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Managing Technological Change: Barcode Technology in Health Systems

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This presentation examines the use of barcode technology for machine reading of data and updates a report on the use of barcode technology in the Central Supply Department at the Geelong Hospital by one of the authors at Nursing Informatics '91. It provides an introduction to machine-readable technologies, barcoding in particular, and describes basic barcode technologies and symbologies.

The introduction of new technology is often problematic, regardless of whether the technology is regarded as major, as with the introduction of a computerised management information system, or relatively minor, as with the introduction of barcode technology to assist with inventory control. We update the implementation of just such a barcode system.

Introduction

The introduction of new technology is often problematic, regardless of whether the technology is regarded as major, as with the introduction of a computerised management information system, or relatively minor, as with the introduction of barcode technology to assist with inventory control. This paper briefly describes barcode technology and the introduction of just such a barcode system.

There are several important lessons to be learned from this type of project, thus the project description concludes with guidelines for the successful implementation of any major technological change. This is followed by a recent update, discussing some of the practical problems encountered as the project and barcode usage matured.

The Conference presentation will focus on the use of barcode technology. This will be an introduction to machine-readable technologies, barcoding in particular and describes basic barcode technologies and barcode symbologies.

Background

Geelong is situated about an hour's drive from Melbourne, the capital city of Victoria, and has a population of approximately 130,000. The Geelong Hospital, servicing Geelong and the sizeable surrounding area, operates at about 380 beds.

Materials are ordered by the Central Supply Department (CSD) from the general store of the hospital on a weekly basis and supplied, in bulk, in 'outer' cardboard containers. CSD distributes the contents of whole cartons by breaking up the outer, and supplying in smaller quantities of 'individual packs' and 'items'. The distribution system consists of exchange trolleys. In essence this means that each patient care area, or other cost centre, has two trolleys. One trolley is in the ward and is slowly being emptied throughout the day. The other is situated in CSD and is being restocked to pre-negotiated levels. Once a day the trolleys are exchanged.

The wards and departments have individually negotiated stock levels. While each cost centre normally receives the same level of supplies every day, the levels and varieties of stock for each cost centre are different from all the other centres.

The Problem

Until about 1985 the hospital considered the Central Supply Department to be the only cost centre as far as supplies were concerned. The hospital, and the accountants, considered stock to have been used once it was supplied to CSD from the hospital store. This resulted in several anomalies that had a major effect upon budgeting and costing within CSD and the hospital.

- Because stock was considered to have been used once it was *delivered* to CSD, there was never a stock-take of CSD, and CSD stock was not regarded as part of the stock-in-hand of the hospital.
- The cost of stock supplied to CSD was considered to be a CSD expenditure, and basic stock costs were never handed on to users.

As is obvious, CSD did not actually consume the materials, it simply operated a storage and delivery service for the actual consumers—the patient care areas and other cost centres—who were receiving their materials 'free'.

A Possible Solution

The CSD charge nurse, computer illiterate along with her entire staff, indicated that she had observed people in supermarkets, with handheld black boxes, apparently counting something. Although she had no idea what they were actually doing, it was obvious that they were using an electronic tool of some kind. A pilot project, and full implementation, eventually resulted.

Two barcode readers were borrowed for the trial and were literally left lying around in Central Supply for staff to 'play' with while special barcode sheets were being prepared.

The readers produced some curiosity and everyone tried them out—mainly reading the codes on the back of their lunch time cheese and butter containers. The reader rejected these codes—on the grounds that their symbols had too many characters—but at least the symbols were read. The tiny red light on the wand was seen, the reader made some noises, and users got the idea that the system would not be very difficult to operate.

Implementation

The barcodes arrived as adhesive-backed laminated forms. There was no attempt to put a code on every item of stock. Instead it was decided that the code should go onto the storage rack for the stock. The storage rack was labelled with the stock code in large letters, the name of the item in large letters and, close by on the shelf, the barcode symbol, which also had the stock code displayed in numeric form.

