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School of Electrical and Electronic Engineering

Management & Professional Practice for Engineers

Desk-research Paper on Innovation



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The authors, Zhiyang Ong [REDACTED] and Benjamin Kaye [REDACTED], declare the following to be of our own work, unless otherwise referenced, as defined by The University of Adelaide's policy on plagiarism.

Acknowledgements

The authors would like to thank Associate Professor Piet Beukman for his interesting lectures and for stimulating the minds of the authors. He has encouraged the authors to be entrepreneurs and to innovate as graduate engineers for a competitive advantage over rival firms.

The authors wish to express their gratitude to Mahendrarajah Piraveenan and Vishisht Srinivasan for their contribution in a joint brainstorming session. The authors were able to narrow down on their innovative product/service from the ideas brainstormed. The authors had also received input from Luke Nuttall and Anton Emil Rast about which innovation to select.

Lastly, the authors wish to recognise the contribution of opinions by Leon Khoo, whom took part in The University of Adelaide's Entrepreneurs' Challenge last year.

Executive Summary

This document discusses the bar code innovation as well as how and why bar code technology is employed by firms to gain a competitive advantage. Its scope is limited to the invention of the bar code system in 1949, through its several forms of innovation to its current state in 2004.

As the grocery and retail industry become oligopolies in the mid-twentieth century, the incongruity of stocktaking spurred the bar code innovation. This coincided with the need for a better inventory tracking process to cope with the increased demand of consumer goods due to the baby boom. The employment of bar code systems by grocery stores and retail outlets to automate the recording of product information at checkout counters created wealth for those companies by adding value.

The bar code system adds value to companies by improving labour productivity since employees do not have to manually record product information at checkout counters and during regular stock taking. This allows queues at sale counters to shorten as more customers can be served since product information is recorded efficiently and accurately. Lower wage costs, which increase profitability, result from eliminating the menial task of manually recording information of sale items.

In the 1960s, the financial investment by large and medium sized companies in developing better bar code systems fuelled economic demand for such systems. The availability of lasers and cheaper integrated circuits in the same decade also allowed entrepreneurs to employ bar code systems at a reasonable cost. These entrepreneurs wanted to improve their inventory tracking processes in order to gain a competitive advantage over rivals.

The bar code innovators succeeded by identifying various technologies that can be synthesised into the bar code system. This synthesis required the modification, experimentation and analyses of system components. The innovators also had to evaluate the system's applicability and predict its acceptability.

Although the bar code system does have limitations, it has proven to be a resounding success. To ensure further success, future innovators must employ creative uses of bar codes so as not to lose out to competitive substitutes like RFID tags.

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1. Introduction

Some goods and services, while now commonplace, were once deemed to be ridiculous and impractical [1]. This is the case for the humble bar code. Starting out modestly with a device to read patterns of ink that glow under ultra violet light, Norman Joseph Woodland and Bernard Silver created the first bar code in 1949 with the intention of automating the recording of product information at checkout counters [2].

This predecessor of what we now know as the bar code was called the bull's eye code. As shown in Figure 1.1, it consisted of concentric circles of differing widths so that the code could be scanned in any direction.



Figure 1.1 Example of a Bull's Eye Code



Figure 1.2 Example of a UPC bar code

The code reader was impractical as it was the size of a desk and required an inefficient five hundred watt incandescent bulb. The bulky device also produced crude electronic responses, which were unable to be converted into anything useful in this era prior to cheap electronics and computing [3]. Thus, even if code readers could be cheaply produced and efficiently run, information about the product being scanned could not be recorded.

In the following years, several companies experimented with the idea of bar codes. In 1971 while working for IBM, Woodland was instructed to facilitate George J Laurer in the development of the Universal Product Code (UPC). The UPC used vertical black and white lines instead of the circles of the bull's eye code, as this avoided problems of ink smearing during printing. An example of a UPC bar code is shown in Figure 1.2. The UPC was an overwhelming success and was approved by the United States Supermarket Ad Hoc committee on April 3, 1973 to be used as the standard coding scheme for bar codes. This standardisation, along with the advent of integrated circuitry and lasers, led to the rapid commercialisation of bar codes [3][4].

The success of the bar code can be attributed to the apt marketing, and innovation and technology management of the entrepreneurs and innovators. This also led to the development of various successors such as Radio Frequency Identification (RFID) [5][6]. The scope of this report is limited to the invention of the bar code, through its several innovations to its present state in 2004.

2. The Technology

2.1. Introduction

Technology is defined by *Dictionary.com* [7] as the application of science to achieve commercial and industrial objectives. An alternate definition of technology is the products and systems that are related to science and engineering, which is commonly used in the form of jargon by marketing personnel [7]. An example of this is the Windows operating system, Windows NT (New Technology). An innovative corporation, however, that is constantly dealing with technology may prefer to define it as the expertise and various aptitudes that people use to produce, employ, retain or dispose of useful items [8].

