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A Prototype for real-time price and advertisement display on shelves in retail stores

Denis Kioko Nzomo
Faculty of Information Technology (FIT)
Strathmore University

A Prototype for Real-time Price and Advertisement Display on Shelves in Retail Stores

Nzomo Denis Kioko

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Declaration

I declare that this work has not been previously submitted and approved for the award of a degree by this or any other University. To the best of my knowledge and belief, this thesis contains no material previously published or written by another person except where due reference is made in the thesis itself.

Name: Nzomo Denis Kioko

Signature: .....

Date: 7 June 2017

Approval

The thesis of Nzomo Denis Kioko has been reviewed and approved by the following:

Dr. Vincent Omwenga,

Senior Lecturer, Faculty of Information Technology,

Strathmore University.

Dr. Joseph Orero,

Dean, Faculty of Information Technology,

Strathmore University.

Prof. Ruth Kiraka,

Dean, School of Graduate Studies,

Strathmore University.

Abstract

Price display is an integral part of the shopping experience in retail stores in Kenya. It helps the customer make an informed purchase decision while in the product aisle without the need for involvement of retail store staff. Current paper based price displays on retail store shelves lack reliability, durability and accuracy required for the retail stores operations. They are susceptible to wear and tear, and can be tampered with. It is also very difficult to tell exactly what price is currently displayed for a specific product on a shelf without being physically at that location. They also act as a bottleneck to these operations where other systems from the store management to the point of sale systems are computerized.

This research aimed to come up with an Electronic Shelf Label system that will allow for real-time price and advertisement information update and display on retail store shelves. It will be able to integrate with store management and point of sale systems seamlessly and facilitate instant price changes when necessary. Similar systems are already in use in developed countries with varied rates of adoption and success. The key differentiator for the architecture of the proposed model is that it also provides an advertising platform where retailers can charge vendors to advertise their products. This not only creates various cross-sell and up-sell opportunities for the vendors, but also provides an income generation avenue for the retailers, which overcomes the initial setup costs that have otherwise made retail stores particularly in Kenya shy away from such systems in the past. It will, in the long-term, also provide a platform for analytics for both retail stores and vendors to gauge correlation between customer purchase patterns and the prices of their products as well as competitors.

The research is a form of applied research. The sample size was computed through convenience non-probability sampling. Most of the respondents recommended an automated system hence the reason for creating this prototype. The prototype was developed using v-process methodology since the clarity of the user requirements was high and the technical expertise needed was readily available. The prototype produced 98% accuracy in real-time price information update and display with alerts for the non-successful updates generated by the prototype to inform the operator so that they resend the information.

Dedication

I dedicate this work to my late father, Francis Nzomo Mwololo and mother, Mrs. Erica Mwololo, whose love and dedication to my education has seen me come thus far.

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Abbreviations

ACES	-	Application and Controlling Framework for Electronic Shelf Labels
CBS	-	Communication Base Station
DFD	-	Data Flow Diagram
EBS	-	Event Builder Service
ERD	-	Entity Relationship Diagram
E-Commerce	-	Electronic Commerce
E-ink	-	Electronic Ink
E-Paper	-	Electronic Paper
ESL	-	Electronic Shelf Label
IR	-	Infrared
ISP	-	In-Store Processor
LCD	-	Liquid Crystal Display
NFC	-	Near Field Communication
OLED	-	Organic Light Emitting Diode
POS	-	Point-of-Sale
QR	-	Quick Response
RF	-	Radio frequency
WSN	-	Wireless Sensor Network

Chapter One: Introduction

1.1 Background of Study

The provision of unit prices on retail shelf labels is standard practice for retail stores and has remained largely unchanged for the last 30 years with retailers relying on the paper printed price labels to display prices on their shelves. They have the advantage of being cheap on the short term and well known by customers (Miyakazi, Sprott, & Manning, 2006). The retail industry itself however has not remained stagnant as some of its standard practices, with continued growth and ever-changing market forces requiring retailers to continuously adapt to survive.

As electronic commerce (e-commerce) and brick & mortar channels continue to converge, the retail outlets have looked to various ways to differentiate themselves from the competition (Evans, Shober, Wilkus, & Wright, 2002). This includes significant variation in the many aspects of unit price presentation (positioning, size, color, font style, etc.) across retailers. This led to retailers trying to achieve competitive advantages or financial gains by presenting unit prices in a format that maximizes retailer objectives. Supermarkets have turned to technology to automate their processes, improve efficiency, reduce expenses improve customer service. Retail stores have quickly taken up computers as both point-of-sale (POS) terminals and inventory management. They also use barcode scanners and various other electronic products to automate checkout and streamline the retail business. Up until about ten years ago, the one aspect of the retail store process has been most problematic to automate is ensuring consistency between the prices on display on the shelves with those at the payment counter.

1.1.1 Challenges Facing Paper Labels

According to research carried out by Kahl and Burckert (2013), paper printed labels, though cheap and well recognized, are not without their problems. As the retail industry becomes increasingly competitive, one strategy that has been adopted widely is to change prices of goods be it via discounts, sales promotions and offers in order to attract and maintain customers. The need to change more frequently than ever before has led to the inception of a host of problems for retail stores.

Frequent price changes have led to an astronomic rise in the cost of printing new paper price labels to keep with the ever-changing prices of goods (McKenzie & Taylor, 2016). This in addition

to the cost of reprinting worn out, faded as well as lost paper labels means costs have reached unprecedented levels. Evans et al. (2002) point out that going hand in hand with the cost of printing the labels is the cost of labour required to constantly put up new paper labels every time there is a change or need for replacement. The increased man power involved, raises likelihood for human error with more often than not prices on the shelf differing from those at the till because a member of staff forgot to remove prices of an offer that's ended or not updating to a new price as is required.

This also means that price updates are not real-time, with the retail store having to wait for new labels to be printed then put up before making them take effect at the till. Depending on the size of the store, this can be a painstakingly time consuming task which means that sores cannot react to market forces quick enough to gain a competitive edge. According to Evans et al. (2002), retailers are looking for fast, reliable and secure means of updating their prices in order to remain competitive in the marketplace.

Electronic Shelf Label (ESL) technology fits all these requirements, and has matured to become a relatively inexpensive solution for retailers around the world. According to research done by Chunhui, Pan, Liwen and Kezhong (2013), it can overcome many of the shortcomings of the traditional paper label system particularly the susceptibility to errors, massive rate of loss, increasing printing and labour costs and non-real-time update caused by paper based systems.

ESL technology brings with it many advantages from it being a one-time capital investment to the long-term benefit application of Internet of Things (Mishra, Patel, & Mehar, 2014). This application can save the management cost, improve efficiency as well as providing benefits that fit with a retail company's non-revenue strategies such as going green by embracing paperless technologies thereby enhancing the image of the stores.

1.1.2 Electronic Shelf Label

The ESL is a display device based on electronic paper (e-paper), Liquid Crystal Display (LCD) or Organic Light Emitting Diode (OLED) display technology where the price of a commodity is displayed and updated electronically (Akwukwuma, & Chete, 2012). These are typically reusable modules with a low profile, and of credit card size. These display systems are attached mechanically to the racks holding the article. A communication network, either centralized or manually operated, allows the display to be automatically updated whenever an article price is changed (Kai, Zhijun, Jiangbo, & Guang, 2013). This communication network can

be based on different media, Radio frequency (RF) and light-wave with RF being the most commonly used. Automated ESLs reduces pricing costs and improves pricing accuracy. In addition, no print job is required each time an update is to be done; hence, it is an environment friendly option as well.

E-Paper or electronic ink (e-ink) is a revolutionary material that is made with the promise to hold libraries on a single chip (Kahl, & Burckert, 2013). Currently, various technologies are used to create ESL tags with those using e-ink, and advanced version of segmented e-paper displays being the most in-demand type of tags (Mishra, Patel, & Mehar, 2014). These tags have several advantages including low power consumption, which improves longevity as well as ability to display digital content, which can be changed on the fly thus facilitating real-time product positioning. Therefore, the benefits of full-graphic ESLs would attract more retailers and is likely to play a key role in developing the overall market.

Wireless technologies play an integral part in the framework of ESL system (James et al., 2013). The communication network links the various parts of the system enabling the retailers to be able to access and make changes to the content on any of the display tags in real-time. Though various technologies are used in this communication, Radio frequency (RF) is the most commonly used and looks to remain as the most dominant technology for the near future. It is expected to dominate the market during the forecast period; RF technology can be easily integrated with various electronic devices, is very stable and reliable thus is convenient for data transfer. It also possesses an electronic memory, which is beneficial for information storage with respect to assets, which strengthen the ESL network.

1.1.3 Retail Industry in Kenya

The Global Retail Industry has seen a steady growth in recent times with Africa, and in particular sub-Saharan Africa showing great potential for development. The formalization of the sector has been a key trend underlying the sector's expansion with a research by Ouma (2013) highlighting Kenya as sub-Saharan Africa's second-largest formalized retail economy after South Africa and ahead of Cameroon, Ghana and Nigeria.

Buoyed by years of robust Gross Domestic Product (GDP) growth, a rising middle class, increased purchasing power and shifting consumer habits that have helped to drive the development of new shopping malls and e-commerce activities, Kenya's retail market is poised

for considerable growth in the coming years (Omany, Njeri, & Mungai, 2013). The retail market consists of predominantly traditional, informal sector namely the kiosks and local shops where up to 70% of Kenyans do their daily shopping. However, there has been a steady increase in dedicated retail properties and formal retail outlets in the country with a large percentage of shoppers saying that they shop from both informal and formal outlets. According to a report by Klynveld Peat Marwick Goerdeler (2015), 95% of Kenyan shoppers frequent small local shops, 92% shop at kiosks and 89% shop at supermarkets. While these numbers don't highlight the percentage that shops exclusively from formal retail outlets, it shows that in as much as Kenyans shop in all three locations, the percentage of shoppers visiting retail stores has almost caught up to those who buy from kiosks and local shops.

Kenya's domestic formal supermarket segment, which includes a number of formidable local firms that maintain an important regional presence, most notably Nakumatt, Tuskys, and Naivas, has expanded significantly since 2012 (Ouma, 2013). Several small retailers including Mulleys & Sons, GreenMart, and EastMatt are in the midst of ongoing expansions. International retailers are also eager to cash in on this sector dominated by local players with Carrefour, Walmart and Choppies looking to shake up Kenya's family-run private retailers.

Demand for formal retail space is also extremely high. Shifting consumer trends have driven growth in the formal retail segment, with 30% of Kenyans now shopping in formal outlets. The rise in formal outlets is in part a result of increased availability in terms of dedicated retail property. It has led to saturation at the top-end premium retail segment, occupied by supermarkets and malls. This saturation has led to the need for greater differentiation from their competition with retails stores looking at ways to attract more shoppers while reduce operating costs (Klynveld Peat Marwick Goerdeler, 2015). This means frequently changing their pricing due offers, promotions and reaction to various other market shifts.

1.2 Problem Statement

Paper price labels are still physically fixed on shelves and display counters in most retail outlets in the country. This method is not only time consuming, but also labour intensive, prone to errors and is a high expense endeavor. Furthermore, the loss of business brought about by discrepancies between shelf and counter prices has adverse effects on the retail business, which relies on the low product margins it makes on sales (Kahl & Burckert, 2013). With competition at

an all-time high, retailers have looked to various options to not only streamline their operations and cut costs, but also provide a pleasant shopping experience to their customers (Evans et al., 2002). Point-of-sale (POS) terminals, electronic cash registers, computers, barcode scanners, and many other products are being used today to automate the retail business (McKenzie & Taylor, 2016). One difficult-to-automate process, however, is ensuring that the prices shown on store shelves agree with those displayed and registered at the checkout counter. There exists solutions in place that alleviate some of the problems above, but their adoption has been limited to developed countries. The lack of uptake particularly in Kenya is mainly due to the apprehension brought about by perceived high cost of initial investment in the infrastructure.

There is need for a real-time price and advertisement update system (Chunhui et al., 2013). Using the proposed systems, retail stores will be able to update prices displayed on the ESL Tags in real-time. Not only does this system eliminate printing and labour costs involved in printing paper labels every time they need to be replaced and updated, it also reduces the error rates that have plagued the paper-based systems as well. The bright displays of the ESL tag also provide a dynamic surface to not only display product prices but also offers, promotions as well as advertisements. The revenue from advertising provides an additional incentive to adopt this solution since it offsets the cost of implementation.

1.3 Research Objectives

The general objective of this study is to develop a prototype that performs dynamic, real-time product and price information display.

1.3.1 Specific Objectives

1. To identify the variables and data currently being used for price and advertisement display in retail stores.
2. To examine the challenges facing price and advertisement display in retail stores.
3. To review existing methods and technologies currently used for price and advertisement display in retail stores.
4. To develop a prototype that performs real-time product and advertisement update and display in retail stores.
5. To carry out testing for the prototype for real-time price and advertisement display.

1.4 Research Questions

1. What are the variables and useful data in price and advertisement display?
2. What are the challenges currently facing price and advertisement display in retail stores?
3. Which methods and technologies are currently used to display price and advertisements in retail stores today?
4. How will the proposed prototype be developed?
5. How will the proposed prototype be tested?

1.5 Justification

This research is significantly important for players in the retail sector due to the effects of increased market saturation and competition. Retailers constantly face the shortcomings of manual systems such as the high error rate, high loss rate, increasing cost and unreliable price updates. The incident at a major retail store last year, involving different prices at the till from those at the shelf is one high profile case highlighting the need for such a system.

With customers embracing technology at an ever increasing rate, from shopping online, to using mobile devices to maintain shopping lists and carry out price comparisons, retailers are looking to technology to enhance their operations and provide customers with a much richer and engaging shopping experience. The ESLs can display prices, barcodes and quick response (QR) codes, which the customers can scan with their phones. They can also display mini advertisements for complimentary goods that the customer would have otherwise overlooked or forgotten to purchase. More advanced features such as Near Field Communication (NFC), weight sensors not only enhance communication with customers but can also help work with back end systems to notify retailers of reduced stock levels at the shelves.

ESLs have been adopted in some supermarkets, mainly in western developed countries, Australia, Turkey in Middle East, Japan and Korean in Asia (Markets and Markets, 2015). There are some existing solutions in place that alleviate some of the problems above, but their adoption limited to developed countries. The lack of uptake particularly in Kenya is mainly due to the apprehension brought about by perceived high cost of initial investment in the infrastructure. This solution differs from others in that it provides not only a price display platform but an advertising platform as well and as such, providing the retailers with a way of recouping their investment. This coupled with emergence of cheaper technology means that retailers in Kenya would be receptive of these systems especially if it gives them a competitive edge. With studies by Research and

Markets (2014) indicating that the global ESL market could reach US$ 2 Billion by 2019 its clear that adoption of ESL technology is on the rise and is changing price display in the retail industry.

1.6 Scope

This research will be limited in scope to the top tier of the Kenyan retail sector. The definition of top tier in this case being the formalized markets, specifically the supermarkets and retail stores that are franchised, located in malls and up market areas that are frequented by the middle class. It will specifically focus on how retailers can adopt ESL technology to improve operation efficiency and reduce costs and errors experienced using the traditional paper based systems. It will touch on how to overcome the biggest obstacle to adoption of this technology, which has been cost of investment, by providing a source of revenue stream through running of adverts on the ESLs alongside display of product information.

Chapter Two: Literature Review

2.1 Introduction

Price display is an integral part of the self-service retail store experience. It enables the customer to know the price of a particular item without having to engage the staff of the store. The provision of unit prices on retail shelf labels is standard practice for most retail stores with retailers relying on the paper printed price labels to display prices on their shelves (Miyakazi, Sprott, & Manning, 2006). It has been a largely satisfactory way of price display with its longevity highlighting how effective the system has been over the years.

As retail stores look to Point-of-sale (POS) terminals, electronic cash registers, computers, bar-code scanners, and other products to automate their operations, price display has remained a difficult-to-automate process (Evans et al., 2002). As other processes become computerized while the price display remains paper based it becomes more difficult to ensure that the prices shown on store shelves agree with those displayed and registered at the checkout counter, particularly with the frequent price changes in today's market space.

2.2 Price and Advert Display in Retail Stores in Kenya

Kenya's retail market segment has grown tremendously in recent times, buoyed by economic factors. The middle class, which comprised of 45% of the population has continued to grow and has more access to finances, which has increased their purchasing power. (Omany, Njeri, & Mungai, 2013). The arrival of new supermarket chains in Kenya highlights the potential of the country's retail sector, and with this, increased competition in an industry dominated by local retailers. As competition increases, retailers have looked to different pricing strategies to attract and retain their customers.

2.2.1 Price Display

Retailers have stuck to the time tested printed-paper label to display their prices. Whenever there is a price change then one of several outcomes is likely to occur. The price label is corrected with a hand written replacement, or the wrong price tag is removed all together while awaiting printing of new price labels (Orori, 2011). Items whose prices hardly change usually have faded price labels that have not been replaced in a long time with some completely missing altogether.

2.2.2 Sales Offers and Promotions Display

Orori (2011) notes that when there is a sale, offer or promotion for particular item retailers and vendors will put temporary price stickers on each of the items as well as on the shelves to attract customers to those shelves. For other items, they will even create special mid-aisle shelves to separate those items from those on the usual shelves. All these temporary price labels then have to be removed once the offer is over to revert the price back to the usual pricing.

According to Ouma, Mwangi and Oduk (2013), when a new product is introduced in a retail store, vendors as well as retailers hire temporary promotion staff to stand in the store aisle and physically call to customers to their products regardless of the customers' interest in that particular product.

2.2.3 Advertisements

Vendors have realised the importance of advertising with most using the traditional avenues of television, radio and billboards to market their products. Others have looked to social media to capture a growing demographic of their customers. However apart from the few retail stores that have in-store advertising screens, none of the aforementioned media reach the customer at the point of purchase (Ouma et al., 2013).

2.3 Challenges Facing Retailers

Retailers are constantly coming to grips with various challenges that not only have an effect on their operations but also affect their bottom-line as well (Andrew, 2015). The section below covers these challenges in detail.

2.3.1 Costs

To ensure that prices remain up-to-date and legible on their shelves, retail stores are forced to spend large amounts of money to print and maintain the paper price labels (Orori, 2011). Weekly sales, last-minute promotions and internal price audits further add to the workload. The cost of printing and labour required to check and change the paper labels is constantly on the rise and is harming the bottom line of the retail stores operations.

2.3.2 High Error Rate

Ouma et al. (2013) noted that the increased workload due to frequent price changes comes with higher probability of error. After offers and promotions end, prices usually revert to the normal price at the till, but this change is not always reflected on the shelf. This could be due to delay, miscommunication or forgetfulness of the staff involved. There have been notable cases of customers complaining about different prices on the shelf and checkout, which could tarnish the reputation of the store.

2.3.3 Moving nearly expired product

Perishables are always a cause for concern for retailers with losses sustained from expired goods being one of the major factors affecting their bottom line (McKenzie & Taylor, 2016). Retailers look to various tactics to minimize losses, from placing fresh product at the back of the shelf to not putting it on the shelves at all to try to move the old product first. When the expiration or sell-by-date reaches, supermarkets are forced to donate, sell to salvage stores or throw away all the goods resulting in losses.

2.3.4 Engaging and Enticing Customers

In a fiercely competitive retail industry, creating a differentiated shopping experience is critical to build customer loyalty and retention, which contribute towards maximum value for the brands available (Evans et al., 2002). The digital age has opened up multiple channels for businesses to connect to their consumers. Retailers are looking to of new technologies to create a more memorable and valuable experience will have a better chance of motivating consumers to come back frequently, and shop for longer (Miyakazi et al., 2006).

2.3.5 Increasing New Product Success Rate

The success rate for newly introduced brands and products is very low, with most introductions not gathering any traction and eventually failing. One of the hardest things for a brand to do is introduce a new product and get consumers to notice it (Omany et al., 2013). Consumers need a compelling reason to switch from a product or brand that they already use and trust no a completely new unknown brand. Retailers are constantly looking for new innovative ways to increase uptake of products in their retails stores.

2.4 Technologies used in Electronic Shelf Labels

The ESL systems hardware components mainly comprise of the tags and the wireless transmitter that sends information to the tags. The miniature display modules on the shelf must remain in constant communication and are powered for up to five years from an internal battery. Signals from the Communication Base Station (CBS) to the ESL unit (downlink) uses the simplest and lowest cost wireless communications (Infrared, Bluetooth and Radiofrequency) available (Evans et al., 2002). This radio has a tuned antenna is connected to a diode that rectifies the signals sent from the CBS. After rectification, the signal envelope matches the modulated data stream. Thus, low-cost electronic circuits that operate on low battery current can be used to process them. (Evans et al., 2002). According to Kahl and Burckert (2013), radio signals into the diode as weak as –60 dBm can be readily detected. However, the diode output signal will be only several microvolts in amplitude with such a weak input. Thus, this weak signal must first be amplified to logic circuit levels before it can be processed, a challenging task given the need for long battery life.