Cost Centre codes were placed on the trolleys belonging to each Cost Centre. This meant that they were easily accessible when staff went to stock a trolley.

- Turning the reader on produced prompt for the date and the invoice number. Once that was entered, a prompt appeared for a Cost Centre number. This was read with the wand from the trolley to be stocked. This produced a prompt for a stock code number, readily read from the storage rack for the stock required.
- Next, quantities were requested and keyed in. As soon as the quantity was entered, a prompt appeared for the next stock code number and so on.
- At the end of the day the data collected was downloaded via modem to the hospital's central computer.

Barriers to Progress

After a few weeks of trial it was announced that in one week, recording would commence for the purposes of accounting. It was at that time that the barriers, which can be divided into three major categories, became evident.

The first barriers were generated by people. This included the general computer illiteracy of the staff, the threatening effects of any change, a push for added pay for the 'increased work', and a perception that the stocking process took longer with the new system (true, because items were now actually being counted).

The next category was technical. The software controlling the readers failed to verify the information collected, for example, and the initial readers were unreliable in operation (perhaps because of sabotage).

The third category was logistical. The finance computer dealt with different units (bulk) than those used for supplying materials (individual items and smaller packs). A formal negotiation about units of supply resulted and it was eventually decided that the only logical common unit is the single item. These negotiations and decisions led to major changes in the information in the finance computer and took some weeks to accomplish. It also required a new format for the supply department stock catalogue when it was reprinted.

New Equipment

Eventually new programmable readers arrived to replace the borrowed readers. The major change was that information entered into particular fields could now be verified and limited.

This meant that the reader would only accept a valid Cost Centre code when the user was prompted for the code—one alpha and four numeric characters. Similarly, for a stock catalogue code it would only accept 5 numeric characters and would only accept quantities as a maximum of three numeric digits. The synchronisation problem had thus been eliminated.

The new readers also required user identification, helping to check that everyone was using the readers. It also identified people making mistakes to assist in staff development—the policy of the department is to prevent further errors, not persecute people who make them.

At the same time the number of readers in use increased. More than two people can stock trolleys at any one time. With these changes the system at last seems to be working, allowing attention to be moved from getting the system to work, to how the information it generates should be reported.

Reporting

The original report from the finance department was a pile of paper two inches high and every operation which removed stock from central supply into a cost centre was reported chronologically. Negotiations took place with the finance department about modification of the reporting system to provide two reports—first, a monthly transaction report arranged in order of decreasing dollar value, and second, an exception report flagging any item in which the monthly expenditure had changed by 5% in either direction.

While the computer centre continues to supply the old reports as well as the new, CSD believes that the first 'top of the pops' report, that is the report in dollar value order, provides the most useful information for Cost Centres. Using the 20/80 rule, 80% of the expenditure of the cost centre can be checked by examining only the first fifth of the list. The remaining items are of little interest and need not be considered if time is short.

Subsequent Spread

The system developed in Central Supply was subsequently modified for use in Pharmacy, the Linen Store, and then the General Store. It was also modified for use in Medical Records to tag patient histories. It has now been sold to a major computing supplier and is marketed by them as part of the package that they supply to hospitals.

The staff in Central Supply regard the barcode reader as an essential piece of equipment. After the staff became accustomed to the barcode readers they began to see ways in which they could be used for themselves, many of which are now in operation. These suggestions give great satisfaction to the charge nurse. She is delighted that the staff members are thinking for themselves how they might exploit the new technology, and that they have a sense of ownership of the work.

Achieving Success in Technology Adoption

To be successful in adopting a new technological innovation, management of the people who will use the innovation is as important as managing the technology itself.

