BAR CODE DESIGN

WHERE TO START: Start by listing the constraints within the project. These would be the components that cannot be changed. These may include the scanning distance required, the number of characters to be encoded, the type of characters to be encoded (alpha and/or numeric), the size and orientation of the area to which the label or tag will be affixed, and (if printed on site) the width of the print head.

Once the constraints have been identified, the rest of the process can be designed. Depending upon the constraints identified, you can start by defining the label size or the bar code size. Remember, in both instances, to include the quiet zone requirements of the bar code chosen. If you start with the bar code size required, you can then design the label/tag size around it. Conversely, if you start with the label/tag size, you must design the bar code within it.

Once these steps are completed, you can move on to adding fields to the label/tag format and determining data sources for the identified fields.

DESIGNING FOR MAXIMUM SCANNING SUCCESS: The following four (4) elements and their compatibility contribute to the successful, high (99.99%) first read rate and high (99.5%) read rate, use of bar codes in any data collection application.

The most critical relationship in these elements is the density of the bar code, which determines the scanning depth-of-field. The density of the bar code is determined by the size of the "X" dimension (the width of the narrow bar or element) and the ratio of wide to narrow elements within the symbol. The compatibility of the "X" dimension of the bar code to the light source of the scanner determines the system requirements for scanning distance.

Each scanning device has a depth-of-field for each increment in the size of the "X" dimension. For a standard range distance scanner a 20 mil "X" dimension can be scanned from about 2 inches to 18 inches. A 50 mil "X" dimension can be scanned from about 3 inches to 36 inches. This would be with standard white material with or without a laminate. The long range distance scanner has a greater depth of field which can be extended even more when using retro reflective material extending the scanning distance to over 28' using a 100 mil "X" dimension. Each scanning device manufacturer has its own specifications for each of their distance options. Testing is always recommended because of the other elements than contribute to successful bar code scanning.

It is imperative that the system development and implementation teams match the actual scanning requirements with the proper bar code configuration and scanning devices. Many times the system requirements for scanning a bar code are discussed after the scanning equipment has been chosen and the bar code configuration has been determined because of constraints on the size of the label.

The coordination of these four elements determines the success or failure of all scanning systems. The data collection software and hardware can be the best but if the bar codes either cannot be read or are difficult to read, the system will not achieve its anticipated benefits and savings.

A description of each of these four elements and how they relate to each other is given below. It is like five fingers fitting perfectly in the five fingers of a glove. Each is important by itself but they work together as a hand to complete tasks.

1. Bar code:
   - The type of bar code symbology to use is dependant on whether you are scanning numeric or alphanumeric information (see symbology selection below).
   - Narrow Element / "X" dimension and ratio where applicable to determine density and the area required for the bar code including quiet zones at both ends. The quiet zone, the clear area to the left and right of the bar code is a function of the "X" dimension (see "x" dimension, ratio, resolution, and quiet zone sections below).
   - Height (redundancy) of bars for quicker scanning.
2. Scanner (Hardware):
   - Wand / Slot (Contact)
   - CCD (minimal non contact, .5" up to 3")
   - Laser
     - Single Line
     - Single Line Moving
     - Raster
     - Holographic
     - Standard, Long Range & Extended Long Range optics for scanning up to 18 feet with standard material and 28' with retro-reflective material using a 100 mil "X" dimension.
3. Material/label:
   - Paper: Lowest cost but should be laminated for durability (see Materials in Reference Center).
   - Plastic: More durable and many times doesn't need lamination
     (see Materials in Reference Center)
   - Retro Reflective: Includes imbedded glass beads to enhance distance scanning (see Materials in Reference Center).
   - Lamination: Matte laminate can perform better with wand readers
     (see Materials in Reference Center).
4. Environment:

- Indoors: Light Source is important, as you don't want too much or too little light. Certain lights, mercury vapor & helium neon, can affect scanning performance.
- Outdoors: Sunlight can affect scanning so special optics have been developed for this purpose.

WHICH SYMBOLOGY TO SELECT: A symbology is a bar code language. Examples include UPC, Code 128, and Code 39. Each symbology has its own set of rules describing how the data is incorporated into the bars and spaces. Each bar code language has different capabilities and characteristics. Most scanners are typically programmed to decode one or more symbologies. Each symbology differs in the amount of data that can be encoded. Some are fixed length, while others can encode variable data. The ultimate goal of any business bar code application is to get information into a software package used to help automate workflow. Whatever the application, start by setting goals for the software that will provide you with the desired reports and information.