Evans et al. (2002) notes that once the signal has been amplified bit and frame timing must be recovered from it. This is a standard operation in any data modem and is simplified by encoding the data (in which the clock is transmitted along with the downlink data). The final link operation is decoding the address to determine if the downlink message is addressed to a particular tag. If so, a tag performs error checking on the received data and interprets the signal to drive the displays (Evans et al., 2002). The tag then acknowledges the communication.

Furthermore, the area taken up by the antenna is enhanced by increasing its size to the largest possible dimensions without surpassing the desired dimensions of the ESL module. This is because the entire module must be able to fit on a shelf and be of an acceptable weight such that several modules fitted on one rack do not put considerable strain on it and cause it to come off the shelf. It is the limitations of both size and weight of the desired ESL tags that has led to research looking to microwaves frequencies with the frequencies chosen found in the band between 2.40 and 2.4835 GHz.

These frequencies have several advantages notably being above the man-made noise sources from other devices that are usually found below thermal noise at frequencies above 1 GHz. They also have very short wavelengths hence guaranteeing that their transmissions are reflected on various surfaces that will be found in a typical store. This eliminates the need for line-of-sight

transmission and signal repeaters to get to far off distances within the store. They also travel over many paths and as such can combine constructively and destructively depending on whether they are in phase or not. The constructive interference boosts the signal while destructive interference can cause nulls, which though unavoidable in RF communications, can be mitigated by moving the receiving module by fractions of an inch (greater than their wavelength).

2.4.1 E-Paper

Electronic paper, also called e-paper, is a display technology designed to mimic the appearance of ordinary ink on paper (Akwukwuma, & Chete, 2012). Unlike a conventional flat panel display, which uses a backlight to illuminate its pixels, electronic paper reflects light like ordinary paper and is capable of holding text and images indefinitely without drawing electricity, while allowing the image to be changed later (Johal, & Chaudhary, 2013). According to a research carried out by Mishra, Patel, and Mehar (2014), there are various technologies used to build e-paper, some using plastic substrate and electronic so that the display is flexible. They include gyricon, electrophoretic, electrophoretic, electro wetting and electro fluid displays (Johal, & Chaudhary, 2013).

The most commonly used process of making e-paper is the electrophoretic technology. Electronic ink is the material that is made into a film for incorporation ink a paper-like display (Akwukwuma, & Chete, 2012). The electrophoresis technology allows for separation of molecules based on their physical size and the electrical charge by applying an electric current. In an electrophoretic front plane, small charges submicron particles are suspended in a dielectric fluid that is enclosed into a sub-pixel size cell or microcapsule as shown in Figure 2.1. When an electric current is run through the capsule, the ink particles will be attracted to the node with the opposite charge (Johal, & Chaudhary, 2013). With a transparent electrode, the cell or capsule takes in the color of the ink when current is applied. The contrast is improved by using opposite colored particles such as black and white- and charging them with opposite polarities. When current is applied, all the black ink particles move in one direction and all the white ones move in the opposite side. If the applied current is changed to switch the field, capsule will change color. This enables switching between all black particles and all white particles on the transparent front electrode of the cell or microcapsule. This is how the high contrast ratio of electrophoretic display is created (Akwukwuma, & Chete, 2012).

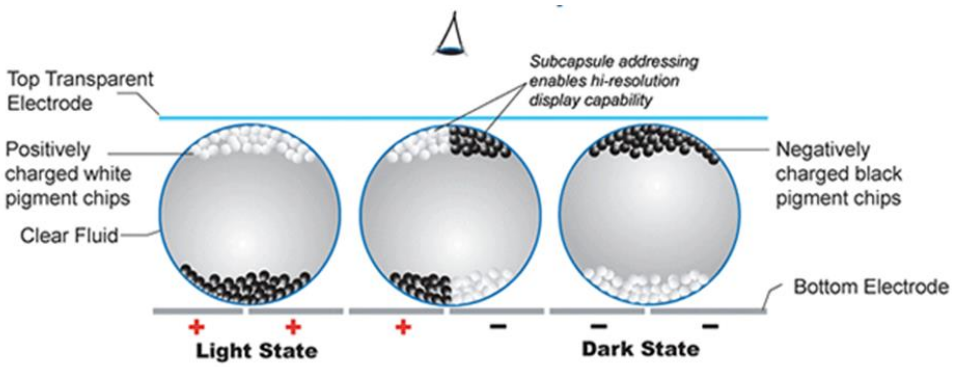

Figure 2.1: Cross-Section of Electronic Ink Microcapsules (Akwukwuma & Chete, 2012)

2.4.2 Wireless Communication

Wireless communication is the transfer of information or power between two or more points that are not connected by an electrical conductor (Rappaport, 2002). The transmission of data without any form of conductor is widespread in modern day application with personal, commercial as well as industrial use being commonplace. According to Wang and Poor (2004), the principal technologies involved in wireless communications are Infrared (IR), Bluetooth and Radiofrequency (RF).

There are several advantages achieved by use of wireless as opposed to wired communications. It can go across obstacles, allows for short to medium range communication without need for a physical link and does not need a module as a host to communicate (Mark, & Zhuang, 2003). The main components of a RF communication are the transmitter, which modify the original signal to be suitable for the transmission, the mean of transmission where the signal travels between transmitter and receiver, and the receiver, which transforms the information into the original signal to process it later. Figure 2.2 highlights the main components in RF communication.

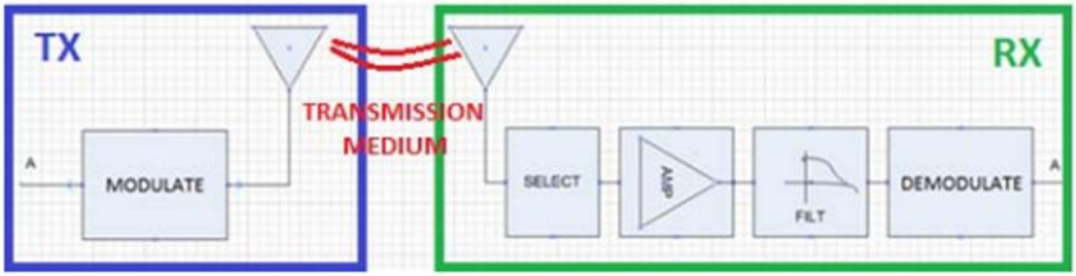

Figure 2.2: The main components in RF communication (Mark, & Zhuang, 2003)

According to Wang and Poor (2004), the main components to implement a RF communication system are the transmitter and the receiver which in the case of this research will be located in the AP and the ESL tags respectively. The transmitter contains a modulator transforms the signal in baseband (modulating signal) into a passband signal (modulate signal) at high frequencies and an antenna to transmit the signal. The receiver contains an antenna to receive the signal, a selective module to determine the dynamic range of operation of receiver, an amplifier to boost the signal when necessary, a filter to eliminate harmonics and finally a demodulator to convert the received signal into the original signal send it by the transmitter (Wang & Poor, 2004).

2.5 Approaches to Price Display

Price display is an essential part of the retailer-customer interaction in retail stores. The next section covers the various approaches to price display in retail stores, from the more traditional paper based approaches, to technology-based approaches that are being tried out in developed countries in the West and Far East.

2.5.1 Paper-Label Based Price Display Systems

A retail store normally has a computer or server where products and pricing information is stored. This database or file record normally contains the product, associated barcode and price (Evans et al., 2002). The ISP controls the POS terminals and their bar code scanners. The ISP has the only price database, which is used by the staff to print out paper labels. Once the store staff is certain that the prices have been updated on the shelves with the newly printed label, they can then update the prices on the POS terminals to reflect the shelf prices.

This process though familiar and having the advantage of being the most widely used way of price display, is quite labour intensive. As such, the task of price change involves many operations with different personnel involved in the printing, removal and putting up of new labels. Being time consuming as it is, it cannot be a storewide operation with stores usually doing it in bits, usually a few shelves at a time and mostly during non-operational hours so as not to disrupt customers shopping experience. It also limits the frequency with which stores change their pricing because it requires a lot of involvement for a small task. The disadvantage of this way of doing things is human error element, which comes about with various parties, involved not synchronizing their operations resulting in different prices at the shelves and at the counter.

2.5.2 Electronic Shelf Label System Based on Wireless Sensor Network

In this approach, a retail store uses ESLs, which comprises of four major components. They are label management software, which connects to the ISP, control platform, wireless communication base station and the display tags (Kai et al., 2013). The label management software is responsible for setting up the configuration parameters, the display tag properties, database update and so on. The control platform's function is set up and maintenance of the network parameters to ensure optimal communication between the display tags and the computer running the management software. The wireless communication base station is responsible for stable and reliable data transmitting with a certain long distance; the ESL functions as a terminal display device (Chunuhi et al., 2013). The network architecture of the ESLs is based on the Wireless Sensor Network (WSN).

According to the research done by Chunuhi et al. (2013), while the ESL system is active, the label management software prepares the information, be it product name and pricing and puts it in a format that can be transmitted over the communication network, normally data packets. These packets are then sent to Sink (control platform) through the serial port. After Sink receives the packets, they are scrutinized before being transmitted via a route through the wireless communication network (Kai et al., 2013). Finally, the router will transmit the analyzed packets to a certain Label, and the Label can act following the instruction given in the packets. The wireless communication network is a self-organized network, integrated WSN. Router functions as a relay station between Sink and Label. This approach has each router in the network connecting to and managing 256 display tags. Chunuhi et al. (2013) notes that a new ESL tag can be added in at any time and there is no need to change the network architecture. Considering the security of the network, the label would never be accepted until the specific access mode is used. The data should be encrypted before transmitting in order to prevent malicious attacks.

Figure 2.3 below shows the clustering and hierarchical structure model used to implement the ESLs in this framework. Not only does it provide stability of the data transmission, but also significantly optimizes the topology of the network, which contribute to the route selection, data fusion and energy saving.

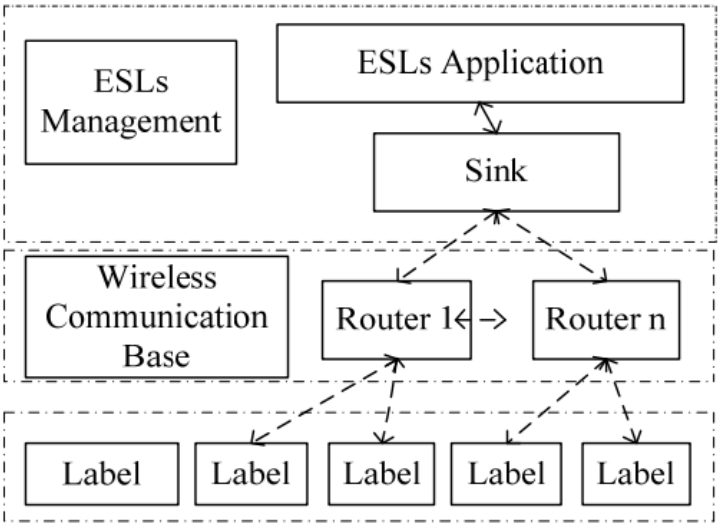

Figure 2.3: Architecture of ESL System Based on WSN (Chunhui et al., 2013)

Below we discuss the various components of the framework in more detail.

2.5.2.1 Wireless Communication Base

The Wireless Communication Base (Area Controller) in the framework adopted by Kai et al. (2013), shown in Figure 2.4 consists of several components namely the Processor Module, Wireless Communication Module and Power Supply Module. The processor is embedded with an operating system to provide efficient management and scheduling and is compatible with the network communication protocol of the ESLs. In order to achieve large-scale distribution networks, the front-end of Transceiver Module adds a power amplifier to improve communications transmission capacity. Area Controller can be powered over Ethernet or AC power.

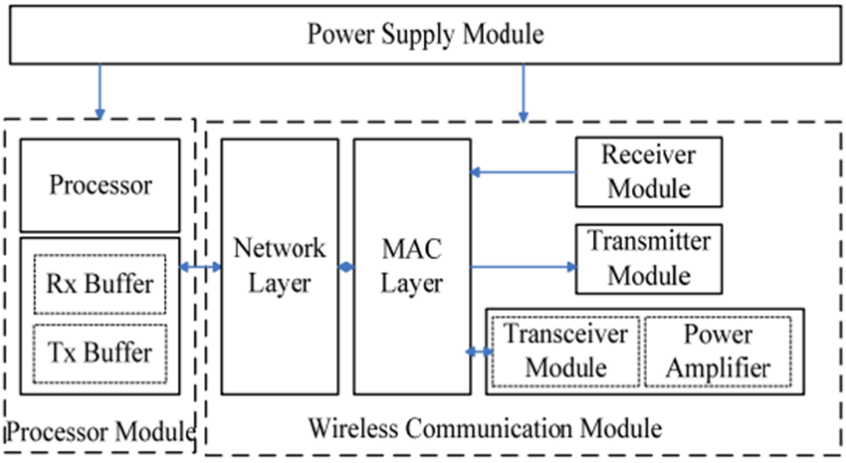

Figure 2.4: Structure of an Area Controller (Kai et al., 2013)

2.5.2.2 Sink

The structure of Sink is a scaled-down version of the Area Controller. It uses similar processing and memory units as the area controller and maintains asynchronous communication with the server via wireless or Ethernet connection (Kai et al., 2013).

2.5.2.3 Electronic Shelf Label

According to research carried out by Chunuhi et al. (2013), the structure of the ESL tag is dependent on the modules it contains, with the most basic having just a display module while other complex versions integrating a sensor module as well. The Sensor Module can have various sensors, such as temperature, humidity, pressure and is used to collect local environmental information. The display Module mainly displays price and product related information. Wake-Up module triggers the processor external interrupt to wake up the sleeping ESL. In order to improve their mobility, the ESL uses the battery power supply. The Transceiver Module of ESL adopts low-cost and performance chip with an embedded baseband protocol engine, suitable for ultra-low power wireless applications. Figure 2.5 shows the various components of an ESL and how they integrate.

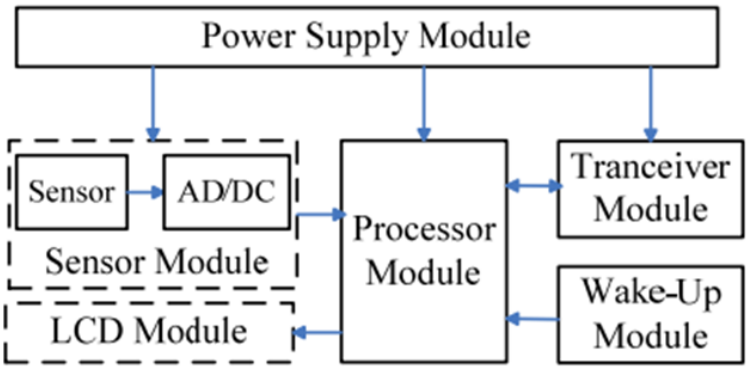

Figure 2.5: Structure of an Electronic Shelf Label (Chunhui et al., 2013)

This model has been used to implement ESL solutions in some retail stores in China with retail stores opting for the most basic tags with support for word and number display. These can also be updated with a handheld PDA in case of select tags not receiving the update communication from the communication base. Such systems though cost effective, do not support images and as such are not designed with advertising in mind.

2.5.3 Application and Controlling Framework for Electronic Shelf Labels

Application and Controlling Framework for Electronic Shelf Labels (ACES) framework is based on a plugin approach and a variety of applications can be supported by ACES, while the applications can react on changes gathered by sensors in an instrumented environment. The core of the framework consists of the controller, the display manager, the application manager, and the data source manager. Figure 2.6 illustrates the communication flow within the core as well as the connection to external services (Kahl & Burckert, 2013).

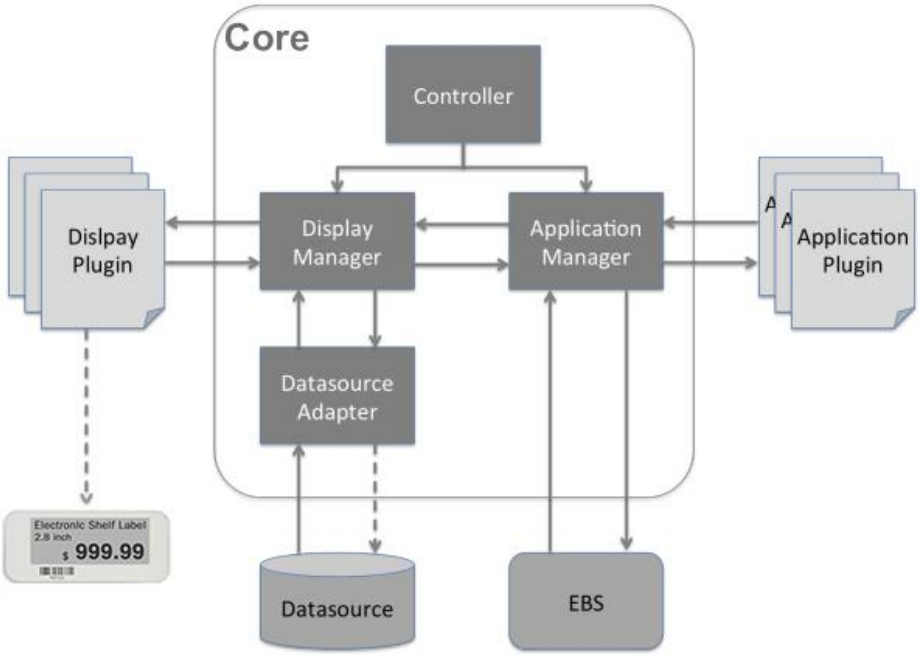

Figure 2.6: Architecture of the ACES Framework (Kahl & Burckert, 2013)

Event Builder Service

The Event Builder Service (EBS) is an event-based communication infrastructure for smart environments. All components of the environment can communicate with each other by encoding the information into events, which are sent to a central server (Kahl & Burckert, 2013). This server broadcasts the event to all connected clients, which can process the information. ACES registers to the EBS and retrieves all data gathered by sensors installed in the environment

Controller

According to the research by Kahl and Burckert (2013), the Controller acts as the starting point of the framework and manages the further components. It parses configuration files including the plugins to be used. For managing the used plugins, a web interface is provided by the controller.

Data source Adapter

The data source Adapter manages the communication to the data source. By implementing several data source plugins, information can be taken from a standard database, a merchandise information system, or even an XML file. It provides lists of all displays placed in the supermarket, products, and shelves including the geometric information, such as positions and orientations.

Application Manager

The Application Manager organizes the connection to the EBS. Whenever a new event is received, it is forwarded to all registered application plugins (Kahl & Burckert, 2013). These plugins encompass the functionality of the associated applications, which comprise the filtering of events they are interested in and the generation of the content for the ESLs.

Display Manager

The Display Manager holds a list of all displays connected to the framework and manages the information transmission to them. The connection itself is realized using display plugins, which includes both the physical information of the display and the communication channel (Kahl & Burckert, 2013). In order to ensure that only one application can make use of a display at the same time, the display manager provides a locking mechanism. This locking mechanism is decentralized by issuing tickets to the application plugin. The display manager can also invalidate these tickets in order to prevent deadlocks. In addition to the communication to the displays, the display manager is also able to alter the underlying data source by communicating with the data source adapter (Kahl & Burckert, 2013).

If an application plugin wants to connect to a display, this request is forwarded by the Application Manager to the Display Manager, which checks if the display is used by another application. If it is free, a new ticket is granted and the corresponding display plugin is forwarded to the application plugin. The display plugins can also store a standard screen content, which is sent to the displays if specific screen content should only be displayed temporary.

A solution from Austrian company SES uses such a framework, which supports both very low RF frequencies as well as infrared. Even though Wi-Fi and Bluetooth do not occupy the ultra-low frequencies, they are extremely slow, while infrared though able to update quite fast has the problem of security since it can be easily hacked. With technology continuously evolving and hacking kits becoming readily available, such frameworks, which were secure in the past, are increasingly vulnerable and their use has been on the decline as people move towards more robust technologies.

2.6 Conceptual Model

From this literature, the researcher has conceptualized the use of a model for electronic shelf price display. From the WSN framework, the researcher borrows the application to synchronize to ESL layout with the APN acting as the communication base that translates the application instructions into a signal that can be transmitted to the ESL tags. Each APN will have specific tags that it communicates with to ensure that it only caters to those that are within its transmission range. The ESLs that will be used will be as suggested in the research, containing low-cost antenna, which are the easiest to acquire and use in this research. The application will be cloud based and would be hosted on an external server from the retail store. This facilitates ease of access by both the vendors as well as the various branches of the retail chain particularly while dealing with the advertisement part of the tags. Vendors should be able to see that the adverts that they are paying for are actually on display on not only the specific number of tags that has been agreed upon, but also tags in the right location of the retail store.

The application will borrow from the multi display and multi-channel approach of the ACES framework where it will be designed to handle ESLs that can display both price and advertisement information to start with the ability to add on plugins for different display types and communication technologies in the future. However, the first phase of the prototype will focus on e-paper based ESLs since these are the most cost effective and more likely to have the highest uptake in the Kenyan Retail industry.

Figure 2.7 illustrates the conceptual framework of the proposed system from the back end, which will be accessible to both the store staff as well as the vendors to the AP bases controlling the ESL tags in various stores that can be controlled from both individual stores and the head office.