- Involve users so that they feel 'ownership' of the project.
- Plan the implementation well, explain the implementation and the role of every individual involved, prepare training materials and other aids to implementation, and schedule the implementation so that everything isn't happening at the same time.
- Provide opportunities, as appropriate, for both professional education and training on the specific system.
- Be aware of individual problems and 'fears', they are often very rationale impediments to change.
- Identify and resolve the real problems—use the implementation process to examine and resolve existing system problems.

Update 1993

This update is based on extensive use of the barcode system within the Central Supply Department for approximately one year and identifies several areas for improvement.

CSD has faced two major 'housekeeping' problems with the use of the barcode readers. These problems have been the cause of a certain level of aggravation among the staff and have sometimes resulted in data loss or a reader being out of service for several days.

- First, the labels being used are not durable enough for the service required and must be constantly replaced. Every time that an item is taken from that shelf, the barcode is read by physically passing the wand across the label. Obviously, the more frequently an item is used, the faster the label wears out, with the result that the labels for the most common items, labels that are scanned several dozen times per day, require frequent replacement.
- Second, the wands on the particular readers used in CSD are fastened to their reader with a connector that uses a sliding lock mechanism. Whenever the wand is removed, such as when attaching the modem to perform the daily data upload, the wand must be unlocked and removed. The modem cable is then attached and the lock refastened. The process is reversed at the conclusion of the data transfer. This connector is easily damaged with consequent data loss.

  It seems to me that the connection was made by people who had no idea of how this would be used or the frequency with which it would have to be detached and reattached.

In the past, CSD relied entirely upon the hospital's Management Information System (MIS)for maintaining and programming the bar code readers. Now, however, the need for additional programming is occurring so frequently, and the readers are in use so continuously, that it may be necessary to train someone in CSD to program the readers.

> *MIS is not too keen [to train CSD staff to do the programming], but they are also not very keen about the time that it takes to make the additions and subtractions in programming that we have asked them to do on fairly frequent occasions over the last few months... So we are negotiating to have at least one person, and possibly two, trained to do quite specific tasks with regard to programming the readers.*

Until recently, the only items charged out through the barcode system have been items 'bought' into the hospital—items purchased by the hospital and charged against the units using them. Recently CSD has been attempting to replace disposable items with non-disposable items which are being produced within CSD itself. This often results in a lower cost per use, and is intended to result in a more environmentally friendly operation.

While CSD has no need, and no desire, to charge these items out—to transfer the costs to other departments—CSD decided to have codes issued so that the items could be charged out through the barcode system. This should then result in a better picture of usage.

> *We got a wail of anguish from MIS recently. Because this stuff is produced within the Department [CSD], it never becomes part of the stock inventory... and if it isn't in the inventory there are no stock levels from which our out-going stock can be subtracted... and the computer won't let stock go into negative numbers. So every time that we tried to charge the stuff out, the computer knocked back the information.*

The problem was solved by putting a nominal quantity, 10,000 units, into stock. This nominal quantity will be replenished when the stocking level gets too low.

> *Of course, 10,000 bears no relationship to reality—to how many are actually in stock. It has been put in purely to allow us to generate information about our stock—where it goes and who uses it.*
>
> *It seems to me that if I was computer literate I would be able to work out a better way of doing this.*

Barcode Technology

Barcodes are self-contained messages which use the width and spacing of printed bars (lines) to encode their messages. The messages are read by light wands (pens), light guns or fixed scanners which convert the light reflected from the bars and spaces into digital codes. Barcodes use parity and/or checksum information to improve accuracy. While barcodes are only one of several forms of machine-readable messages in common use they are fast, reliable and inexpensive in many applications.

Figure 1: The larger-than-life UPC Symbol on the left, used for identifying grocery items, decodes into two separate halves, each with a different parity. The central guard bars, duplicated in the symbols on the right, serve to delineate both halves.

Barcodes are not generally useful for large amounts of data—large data sets being slow to read and inconsistencies in printing and scanning produce problems—but they are very useful for applications such as inventory control where there are large numbers of discrete, and uniquely identifiable, items.

