shown below. Each has certain advantages in specific applications. All require camera based systems to be read them.

MaxiCode

Four-State Postal

QR Code

RSS

Postnet/Planet
Introduction to RFID

Radio Frequency Identification (RFID) is an evolving automated ID technology that is quickly being adopted by suppliers of all sizes. It is a method of identifying unique items using radio waves. RFID technology can be used in many applications, including security and access control, transportation and supply chain tracking. It works well for collecting multiple pieces of data on items for tracking and counting purposes.

RFID promises benefits, such as increased security and theft protection, reduced labor costs, better supply chain visibility and improved product availability. RFID adds value and accuracy to applications such as:

- Compliance labeling in retail distribution centers
- High-speed sortation in postal and parcel distribution
- Manufacturing process control/verification, material tracking
- Airline baggage identification and routing systems
- Single-pass multiple item identification

RFID differs from bar code tagging in a number of ways. In a bar code system, a laser reader interprets the bar code to “read” the information it carries. For bar codes to be read properly, a clear line of sight between the label and the scanner is required. This often means that a package must be labeled on several sides to ensure that the code is read. In addition, bar codes provide only static information that cannot be changed or updated. At the UPC level, bar code scanning systems cannot identify packages uniquely.

RFID provides offers several advantages that complement optical data capture devices. RFID is not impacted by poor printing, harsh environments, or visual barriers – no line of sight is required. RFID tags provide the added benefit of read and write capability. The interaction between tagged items and their environments creates an uninterrupted flow of information.
### RFID vs. Barcodes

<table>
<thead>
<tr>
<th>Factor</th>
<th>RFID</th>
<th>Barcode</th>
</tr>
</thead>
<tbody>
<tr>
<td>Line Of Sight</td>
<td>Not usually required</td>
<td>Required</td>
</tr>
<tr>
<td>Human Intervention</td>
<td>Not required</td>
<td>Sometimes required</td>
</tr>
<tr>
<td>Tag Placement</td>
<td>Can be placed inside the packaging or on the product (depending on material)</td>
<td>Must be placed on the outside of the packaging</td>
</tr>
<tr>
<td>Read Rate</td>
<td>99.9% (depending on application)</td>
<td>99.5% (depending on application)</td>
</tr>
<tr>
<td>Labels/Tags per read</td>
<td>Up to 1000 tags/second</td>
<td>Up to 10 labels/second</td>
</tr>
<tr>
<td>Readability</td>
<td>Good for non-line of sight, painted, dirty, weathered environment</td>
<td>Can be impaired due to presence of dirt and moisture</td>
</tr>
<tr>
<td>Read Range</td>
<td>Up to 7 m</td>
<td>Up to 2 m</td>
</tr>
<tr>
<td>Cost/Tag</td>
<td>$0.10 to $10</td>
<td>0 to 5 cents</td>
</tr>
</tbody>
</table>

An RFID system consists of a fixed or portable reader, RFID tags and application edgeware. The reader sends RF data to and receives data from the tag via antennas and can have multiple antennas. The tag consists of a microchip that stores the data, an antenna and a carrier to which the chip and antenna are mounted. A clear line of sight is not required for the reader to detect the tag. Also, RFID tags are dynamic in that the information they contain can be changed or updated. They can also carry information that allows for the unique identification of each instance of a product passing the reader, as well as the product type.

### RFID Scanning

RFID tags consist of three parts, as shown below.
RFID Tag Construction

- The **ASIC Chip** contains the memory that stores information about the object to which the tag is attached. It also holds the circuitry to detect the reader signal and respond to it.
- The **Antenna**, consisting of traces made of copper, aluminum or conductive ink, transmits information to a reader (handheld, warehouse portal, store shelf) using radio waves.
- The packaging (or label) encases the chip and antenna so the tag can be physically attached to the object. It consists of an **Overlay** that protects the antenna and chip layers and a **Substrate** that supports the tag elements. The overlay can be made from paper, PVC or other laminate material. The substrate can be paper, epoxy, PVC or other laminate material.

Many different types of RFID tags are available to support a variety of applications. Tags can vary in terms of communication frequency, the protocol (or language) they speak, how they are powered and how they store data.

**Tag Frequency** – Different versions of RFID operate at different radio frequencies. The choice of frequency depends on the application. Three primary frequency bands have been allocated for RFID use.

- **Low Frequency (LF):** 125-134 kHz signals; most commonly used for access control and asset tracking.
- **High Frequency (HF):** 13.56 MHz signal; used where medium data rate and read ranges are required.
- **Ultra High Frequency (UHF):** 850 to 950 MHz and 2.4 to 2.5 GHz signals; provides the longest read ranges and high reading speeds.

