

IMPLEMENTING BAR CODING - JUST JUMPING ON A BAND WAGON ?

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Bar coding is becoming an increasingly popular method of data capture for many different types of manufacturing companies. This is hardly surprising given the large number of possible application areas. For example, where computerised systems for stock control are already in place, bar coding can be used to register the arrival of raw materials/components and the dispatch of finished goods. In addition, where computerised planning and scheduling systems, such as MRPII, are installed, bar coding can help track the movement of parts through the shop floor. It is intuitively obvious that if it is properly implemented, this will lead to better data in the computer system which will in turn lead to more accurate planning and control. This will then lead to better company performance. However, some companies are rightly questioning the extent of such improvements in performance and asking whether the inevitable costs of implementation weigh these benefits.

It is from this starting point that Baxi, a gas appliance manufacturing company based near to Preston, decided to investigate the possibility of implementing bar coding for data capture for several of their key operations. These operations were the recording of stock movements and the receipt of product against works orders. The primary objectives were to improve stock record accuracy and increase the frequency of system updates at an acceptable cost. The company management were keen to explore all of the alternative methods of data collection rather than just estimating the costs and benefits of bar coding. The latter is an obvious choice only because other companies are implementing it. However, various other new technologies are available and it was thought to be necessary to investigate all of the options instead of simply jumping onto one of the latest band wagons.

Hence, a consultancy style MSc project was carried out at Lancaster University to study the 'state-of-the-art' data collection technologies and then to determine which methods were most appropriate to Baxi's manufacturing environment, if any. This paper describes the alternative data collection technologies studied and explains how conclusions were reached in Baxi's case.

ALTERNATIVE DATA COLLECTION TECHNOLOGIES

Ten alternative data collection technologies were considered. The first of these, simplified data screens is a semi-automatic method. The remainder are fully automated technologies. Each of these technologies is described below along with its advantages, disadvantages and examples of areas of application. In some cases, the only documented applications were outside the manufacturing environment. However, such methods were still considered as possibilities for transfer into the manufacturing field.

1. SIMPLIFIED DATA ENTRY SCREENS

Description: The keyboard is programmed to allow data entry via single designated keys rather than entering a product code by a series of characters.

Advantages:

- Reduces the number of key entries, therefore reduces the potential for human error when recording data.

Disadvantages:

- There is still a risk of human error.

Applications:

- Pub tills where each type of drink has a separate key which triggers its price.
- Alongside bar coding and other fully automated methods, providing a manual override facility.

2. BAR CODING (BC)

Description: a bar code is rectangular in shape and consists of light and dark vertical bars, designed for optical reading and automatic de-coding. The codes can represent either numeric, alpha-numeric or the full set of ASCII characters. 'Code 128' and 'Interleaved 2 of 5' are examples of this standard bar coding method.

Advantages:

- The bar codes can be easily and economically printed
- The scanners can operate from a distance.
- Bar coding is a flexible system in that the scanners can be portable or fixed.
- Bar coding is faster than manual methods of data collection and is far more accurate.
- Only basic employee training and education is required.
- Can be interfaced with almost any software.
- A tried and tested technology.
- Standards in bar coding formats and symbology are widely acceptable.
- Bar codes have an average error rate of 1 character per 1 million, in contrast to keyboard operators with a rate of 1 every 300 characters.

Disadvantages:

- Bar codes may be partially or wholly unreadable due to corruption caused by harsh working environments or bad printing quality.
- Employee discipline is required in positioning the codes for fixed scanners.

Applications:

- One of the most common uses of bar coding is within the supermarkets for stock control and check-out procedures.
- Bar coding is used on conveyer belts along assembly lines.
- The automotive industry have used bar coding for stock control.

3. RADIO FREQUENCY IDENTIFICATION (RFID)

Description: the 3 main components of an RFID system are:

- i) an electronic ID tag
- ii) an antenna / communication unit
- iii) a control and processing unit.

The tag is located on the object and the antenna is attached to the control unit. When the object passes an antenna, the tag is stimulated by a signal sent by the antenna. The tag operates at a unique frequency and transmits information back to the control unit, where it is de-coded by the processing unit and transferred to the host computer. This system identifies the tagged object. In more sophisticated systems, a 'write' option is available and the data stored on the tag can be altered creating a 'portable database'.

Advantages:

- RFID has read and write capability.
- A high data capacity is possible on the tags (up to 64,000 characters).
- RFID can identify objects that are out of the line of sight of the reader.
- RFID can identify objects in hostile environments, for example within a paint plant.

Disadvantages:

- Expensive to make electronic tags.