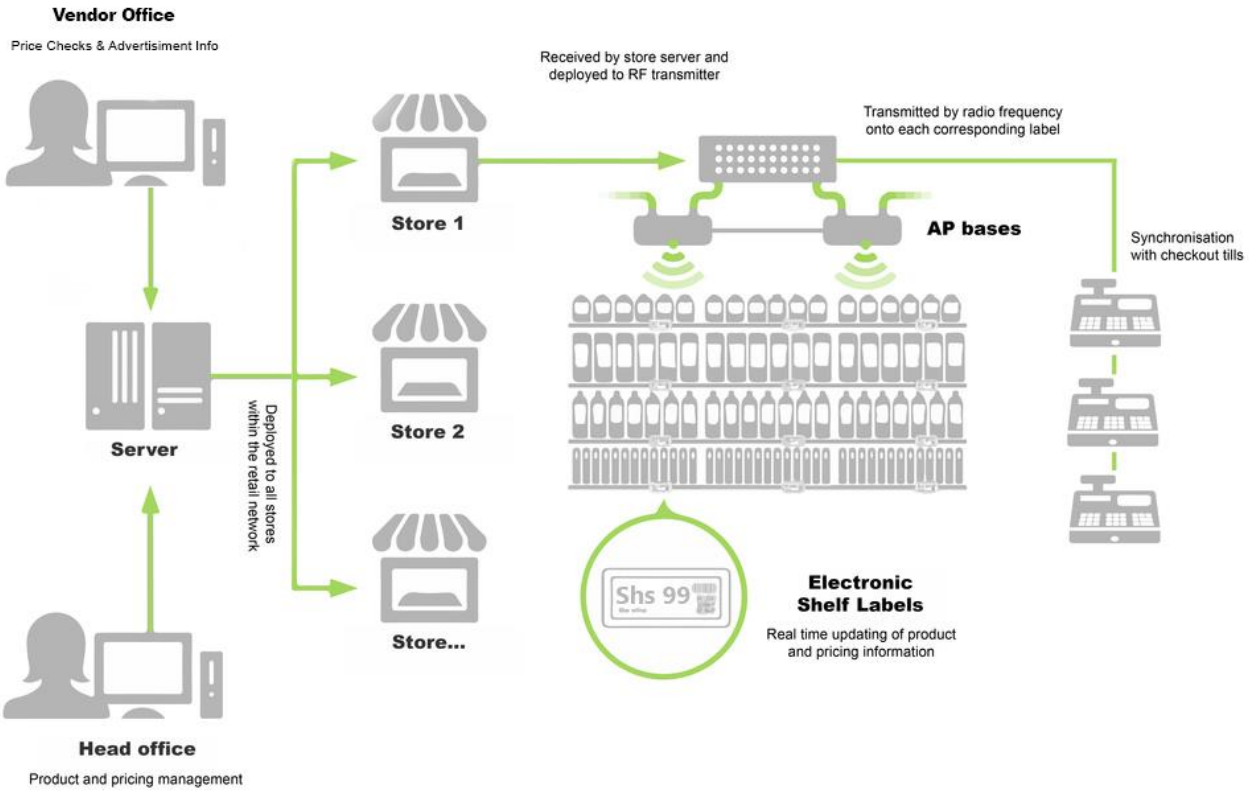

Figure 2.7: Conceptual Framework for the Proposed Prototype

Chapter Three: Research Methodology

3.1 Introduction

Research is defined as a scientific and systematic search for pertinent information on a specific topic. A research can be explorative, descriptive or diagnostic in nature and thus qualitative or quantitative approaches are applied as per the research design. Research has been proved a vital tool that provides the basis for economic decision making by government institutions and policy makers (Mackey & Gass, 2013).

This chapter discusses the research strategy, tools and techniques chosen and how they were applied. It also describes the population and the sampling technique to be used in collecting the data.

3.2 Research Design

The overall approach was applied research. The main goal of the study was to describe and analyse the main components of the current price and advertisement operations in Kenyan retail stores. The descriptive analytical design was ideal for the collection of unbiased information and thus coming up with the best way of answering the main research questions and attaining the objectives. This ensured an effective understanding of the problem statement making sure it was well addressed without any omissions in relation to the retails stores operations.

The existing systems and operations were evaluated and deficiencies identified. This was done by interviewing users of the current system and support personnel involved in the day-to-day operations. The new system requirements were then defined, with deficiencies in the existing system addressed by proposals in the prototype.

The prototype was developed using rapid application development (RAD) methodology. This methodology was appropriate due to its iterative nature and the limitation of time and other resources for the researcher. This approach offered fast development and delivery of optimal quality software at a cost, which is relatively low. This inherently reduced the overall risk as it broke the prototype into smaller manageable subtasks (Nashawaty, 2015).

3.3 System Development Methodology

A system development methodology is the framework for structuring, planning, and controlling the information development process (Centres for Medicare & Medicaid Services, 2008). Since there was a clear understanding of the user requirements and the researcher possessed the necessary technical expertise for system development, the researcher will apply the V-Process model of system development (Khan, Perveen, & Sadiq, 2014). V-Process model is simply a Verification and Validation model. It follows a sequential execution of processes. Each development phase had corresponding test cases (Khan & Beg, 2013). The first phase involved user requirements gathering and analysis. This formed the basis for system design and user acceptance testing (UAT) when the system goes live. The system design phase extracted the desired design form the user requirements and created a system test design. The architecture design and module phases followed with their test designs .The module design was then converted into a working system by the programmer as shown in Figure 3.1.

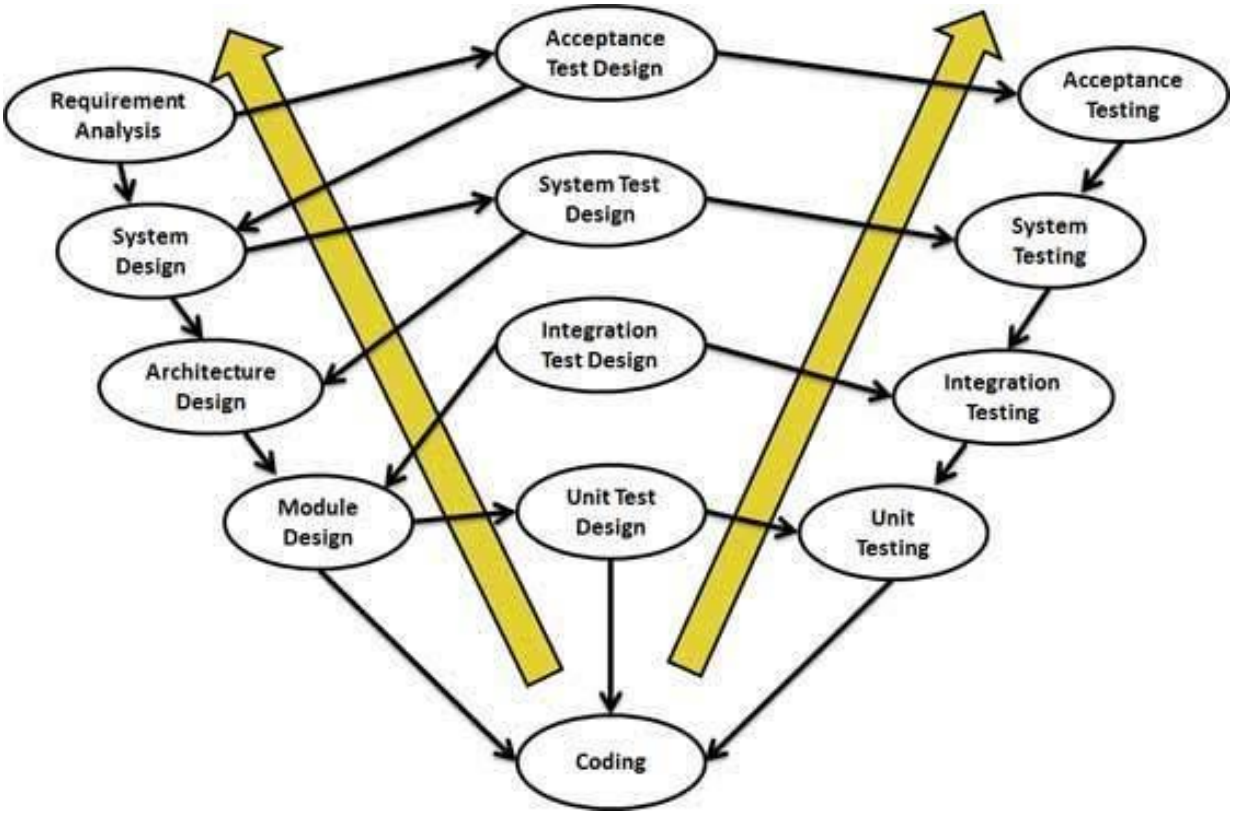

Figure 3.1: V-Process Model (Khan & Beg, 2013)

3.4 Population and Sampling

The research will be based in the entire country of Kenya. The target population is the back end staff of the retail stores and product managers from vendors with products in the stores who would wish to post advertisements. According to the latest internal reports from various leading retail stores in the country, Nakumatt has fifty-seven branches, Tuskys has fifty branches, Naivas has thirty-nine branches, Uchumi has twenty-four branches while the remaining stores (Ukwala, Carrefour, Game, Woolworths) having a combined total of nineteen outlets. Each with a store manager and three to four support staff who would have access to the system. This brings the total number of retail store staff to about nine hundred and forty-five. The leading retail stores have up to thirty-five thousand different products from about two thousand vendors each with their own product manager who interacts with the retail store staff in regards to price changes, promotions and sales offers to be run in the store. The product managers in addition to the retail staff brings the target population of the research to about two thousand nine hundred and forty-five.

The participants were selected through convenience non-probability sampling since the researcher is bound by time and other resources. The researcher applied random sampling technique in order to obtain the desired sample size. To obtain the required sample size, equation 3.1 was used.

$$n = \frac{NZ^2 \times 0.25}{[d^2 \times (N-1)] + (Z^2 \times 0.25)},$$ Equation 3.1 Random sampling (archive-edu, 2013)

Where:
n = Sample size
N = Total Population size (known or estimated)
d= Precision level (usually 0.10 or 0.05)
Z = Z statistic for a level of confidence (e.g. 1.96 for 95% confidence level)

$$n = \frac{2945 \times 1.96^2 \times 0.25}{[0.1^2 \times (2945-1)] + (1.96^2 \times 0.25)}$$

n = 93.0375

The questionnaire was issued to 93 respondents.

3.5 Data Collection and Requirements Gathering

During this research, the researcher aims to collect both primary and secondary data. This involves the use of structure questionnaires, interviews and secondary data collection. Structured online questionnaires were administered before and after developing the prototype. Before developing the prototype, the researcher wanted to understand the user requirements. After the prototype is developed, the structured online questionnaires will play a key role in gathering information on how the target users feel about the newly developed price display and advertising prototype. The online questionnaires were chosen for their convenience.

Interviews were carried out to gather information from the store managers. Interviews offered a better approach to understanding the current process of price updates and display. What systems are involved, who needs to approve the prices, how long does it take. Open interviews provided an avenue for more explanations, which helped the researcher to understand the process better. They also played a very crucial role in gathering user requirements.

Secondary data collection was done to understand the existing worldwide standards for business automation, the researcher studied several architectures, frameworks, tools and technologies, which are not resource intensive yet effective. The researcher also used observation of what is used in retail stores, the information displayed, format as well as designs preferred amongst the various retail stores in the country. This aided in selecting the optimal development tools and technologies.

3.6 Data and Requirements Analysis and Presentation

Data requirements analysis and presentation involved organizing data collected and breaking it further into smaller parts, which could be easily understood. Quantitative data was analyzed using Microsoft Excel. Microsoft Excel allows for a number of statistical analysis functionalities. Data analysis results were presented using the following tables and pie charts. Tables were used to summarize the significant variables, while pie charts were used to provide a visual representation of the quantitative data and to facilitate comparison and correlations within the data.

User requirements were analyzed and system design models generated. These included dataflow diagrams (DFDs), use case models, sequence diagrams, sequence diagrams, entity relationship diagrams (ERDs) and class diagrams.

3.7 Research Quality Aspects

Research quality aspects is the degree to which the research was carried out correctly. Validity and reliability were used to test the quality aspects.

3.7.1 Validity

Validity decides whether the study truthfully and accurately processes what it was intended to measure or how frank the research results are (Golafshani, 2003). Content validity was used to authenticate the research by systematically examining the test content to determine whether it covers, a selected sample of the behavior domain to be measured (Anastasi, 1997).

A pilot study that resembled the main study was used to measure the validity of the research. This was done by inspecting the preliminary concept, idea and research questions that discerns which data is to be collected and how it is to be grouped. The researcher also ensured that the system implemented was developed in a way that it was as close as possible to an actual application that users updating prices and advertisements on retail store shelves would use.

A part from the piloting, survey questions were also send to respondents. Responses of the questions given were analyzed to check whether the new system was of value to the users. To establish the notch to which the content domain associated with the construct, content validity was chosen matches the test content.

3.7.2 Reliability

Reliability is the extent to which there is consistency in results over a specified time and a correct illustration of the aggregate population under research. If the outcomes of a research can be replicated in a comparable approach at that point the research mechanism is considered reliable (Golafshani, 2003).

Inter-rater reliability was used in the research to measure the level to which information being gathered by different interviews is collected in a trustworthy manner (Keyton, 2004). In this research, reliability was attained by giving respondents questionnaires to fill after one week and the correlation between the two checked. This gave the researcher a go ahead with the study. The questions were then refined based on the feedback obtained from the pilot test.

Inter-rater reliability was used because it ensures that the procedures used to gather the information and the data collection instruments are solid enough and that the same results can be obtained repetitively.

Chapter Four: System Design and Architecture

4.1 Introduction

This chapter reviews an analysis of the data collected using both quantitative and qualitative methods of data analysis. It focuses on data analysis, and system analysis, which are discussed in detail. The findings from data and system analysis were then used to come up with comprehensive system design and system architecture.

System design is the process of defining the top-down description the system's structure (architecture), modules, interfaces, components for a system in order to satisfy the specified user requirements (Faisandier, 2012). This process involves collecting and analyzing user requirements and modeling them in both conceptual and logical representation.

4.2 Data Analysis and Findings

To extensively gather user requirements, questionnaires were administered to system administrators, store managers and support staff in retail stores. Interviews were also done to retail store managers and vendor product managers in order to understand how the price changing process is carried out beginning from the vendors all the way to the retail store shelves. The results were analyzed and presented using pie charts as shown in the section below.

4.2.1 Retail store that respondents worked for

As illustrated in Figure 4.1, 37% of respondents work for Nakumatt and 29% work for Tuskys, representing a majority of the respondents, which is also indicative of the number of retail branches, those organizations have countrywide. 19% and 10% work for Naivas and Uchumi respectively to round of the top four most popular retail outlets with the remaining 5% respondents shared amongst the other outlets.

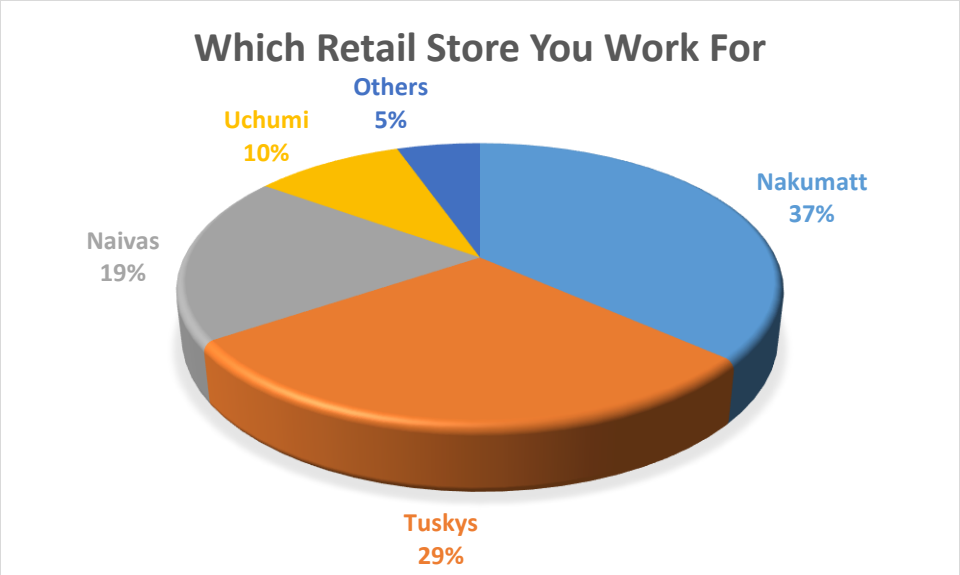

Figure 4.1: Which Retail Store you work for

4.2.2 Respondent's role in the retail store

Figure 4.2 below shows that 39% of the respondents work in the marketing department while 33% have the responsibility of ensuring all pricing is in order. Store management made up 15% of the respondents whose role is to oversee the various departments involved in the price and product update process. The remaining 13% was made up of system administrators who maintain the systems that take care of inventory, printing paper labels, point of sale and other various tasks in the retail store.

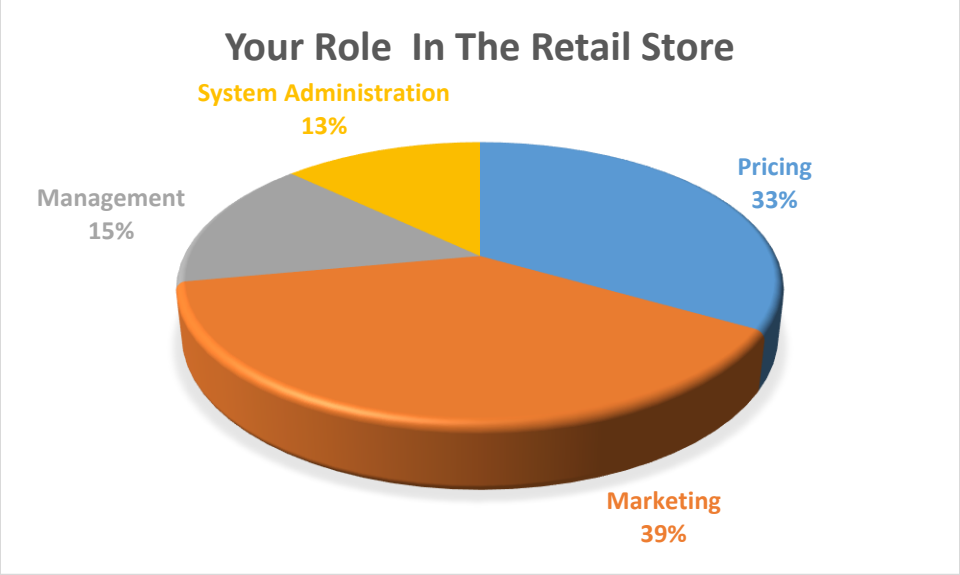

Figure 4.2: What your role is in the retail store

4.2.3 Information displayed on retail store price labels

When asked what information they currently display on price labels on their retail store shelves, a majority of the respondents said that the product name, price weight and size were the most important details that they include while a few also added other attributes such as colour, barcode and sometimes discounts when available. This information is shown in figure 4.3 below.

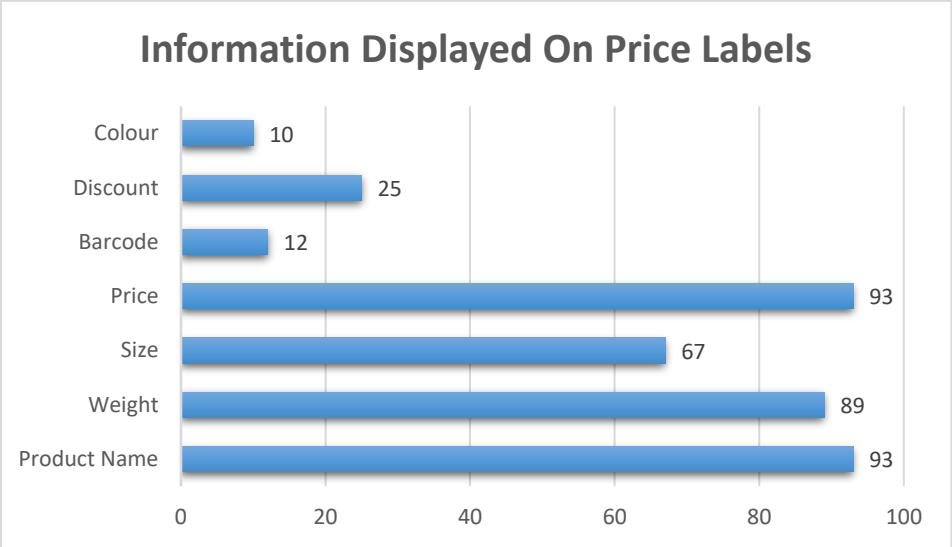

Figure 4.3: Information displayed on price labels

4.2.4 Sources of prices that are displayed on shelves

61% of respondents get their pricing information from the product managers while 35% do their own pricing internally representing a majority of the price sources for the respondents polled. This is summarized in figure 4.4 below.