The goal is to maintain the highest degree of data integrity usually in the smallest area possible. The denser the code, the smaller the space required. However, denser codes can result in lower read rates. Check digits can offset some read failures. Several questions need to be answered before a symbology can be selected:

1. What character set needs to be encoded?
   - Numeric only.
   - Alpha/numeric.
   - Special characters.

2. How much data needs to be encoded?
   - Different symbologies have different densities. Depending on the amount of data and the space available on the document, some codes are more appropriate.
   - The space available on the document defines how many characters can be encoded or what symbology, density and ratios may be used.
   - If the scanning resolution is high, more characters can be encoded.
   - What is the tolerance for misread bar codes?

3. Do you want to have a check digit/check character?
   - Some bar code symbologies have this feature built in and don't need an extra check digit.

4. What is the position in the document?
   - Some bar code symbologies are more tolerant on quiet zone requirements. If the bar code is on the edge, some misreads can happen because the bar code can be cut.
   - Content of human readable label information.
   - Label or document graphic requirements.

5. Determine if there is a standard for the industry. Many industries have standardized symbologies for use within the industry. In some situations there may be no choice regarding the symbology or label design. Inter-industry groups such as the Uniform Code Council (UCC) and the Automotive Industry Action Group (AIAG) have chosen their members' symbology and have published standards. A good place to stat may be trade associations, or other organizations to which you belong. A little research in the beginning could eliminate a lot of headaches later on.

SYMBOLOGY RECOMMENDATIONS: Consider the simplest symbology that solves the problem. These symbologies offer more accuracy and provide faster reading. Choose the symbology with the highest inherent message density, if possible. If you will be encoding only numeric data, try I 2/5 or code 128C. If you are encoding alphanumeric data, consider 128B. If you are encoding large amounts of data, try using one of the two dimensional symbologies such as PDF 417. The disadvantage of two-dimensional symbologies is the limited number o readers available to decode the code. In addition, the cost of a reader capable of decoding two-dimensional bar codes is more expensive and allows fewer input options then standard readers.

With the development of scanners that can auto discriminate among several linear symbologies, many companies are using two or more linear symbologies on the same label. Substantial cost savings can be realized when two requirements are satisfied with one label. Another valid reason for using different symbologies on the same label is to assure that the correct bar code will be scanned. Auto discriminating scanners can be programmed to read only a specific code, thereby reducing errors from scanning the wrong code.

Label design should allow for modifications over time as departmental needs change or as industry standards evolve. For the ease and simplicity of scanning, use the shortest possible encoded fields even if a directory file is required.

"X" DIMENSION: The smallest element in a bar code is called the "x" dimension. This is the narrowest bar or space in the code. The choice of this dimension is based not only on the space available on the document to print the code, but also on the type of scanner and environment in which the label will be scanned. The minimum "x" dimension for Code 39, Codabar, Code 93, Code 128, I 2/5, Code 49, and Code 16K is .0075 inches. Usually, the larger the "x" dimension, the more forgiving the bar code is when scanned. For the most effective and reliable scanning, use the lowest possible density.

The most reliable and effective scanning takes place with a wide-to-narrow element ratio as close to 3 to 1 as possible. A larger "x" dimension requires a larger label area. Most applications use "x" dimensions in the range of 10 mils to 25 mils. It is preferred practice to have all bars and spaces in whole multiples of the "x" dimension. For the most effective and reliable scanning, use the 3.0:1 element ratio whenever possible.

RESOLUTION: Resolution of a scanner refers to the smallest element it can see. If the resolution of a scanner is not high enough, it will not be able to see small elements in high-density bar codes. On the other hand, a high-resolution scanner will see "defects" in low-density symbols that would be ignored by a properly matched scanner. One of the problems end users have is the failure to match the resolution of the scanner to the density of the media. The size of the spot of light emitted by a scanning device should be slightly less (80-100%) than the narrowest element. If the spot of light is significantly larger than the narrowest element, a distraction occurs when scanning is attempted. Therefore, scanning becomes more difficult. If the spot of light is significantly smaller than the narrowest element, scanning is not only difficult but errors can readily occur. For the most reliable scanning, be certain that the resolution of scanning devices be matched properly to the narrowest element of any one symbol.

DENSITY: Density is usually measured in one of two methods. Density is measured in either characters per inch or by the narrow bar size. The character per inch density is determined by the combination of the “x” dimension and the element ratio. The wider the “x” dimension (bars) and/or the larger the ratio, the fewer characters per inch (lower density). Narrower bars provide greater density, however they are more vulnerable to print voids, stains, and dirt, which can affect bar width interpretation.