Applications:

- RFID is used by trucking companies to track trucks passing through toll booths. The company is billed rather than each truck paying separately.
- RFID is used to track the movement of farm animals.
- RFID has been used for tracking barrels in the brewing industry.

4. OPTICAL CHARACTER RECOGNITION (OCR)

Description: OCR is a symbol based system of numbers or letters. These characters are scanned by a light source and the data is converted to electronic impulses for transmission to the computer.

Advantages:

- The symbols are easily produced.
- The symbols have a meaning and can be easily understood by the operator due to the nature of the characters.

Disadvantages:

- A near contact reader is required thus scanning from a distance is not possible.
- OCR has limited accuracy and convenience in comparison to bar coding.
- High quality printing is necessary, to prevent reading errors.

Applications:

- This method of data collection has been implemented in the retail environment, but with a high failure rate of first time readings of 30%.

5. MAGNETIC INK CHARACTER RECOGNITION (MICR)

Description: Data is stored in a printed code consisting of a circular pattern of magnetic ink. MICR has a OCR font but when read by a computer only the magnetics are picked up.

Advantages:

- The ink can be printed onto cloth.

Disadvantages:

- The amount of information that can be encoded is limited.
- *Printing code that consists of circular patterns of magnetic ink has proved to be difficult.*

Applications:

- The labels found attached to clothes and soft toys
- The numbering system found at the bottom of cheques.

6. MAGNETIC STRIPE

Description: This technology was first introduced by the financial services, in the form of credit cards to provide identification of accounts and as a security measure. It's use has expanded to automatic cash machines, debit cards and data collection uses in a manufacturing environment.

High and low electro-magnetic charges en-code data onto a material. A de-coder is then used to read these charges, which in turn translates them into numbers and letters for a computer to identify.

Advantages:

- Flexible data format.
- High level of durability.
- Relatively high level of security.
- Higher data capacity compared to bar codes.
- It is claimed that data can be easily changed.

Disadvantages:

- Difficulty in reading magnetic stripes when dirty
- Magnetic fields can destroy or damage information encoded on the stripe.

Applications:

- They have been used to identify employees by the use of employee ID badges.
- Time attendance systems have used this technology to keep records of employee working hours.
- For security reasons magnetic stripe cards have been used to allow access into buildings or into information.
- Currently the airline industry are carrying out research into the automated ticketing boarding pass containing a magnetic stripe.

7. VOICE RECOGNITION (VR)

Description: Instead of scanning visual patterns, these systems recognise pre-programmed vocabulary and therefore use voice pattern recognition. A microphone is used to collect the word or phrase which is recognised by the system and then transmitted as electronic impulses to the computer to process. This type of data capture allows the employee to transmit data instantly without the use of hands, therefore providing a live inventory system.

Advantages:

- This system is user friendly as it requires no technical knowledge.

Disadvantages:

- Employee discipline is required to ensure that spoken words are found in the vocabulary of the computer.
- Background noise will hinder speech detection.
- The system may have difficulty recognising words due to accents. This will cause higher failure rates compared to other systems. Speech rates may cause similar problems.

Applications:

- These systems are currently used in laboratories, during product inspection, baggage handling and order processing. In all these examples the operator's hands or eyes are preoccupied.
- VR can be integrated with other methods, for example when bar codes do not hold information on quantity or other required information must be entered separately.

8. MACHINE VISION (MV)

Description: This type of technology is able to identify a code, object, or document and to interpret what it sees or reads by means of a scanner.

Using electronic clipboards the MV technology is able to scan and recognise handwriting. An employee either writes information to a screen by using a special pen or stylus, or by entering information by touching menu selections in the same way with a pen or stylus. A full size screen of the entered form is displayed, which allows the employee to verify the written information and change or correct entries where necessary. The written data is then transmitted to a host computer via a standard communications port.

MV is becoming more versatile due to the advancements made in the areas of artificial intelligence and pattern recognition.

Advantages:

- The major advantage of MV is the capability of reconstructing damaged or partially destroyed code, this is done by enhancing the image allowing the code to be read.
- Another advantage over bar code is the ability of MV to scan low contrast codes, for example dark codes encoded on dark backgrounds.

Disadvantages:

- Presently the hardware for this technology is expensive. However, as equipment becomes cheaper, MV is expected to replace some bar coding applications.

Applications:

- As MV equipment is able to scan objects, a use of this characteristic is implemented during manufacturing inspections. In these situations MV is used to check the dimensions, component position, and the presence of an item on a conveyor belt or assembly line.