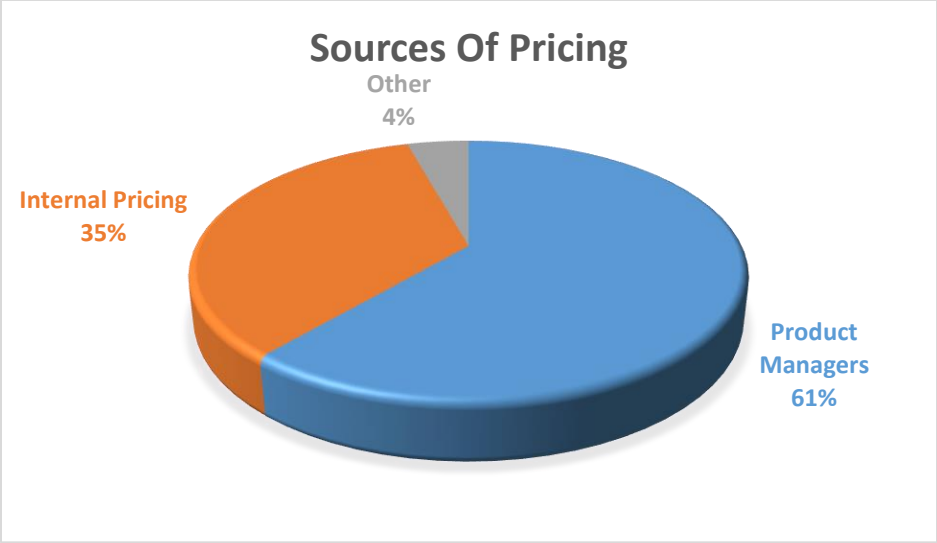

Figure 4.4: Sources of Pricing

4.2.5 Approaches for in-store advertising, offers and discounts in your retail store

When the respondents were polled on what approaches they currently use for in-store advertising offers and discounts, a majority said they use paper labels and cardboard banners on various sections of the shelves to attract customers' attention. About half of the respondents said they also use brand ambassadors who stand in the aisles next to the products. This is shown in figure 4.5 below.

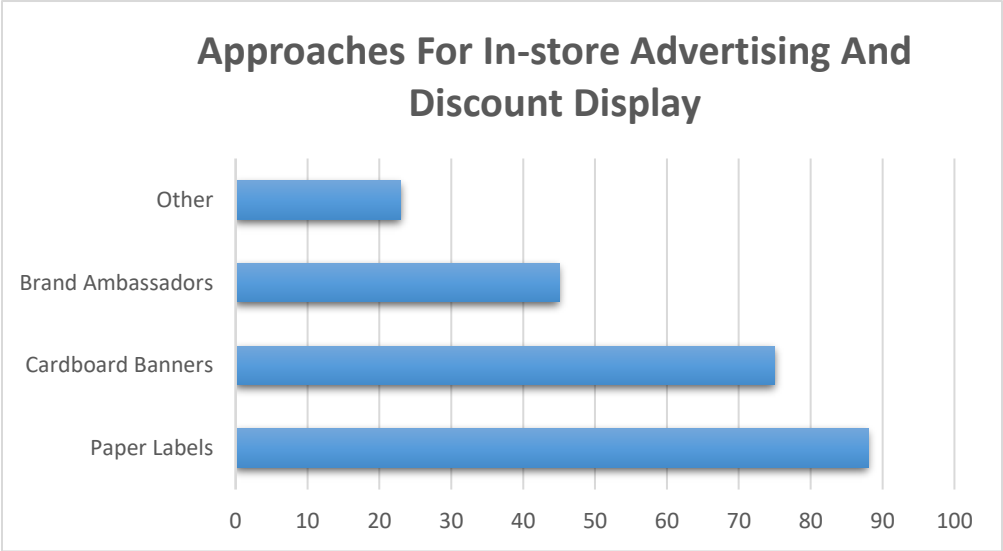

Figure 4.5: Approaches for in-store advertising offers and discount display

4.2.6 Rank the challenges in order of their significance

When polled on which challenges are most significant to their operations in the responses varied depending on the challenge that had the most impact to their operations. Concerning costs, 19% considered it very significant while 17% considered it significant. 15% were neutral with the remaining 20% and 27% regarding costs as not significant and not at all significant respectively.

Regarding the high error rate nature of current methods however, a majority considered it very significant and significant with 37% and 34% of respondents highlighting this as their biggest concern. 13% were neutral while only 11% and 5% felt that it was not significant and not at all significant.

In response to the challenge of how time-consuming current methods were, 21% felt it was very significant with a further 26% noting that it was a significant concern. 31% were neutral indicating that they were impartial to the time it currently takes to update prices on the shelves.

The remaining 12 % and 10% considered the t not significant and not at all significant to their tasks.

When polled on engaging and enticing customers, only 10 and 12% respectively considered this as very significant and significant respectively. 22% were neutral while 25% considered this not significant. The remaining 31% with was the majority considered this not significant at all, showing that they viewed price display as purely informative rather than an enticing measure for customers.

Finally, the challenge of dealing with nearly expired product, an issue mostly faced by those in decision-making capacity, was considered very significant by 13% and significant by 11% of respondents. 18% were neutral while the remaining majority constituting 25% and 29% of the respondents thought the challenge not significant and not at all significant. Figure 4.6 below summarizes these findings.

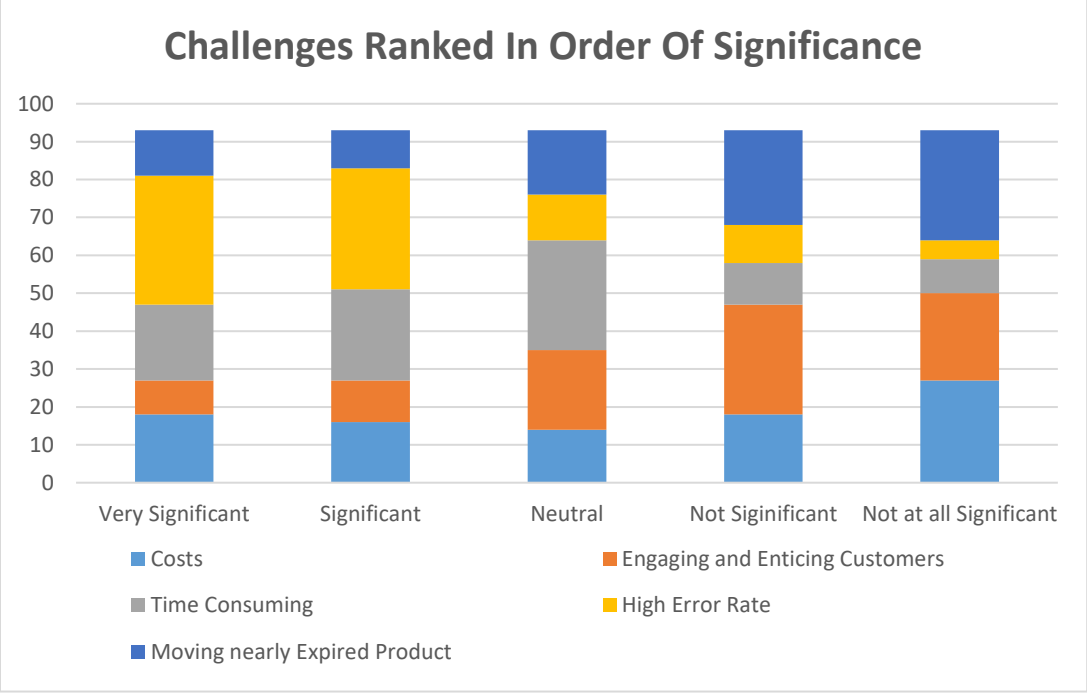

Figure 4.6: Challenges ranked in order of their significance

4.2.7 Ease of price and product information update and display

As illustrated in Figure 4.7, only 10% of the respondents strongly agreed price and product information update and display is easy with current systems. 17% of the respondents agreed with the notion. 20% were neutral saying it was neither particularly easy nor hard to work with the

current procedures. A majority of respondents were against this sentiment with 29% percent and 24% disagreeing and strongly disagreeing with whether the current systems were easy to use.

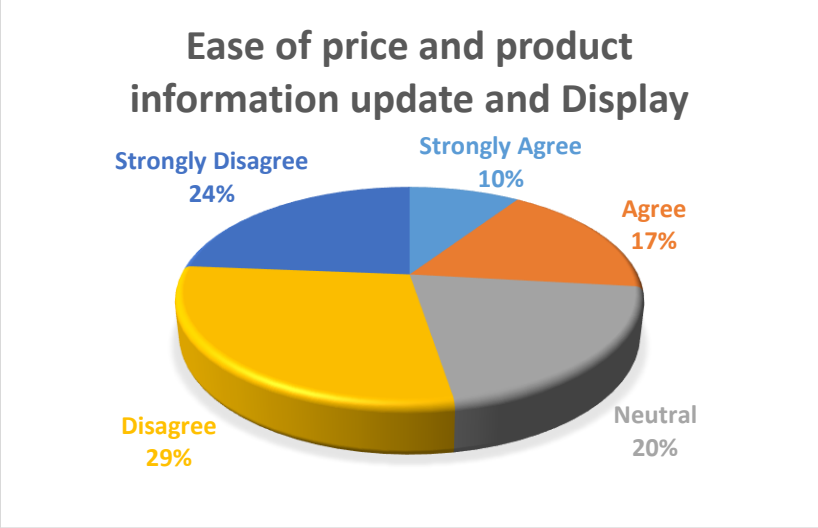

Figure 4.7: Ease of price and product information update and display

4.2.8 Efficiency of the current method of price and advertisement update and display

37% of the respondents strongly disagreed that the current method of price and product information update and display was efficient. 28% disagreed, 24% were neutral about the matter, 7% agreed that the process was efficient and only 4% strongly agreed to this claim. This shows that a majority of the respondents as is illustrated in Figure 4.8 below does not consider the current method efficient.

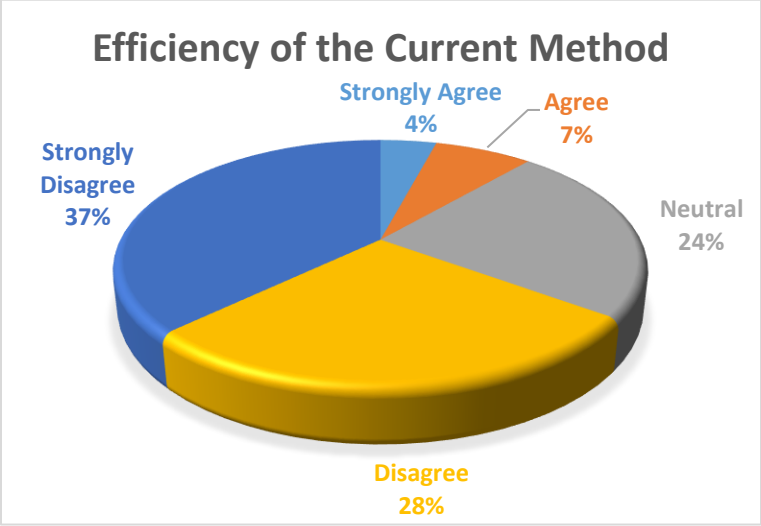

Figure 4.8: Efficiency of the current method of price information update and display

4.2.9 User-Friendliness of Current Process of Updating Prices

When polled on how user friendly the current systems are, only 5% of the respondents strongly agreed that the system and procedures are user friendly to all involved, with 13 % agreeing to the same. 16% were neutral, 30% disagreed while 36% strongly disagreed with this sentiment showing how high a percentage of the respondents felt that current systems were did not meet expected levels of user friendliness. This is illustrated in Figure 4.9 below.

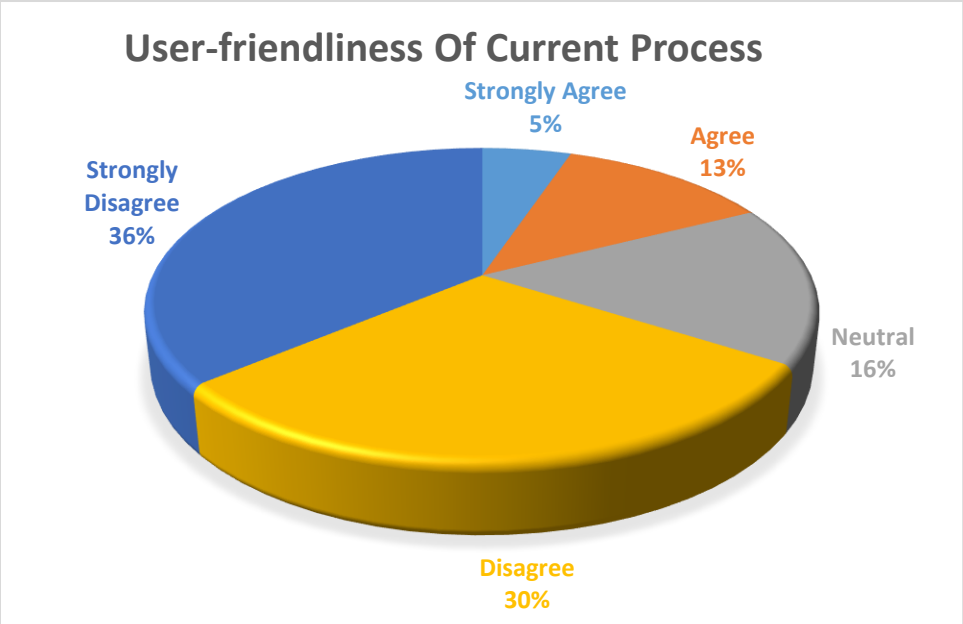

Figure 4.9: User-friendliness of current process of updating prices

4.2.10 Accuracy of Current Process

39% for the respondents strongly disagreed when asked whether the current measures for price and product information update were accurate with a further 34% disagreeing with the sentiment. 15% were neutral with only 9% and 3% agreeing and strongly agreeing that the measures that are in place are accurate. This is illustrated in Figure 4.10 below.

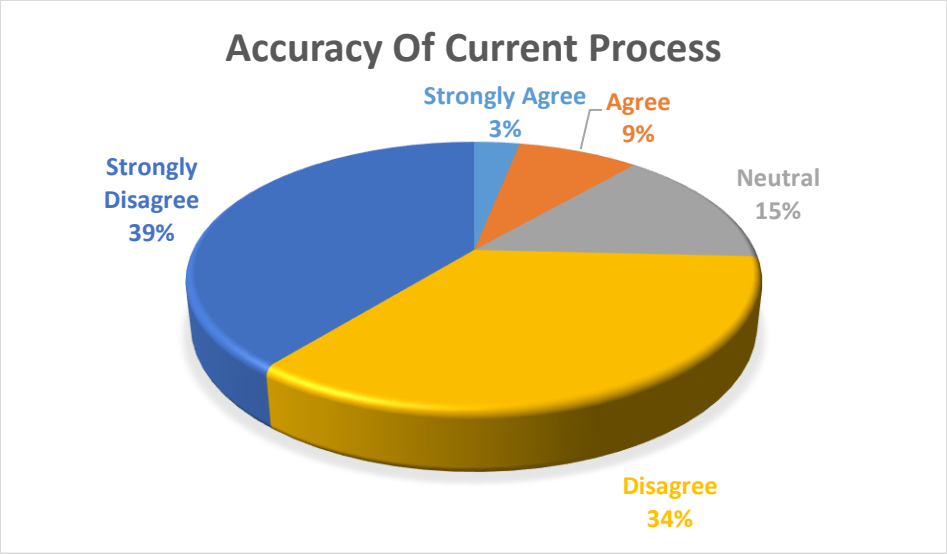

Figure 4.10: Accuracy of current process

4.2.11 Integration with other retail store systems

As illustrated in Figure 4.11, 8% of respondents strongly agree that the current process integrates seamlessly with other retail store functions and tasks while a further 17% agreeing with this notion. A majority of respondents were neutral with 41% neither agreeing nor disagreeing with the sentiment. However, 19% of respondents disagreed with a further 15% strongly disagreeing that there was seamless integration and continuity of retail store processes.

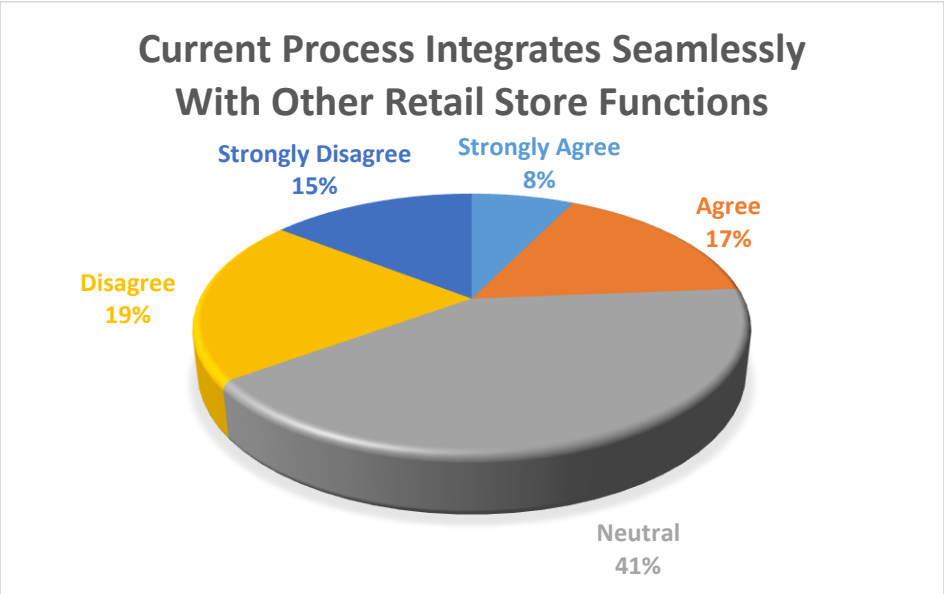

Figure 4.11: Current process integrates seamlessly with other retail store functions

4.2.12 What is currently use to display prices and advertisements

When the respondents were polled on what they currently use to display prices and advertisements in their retail stores, 96% said that they use paper labels while 3% of the respondents said that they use electronic media, usually the item that is for sale to display its own price, mostly in the electronics section while the rest said that they employ other media on rare occasions. This highlighted the overwhelming dependence on paper in retail stores in the country and is summarized in figure 4.12 below.

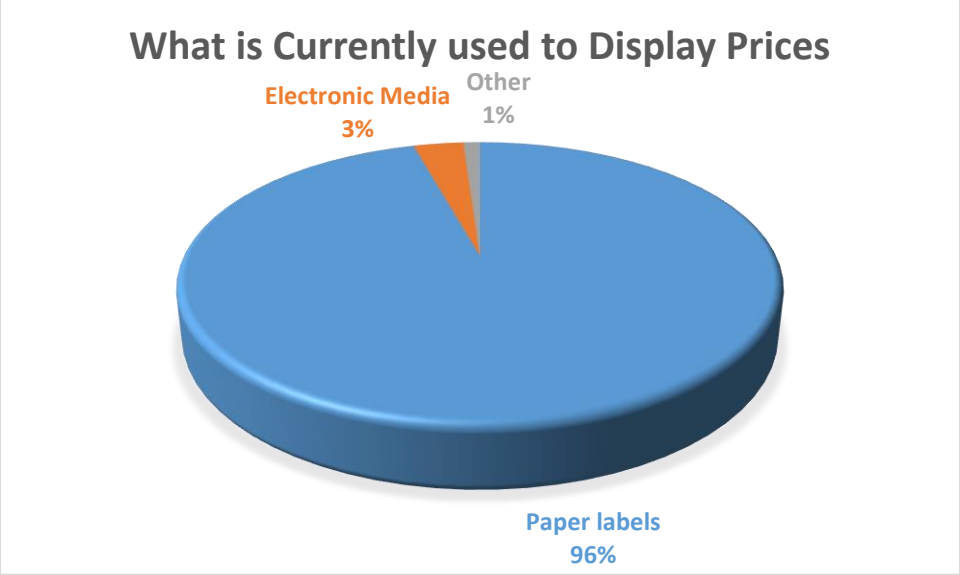

Figure 4.12: What is currently used for price and advertisement display in retail stores

4.2.13 Recommendation for an Automated System

When polled on whether they feel that an automated price and product information system would make the process much easier, 50% strongly agreed while a further 33% agreed with this. This formed a vast majority of the respondents with 10% being neutral, 4% disagreeing and only 3% strongly disagreeing that an automated system would make work easier. This is illustrated in Figure 4.13.