A variety of RFID solutions may be required to meet the needs of the marketplace. Most supply chain applications for item, carton and pallet labeling will be met with either UHF or HF tags. The table below outlines the basic properties of these frequencies.
Characteristics of RFID Tags

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>HF (13.56 MHz)</th>
<th>UHF (860 - 960 MHz)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maturity</td>
<td>In use since 1995</td>
<td>Recent widespread use (2004-2005)</td>
</tr>
<tr>
<td>Read Range</td>
<td>Less than 5 feet</td>
<td>Up to 20 feet</td>
</tr>
<tr>
<td>Field Consistency</td>
<td>Well-defined read zone</td>
<td>Peaks and valleys in read field</td>
</tr>
<tr>
<td>Liquid Performance</td>
<td>Better able to penetrate liquids</td>
<td>Absorbed by liquids</td>
</tr>
<tr>
<td>Performance on or near Metal</td>
<td>Lower read range on metal</td>
<td>Unpredictable performance near metal</td>
</tr>
<tr>
<td>Tag Form Factor</td>
<td>Many options for small tags in variety of form factors including washable 'buttons'</td>
<td>Fewer options available, new options being developed</td>
</tr>
<tr>
<td>Global Standards</td>
<td>Generally available throughout the world</td>
<td>Interferes with existing bands in many countries</td>
</tr>
</tbody>
</table>

UHF can cover dock door portals up to 9-feet wide; therefore, it has gained widespread support as the bandwidth of choice for inventory tracking applications including pallets and cases. For item level applications, read range requirements are not as long. Also, it is more difficult to place tags in positions to avoid liquids and metals for some item level tagging applications such as pharmaceuticals. Therefore, the industry is still debating whether item level tagging will be served best with UHF, HF or a combination of both.

Tag Protocol – Each RFID tag is designed to a specific protocol, which defines how the tag communicates with the outside world. If a reader is set to receive one protocol and the tag transmits in a different protocol, the reader and tag will not be able to communicate. Built into the protocol are features such as security (data encryption, lock abilities, etc.) and anticollision algorithms.

Technology providers are developing readers that work with multiple system protocols and frequencies so that users will be able to choose the RFID products that work best for their market and products.

Since their introduction, RFID tags have undergone several design changes as shown in the diagram below.

Evolution of RFID UHF Tags

Read/write characteristics of the different tags are:
• Class 0 (Matrics/Symbol) – Write once, read many (WORM).
• Class 0+ (Matrics/Symbol) – Write and read many times.
• Class 1 (Alien) – Write and read many times.
• Gen2 (Impinj, Phillips, Texas Instruments) – First standard across multiple vendors where the same protocol can be read by all RFID readers on the market.

Classes 0 and 1 were proprietary products and could be read only by a specific company’s readers, or they required “bilingual” readers, which slowed the identification and tag reading process. Gen2 tags, on the other hand, were designed by member companies of EPCglobal to create a standard tag communication language that can be read by all readers on the market. Gen2 tags provide a number of advantages including faster interrogation, more accurate reading of multiple items on a pallet (including nested items), dense reader mode capability – allowing for multiple readers and tags to work in close proximity – and improved security.

Active vs. Passive Tags – RFID tags are categorized as active or passive. Active tags are battery powered. They broadcast a signal to the reader and can transmit over the greatest distances (100+ feet). They can cost $4.00 to $20.00 or more and are used to track high value merchandise like vehicles and large containers of goods.

Passive tags draw their power from the reader. The reader transmits a low power radio signal that energizes the tag’s integrated circuit (chip). The tag briefly converses with the reader for verification and to exchange data. Passive tags can transmit information over shorter distances (typically 10 feet or less) than active tags. They also have a smaller memory capacity and are considerably less expensive (50¢ or less) making them ideal for tracking lower cost items.

Data Storage – Two types of chips are available on RFID tags, Read-Only and Read-Write.
• Read-Only chips are programmed with unique information during the manufacturing process. The information on Read-Only chips can never be changed.
• Read-Write chips can be rewritten, or information can be added when the tag is within range of the reader. Read-Write chips are more expensive.

Another data storage method is called WORM (Write-Once Read-Many). It can be written once and becomes Read-Only afterward. Chips can also vary widely in their data storage capacity.