9. SMART CARDS

Description: These programmable cards are made of plastic, with one or two micro chips embedded into them. The cards are the size of a credit card, carrying a database which is capable of holding large amounts of data, equivalent to that of a PC. They are able to have their own battery run keyboards, with a liquid crystal display. They can distinguish between multiple uses of the card, hence the reason for 'smart' in the name smart card. As a security measure the card carries no visible signature which can be forged or copied. Instead, when a transaction is made, the owner is instructed to sign with a pointed stylus leaving no visible mark. An electrical pattern of the fresh signature is compared to that of the original stored in memory. The comparison is performed on the shape and speed at which the signature is written.

Advantages:

- Has the ability to hold a large amount of different information, and the ability to distinguish between the data.
- Security of no visible signature.
- Smart labels can be used in the dark.

Disadvantages:

- No information of applications of smart cards used in a manufacturing environment was found.

Applications:

- At present this type of data storage has been implemented in some American colleges for student ID cards, as a key into halls of residence and to debit accounts when expenditure on meals, books, vending machines and ticket outlets occur on campus.

10. RADIO FREQUENCY DATA COMMUNICATION (RFDC)

Description: This is a method of data transfer rather than data collection, however, when combined with one of the above technologies, such as bar coding or voice data collection, it can be regarded as an automatic data capture system. This is an alternative to the standard network of PCs. It gives access to the main computer from the shop floor eliminating the need for data transfer by paper or batch. It therefore can create a live system.

RFDC consists of wireless multi-purpose computer terminals that are connected to the host computer by an on-line, real time radio link. The terminals can be hand-held, mounted on forklift trucks or whatever suits the particular environment.

Spread spectrum radio communication is used to spread the signal over a range of frequencies to minimise problems of interference.

Advantages:

- Up to date data is transferred without the need for paper.
- It does not require extensive connecting cables to link computer terminals.

Disadvantages:

- No protection to frequency therefore interference is possible.

Applications:

- Retail chain stores for stock control.
- In conjunction with bar coding, British Airways baggage handlers use RFDC as a link to their central computer.

COMPARING THE ALTERNATIVES

At Baxi, with product ranges changing rapidly and many transactions needed in shop floor data capture, it is essential that the chosen system has the flexibility to cope with a large quantity of regularly changing works order numbers. Semi-automatic systems do not cope easily with this requirement and hence they were quickly ruled out. For example, a designated keyboard would need to be changed every time a new works order number is invented. In addition, the number of keys at a terminal would restrict the number of works order numbers that could exist in total. As Baxi have a unique number for each production operation for each top level customer order, it was thought that there would be insufficient keys to set this system up in the first place.

Three of the automatic data capture methods - smart cards; magnetic stripes and MICR - were also ruled out quickly on the grounds of being unsuitable for shop floor data capture. They are all aimed at a specific sector of the data collection market which is not relevant to Baxi's requirements.

In addition, RFDC on its own is not a data collection technology, it needs to be integrated with one of the other technologies.

The remaining five methods are compared in Table 1.

CHARACTERISTIC	DATA COLLECTION METHOD				
	BC	RFID	MV	OCR	VR
Relative cost of system	low	medium	high	medium	high
Accuracy of data capture	high	high	medium	medium	medium/low
Level of employee training	medium	low	medium	medium	low
Commercial usage	v. high	medium	low	low	medium/low
Additional software required	medium	high	high	medium	high
Level of technology	low	high	high	medium	medium
Performance within hostile environment	medium	high	high	low	low
Write capability	no	yes	yes	no	yes

It can be seen that both MV and OCR have not been on the market for very long and hence have not been fully tried and tested in a working environment. They both offer more facilities than are required by Baxi as is reflected in their relatively high costs which may not be justifiable. It was therefore concluded that these would not be the best methods.

VR is also a new technology but has the advantage of low employee training. However, its performance is poor in noisy working environments. This is a critical issue in most manufacturing environments including Baxi. For this reason, along with its high cost and high level of additional software required, VR was not considered to be appropriate.

This left bar coding and RFID which were then compared in more detail. Firstly, in terms of implementation, bar coding is a more risk free option. It has been used in many manufacturing environments whereas RFID is a relatively new technology. As a result of wide implementation, regulatory standards have been developed which make it possible for suppliers to code raw materials for manufacturers and manufacturers to code finished goods for their customers. This leads to better customer and supplier relations and a more trouble free flow of material through the supply chain. In fact, one of Baxi's main customers had already requested that their products should be bar coded.

Secondly, in terms of flexibility, bar coding tags can be made in-house at low cost whereas RFID tags are usually purchased and are more expensive. Given Baxi's requirement to produce new works order numbers regularly, it is essential that new tags can be generated quickly and easily.