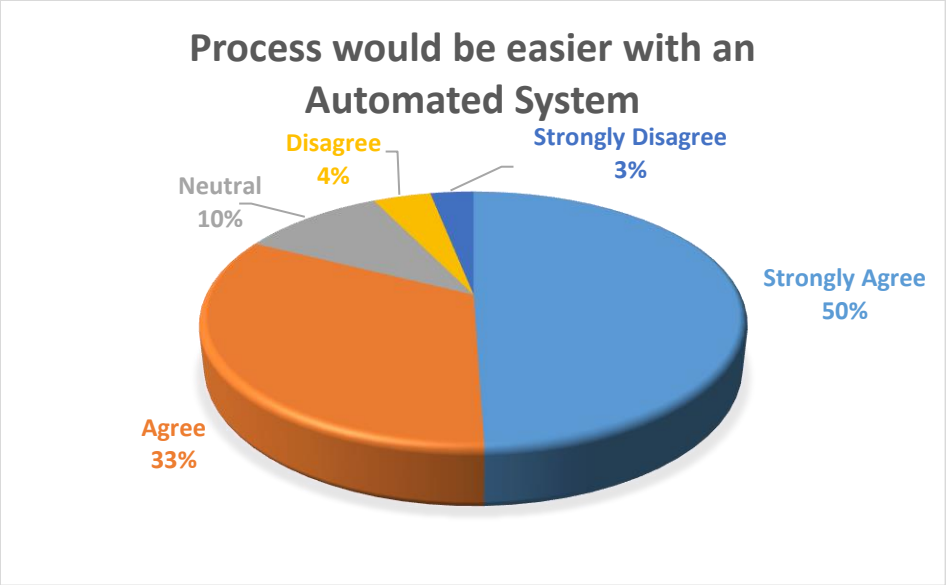

Figure 4.13: Process would be easier with Proper System

4.3 Requirements for the Proposed System

4.3.1 User Requirements

Through the questionnaire and interview questions administered, the research found out that the users needed:

i. A system that would enable automated, real time price and product information and display from a centralized location.
ii. A system through which offers, sales and promotions can be managed in order to seamlessly change prices when offer begins and revert back to original price when offer period ends.
iii. A system that would notify the users when a product's price is not being displayed at any one time due to an error or faulty price tag.
iv. A user friendly and intuitive system.
v. A secure system in terms of privacy issues and access.
vi. A system, which generates intelligent reports crucial for decision-making.

The user requirements were then grouped into functional and non-functional requirements. Functional requirements capture the intended functioning of a system while the non-functional requirements form constraints of the functional requirements (Zhou, 2004). From these requirements, system requirements were also extracted.

4.3.2 Functional Requirements

i. The system users (store managers, product managers and support staff) shall be registered by the system administrator before using it.
ii. Support staff shall be able to create and update prices for relevant products in their sections only.
iii. Only the store management will have authority to approve the price changes providing extra layer of security and authentication.
iv. Vendor product managers should only have access to product information pertaining to their respective products.
v. The developed system should allow the staff to change product prices in real-time.
vi. The system should allow the staff to create offers promotions and adverts that run for specific periods and automatically return to normal product price display one finished.
vii. The system should send notifications to users in case a display tag is not showing anything or did not receive updated pricing once it was sent.
viii. The system should generate different reports when required.

4.3.3 Non-Functional Requirements

i. The system should be reliable, timely in generating reports, efficient and secure.
ii. The system should be easy to use for users with basic computer knowledge, if they have the rights to access it.
iii. The system should be robust and able to cope with multiple user carrying out various operations.
iv. The system should be flexible to allow future customizations.
v. The system should integrate seamlessly with the systems in the retail store with minimal changes to how those other systems operate.
vi. Any unauthorized user should be denied to access the system.

4.3.4 System Requirements

The proposed system has the following system requirements:

a) Relational Database Management System

For easier organization and storage of data and to facilitate creating, updating, extracting and analyzing data; a central database shall be used. This system uses SQLSERVER due to its robustness, ease of integration and expertise of the researcher.

b) Graphical User Interface

To enhance usability, a user-friendly interface shall be developed. This shall provide a console for users to add new products product information and tags. They shall also be able to map products, offers, promotions and advertisements to specific tags from the interface.

c) Security

To ensure data integrity, authenticity and confidentiality, user authentication shall be done before using the system. Database backups shall also automatically be run regularly to prevent data loss in case a disaster strikes.

4.4 Process Modeling

Software process model refers to an abstract representation of a software process (Scacchi, 2001). This represents a standardized format for planning, organizing and implementing a software development project. It is composed of objects, networked sequences of activities and events that entail strategies for handling software evolution.

4.4.1 Data Flow Diagram

a) Context Level Diagram

This process is handled by four categories of users namely: retails store staff, store manager, system administrator and vendor product manager. The system administrator registers and views the authorized users of the system. He creates the credentials for the users, defines user groups and grants different levels of access right to the various levels. The store staff input all the product details such as quantities, prices offers and promotions. The also assign the details to ESL Tags on the shelves. The store manager approves all the details and changes implemented by the store staff before they are forwarded to the ESL tags. They also generate and view reports that can further streamline their operations. The vendor product managers have access to information pertaining to their specific products only. They can view reports such as if offers and promotions were run on for the period they specified. Figure 4.14 shows the context level diagram.

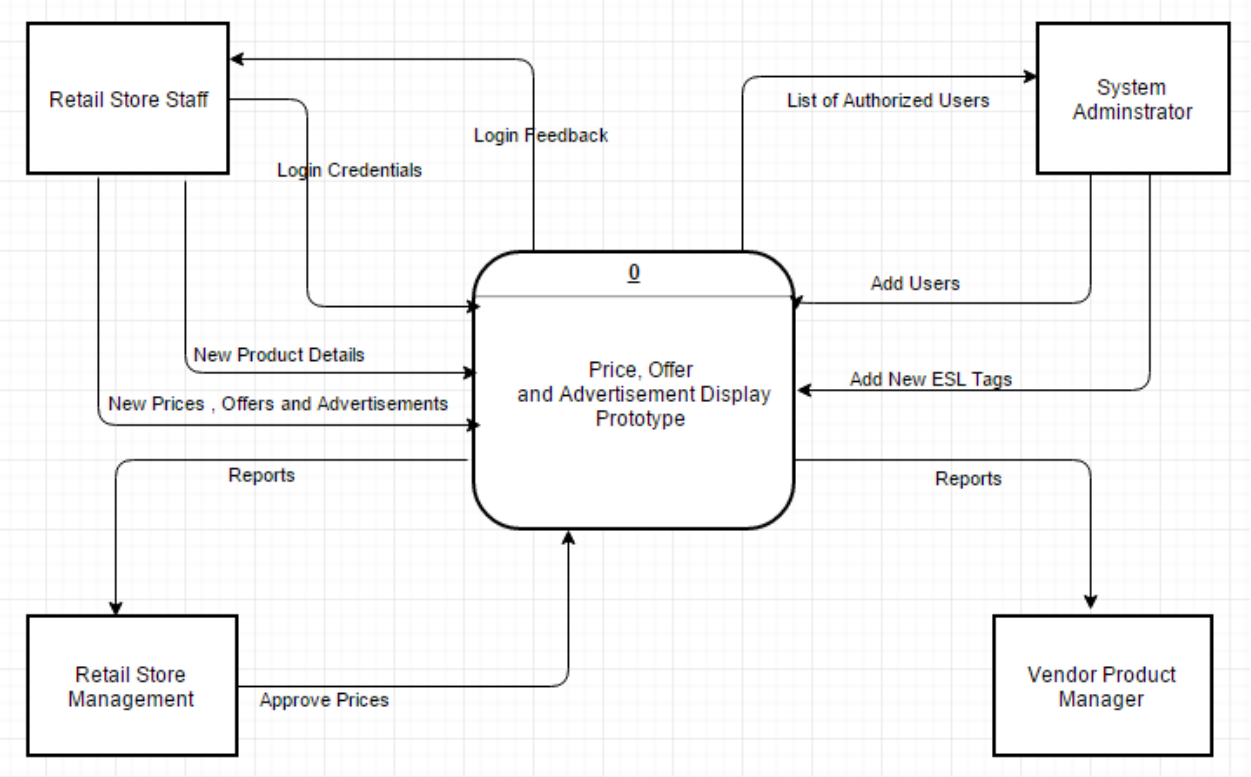

Figure 4.14: Context Level Diagram

b) Level 0 Diagram

As illustrated in the context diagram in Figure 4.14, the major processes involved in price and product information updating are as explained below.

i. Managing users

The managed users include the store staff and managers as well as the product managers from the vendor side. This process involves creating new users and their roles, modifying and deleting the existing users.

ii. Adding Products

This process provides an interface to input new products into the system. This data includes but not limited to product name, size, colour, and packaging.

iii. Add Pricing, Offers, Promotions and Advertisements.

This process provides an interface for creating and managing pricing offers and promotions. The specific details of an offer such as discounts, durations, and type of promotion are created here. The staff specify which products are involved such as two for the price of one or buy one

and get a complimenting product free. This information is passed on to the retail store staff from the vendors. Once it has been created, it awaits approval by the store manager before being effected on the product shelf.

iv. Adding Advertisements

Here is where the advertisements are created. The designs to ensure that they fit the different types and sizes of ESL tags on the shelves. This is also where the parameters of the advertisement are set, like how long it should run, at which times during the day it should run are also defined here.

v. Price, Offer and Advertisement Approval.

Once the prices, offers and advertisements have been created, they have to be vetted by the store management before approval. Once they have been checked for accuracy and approved, they can then be sent to the display tags on the shelves.

vi. Preparing Reports

The system administrator and/or the managers enter the desired report dates. This is followed a selection of the report category and sub-category, if necessary, and clicking the ‘view report’ button. This process extracts reports of current product prices, offers and promotion information such as dates, offer pricing and products on offer. It also can also bring up reports on adverts, durations they ran and products involved which can be useful to the product mangers form the vendor side. All these processes have been summarized and represented in Figure 4.15.

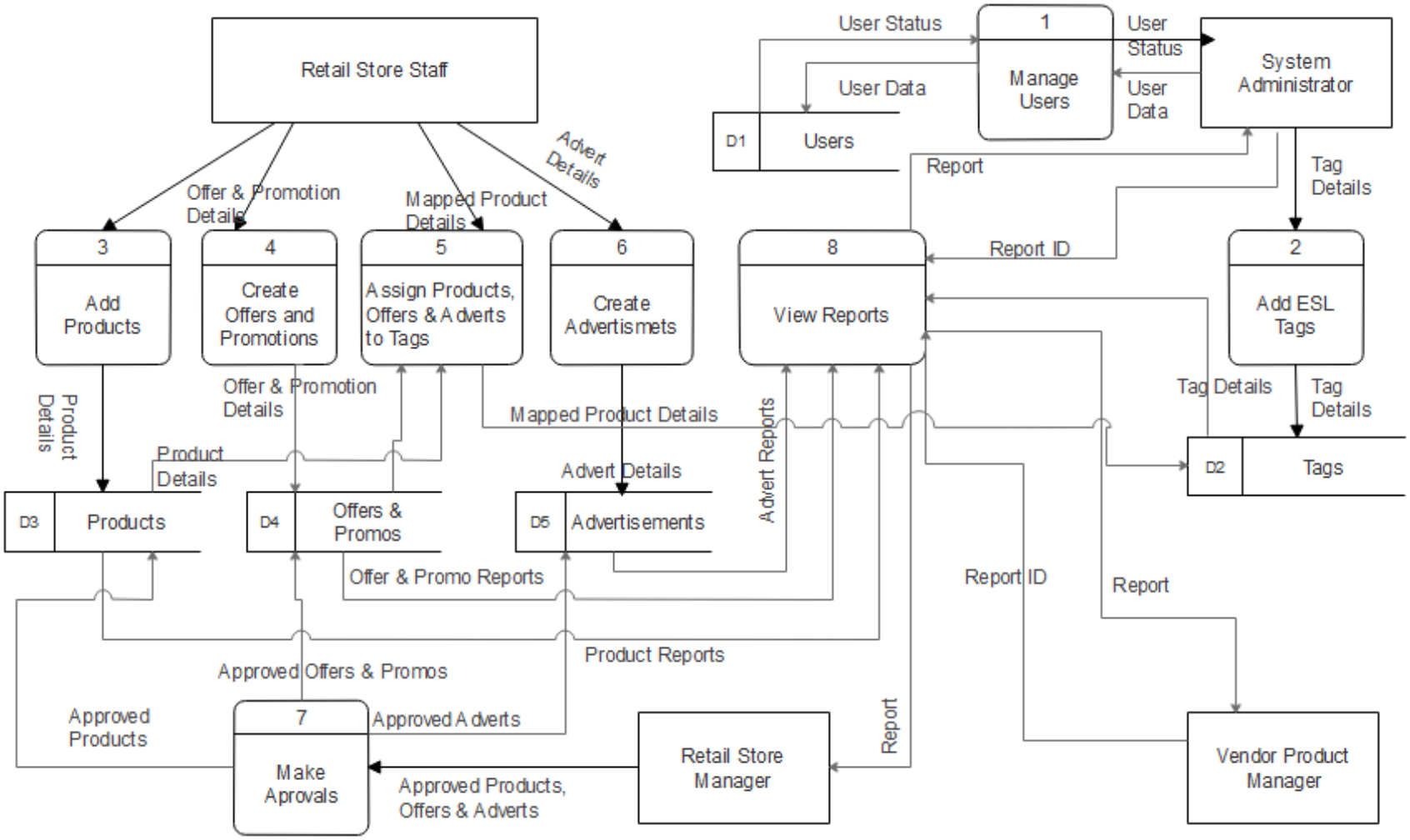

Figure 4.15: Level 1 Data Flow Diagram

4.4.2 Use Case Modeling

A use case is simply a list of actions, which typically define the interactions between an actor and the system with an aim of achieving a certain goal. Each interaction is a single unit of work and captures a "contract" for the behavior of the system under discussion to deliver a single goal (Kettenis, 2007). Most of the functional requirements are captured by the use case. Figure 4.16 presents a graphical representation of these interactions.

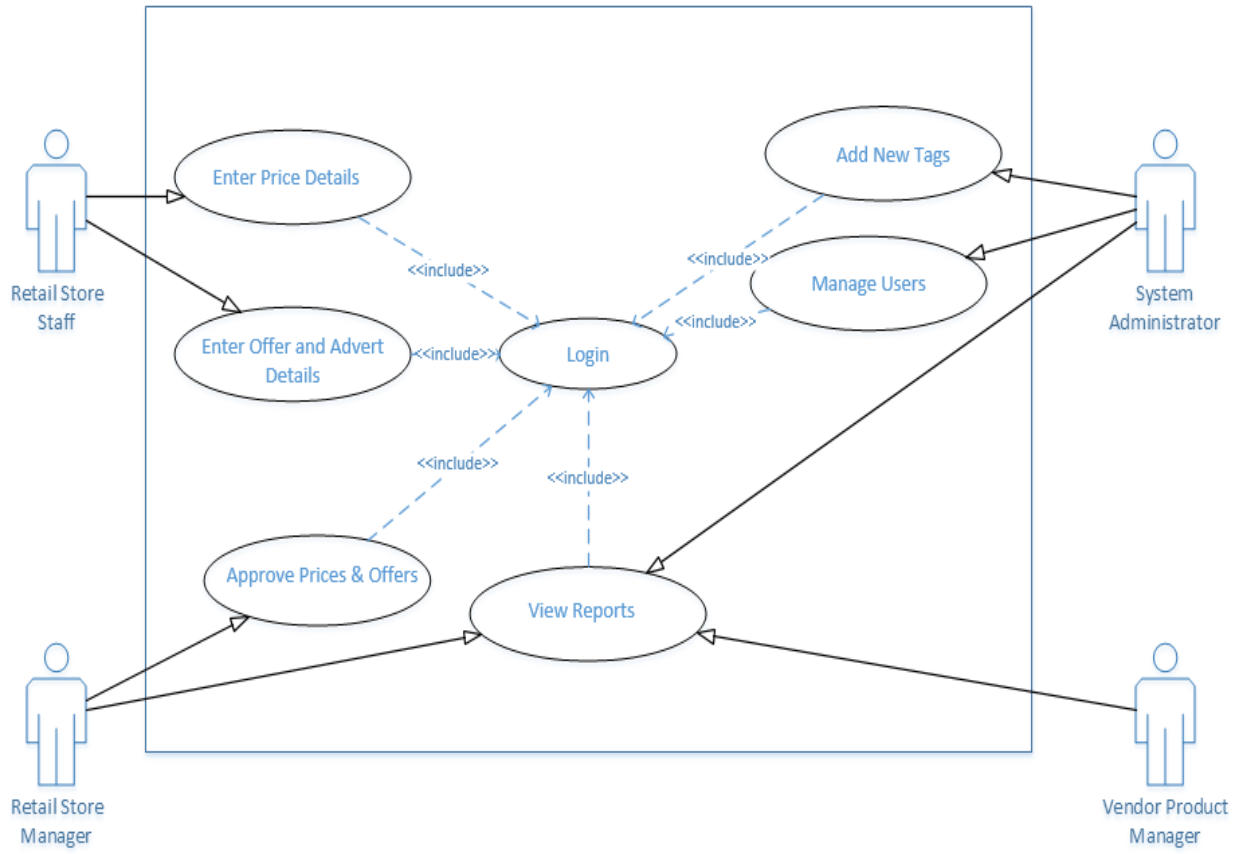

Figure 4.16: Use Case Diagram

These use case can be summarized and represented in a tabular format. Table 4.1 shows the major use cases and the actors in this system.

Table 4.1: The Main Use Cases

Actor	**Use Case**
System Administrator	Manage Users Add New Tags
Retail Store Staff	Enter Product & Price Details Enter Offer & Advert Details
Retail Store Manager	Approve Prices & Offers View Reports
Vendor Product Manager	View Reports

The user management use case deals with registering, updating, deleting as well as setting the status of their accounts as either active or inactive when needed and is done by the system administrator. User registration involves inputting the new users' personal details, their roles, their organizations and where they are located. An update involves selecting the desired user, clicking the 'edit' button, supplying updated details and clicking the 'update' button. Deletion removes the selected user from the list of users. Only the users with active accounts are allowed to login into the system. The use case is shown in Table 4.2.

Table 4.2: Manage Users Use Case

ID	**UC1**
Title	Manage Users
Description	Register, update and delete users
Actor(s)	System Administrator
Pre-conditions	The system administrator is logged in
Post-conditions	Users successfully added/updated/deleted
Main success scenario	i. The admin enters the data for the new person; or selects the desired person and click "save". ii. In case of an update, the user click on "edit" button, enters the new data and clicks "update"

The adding of new tags use case involves adding new tags to the system, assigning them to base stations and assigning them to sections/shelves that they shall be attached. The serial number of each of the tags is used as a unique identifier to be used in the allocation of the tags to various locations in the store. A summary of this use case is shown in Table 4.3.

Table 4.3: Adding New Tags Use Case

ID	**UC2**
Title	Adding New Tags
Description	Adding and allocating Tags
Actor(s)	System Administrator
Pre-conditions	The system administrator is logged in
Post-conditions	Tags successfully added
Main success scenario	i. The admin enters the data for the new tag; or selects the desired tag and click “save”. ii. In case of an update, the user click on “edit” button, enters the new data and clicks “update”

The add product and price use case is a use case for the retail store staff. The products attributes such as name, quantity, colour, and packaging are all added to the system. The retail store manager then adds the pricing to the product to await approval before they can be sent to the respective display tags. Table 4.4 represents this add products and prices use case.

Table 4.4: Adding Product and Price Details Use Cases

ID	**UC3**
Title	Adding Products and Prices
Description	Adding Products and product pricing
Actor(s)	Retail Store Staff
Pre-conditions	The staff member is logged in
Post-conditions	Product and Prices successfully added
Main success scenario	i. The staff enters the data for the product; or selects the desired product and click “save”. ii. In case of an update, the staff clicks on “edit” button, enters the new data and clicks “update”

The add offers and advertisements use case is follows a similar procedure to the adding a product use case. The staff member creates the offer or advertisement, adds its specific attributes like duration, associated imagery and numbers involved. Table 4.5 represents this add products and prices use case.

Table 4.5: Adding Products and Pricing Use Case

ID	**UC4**
Title	Adding Offers and Advertisements
Description	Adding Offers and Advertisements
Actor(s)	Retail Store Staff
Pre-conditions	The staff member is logged in
Post-conditions	Offers and Advertisements successfully added
Main success scenario	i. The staff enters the data for the offer or advert; or selects the desired offer and clicks "save". ii. In case of an update, the staff clicks on "edit" button, enters the new data and clicks "update"

After products, pricing, offers and advertisement the retail store manager has to approve them before they are assigned to a display tag. The manager checks that the correct details have been assigned to the products. The manager also checks that the offer details are correct and they have been assigned to the right product. If there is an error, the manager passes approval on the specific item until the store staff have made the necessary alterations. Table 4.6 summarizes this process.

Table 4.6: Approving Product, Pricing, Offers and Adverts Use Case

ID	**UC5**
Title	Approving product prices offers and adverts
Description	Approving product prices offers and adverts
Actor(s)	Retail Store Manager
Pre-conditions	The staff member is logged in
Post-conditions	i. Retail Manager is successfully logged in ii. Products, Prices, Offers and Adverts have been approved
Main success scenario	i. The manager approves the product pricing and offers

The use case for viewing reports is accessible by both the system administrator and the managers. However, the managers cannot extract reports on user management. Both the system administrator and the manager view reports on the product pricing, product offers and active advertisements. In order to generate a report, one has to select the main category in which the desired report is found. This is followed by an optional selection of a sub-category. Date selection

is also optional and therefore can be ignored. Once done, a ‘download’ option is availed to the user. The use case for viewing reports is shown in Table 4.7.