Entrepreneurs around the world are shifting their focus from speculative investment in currencies, property, stocks and shares to productive enterprises that add value to their companies. The reason for this is that speculation does not lead to an increase in wealth in the long run. This change in the world economy is a result of rapid improvements in technology that led to better labour productivity and profitability in recent times [8]. Hence, in order to generate wealth many companies are investing heavily in technology, especially in the disciplines of biomolecular engineering, nanotechnology, megacomputing as well as robotics [9].

2.2. History

In 1932 a business student named Wallace Flint suggested that automatic checkout systems should be adopted using punch cards, conveyor belts and other machinery in supermarkets to shorten queues at point-of-sale counters. This method proved to be economically unfeasible as the card reading equipment was extremely expensive and bulky. In addition to this, it was the

period of the Great Depression so firms were trying to cut costs [4][3]. However this was the first step in a previously unexplored area of technology.

Sixteen years later, Bernard Silver overheard the president of a local food chain requesting a dean of Drexel Institute of Technology, Philadelphia, to undertake research on recording product information automatically at a checkout counter. It was proposed that having such a system would reduce the need to close the stores regularly in order to manage inventory, and increase productivity since employees at the store will be freed from the menial task of recording product information manually. The dean declined the request, but Silver was intrigued by the problem and along with fellow student Norman Woodland, he sought to find a solution [3].

Initially Woodland designed a device to read patterns of ink, which would encode product information under ultraviolet light. However he encountered problems with the stability of the ink and printing the patterns was costly. Convinced that they were close to a feasible solution, the pair began to seek a more economical approach [10].

Serendipitously discovering that Morse code could be applied to the problem, Woodland extended the dots and dashes to form narrow lines of various widths that could encode data. Having partially solved the problem, he sought a method to read the data using technology from Lee de Forest's movie sound system. Woodland placed patterns of linear bars of differing thicknesses on a transparent film and converted reflections of light from the film into electrical signals for processing [2]. Woodland replaced the linear bars with concentric circles to form the bull's eye code.

Woodland and Silver filed a patent application on October 20 1949 for a method of categorizing items on a basis of the photo-response to an arrangement of lines or colours. After waiting for about three years, they had their patent application granted on October 7 1952 [11]. The patent was sold to Philco Corporation in 1962, which later sold it to RCA Corporation.

RCA persisted with the bull's eye code and installed the first automated checkout counter in the late 1960's. Various companies produced their own versions of the bar code that were not only different but also incompatible. This resulted in each firm being able to read only a particular bar code symbol. This would make it more difficult to introduce a common standard later on. A National Association of Food Chains (NAFC) committee was formed to select a standard form of bar code. Meanwhile IBM, concerned with the growing popularity of the RCA product, enlisted the help of Woodland. He, along with IBM employee George Lauer, came up with a code of

rectangular bars and the IBM code (with some minor modifications) was chosen as the industrial standard. April 3 1973 marked the birth of the Universal Product Code (UPC), the bar code as we know it [4].

2.3. Universal Product Code

Unlike the bull's eye code, which often had smeared ink due to the inferior printing presses, the technically elegant UPC was selected by NAFC to be the standard bar code symbol. This meant that bar code labels were required to be printed by manufacturers according to specified tolerances.

Grocery chains would install bar code scanners and data processors that could scan and process bar code information labelled by any manufacturer/wholesaler. UPC bar codes allowed cashiers to checkout items faster and improve labour productivity by reducing the need to track stocks regularly [3].

2.4. Contribution by other areas of technology

The advent of lasers in the late 1960's was a huge factor in the popularity and eventual acceptance of bar codes. Prior to lasers, large and inefficient light bulbs were required for bar code scanners. According to Woodland, the "bulb was an awful thing to look at... It could cause eye damage" [3]. This indicates the benefits inherent in a focused light source such as the laser. The laser also consumes power in milliwatts, as opposed to the several hundred watt light bulbs of the original scanners [3]. Another advantage of the laser is its ability to sweep to and fro thousands of times per second, allowing measurements from a wide range of angles and distances [2].

The electronics industry started to boom in the late 1960s and the price of integrated circuits dropped exponentially owing to Moore's Law, which articulates that the number of transistors on an integrated circuit chip doubles every eighteen months [12]. This enabled electrical engineers to develop cheap integrated circuit components for bar code scanners as well as the computers to process the collected data.

Due to economics of scale, printing labels by the millions resulted in cheap and easy to print labels. Similarly, bar code scanners and data processors are produced cost-effectively through mass production, which was popularised by Henry Ford early in the 20th Century [13].