Thirdly, RFID offered more facilities than Baxi required in terms of the long durability of the tags; their write capability and their capacity to hold a large quantity of data. These facilities are more appropriate for long term tagging of objects and consequently the price of this option is higher than for bar codes.

In conclusion, the ability to use a high volume of different tags over a short time horizon made bar coding the recommended option for Baxi. Integration with RFDC was thought to be an expensive and unnecessary extra in this case.

Reaching this conclusion did not completely answer the questions of the company management. It only indicated that if automatic data collection is to be implemented, then bar coding is the preferable method. However, it was still necessary to estimate costs and benefits to determine whether or not this method could be justified.

COSTS AND BENEFITS ASSOCIATED WITH BAR CODING

Many of the costs and benefits of bar coding can not be quantified easily. Hence, a full formal cost benefit analysis was not attempted. Instead, all of the factors affecting each side of the equation were listed with approximate costs/savings estimated where possible. The factors affecting costs are listed in Table 2; Table 3 lists the factors affecting benefits. In both tables the method of analysis is briefly described along with appropriate comments. The estimates of costs and benefits are not included here for reasons of confidentiality.

It should be noted that only the first three factors listed in Table 3 are direct benefits of implementing bar coding. The remaining benefits will only be achieved if good use is made of the better data available. This will depend on employee discipline and on the use of other computerised planning and control systems. For example, factor 4 also depends on the type of stock control system and the availability of good demand forecasts as well as on accurate stock records. However, in Baxi's case the environment is such that these benefits are thought to be attainable.

TABLE 2

FACTORS AFFECTING THE COST OF BAR CODING

FACTOR	COMMENTS / METHOD OF ANALYSIS
1. Purchase of new software and hardware	Example quote from a supplier.
2. Consultancy and training	Example quote from a supplier.
3. Printers	Either a thermal bar code printer OR a laser printer with a standard converter to distinguish between bar codes and normal text is needed.
4. Cabling	Depends on size of shop floor and number of terminals installed.
5. Maintenance	Not estimated.
6. Housekeeping	Required to ensure that the memory is not exceeded by the historic data recorded in the system. Can be done by in-house employees.
Lost production due to training	Expected training time is one hour per employee.

TABLE 3

FACTORS AFFECTING THE BENEFITS OF BAR CODING

FACTOR	COMMENTS / METHOD OF ANALYSIS
1. Reduced error potential	Determined by estimating the number of transactions at Baxi and using standard figures of 1 error in every 300 characters for keyboard transactions; 1 in 30 for manual and 1 in a million for bar coding.
2. Reduced time delay to record shop floor activities in the computer system	Can be reduced to almost zero; depends on company set up of system.
3. Reduced time spent at keyboard	Can be reduced to almost zero although some time is still required for the swipe of the bar code. Saving estimated by summing the total number of transactions and assuming 4 minutes required to receive a works order and 1 minute to do an add or move transaction.
4. Reduced stock outs and hence fewer lost sales	Exact value of current lost sales is unknown. Estimated by multiplying current stockouts by profit of product.
5. Reduced part shortages at assembly, hence reduced production stoppages	Exact cost of current production stoppages is unknown. Estimated by multiplying weekly down time at assembly by average employee wage.
6. Reduced inventory holding costs due to better stock control	Current stock holding costs estimated. Actual reduction in these costs is unknown.
7. Reduced production lead times giving increased flexibility and quicker customer response times	Not quantified. Improved stock accuracy allows automation of manufacturing systems, reducing total manufacturing lead times.

By inspecting these lists, it quickly became clear that the benefits will outweigh the costs if bar coding is implemented at Baxi. By just comparing the costs of items 1 and 2 in Table 1 with the lower limit of one of the savings listed in Table 2, the cost of bar coding could be justified. In fact, by summing some of the estimated savings, it was predicted that the benefits will outweigh the costs by a factor of 10.

CONCLUSIONS

It was therefore concluded that choosing to implement bar coding would not simply be choosing to jump onto the latest band wagon. On the contrary, it is an easily justifiable method of improving many aspects of company performance. In some ways, this was a reluctant conclusion! Many of those involved in the project would have liked to have proven that the obvious answer was not the best. However, this was not to be.

It is hoped that the simple methods of comparing the alternative technologies and of analysing the costs and benefits of bar coding will be of use to other companies involved in making similar decisions.

About the Authors

Linda Hendry is a member of BPICS and a lecturer in the Management School at Lancaster University. She is involved in teaching manufacturing planning and control methods. Her research interests and project work have led to collaboration with several manufacturing organisations. This recently included a three year research project with Pilkington Optronic which was funded by the ACME Directorate of the SERC (now the EPSRC).

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