ELEMENT RATIO: To enable a scanner to distinguish between the wide and narrow elements, a minimum ratio is needed depending upon which resolution has been used for printing the bar code. The width of the wide element should be at least twice the narrow element. A range of 2.2:1 to 3.0:1 is recommended. Some symbologies have fixed element ratio options. Code 39 allows the user to determine the element ratio. The width of bars and spaces can and do vary unintentionally as a result of the printing process. As long as this variance is within accepted tolerance ranges, the deviations are not detrimental. However, the smaller the element ratio, the lower the tolerance range. The most reliable scanning takes place with a wide-to-narrow element ratio as close to 3:1 as possible. It is preferred practice to have all bars and spaces in whole multiples of the "x" dimension.

QUIET ZONE: Code designers specify a zone be just to the right and left of a bar code that shall be free from all printing. This “quiet zone” gives the scanner time to adjust its opto-electronic measurement circuits to properly determine the critical width of each bar in the code message and determine the contrast between the bar and the space between each bar. Quiet zones at the beginning and end of a code signal the scanner where to begin and end. The quiet zone should be 10X the “x” dimension of the symbol, or one-quarter inch, whichever is greater. A clearance of 1/16” above and below the code is recommended.

CONTRAST: Bar code scanning takes place by focusing light on a pattern of bars and spaces. The bars should absorb most of the light, and the spaces should reflect most of the light back to the scanning device. The two primary ways of measuring the correct absorption and reflection factors is by print contrast signal (PCS) or minimum reflectance difference (MRD). The result of these calculations must be substantial enough that scanners are able to properly distinguish between bars and spaces. The higher the difference between light and dark spaces, the better the read.

Bar codes produced with carbon-based inks normally ensure a higher PCS or MRD than alcohol-based or dye-based inks, thus providing better scanning characteristics. All scanners can accommodate carbon-based inks. However, infrared scanners are unable to read media produced with alcohol-based or dye-based inks. Using carbon-based ink to create bar code symbols may prove to be a significant asset when the media is used in hostile operating environments. Infrared scanners can often read these symbols even when they are contaminated by marks from ballpoint pens, dirt, or other foreign matter.

Ideally, use black carbon based ink or toner for bars and an opaque white matte finish print surface. Other combinations of code and background color can also be used as long as there is a 50-60% contrast between the light reflectance of the printed code and the background.

MEDIA: Media also contributes to contrast. Opacity must be sufficient to prevent background surfaces from interfering with the scanners ability to read the media. If a dark background shows through a label, the scanner may interpret some spaces as bars. This can readily happen when a white adhesive label is placed on a dark surface. The higher the initial reflectivity of the face sheet, the higher the difference between light and dark spaces and the better the read.
Your substrate choice should have high opacity.

MEDIA COLOR: Color of substrate can impact contrast. The contrast point of reference for scanning is based on the 633 nanometers of the red-light helium neon laser scanners. Therefore, you must avoid using paper or background label stock that contains any significant blue component that reduces contrast. White substrate should be the first choice. Ideally this would be of OCR quality. However, in some applications where there are multiple bar code labels, there could be operator confusion. Color-coding labels can reduce such confusion. When using label stock other than white, avoid colors with blue content. Pink or yellow background colors are the safest choices. An alternative is to have preprinted colored boxes around a bar code to color identify the specific code. Alternately, a colored stripe can be preprinted on the side of a label.

HORIZONTAL VERSUS VERTICAL ORIENTATION: Labels can contain bar codes in two distinctive orientations, called picket fence or ladder codes. Applications that exclusively employ light pens should choose the horizontal orientation to support the more natural motion of the hand sweep.

BAR CODE HEIGHT: Hand scanning is not naturally done in straight lines; it is done in arching motions. The MINIMUM bar height should be .24 inches or 15% of the bar code length, whichever is greater for Code 39 and 128. For optimum scanning, it is recommended that the code be .375" tall. UPC and EAN codes should be at least 1.02" tall.

HUMAN READABILITY OF A BAR CODE: Ensure that the coded information is printed above or below the bar code in an alphanumeric human readable font. This allows for key entry, if the bar code is not readable.

BAR CODE PRINT QUALITY STANDARDS: In 1990, the American National Standards Institute (ANSI) published ANSIx3.182-1990 Bar Code Print Quality Guidelines. These guidelines define measurement procedures and standardized methods of evaluating bar code print quality. A bar code is measured on an A-F range. A perfect symbol is not always achievable. This can be the result of a variety of reasons. Pointil verifies all work and provides samples pulled periodically during the production process.