Open Loop vs. Closed Loop Systems
RFID systems can be either closed loop or open loop. In a closed loop application, the user has control of the items to be tracked throughout the application. There is no need to share data outside the user organization, and users outside the organization do not need to be able to read the RFID tags. Here, the protocol chosen does not necessarily need to comply with an open standard.

For many RFID applications, the tagged items must be readable by many companies such as manufacturers, logistics hubs and retailers. In this case, open loop standards for tag protocol are essential.
Standards Organizations
EPCglobal is one of the governing bodies for the development of global standards for the RFID industry. It is refining and updating its standards to improve cooperation among RFID tag and reader suppliers. EPCglobal, Inc. is also working to develop a global standard for transmission and storage of data via the Internet. Full implementation of this data sharing capability will be critical for RFID technology to reach its full potential.

EPCglobal, Inc has also defined a global protocol operating in the UHF range for carton and pallet labeling. This protocol, called EPC Class 1 Generation 2 (or Gen2), will replace several older Class 1 protocols that did not provide global interoperability. Tags and readers to support the Class 1 Gen 2 protocol are readily available. EPCglobal, Inc. continues efforts to determine the optimal protocol and frequency for item level applications.

While EPCglobal focuses mainly on open-loop supply chain tracking applications, ISO has defined many RFID protocols at various frequencies and for numerous applications. In addition, ISO is working on a new standard, ISO 18000-6C, that will be compliant with the Gen2 protocol.

Electronic Product Code (EPC)
EPCglobal has developed a new Electronic Product Code (EPC) as the next standard for tracking products through the supply chain. The goal is not to replace existing bar code standards but to expand the information available down to unique identifiers for each marked item, and to enable more automatic reading. The EPC uses the basic structures of the Global Trade Item Number (GTIN) and Serialized Shipping Container Code (SSCC), as well as others.

The EPC is a 96-bit number consisting of a header and three sets of data. There are several versions of the EPC, depending upon application. A typical EPC code is shown below.

<table>
<thead>
<tr>
<th>ELECTRONIC PRODUCT CODE TYPE 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>01 • 0000A89 • 00016F • 000169DC0</td>
</tr>
<tr>
<td>Reader</td>
</tr>
<tr>
<td>8-bits</td>
</tr>
</tbody>
</table>

The header identifies the EPC version number, which indicates the type of EPC data to follow (for example SSCC or GTIN). The second part of the number identifies the EPC manager, typically the item manufacturer. The third part is the object class and refers to the exact type of product – usually the stock-keeping unit (SKU). The fourth series of numbers is a serial number unique to the item.

The 96-bit EPC allows sufficient capacity for 268 million companies. Each manufacturer will have the ability to create up to 16 million object classes with 68 billion serial numbers in each class. This should provide sufficient capacity to cover all products manufactured in the world for many years to come.

RFID Implementation – Follow a Process
In planning an RFID compliance strategy, it is important to follow a logical, step-by-step process. A key point to remember is: Intelligent compliance today ensures scalability tomorrow. A well thought out compliance strategy:

- Eases the burden and costs of the RFID initiative
• Minimizes disruption to the existing infrastructure
• Ensures compliance with RFID mandates
• Allows scalability to be built-in up-front

**Step 1: Perform a Needs Assessment** – One of the most important things to keep in mind when assessing needs is to consider the impact of RFID implementation on the entire organization. Include representatives from all parts of the organization on the RFID implementation team, from Shipping and Receiving to Production, Planning and the IT department. Each department can provide a unique perspective on process flow of current materials, existing data capture and usage patterns, and the challenges inherent in new process implementation. The involvement of a cross-functional team will ensure the development of a comprehensive RFID implementation plan.

Another important factor is to create a plan that meets both today’s needs and future requirements. In this way, a scalable system will be developed that can be modified easily as requirements change.

Finally, establish a partnership with an RFID component supplier with a proven track record of design, performance and support. This will ensure the development of a state-of-the-art system that leverages the experience the supplier has gained from working with companies with similar needs.

**Step 2: Map the Process** – In other words, “Be the Box.” This step involves following the material flow through the warehouse or distribution center and documenting each step in the process. This analysis provides valuable information on the best locations to apply labels. It also indicates points in the process where data can be gathered for input to the business intelligence system. This data will provide information on production throughput and on the efficiency of the manufacturing process.

Finally, enlist a qualified company to perform RF site survey. This study will identify anything in the facility that can interfere with the RF system. RF measurement equipment can quickly pinpoint sources of interference that may affect RFID readers. Common sources of interference include:

• 900-MHz cordless phones.
• Older wireless LANs.
• Metal supports, equipment and cabinets.