Many barcode applications require scanning directly into a computer for immediate processing—the customer at a grocery store checkout counter, for example, wants to know immediately what the grocery item will cost—but there are applications, particularly for stocktaking and similar activities where the information collection occurs over a wide physical area, where portability of the data collection device (barcode reader) is useful.

Why Barcodes?

Getting machine-readable information into the computer, depending on the application, is often many times faster and more accurate than using manual techniques. In addition, machine-readable information can often be directly input to the computer as it is generated by other systems. Manually entered data, on the other hand must be checked for accuracy, a particular problem when transcribing hand-written data.

It would be ideal if the computer could more reliably read the same data as humans, however computers have the same problems as humans in deciding whether a particular character is an S or a 5, a B or an 8. In addition, optical character readers (OCR), only work reliably when the typed or printed line to be read is straight and precisely oriented with a consistent height and regular (2 dimensional) characters. OCR systems do not yet have the capability of reliably reading handwriting, and do best with stylised OCR character sets such as those used on the bottom of cheques for account and bank codes.

Mark sense (also known as optical mark reader, or OMR) and barcode technologies are one dimensional systems developed to overcome some of these problems. Both technologies offer improved data entry accuracy within their areas of utility.

OMR forms allow semi-skilled human operators to enter information, but require large preprinted data input forms. Each character, in each position, requires a full character set of options (the character is read as a position on an imaginary line extending from the timing mark). OMR forms are relatively expensive as they must be very accurately printed in two colours. The character position template, printed in a non-readable colour, requires accurate alignment with the machine-readable timing marks.

Barcodes encode relatively large amounts of information in a small space. Since the barcode symbol is the same for its full vertical height (vertical redundancy) and the codes used usually have built-in check digits, barcodes are extremely reliable. The barcode symbols can be printed with a wide variety of printers—dot matrix, laser, thermal, inkjet, etc.—although data density and scanning accuracy is improved with better quality printing methods.

Scanning for Pattern Recognition

Pattern recognition is one of computing's basic research areas, and implementations include everything from the search and replace function in your word processor, to fingerprint recognition for security systems, object recognition in robotics, optical character recognition for rapid text input, and speech and handwriting recognition.

Scanning of the basic pattern (characters, objects, etc.) can be accomplished using LEDs, lasers, and other purely electronic devices, or by optical systems (video cameras, etc.).

- Checkout counters in Australia are almost all equipped with some form of LED or laser device for reading product tags. Units in supermarkets will read UPC (Universal Product Code) barcode labels (see Figure 1), units in libraries and clothing shops will often read MRC (machine-readable characters) codes which provide stock inventory and pricing data. Banks use a similar system, with a special character set, for cheque processing.
- Red light cameras at traffic intersections, for example, are simply video cameras which operate as data input devices. The computer program scans the video image for recognisable license plate characters. Optical image systems for robots, a 'real time' application, function in the same manner, providing an image that the computer can scan for a recognisable pattern, usually a part to be manipulated.
- Educational institutions, research groups, and various lottery agencies, etc., use special machine-readable forms for individual tests, survey data, and user data input. These OMR (optical mark reader) forms are usually prepared by marking in blanks on a position-dependant matrix corresponding to the desired data.

Note that photocopiers, FAX machines, and graphics scanners use similar input technologies, but they normally use the resulting image without any pattern recognition. The complete image of a page, for example, is scanned by the FAX machine, compressed and sent over the telephone line for decompression and printing by the receiving FAX machine.

Scanning Systems

Handheld barcode readers are household items in many Australian homes—Panasonic (and perhaps other) brand infra-red remote controllers are equipped with digital scanners to remotely program your VCR. They are *contact* readers, the scanning unit must touch the barcode symbol itself during the left-to-right scan. The scan pattern and speed is thus up to the user—make an incorrect scan and the unit 'beeps' at you, requiring a rescan.