Table 4.7: View Reports Use Case

ID	**UC6**
Title	View Reports
Description	Reports on: i. Product Prices ii. Offers & Promotions iii. Advertisements iv. User management
Actor(s)	Management & System Administrator
Pre-conditions	i. User successfully logged in ii. Products and prices updated iii. Offers and Promotions updated iv. Advertisements updated
Post-conditions	Detailed reports extracted
Main success scenario	i. User selects report category ii. User select report sub-category iii. User selects report duration iv. User clicks “view report” v. User clicks “download report” (optional)

4.4.3 Sequence Diagram

The main features of the prototype is the management of the tags used for display as well managing the product, price and advertisement information that will be displayed on the tags. Figure 4.17 shows the sequential flow of the information through the prototype, from when new display tags are added by the system admin to when they are assigned to a particular product for display.

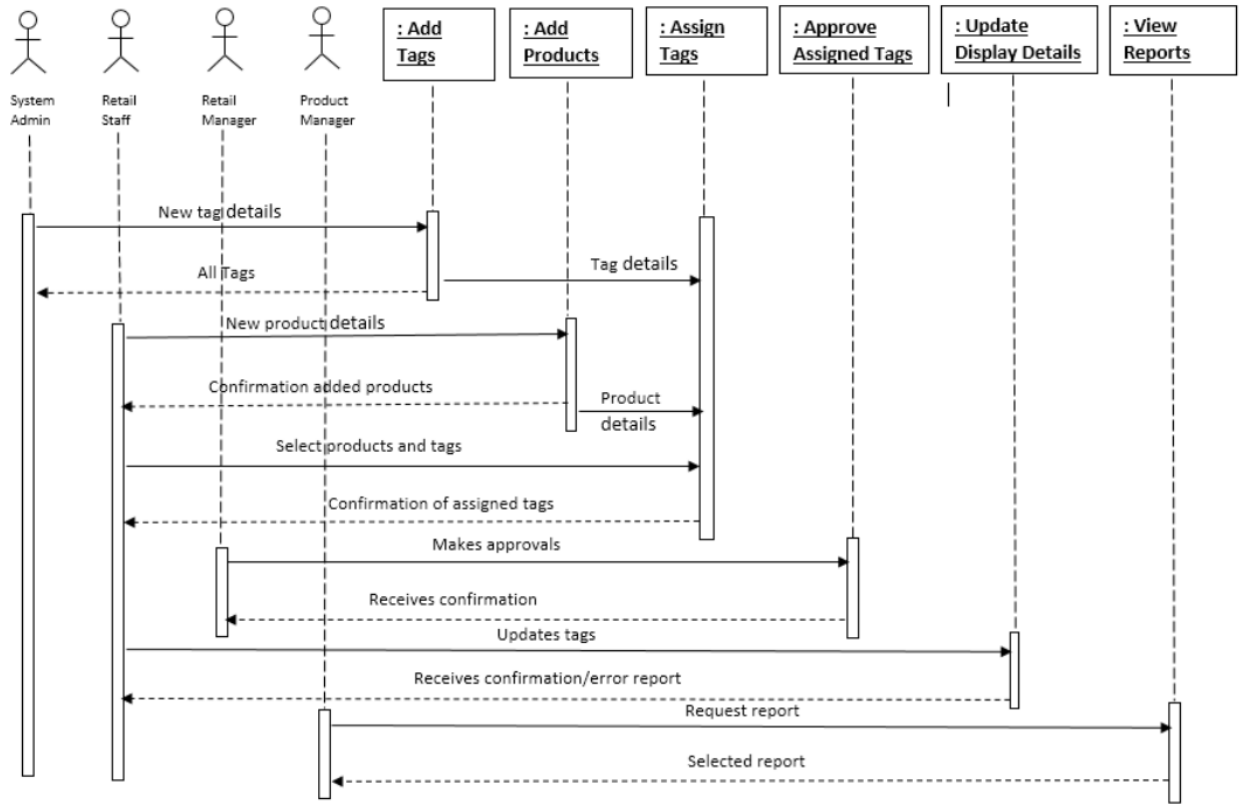

Figure 4.17: Sequence Diagram

4.5 Control Modeling

4.5.1 Entity Relationship

An entity relationship model is a high-level conceptual model, which describes data in terms of entities, their attributes and their relationships (Riccardi, 2002). The entity relationship diagram shows how is represented and organized in the database schema without specifying the actual data (Pagh, 2006).

The system administrator has the user id attribute as the primary key. The relationship between the system administrator and the user is one to many. This shows that one system administrator can manage more than one entity user.

The user entity has username attribute as the primary key. The entities retail store manager, vendor product manager and retail staff borrow attributes from user. These borrowed attributes include name, username and password. The three have “ISA” relationship with the entity user.

ESL Tags have a unique Esl id as well as shelf attributes to identify the location that they will be placed. The relationship between the system administrator and the ESL tags is a one to many relationship. This means that one system administrator can add many ESL tags to the system.

Products have several attributes, which describe them. Their relationship to the retail staff is a many to many relationship. This means that one or more retail store staffers can create or edit one or more products. The product id is the key attribute, with other attributes including product name, packaging, quantity, colour among others the product name.

Adverts have a similar relationship with retail store staff, with one or more staffers able to create one or many adverts. The advert id is key attribute, with other attributes including the advert name, duration and type. Entity report has date, details and report id as its attributes. The report id is the primary key. Considering the relationship between entities system administrator and report, one system administrator can view one or more reports. One or more managers can also view one or more reports. As shown in the one to many relationship. Figure 4.18 illustrates how entities in the price and adverts display prototype interact with each other.

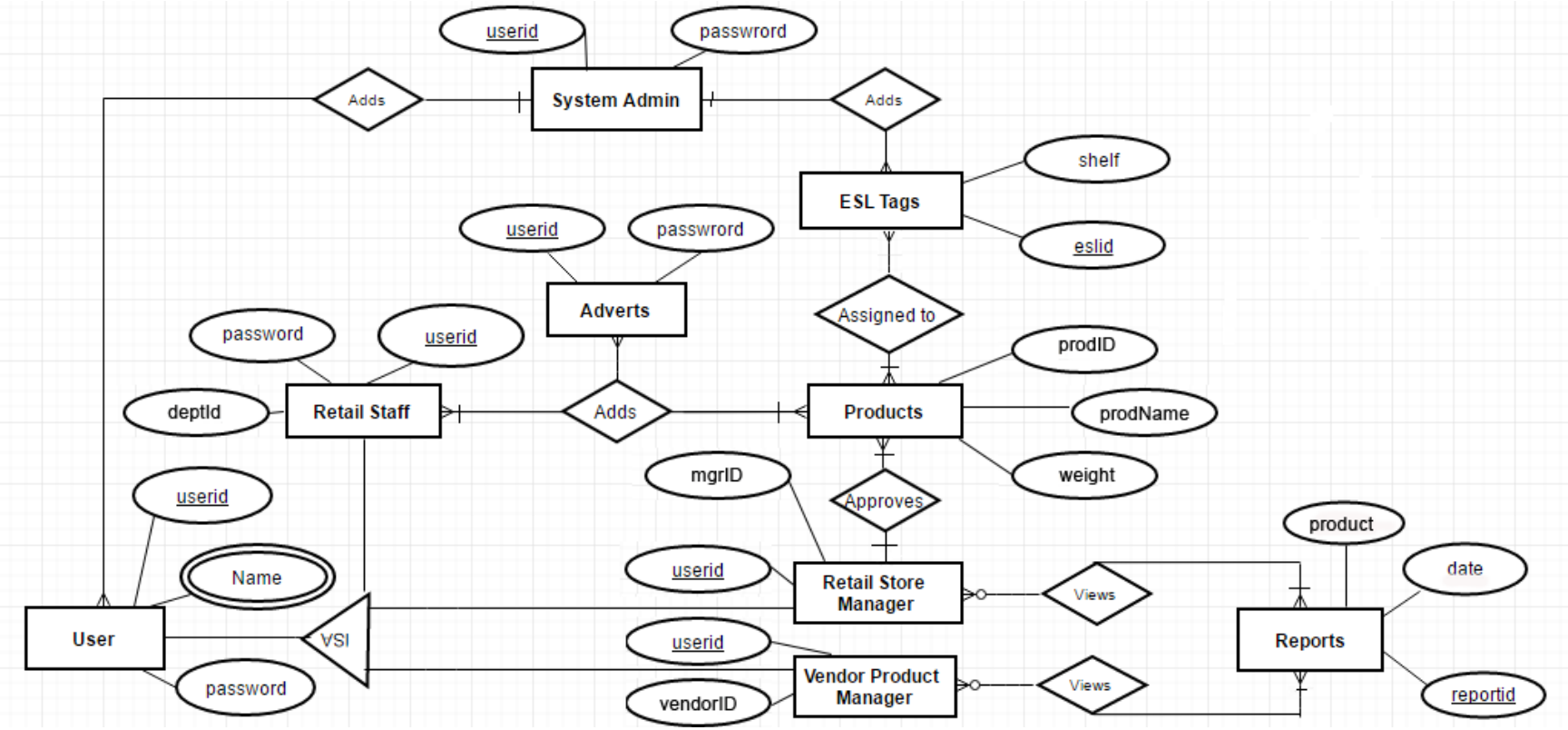

Figure 4.18: Entity Relationship Diagram

4.5.2 Class Diagram

A class diagram provides a pictorial representation of all the classes in an object-oriented system; their attributes and methods; their connections; their interactions and inheritances if any. In simpler terms, classes represent objects whose roles are similar and to what extend the objects of the classes "know" about each other (Felici, 2011).

The system administrator can login, add one to many new users, modify the existing and log out. The system administrator can also view one or more reports. They can finally also add one or many ESL tags. Retail store staff, Retail store managers and Vendor product managers are all users. They inherit attributes; and login and log out functions from the superclass "user". In addition to the inherited functions, one retail store staffer can add one or many products and adverts. One or more retail staffers can assign products and adverts to one or more ESL tags after the retail store manager has approved them. One or many vendor product managers and retail store managers can view zero or more reports. Retail store managers can also approve newly added products and adverts. This is illustrated in Figure 4.19.

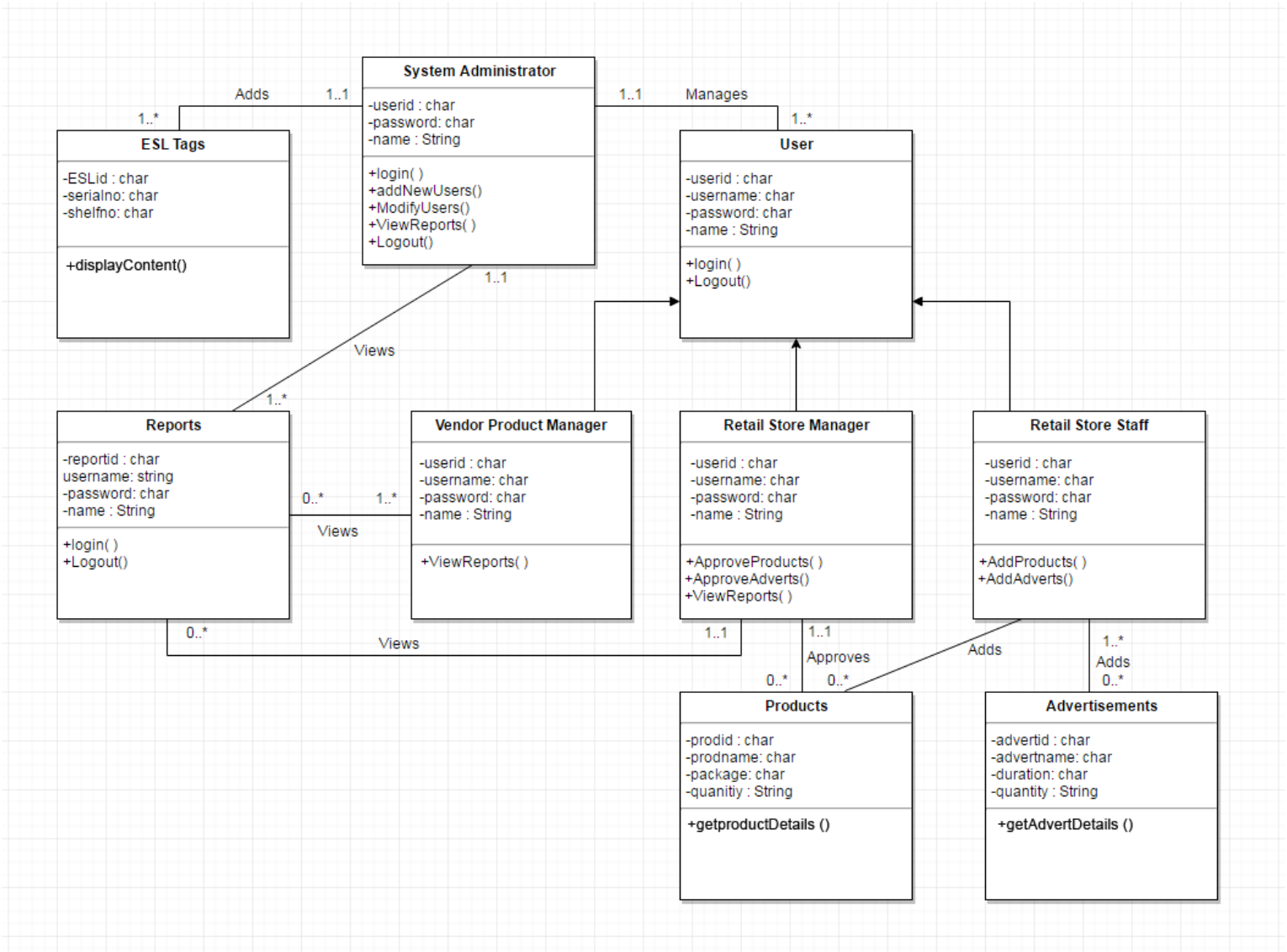

Figure 4.19: Class Diagram

4.6 The Prototype Architecture

The architecture for this prototype is divided into four major components. These include the user interface, the internet/intranet/extranet access, application server and the database server.

The user interface is accessible using a web browser. The users can interact with the system through these interfaces. These are open to any standard browser such as Mozilla Firefox, Google chrome, internet explorer and opera among others. The internet access offers the channel for data transfer from the client browser to the server side. For this case, vendor product managers from outside the retail store organization use the extranet to provide a secure connection for authorized access. Standard protocols like TCP/IP are used here.

The system uses IIS as the web server. The PHP functions are executed at this level. The implementation of the chosen algorithms takes place at this stage and rendered to the user interface using HTML and CSS. Search rules are also generated at this point in the knowledge acquisition facility.

Data storage is achieved using a robust relational database. Set functions here generate views from which the reports are retrieved. This architecture is illustrated in Figure 4.20.

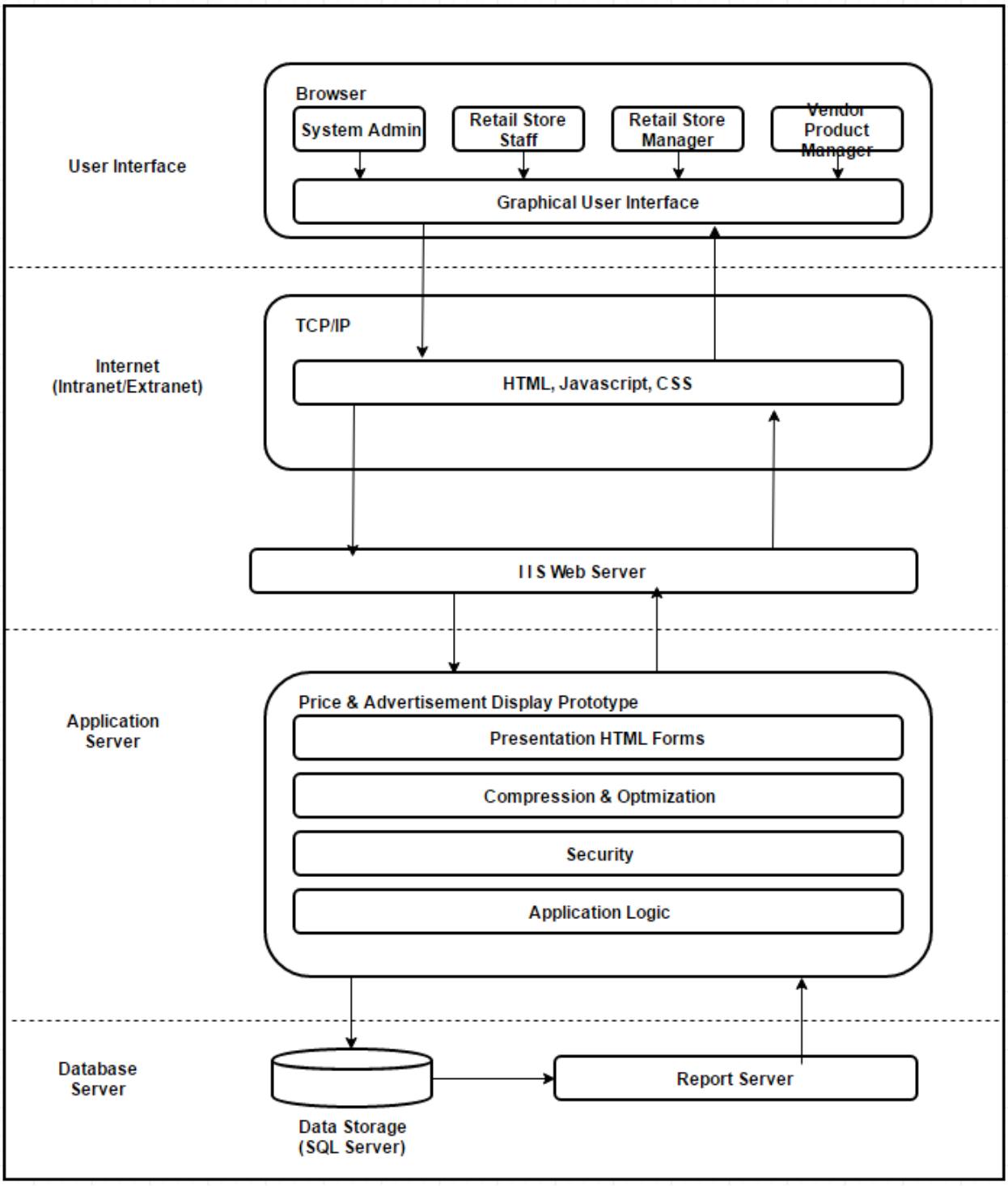

Figure 4.20: Price and Advertisement Display Prototype Architecture

Chapter Five: System Implementation and Testing

5.1 Introduction

This chapter focuses on the implementation and testing of the prototype using the design in chapter four. The prototype was developed using C#, HTML, CSS, JavaScript and Microsoft SQLSERVER database. The C# was used to execute the logic and core system functionality. This includes adding ESL tags, Products, product pricing, advertisements as well as assigning them to specific tags. The HTML and CSS come into play in design of the presentation layer, which is the user interface that end users will use to carry out tasks with the prototype. JavaScript is used for validation and ensuring that the system is dynamic. The Microsoft SQLSERVER database is used to store the data and information necessary for prototype operation.

5.2 Prototype Implementation

Figure 5.1 below shows the implementation of the ESL prototype in a typical retail environment.