In most cases, interference from these sources can be controlled. However, in severe cases, RF abatement procedures may be required.

**Step 3: Design the System** – Provide all the data gathered in the previous steps to experts in RFID implementation and material handling. Allow them to develop a preliminary system design. Again, be sure to build-in scalability.

**Step 4: Pilot the Process** – Integrate and test the system at the RFID supplier’s facility, and conduct a pilot review and approval process before shipment and installation. This will greatly improve the chances that the system will work properly under real world conditions. Test the system exhaustively before integrating it into the existing infrastructure.
**Step 5: Deploy the System** – Take the time to optimize system operation, and do not commission the system until it is completely ready. Time spent to fine tune the system before commissioning is time well spent. This is also a good time to assess the need for RF power tuning or abatement.

Fully train the operating team to ensure that they understand how to run and maintain the system. Finally, continue to analyze results and use this data to guide process improvement initiatives.

**Step 6: Service and Support** – The RFID supplier should be accountable for system service and support. They should have a technical field force that can respond to evolving needs.

**Scalability Is Key**

The need for a scalable system has been mentioned several times. Building in scalability allows a system to meet initial needs and to be expanded to meet future needs by reusing or redeploying existing equipment.

**RFID Scalability Rollout**

For example, a company might begin with a manual “slap ‘n ship” system that allows it to comply with RFID mandates. Then, as production increases, they can move to semi-automated and fully automated systems by adding hardware and redeploying existing hardware. Typically, the crossover point from manual to automated installations is about 2000 tags per day.

As the system becomes more automated, companies can move from simple compliance, to more sophisticated data gathering, to more intelligent workflows. In other words, they advance from simple tagging through automation and full integration.

The foundation of a scalable RFID rollout strategy is a something commonly called edgeware. Edgeware can be understood as distributed intelligence that allows devices “at the edge” of the system (such as RFID tag readers) to communicate with other devices in the system without
having to go through a central processor. With the proper edgeware, decisions can be made at the device level, providing faster throughput and data transfer.

The right edgeware package provides the basis for a controlled rollout strategy based on a company’s changing needs. This approach serves today’s needs and allows a system to grow to meet tomorrow’s needs. It is more cost-effective than buying either an “oversized” software package or buying the minimum today and buying again as needs change. Either of these approaches can result in wasted capital.

### Scalable Edgeware/Middleware

RFID provides more data at the edge today than ever before, and the amount of information available will grow with increased volumes, read points and tagging locations. Managing this vast amount of information requires a simple way to collect, filter and transfer/transport data. In addition, the system should be configured to provide a seamless interface to current and future business systems, as well as an upgrade path to support multisite applications.

The right edgeware provides a foundation for scalability from a simple RFID printer to an automated installation. It also has the modularity needed to support additional devices as they become available. In addition, localized edgeware provides a level of redundancy that will allow intelligent operation through event-based workflows.

### RF Expertise – Getting the System Right

Experience counts in designing a quality RFID system. To ensure that the system is designed properly, it is essential to work with a company with experience and understanding of RF to fine-tune the system. Steps to follow in ensure proper operation include:

- Performing a SKU analysis to determine if the products being processed are compatible with radio frequencies.
- Verification of the RF working environment.
- Automation analysis to provide guidance on moving from manual to automated materials handling.
- Integration analysis to ensure that the RFID system integrates into the existing facility seamlessly and with the least amount of disruption.
SKU Analysis: While RFID tagging provides a number of advantages, it does have some physical limitations. For example, products with high liquid or metal content require special considerations. Liquids absorb some frequencies of radio waves, while some metals can cause unpredictable performance. Such products may require specially designed tags or precise tag placement to ensure readability. The location may differ from product to product, and can impact readability drastically.

Verification: The radio frequencies present in the workplace can have a significant effect on the reliability of an RFID system. To ensure success, the system supplier must assess whether large amounts of metal or stray radio waves are present in the environment and how they may affect operation.

In addition, the RFID system could have an impact on other equipment in the area. Again, an assessment needs to be made on how RF energy generated by the tagging and identification system affects nearby equipment.

A critical point in the verification process is ensuring that objects are properly tagged and that the tags are readable. This includes determining the best way to read tags. Reading options include:

- Over-conveyor readers that capture each product, package or carton on the line.
- Singulation, which distinguishes among individual products, packages or cartons.
- Portals, which read multiple RFID tags at once.

In addition, multiple read points may be needed to track the movement of product throughout the facility. The verification of tagged products by RFID systems provides full traceability from manufacturer to retailer. This provides assurance that a product has been shipped and delivered.