3. Innovation

3.1. Introduction

According to Peter Drucker, innovation is the specific instrument of entrepreneurship that endows resources with a new capacity to create wealth [14]. It creates wealth by adding value to the firm; adding value is one of the three ways of creating wealth [8]. Innovation is the result of technical feasibility, economic demand, willingness to adapt, environment and financial input [15] [16].

Innovation is a process of changes that includes the successful management of a number of interactions between abilities, strategies and technical, market or operational opportunities. It allows the firm to progress by ameliorating core competencies through obtaining and organizing abilities and knowledge. Products and services of the firm will be enhanced through innovation to give the firm increased revenue and a competitive advantage over rivals [15].

Reed [17] puts it mathematically as an equation:

$$\text{Innovation} = \text{uniqueness} = \text{differentiation} = \text{powerful positioning strategy}$$

Reluctance to change continually and repeatedly, and fear of trying new things increases a firm's potential for failure [17] [18].

3.2. Types of Innovation

The three basic types of innovation are Incremental, Substantial and Transformational innovation [15]. The bull's eye code was invented using a previously unexplored synthesis of technology from the Morse code and movie sound systems, so it was a radically new innovation. However, the bull's eye code did not add significant value to the innovators as it was not economically viable to use the bull's eye bar code system in grocery chains [2]. Hence, one can conclude that the bull's eye code was a substantial innovation.

The UPC bar code can be considered a transformational innovation. This innovation was significantly new and it created tremendous value for the retail industry as well as the production and logistic industries [3].

3.3.Sources of Innovation

The four major sources of innovation vital to the existence of the bar code:

The first source of innovation was the incongruity of stock taking and inventory tracking in the retail industry. Enormous amounts of time and labour costs, not to mention the opportunity cost of lost revenue, were being wasted. Stores were regularly closed while inventories were taken by hand, and items that were sold had to be recorded manually, which often led to inaccurate accounts. In order to decrease the frequency of stock taking, store managers were forced to estimate monthly sales, as there was no time-efficient way of tracking inventory. There existed immense potential for a system that could resolve these issues [3].

A second source of innovation was new knowledge in the form of technological advancement. Advancements in printing technology allowed bar code labels to be printed smudge-free and economically, while improvements in computer and laser technology paved the way for cheap and efficient bar code scanners. Lee De Forest's movie sound system also provided the initial bar code scanning mechanism.

Thirdly, there was a need for a better process of tracking inventories as the market structure for grocery stores changed. Early in the twentieth century, small and medium sized grocery stores began to merge and form an oligopolistic industry. For example, supermarket chains like Wal-Mart, Target, Carrefour and Kroger have dominated the grocery industry in the United States since the middle of the twentieth century [19]. As the grocery industry became more competitive, firms were forced to innovate to gain competitive advantages over rivals. This revolution in the perceptions of supermarket chain executives towards accepting continual and repeated change as a requirement of progress, spurred the innovation of bar code technology.

The final source of innovation is the change in demographics that occurred with the baby boom after World War II. The baby boom caused a dramatic change in the consumption of commodities and other consumer goods [20]. This fuelled the need for a better system of tracking goods as the logistics in managing the increased number of items in stores became tedious with existing methods [3].

3.4.Degrees and types of Innovative Differentiation

The three types of innovative differentiation according to Beukman are technical copy, technical follow, and innovation [15]. The bull's eye code was an innovation since there were no formal

procedures to follow whilst developing the code. In order to devise the bull's eye code, Woodland had to practise all of the learning abilities of Bloom's Taxonomy, which is a categorisation of cognitive skills [8].

The UPC bar code was a technical follow, as it was an upgrade of the bull's eye code system into a more economical version. The synthesis of integrated circuits and lasers in the development of UPC bar code scanners fuelled the system's popularity. Laurer and Woodland had the advantage of following the lead of the foremost developers of bar code systems. This enabled them to come up with a technically elegant solution [3].

3.5. Core Competencies involved

The core competencies of the innovators involved are as follows. As graduate students of the Drexel Institute of Technology, Woodland and Silver gained scientific and engineering skills and knowledge to help them develop the bull's eye code [4]. George Laurer was an Electrical Engineering graduate from the University of Maryland and proceeded to practise engineering at IBM [21].

Having worked for several years developing the bull's eye code, Woodland had abundant experience in bar code design. This experience significantly helped the duo of Woodland and Laurer develop the UPC bar code [3]. Systems and procedures to manage people, time and money were in place at IBM to facilitate this development [3]. IBM's innovative work culture and values as well as cutting edge electronic equipment at IBM laboratories in Raleigh, North Carolina, also contributed to the development of the bar code system [22].