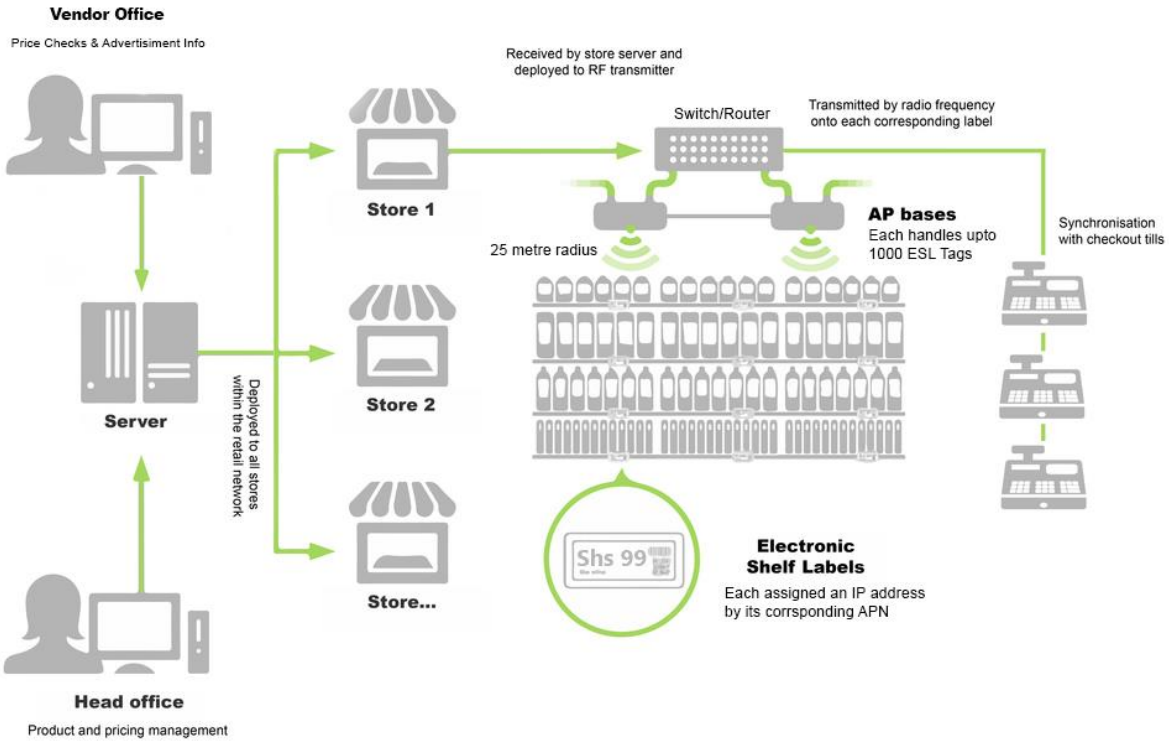

Figure 5.1: Prototype implementation diagram

The ESL Management prototype is located on the server at the head office or in the individual retail stores depending on the requirements of the specific retail chain. The switch/router acts as an intermediary between the server running the software and the APNs that will communicate directly to the ESL tags. It also is used to allocate the IP addresses for all the devices depending on the total number of APNs and ESLs needed in the store. Each APN is designated a specific set of ESLs to handle to ensure a shared workload and ease of maintenance. The ESLs deployed use e-ink technology and have a unique identifier to enable easy location when an update is necessary.

5.3 Program Flow

The system administrator is responsible for adding all other users as well as new ESL tags to the system. After a store staffer successfully logs in, they can either enter details of a new product, edit details of an existing product or assign products to specific ESL tags pending approval that will be sold at the retail store. The store manager's role is to approve product detail updates and changes before they are sent to the ESL tags to ensure validity and verifiability of any alterations. The vendor product manager has access to the system to ensure that pricing for their specific products is correct and up to date, as well as check other details such as running advertisements, offers and promotions.

5.4 Server Requirements

5.4.1 Hardware Requirements

Table 5.1 highlights the minimum hardware requirements for the computer that will run the proposed system.

Table 5.1: Hardware Requirements

Hardware	**Minimum Requirements**
Processor	Intel Core i3
Disk Space	5GB
RAM	8GB

5.4.2 Server Software Requirements

The system requires a specific software environment to run efficiently. The minimum software specifications are summarized in table 5.2.

Table 5.2: Server Software Requirements

Software	**Minimum Requirements**
Server Operating System	Windows Server 2012
Client Operating System	Windows XP/Vista/7/8/10
Web Server	Internet Information Server (IIS) Webserver
Web Browser	Chrome 32+, Firefox 3+, Internet Explorer 6+
Database Management System	SQLSERVER

5.5 Users, Roles and Access

The system is designed to have role-based access. This not only separates the tasks and duties to be undertaken by certain user groups but also provides a layered approach to security and verifiability. The four user roles that were used were; the system administrator, retail staff, retail store manager and vendor product manager. These roles were granted varying privilege levels based on the different tasks that each user would be carrying out with the system and level of access required to fully undertake them.

5.5.1 System Administrator

The prototype's interface is accessed through a web portal and requires user authentication. The system administrator is responsible for registering all other users, namely the retail staff, retail manager and the vendor product manager. They also are in charge of adding new ESL tags to the system and making them available to other users to be assigned product information. They also view reports and logs that pertain to system functionality to ensure that all tasks are carried out correctly and completely. In addition to these, the system administrator also has access to the roles of the other users of the system, meaning that they can carry out all the tasks that are assigned to those various roles as well.

5.5.2 Retail Staff

The retail staff are responsible for adding new product and advertisement details, updating existing products and advertisements as well as assigning these product details to ESL tags pending approval from the retail store manager. They have access to information regarding ESL tag locations in the store, which tags have been assigned a particular set of information as well as those that are unassigned. With this information, they are able to correctly and efficiently select the tags that they wish to push information to with ease.

5.5.3 Retail Store Manager

The main function of this role is to make approvals on changes and updates made by the retail store staff. This creates a ‘maker checker’ principal of authorization where two individuals are required for a change to be effected. They ensure that the price, offer or advertisement information that the retail staff wants to be sent to the ESL tags is accurate before granting approval. They also have access to reports such as who made which changes and reports on offers and advertisements.

5.5.4 Vendor Product Manager

This user is supposed to have access to vendor specific products in order to check whether the products that they are responsible for are currently listed at the right price, advertisements and offers are running for the correct period with the correct details. They can view reports on offers and advertisement as well as prices.

5.6 Sample Code

The major functions of this prototype are the real-time creation and update of price and advertisement information. Price and product information can be created individually or imported from a file in order to populate all the various products, quantities, packaging, pricing and other various pertinent information. Once this information is stored, it can then be assigned to an ESL tag that is on the corresponding shelf where the products are on display. Figure 5.2 shows a snippet of code in the function that is used to assign a product to an ESL tag. The ESL tag and product details have already been added to the system so this function enables the user to select the product from a dropdown list then chose which tag(s) they wish this product information to be displayed on.

```
<div class="form-horizontal">
    <hr />

    @using (Html.BeginForm())
    {
        @Html.AntiForgeryToken()
        @Html.ValidationSummary(true)
        <div class="form-group">
            @Html.LabelFor(model => model.Products, new { @class = "col-lg-2 control-label" })
            <div class="col-lg-10">
                @Html.DropDownListFor(m => m.ProdId, new SelectList(Model.Products, "Value", "Text")
                @Html.ValidationMessageFor(model => model.ProdId)
            </div>
        </div>
        <hr />
        <div class="form-group">
            <div class="col-lg-10">
                <table class="table table-striped table-hover">
                    <tr class="info">
                        <th style="white-space:nowrap;">Tags Selected</th>
                        <th style="white-space:nowrap;">Count</th>
                    </tr>
                    @for (int i = 0; i < Model.TagsList.Count; i++)
                    {
                        <tr>
                            <td>@Model.TagsList[i]</td>
                            <td>@i</td>
                        </tr>
                    }
                </table>
            </div>
        </div>
        <hr />
        <div class="form-group">
            <div class="col-lg-offset-2 col-lg-10">
                <input type="submit" value="Create" class="btn btn-success" />  
                <span class="btn btn-danger">@Html.ActionLink("Cancel", "Index")</span>
            </div>
        </div>
    }
</div>
```

Figure 5.2: The Assign Product to Tag Code

5.7 Sample Forms Used

To enable users to have access to the prototypes functionality, several web-based interfaces were built, each corresponding to a specific functionality. They were broadly categorized into Admin Functions, System Configurations, Manage Prices & Offers and Reports.

5.7.1 Admin Functions

The Admin Functions section is where all the core functions of the system are configured and maintained. It is further subdivided into Manage Stakeholders, Manage Users, Manage Parameters, System Audit, Admin Audit and Error Log as shown below.

- Manage Stakeholders – Where new vendors are added and maintained.
- Manage Users – where users of different types are added and provided access rights
- Manage Parameters – where system parameters are set
- System Audit – where audit logs on users' products and stakeholders can be viewed
- Error Log – where all errors that occur on the system are logged.

The user management interface provides a way of registering, displaying and modifying the system users. The system administrator enters the required details in the provided fields and saves the information. The prototype validates the data fields to ensure the date is in the correct format before saving the data in the database. The system administrator can also modify or delete existing users from this interface. The user management interface is shown in figure 5.3 below.

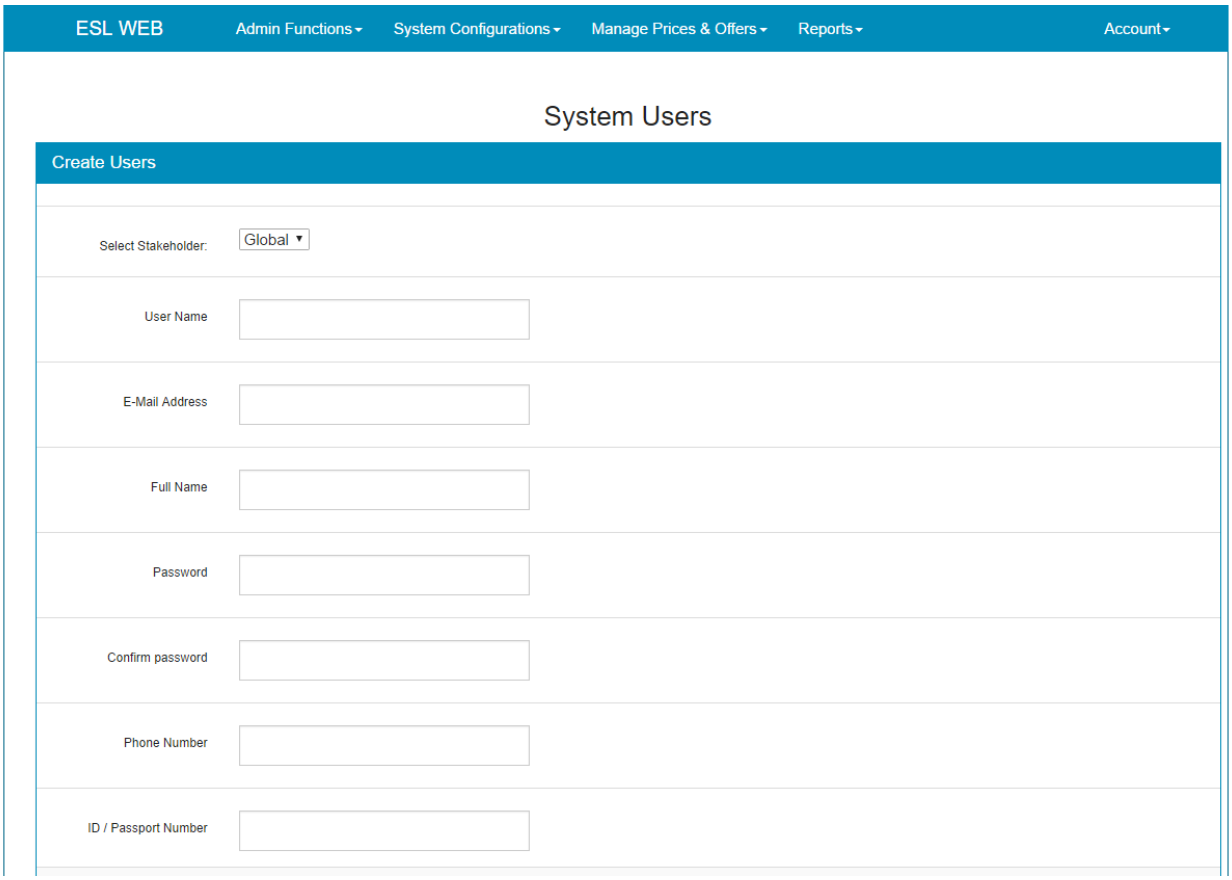

Figure 5.3: User Management Interface

5.7.2 System Configurations

This is the section where the retail functions of the system are configured and maintained. This menu is further divided into Units, Quantity, ESL Tags, Offers and Products.

- Product Unit - where various units are managed e.g. packet, can, bottle, sachet, and bag
- Quantity - where quantities are maintained e.g. ml, kg, g, pack etc.
- ESL Tags - where new tags are added to the system.
- Offers - where offers are created and maintained
- Product - where the actual products are added.

All the interfaces in this section are similar in structure since it is focused with mainly addition of the various core components of the prototype. The attributes are filled in the various data fields and saved in the respective tables in the database. The product interface lets you select the vendor, quantity, barcode type and input other necessary details. Figure 5.4 below highlights the products maintenance process.

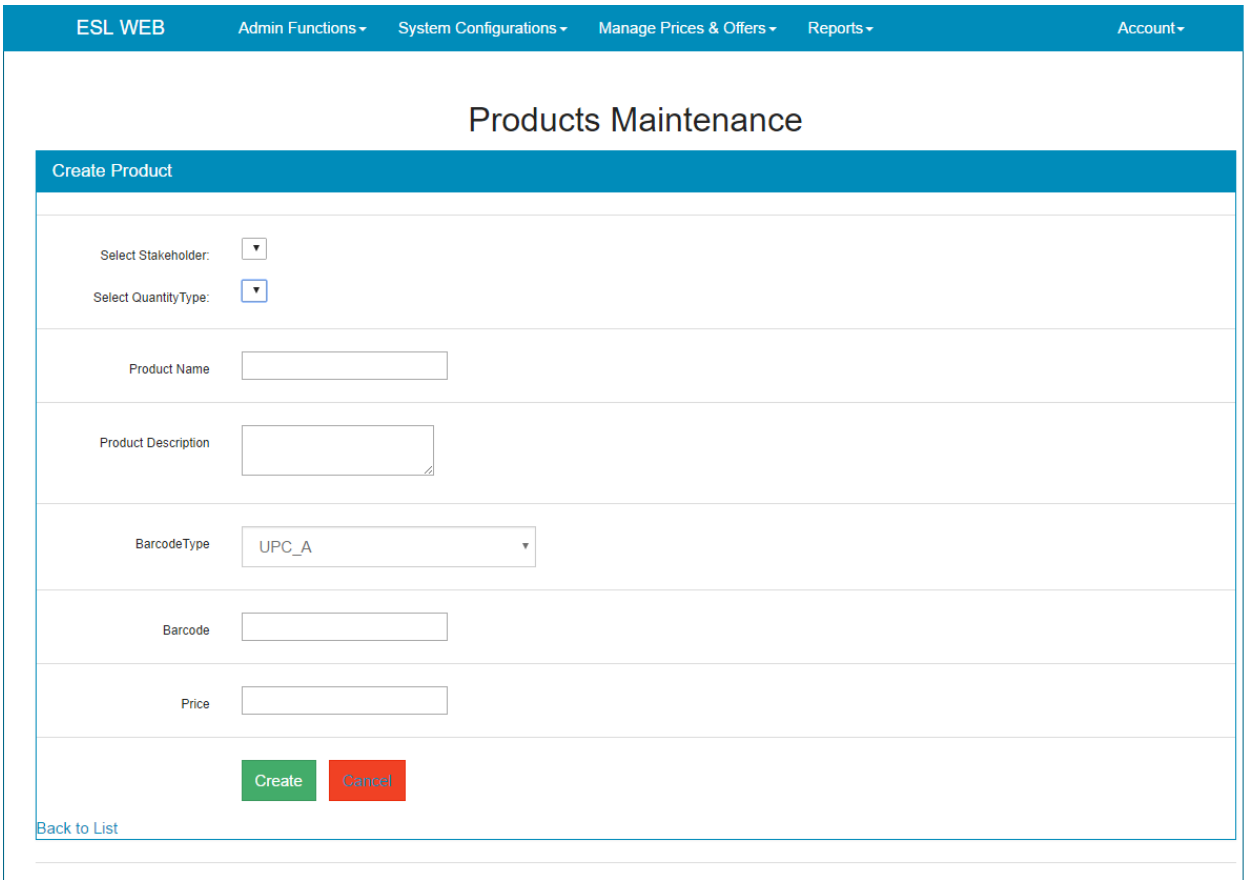

Figure 5.4: Product Maintenance Interface

The offer interface is where all promotions, advertisements and offers are created. Details pertaining to the offer are input including a brief description and the period it should run. An image designed to run on the ESL tags is also uploaded in this interface. Figure 5.5 shows the details that are captured on the offer maintenance interface.

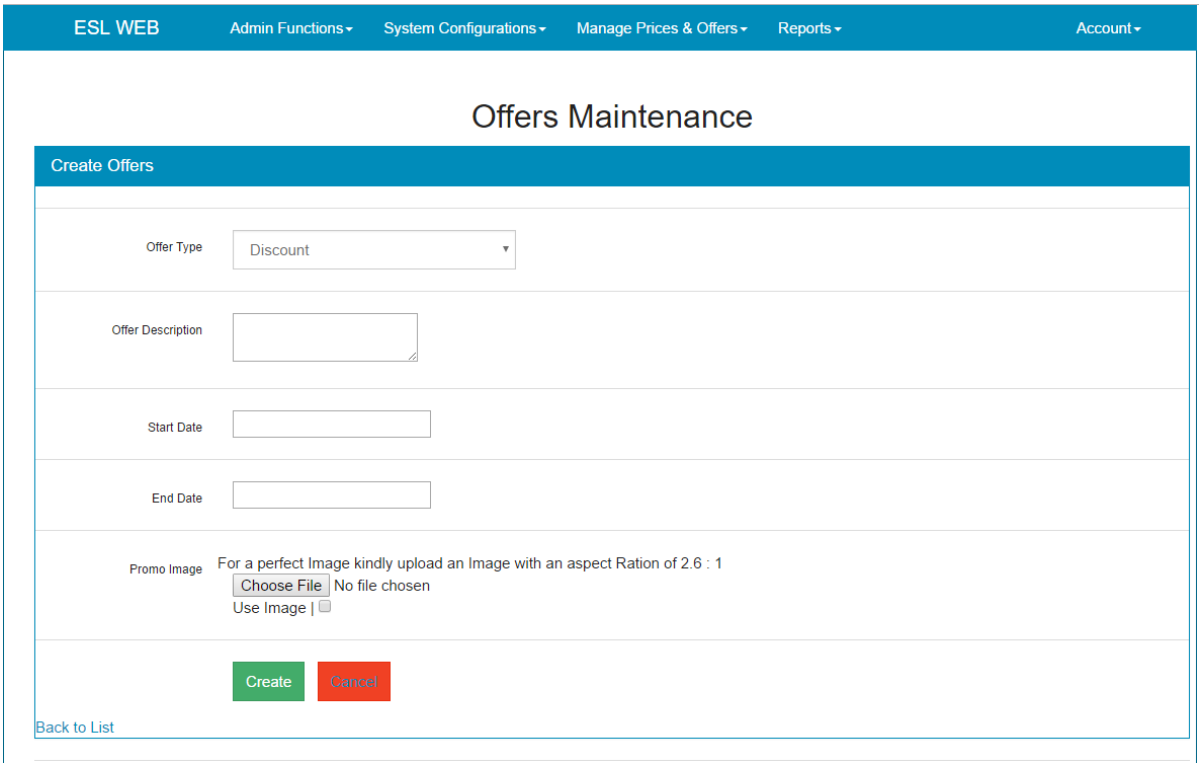

Figure 5.5: Offer and Advertisement Management Interface

5.7.3 Manage Prices and Offers

This is the interface where the products and offers are made active and assigned to ESL tags on the shelves. Product details are assigned to tags that are placed on specific shelves containing the corresponding product. If there are any offers pertaining to that product, they are also assigned in this section. It is divided into Products and Tags, Products and Offers, View Assigned Tags and View Assigned Offers as shown in the figure below.

- Products and Tags – where products details are assigned to specific ESL tags
- Products and Offers – where offers are assigned to a product
- View Assigned Tags - view all the tags that are assigned to products
- View Assigned Offers – view all the offers assigned to products.

The product and tags interface is where ESL tags are assigned products. Once a retail staff member clicks on the assign tag button, a list of all the products is brought up for them to choose. A product can be assigned to one or more tags depending on the shelf size and product location. The same goes for offers and advertisements, once the products and offers have been assigned, the retail store manager can view all assigned products and offers and once they have verified the details, they can approve them. Figure 5.6 shows the assign tags interface.

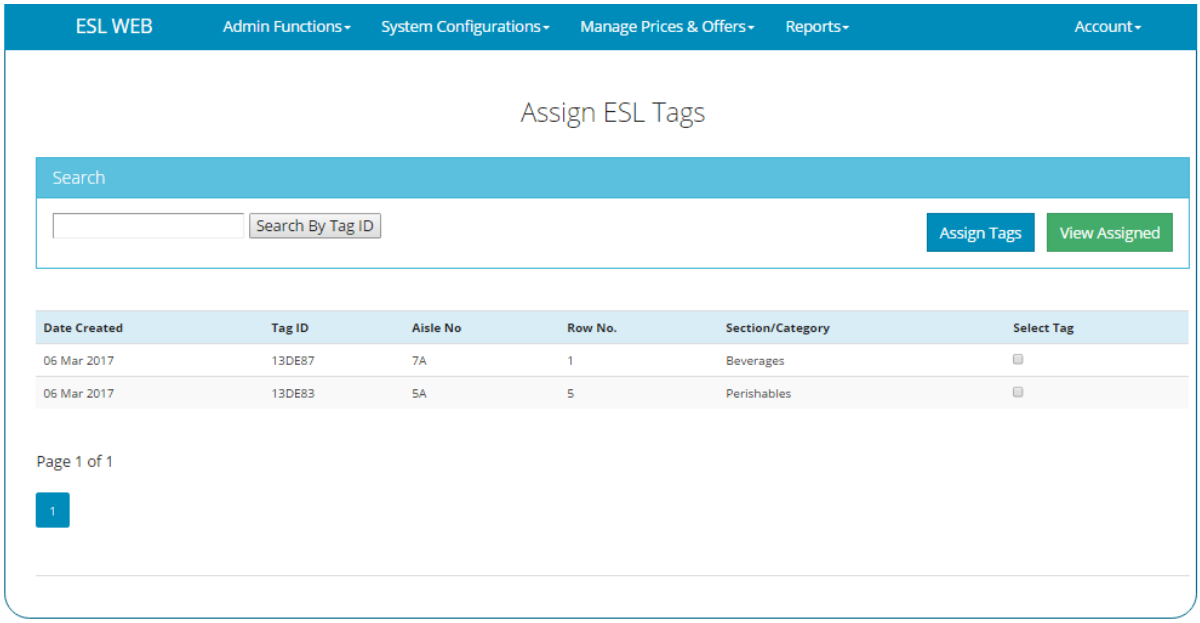

Figure 5.6: Assign Esl Tags to Products interface

The view assigned tags interface shows all the tags that have been assigned products, and which products they have been assigned. It provides a quick way to cross check what is currently on display on the tags at any particular point in time. Figure 5.7 shows how the user can check the tags from the prototype.