CODE VERIFICATION: Whether preprinted or printed on demand, sampling of printed codes to assure readability is critical. If preprinted, ask your supplier to provide you with a sampling of bar code verification (samples with print outs showing bar code readability and quality). If printed on demand, confirm your customer has the capability to verify codes printed. Additionally, two important measurements of bar code system performance are "first read rate" and "substitution error rate."

First pass read rate (FPRR) is the ratio of the number of successful reads to the total number of attempted reads on the first attempt. A low first read indicates that the bar code must be scanned multiple times before a successful read is accomplished. A good bar code system should offer a first read rate greater than 85% and a second pass read rate of 95%. This means that a particular bar code can be read on the first scanning attempt 85% of the time. A first read rate, though, is not a measure of the correctness of the "read." The primary cause of low first read rates is poorly printed bar codes, such as those with insufficient contrast between the bars and spaces, inadequate quiet zones and excessive spots and voids. Operator technique/training directly affect scanning success.

Substitution error rate records the number of characters incorrectly decoded out of the total number of characters scanned. This problem is much more critical because, in most cases, the operator is unaware that an error has been entered into the system. However, many symbologies are self-checking, meaning that codes are designed so that defects render the code unreadable, rather than readable but incorrect.

LABELING STANDARDS: Many specific industries have established label standards unique to their industry. The automotive industry (AIAG), the health industry (HIBCC), the plumbing industry (IBCA), and the electronics industry (EIA) are a few of the industries establishing such standards. Furthermore, individual companies such as WalMart have developed "company specific" labeling standards.

Such standards tell the "labeler" how to create and apply a label that will meet the "recipients" information and application standards. These standards may include the following:

1. What information is required (i.e. p.o. number, quantity, etc.)?
2. What data content code standard to use.
3. What item to bar code and in what symbology.
4. How to arrange the data.
5. What bar code print quality standards to use?
6. Where to place the label (s)

DATA CONTENT CODES: Data content codes make it possible to scan a label containing more than one bar code symbol in any order. Data content codes identify what type of data is encoded in a bar code symbol. For example, a carton label may include a part number, a product number, quantity, and description. The bar code containing the part number would start with "P" if the part number was assigned by the customer and "IP" if the part number was assigned by the supplier. The symbol encoding the production number would start with the letter "T", and the quantity would start with the letter "Q." The data system will then be able to sort the data to the appropriate places in the database.

PREPRINTED VERSUS ON-SITE: There are situations in which preprinting bar code documents/labels is more appropriate and situations in which on-site printing of bar codes is more appropriate. Part of that evaluation certainly includes cost per unit, cost of printing and verification equipment, and on-site expertise to print bar codes. Additional considerations include:

PREPRINTED	**ON-SITE**
Specialty materials required	High quality labels required
Existing QA programs	Moderate quality labels required
Very high-density symbols required	Short lead-time
Over laminates	Variable data
Service Bureau Capabilities	Frequent design changes
Compliance Assistance	Short runs
High quality labels required	

PRINT TECHNOLOGIES: There are a number of printing methods available to print bar codes. Conventional offset or flexography printing is utilized in the printing of UPC retail bar codes. Mechanical numbering machines can be utilized for discrete bar code symbologies (Code 39), but not continuous or 2D codes. Photocomposition can be used to print extremely small bar codes. This process utilizes photo typesetting to create the bar code, number, and text. This process has a resolution of 2000 DPI providing the highest level of quality and also the highest cost. This production process utilizes photographic paper and can include a coating or laminate over the printed image to provide scuff protection. The former is recommended as the latter tends to delaminate.

However, for more complicated bar code applications such as consecutive numbering, random numbering, or data storage, computerized non-impact printing technologies must be utilized

Laser. Pre die cut labels are processed through laser printers with 300-600 DPI resolution. It is difficult (and expensive) to provide laser labels with protective coatings or laminates. Therefore, a clear protective label or tape must be placed over the label to insure it will withstand normal handling and use. Laser printing can be low to high speed, batch or on-demand production. If the document needs any static printing, it must be preprocessed on a conventional printing press.

Ion Deposition. Labels are both manufactured and printed in the same process. Ion Deposition typically utilizes 240-300 DPI resolution. Labels can be provided with protective coating or over laminates. This is the preferred method for medium to high quantity production.

Thermal Transfer. This printing technology utilizes 300 DPI resolution. This is the preferred method for on-demand printing requirements, given its relative lost cost and reliable process. It is the slowest of non-impact technologies. Though they have similar DPI resolution, thermal transfer technology provides higher quality bar codes than laser or ion deposition because thermal transfer technology incorporates square dots while laser and ion deposition utilize round dots. Depending upon the particular type of manufacturing equipment, labels can be both manufactured and printed in the same process. Labels can be provided with protective over laminates.