Fixed location scanners are available in a variety of types and scanning systems. The most common units are the under-the-counter 'X' pattern scanners used for grocery checkout counters. Library applications often use a single beam laser scanner mounted on a small stand; the operator places a book and its bar code symbol at a reasonably fixed location underneath.

Intelligent handheld readers are available to both scan and interpret the barcode symbol, storing the information internally for later use. Grocery stores often use such units for stocktaking; clerks scan the UPC symbol and then enter a quantity manually using the keyboard on one side of the unit. Similar units are increasingly being used overseas for entering bedside data from a patient identification bar code and a combination of barcode work sheets (printed barcode sheets with standard data entry codes) and the keyboard.

Scanning barcodes would be quite easy if all we had to do was *count* the number of bars. Unfortunately, we also need to know the *width* of bars, and usually also the spaces. This means that scan timing is important.

Barcode Symbologies

Barcode symbols have developed to meet the needs of various commercial and industrial applications, thus have a variety of formats. Each symbology has a particular character set—some are strictly numeric, some encode numerals plus a few special characters, and others are alphanumeric (both alphabetic characters and numerals). As well some codes represent each character as a discrete symbol. In such a discrete symbology a series of characters would be represented by a sequence of symbols with intervening spaces, much as a list of single digits separated by spaces. Codabar is an example of a discrete symbology.

Other codes represent a series of characters in a continuous sequence, with no spaces between characters, other than the leading or trailing space that forms part of a such a symbol. Continuous symbologies require an explicit end of message pattern to terminate the last character. Continuous symbologies require less space to encode a message since they do not need a inter-character space. UPC is an example of a continuous symbology.

It should be obvious that a discrete symbology (Codabar, Code 39) can encode a message of any length, albeit requiring a considerable amount of space, as each character is read independently. Some symbologies have a fixed length message, often because of the need to incorporate security measures. The UPC/EAN symbology variations permit encoding messages of 6 to 13 digits, however, not all scanners can decode all variations and specific applications would seldom intermix variations. Other symbologies (Code 128 and others, see references) can encode messages of any length.

Most symbologies only encode one character at a time; others increase information density by coding two characters at a time, one in the bars, another in the spaces (Interleaved 2 of 5).

Conclusion

Technologies for machine-reading are changing almost daily. Only four or five years ago OCR users commonly accepted a 5% error rate and the necessity to 'train' OCR systems. Today there are several OCR systems which can automatically adjust for a wide variety of sizes and variable spaced fonts with 1-2% error rates. As technologies improve we can expect even better rates and perhaps different technologies.

Barcode technologies remain appropriate for applications where the messages are generally fairly short and the variations very large. Airline baggage handling, for example, is an area where barcode technologies seem ideal. Already the relatively small number of destinations worldwide permits the use of barcoded tags displaying airport codes for high-speed automatic sorting and destination verification. The number of passengers requiring unique identifiers is, however, almost infinite. A barcoded ID tag, perhaps coded to the passenger's ticket or computer file number, would permit tracking of individual items.

Similarly in the health field, barcoded identity tags for hospital patients and codes for common procedures would provide better quality assurance and could assist with bedside data collection, particularly with modern diagnostic and monitoring systems. Simple chores such as recording temperatures and blood pressure, for example, could then become more reliable.

Barcodes are relatively inexpensive, very reliable, and as simple as they are, seem destined to be with us for a long time.

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Palmer, Roger C (1991). *The Bar Code Book: Reading, Printing and Specification of Bar Code Symbols*. Peterborough, NH: Helmers Publishing, Inc.

Technical information useful for the system designer or technology developer.

Savir, D, Laurer, G. J. (1977). 'The Characteristics and Decodability of the Universal Product Code Symbol'. *Dr Dobb's Journal*, April, 36-43.

Describes the coding and symbology of the UPC and its decodability, particularly as regards scan patterns and symbol size.

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