3.6. Competitive Advantage of the UPC Bar Code

Competitive advantage is critical to a firm's performance in competitive markets. To gain competitive advantage, a firm must create value for its customers by applying systematic and tactical plans of action. A firm with a margin of superiority over rival firms, in attracting customers and increasing profits, gains competitive advantage [8].

A firm gains competitive advantage through the production of superior products or services, or the sale of its products for niche applications. Consequently, it will be able to meet increasing pressure from competitors, cater to customers' changing needs as well as the evolving abilities of suppliers. However, if it does not innovate perpetually, competitors will overtake the firm and seize its portion of the market [16] [18] [23].

Using the UPC bar code system allowed cashiers to be more productive as they could scan bar codes easily from a wide range of distances and a multitude of angles. They were also able to check out items twice as fast as any other existing check out systems at point-of-sales in the 1970s. This enabled grocery stores implementing the UPC bar code system to service more customers, resulting in increased revenue. Satisfied customers whom had to spend less time queuing at counters will also patronise the store more often.

Cashiers often mistype product information with cash registers; using bar code systems avoids this problem. Savings in man-hours spent tracking stores manually at regular intervals by the adoption of the UPC bar code system, coupled with the increase in revenue allowed grocery stores to recoup the cost of bar code scanners and data processors in two and a half years [3]. This enabled firms employing the UPC bar code systems to gain a competitive advantage over competitors due to the tremendous savings in costs and time, as well as the increase in revenue.

3.7.Limits of the UPC Bar Code Innovation

Whilst bar codes can be used to keep track of inventory, automate a warehouse and track employee movement, they still have some shortcomings. They cannot be used in deterring shoplifters in the retail industry [24]. Nor can they automatically track the movement of goods and personnel, as they still require personnel to manually scan items. RFID integrated circuit chips are an interesting new development that provides solutions for these shortcomings using active antennae to automatically communicate with the central database of the firm [5].

4. The Innovators

4.1.The Learning Paths of the Innovators

As aforementioned in Section 3.5, the three main innovators went to university to pursue tertiary education in science and/or engineering [3]. This allowed the innovators to gain technical knowledge, develop as professionals and broaden their perspectives on life.

4.2.Abilities exhibited by the Innovators

The innovators were able to identify and describe the technologies, such as lasers, Morse code and the movie sound system, which were implemented in the bar code system. Comprehension of these technologies allowed them to be synthesised into the bar code system [8].

The innovators predicted that use of lasers, which concentrate light energy, would allow the power efficiency of bar code scanners to increase dramatically. They used a modified version of Morse code to encode product/inventory information that can be stored or retrieved easily. They also successfully demonstrated that the movie sound system could be extended and modified to interpret electrical signals produced from reading the bar codes [2].

The components of the bar code system were also analysed by the innovators and had their interactions examined. In their analyses, they found that bar code labels should meet certain tolerances so they can be read by any bar code reader effectively. They also realised that bar code scanners must collect data rapidly, and accurately process and transmit the received data so that stocktaking becomes a faster and more reliable process. As recognised by the innovators, the inventory database must update relayed product/inventory information rapidly [25].

Lastly, the innovators evaluated its applicability in various industries such as manufacturing, logistics and retail, and assessed the value of the bar code system. They also estimated and predicted its acceptability and evaluated new technologies, such as integrated circuits and lasers, which had potential for integration into the bar code system [25].

5. Conclusion

Resolving to improve the unproductive process of recording product information at checkout counters, the innovators Norman Woodland and Bernard Silver sought to automate that process to improve its efficiency. Automatic recording of sale items during product purchase was once thought to be impossible due to its technical infeasibility and high costs. However, the bar code system brought about a paradigm shift in the grocery and retail industries as well as the logistics and manufacturing business sectors. This is due to the timesavings and increased profitability resulting from process automation [26].

Bar code systems, however, cannot be used to deter shoplifters in the retail industry nor can they automatically track the movement of goods and personnel. It is predicted that when cheap RFID tags become available to handle those aforementioned problems, bar code systems will be deemed redundant. As a result, bar code innovators have to adapt rapidly and flexibly to satisfy consumers' requirements to gain a competitive advantage over potential substitutes like RFID tags [23].

The bar code innovators have demonstrated that while most people cannot be inventors, everyone can be innovative by discovering new ways of adding value to resources [23]. Since only enormous firms have the financial capability to invest in the development of cutting-edge technology, small and medium sized firms can innovate by creating novel use of existing technology. This is ideal for economic growth as the commercial risks involved and the time delay to commercialise the products/services is reasonable compared to those that employ cutting-edge technology. Also, the frequency of adopting such products and services is significantly greater [8].

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