Automation: There is a strong similarity between barcode labeling and RFID tagging in automated material handling applications. Both processes apply to objects moving on a conveyor, and both processes may be able to support a multiproduct mix.

The key to success lies not only in applying tags properly, but also in understanding and controlling the flow of products through the process. Proper tagging requires verification that the correct tag has been applied to each object.

Integration: Once the optimum solution has been chosen and a process is in place, it is easy to assume that the job is complete. In reality, only half the work is done. Now it is time to implement the solution.

The challenge is to integrate the RFID system into the facility seamlessly with the least amount of disruption. To minimize problems and downtime, it is important to work with a company that has experience in both material handling hardware and IT integration.

Scalability Options
In considering system design options to ensure efficient operation today and scalability for tomorrow, the following questions should be considered:
- How are labels applied today? Typically, manual systems are sufficient for volumes under 2000 labels/day. However, automated labeling may be appropriate for lower volumes if labels must be located more accurately to ensure readability.

- What is the present volume and what will it be in the future? Answering this question provides guidance on when it might be appropriate to implement different solutions or combinations of solutions.

- What is the SKU mix? The main consideration here is whether the production line is dedicated to running a single product or if it handles multiple products. If only a single product is being run, then a batch processing approach can be taken in which only pallet loads of product are labeled instead of individual packages or cartons. If multiple products are handled, then each product or carton should be labeled to allow the system to differentiate among products.

**Intelligent Slap ‘n Ship:** Most RFID start-up systems will involve manual application of tags. Important factors to consider when designing a manual system are:

- Electronic Product Code number management to ensure that the right data is programmed into the tag.
- Putting the right tag in the right location. The RFID system should indicate to the operator where to place the tag on specific products.
- Commissioning of product and pallet tags. The RFID system should be able to handle multiple form factors.
- Production reporting capabilities to indicate not only how much product is shipped but also system status.
- Integration into an existing IT system.

As volumes grow, automation may offer more cost effective scalability. Key data inputs to consider when automating include:

- Application Speed – Auto-applicators are 6-10 times faster than manual application.
- Cost of Labor – Typically, labor costs are higher for manual application.
- Cost of Rejects – Typically, reject rate increases as the number of tags applied increases.
- Cost for handwork
Automated Tagging: Automated tagging equipment provides a number of capabilities, including the ability to perform on-demand or batch processing optimized to individual lines. Such equipment also has the capacity to operate multiple applicators to increase throughput. In addition, if necessary, it can place tags on multiple panels of a carton to ensure readability in all environments.

Automated equipment allows users to place tags in the optimal location to ensure readability by the receiver. Automated systems typically include reporting capabilities to monitor performance and simple interfaces to ensure proper operation. Other benefits include:

- Flexibility in designing label/tag formats.
- Support for different types of print engines.
- Singulation and verification of barcodes and tags on all objects.
- Improved security by providing tighter management of tagging equipment.

**Full System Visibility:** The most advanced RFID tagging systems provide a complete solution that makes it easy to comply with commercial and government RFID initiatives. It consists of a turnkey automated solution for placing, tracking and verifying RFID tags on cartons and pallets. The system integrates seamlessly into existing material handling and data handling systems to provide a low-risk upgrade path from conventional bar code labeling systems. It can incorporate:
- Bar code scanning
- Bar code/human readable labeling
- RFID tagging
- RFID tag reading/writing
- Controls
- Data management including communications with WMS or ERP systems

Fully automated systems allow users to easily add automation and data management tools, as they are needed. The base system consists of an inbound bar code scanner, RF tag applicator, bar code printer/applicator, tag verifier and outbound bar code verifier. Also included are controls for in-feed, tracking, verify/reject outputs and additional configurable I/O and features.

The software runs on a PC platform that can be housed in an industrial enclosure or placed remotely in an office. The software controls all devices, system I/O, diagnostics, communications and reporting functions through an intuitive user interface.

Key features of a fully automated system include on-the-fly tag validation and invalid tag skipping. These processes read and validate tag data before it is applied to a carton. The system also provides 100% item tracking and tracing, ensuring that the right tag is placed on the right box.
Fully automated systems provide automatic placement of RFID tags and bar code labels to reduce the total cost of ownership versus manual systems. They also allow flexible tag placement to optimize read rate. Verification and automatic rejection of defective tags before application to the carton ensures that no defective tags enter the supply chain.

In addition, the system can support automatic/mixed-mode or batch mode operation with full EPC code management. This means that the system operates in the mode best suited for operations and applies tags to only those cartons requiring them.