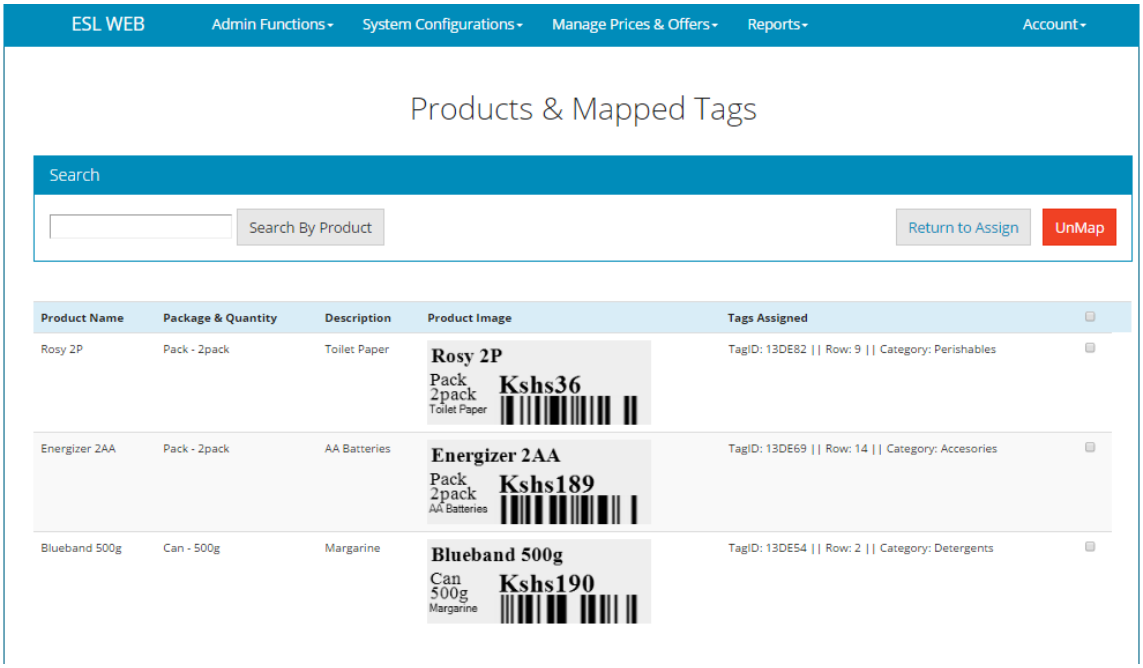

Figure 5.7: View assigned ESL Tags Interface

5.7.4 Reports

This section of the system is where reports are generated. The reports can be as ad hoc or generic as the user requires and are easy to prepare. They can be exported to excel or pdf for processing in other information systems as necessary.

5.8 Prototype Validation

The prototype has an error checking functionality, which validates user input. This dynamic validation was carried out using JavaScript. Error messages are displayed accordingly to inform the user about what has gone wrong and offer a guide on how to resolve it. Among the fields that have validation are those where a user inputs details into the prototype. In figure 5.8 below, the Product maintenance interface highlights how the prototype will not allow the user to save empty records into the database. The system prompts the user to input data into the omitted fields.

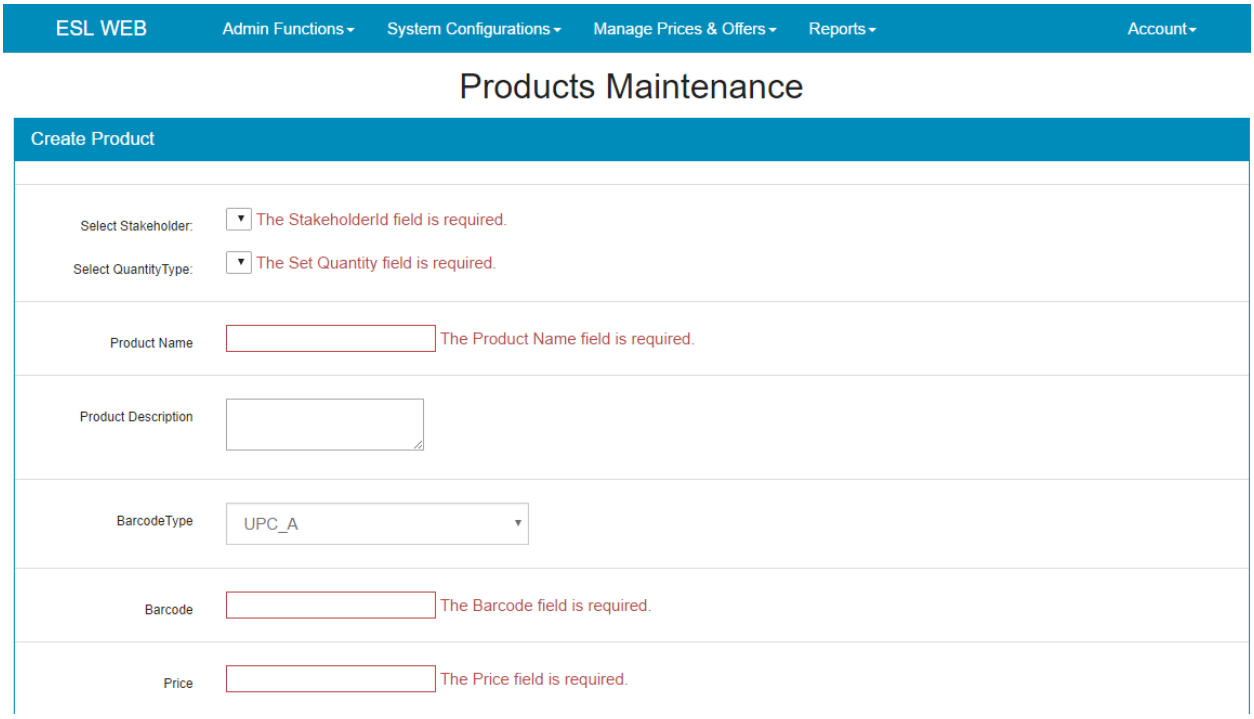

Figure 5.8: Prototype Validation (Product Details Missing)

If the user mistakenly or purposefully tries to enter data of the wrong format into the input field, the prototype warns them to enter data of the required datatype. Figure 5.9 shows what error message is prompted to the user if they try to enter characters into the price field, which requires a number.

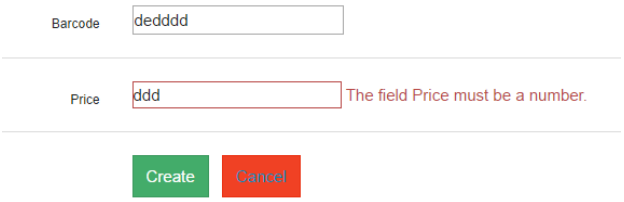

Figure 5.9: Prototype Validation (Wrong Data Format Entered)

5.9 Prototype Testing

System testing is the process of examining the behavior of the developed system based on the system requirements specified by the intended end-users (Faisandier, 2012). The test plan will comprise of unit testing, integration testing, system testing, performance testing and acceptance testing.

5.9.1 Unit Testing

Several tests were carried out to ensure that the prototype carried out its various individual functions in a satisfactory manner. A summary of some of the tests carried out is provided in table 5.3 below.

Table 5.3: Test Cases

ID	Case	Expected Outcome	Comments
1.0	**Login**		
1.1	Password or username left out	Error Prompt	Pass
1.2	Wrong username or password	Error Prompt	Pass
2.0	**User Registration**		
2.1	Leaving out a required field	Error Prompt	Pass
3.0	**Adding Product Details**		
3.1	Leaving out a required field	Error Prompt	Pass
4.0	**Adding Offers or Adverts**		
4.1	Leaving out a required field	Error Prompt	Pass
5.0	**Assigning Products**		
5.1	Leaving out a required field	Error Prompt	Pass
6.0	**Assigning Offers**		
6.1	Leaving out a required field	Error Prompt	Pass

5.9.2 Integration Testing

Once each of the units/functions are tested separately, they are combined to ensure that interactions between the integrated units also works flawlessly. This is to ensure that a new tag and product can be added, the product assigned to the tag and once approved the product information can then be displayed on the tag. The same is done for offers as well as advertisements. Integration testing also ensures that only the stakeholders that are assigned specific products have access to that products information.

5.9.3 System Testing

System testing was carried out to ensure that the fully integrated system met the specified system requirements. These included being able to seamlessly integrate with other systems in the retail store including the POS systems as well as the stock keeping systems. This would facilitate efficient update of prices when necessary as well as being able to allocate different prices to different batches of stock as ad when necessary. The prototype's ability to import and export data in various formats including .xml and .xlsx which accepted by the other systems facilitated these requirements.

5.9.4 Performance Testing

Performance tests were carried out to ensure that it met the levels specified in the user requirements. Not only was the prototype supposed to carry out tasks with faster and with greater accuracy, it was also supposed to them reliably and with consistency. After using the prototype the users were polled on it performance regarding accuracy, performance and reliability.

5.9.4.1 Accuracy

The respondents used the system to carry out price and offer updates to ESL tags over a short period, making as many changes as they wished. They would then check if their changes were accurately effected on the corresponding ESL changes. The results showed that 98% percent of the update information was correct, and the prototype noted the tags that did not display the new information and sent error logs. This is shown in figure 5.10.

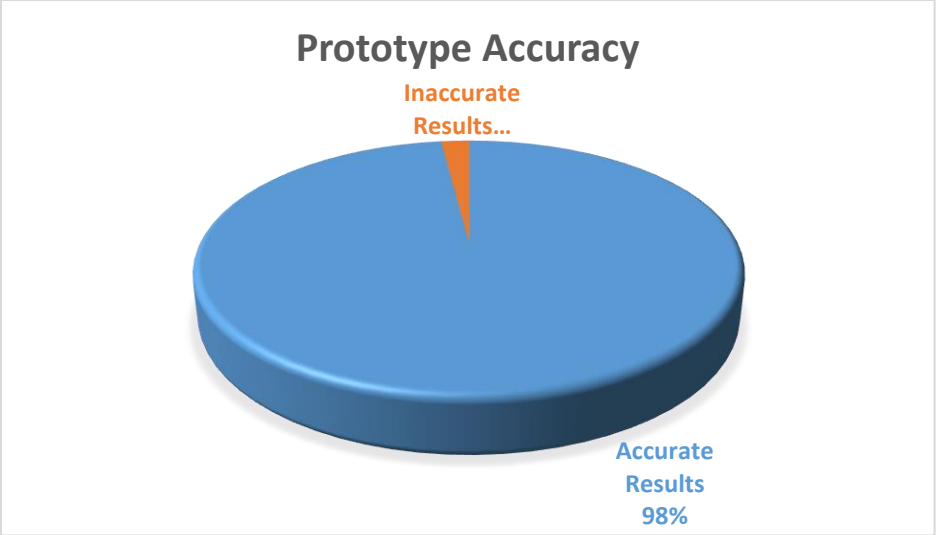

Figure 5.10: Prototype Accuracy

5.9.4.2 Performance

When polled on whether using the prototype made completion of the price and offer update faster, 52% strongly agreed while 38% agreed with the statement. 6% were neutral, 3% of the respondents disagreed while 1% percent strongly disagreed. This is illustrated in figure 5.11 below.

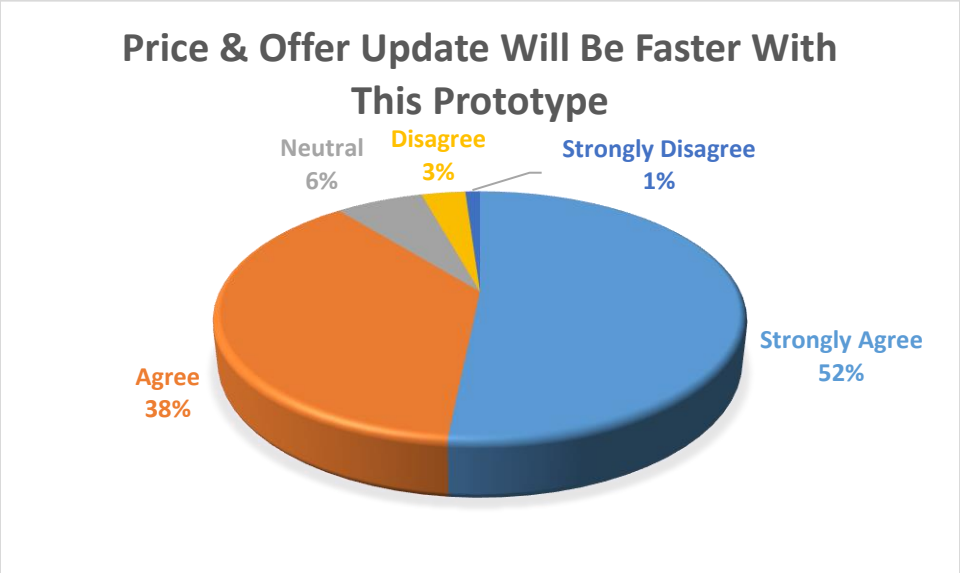

Figure 5.1: The Prototype performance is faster than current systems

5.9.4.3 Reliability

To test the reliability of the prototype respondents' willingness to use the prototype in place of current system and whether they would recommend others to use it was checked. When polled on if they would recommend the prototype to others in a similar use case, 56% of then strongly

agreed while 33% agreed. 9% were neutral with 2% disagreeing. None of the respondents strongly disagreed with recommending the prototype to others. Figure 5.12 summarizes the responses.

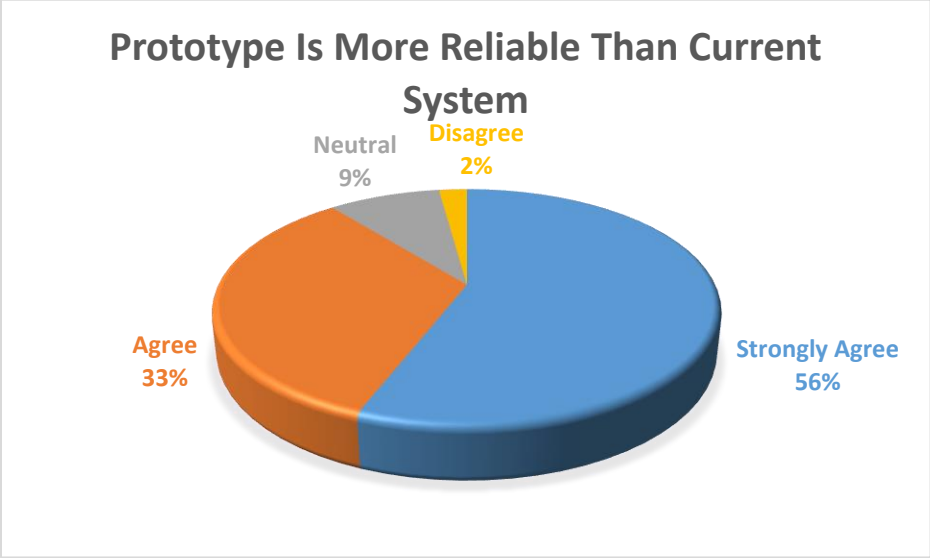

Figure 5.2: Prototype is more reliable than current system

Recommending the prototype to others returned the same results as those willing to use the prototype in place of the current system. 58% said they would very likely recommend use of the prototype while 33% said they would recommend it. 9% were undecided while 2% were not ready to recommend the use of the prototype to others. This is show in figure 5.13 below.

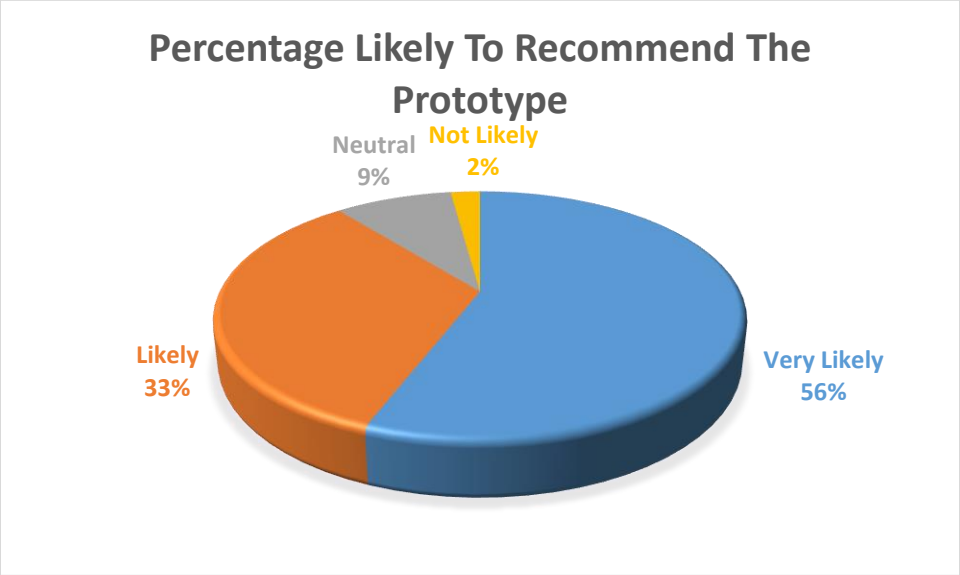

Figure 5.13: Percentage likely to recommend the prototype

5.9.5 User Acceptance Testing

The prototype was tested to ensure it reached an acceptable level of delivery in accordance to the business usability requirements. These mainly included the ease of use of the user interface, the complexity of the processes as well as convenience compared to the current systems. The prototype was given to the end users who after training were polled on the usability of the system in general.

5.9.5.1 User Interface

When asked about the user interface the respondents 43% strongly agreed that it was user friendly, with a further 34% agreeing to the same. Only 13% were neutral, with an even lower 7% and 3% disagreeing and strongly disagreeing respectively disagreeing with the sentiment of user friendliness of the interface. This is illustrated in figure 5.14 below.

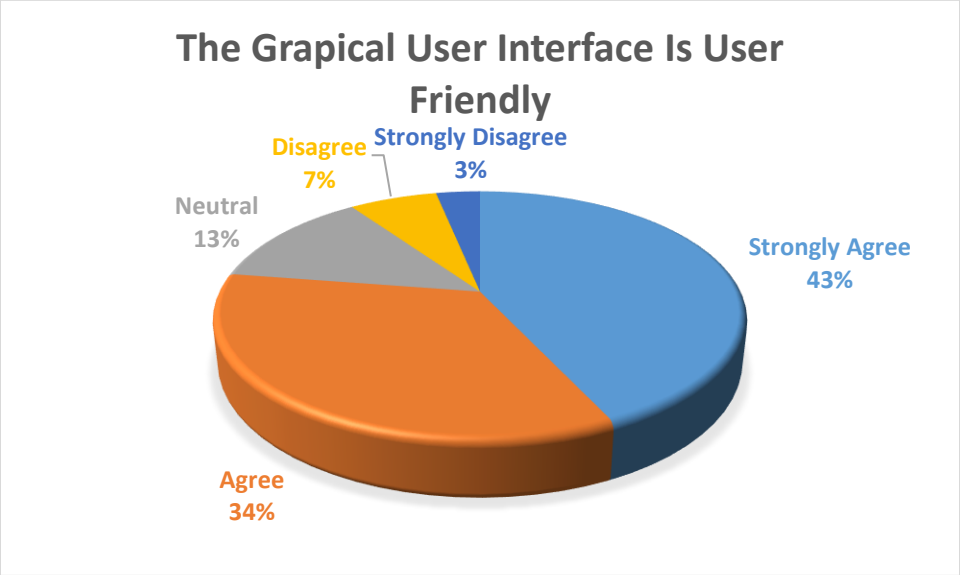

Figure 5.3: The graphical user interface is user friendly

54% and 36% of the respondents strongly agreed and agreed respectively that they were capable of using the prototype with minimum training since they said it was straightforward. 12% were neutral, 7% disagreed and 3% strongly agreed with the statement. The responses are highlighted in the figure 5.15.

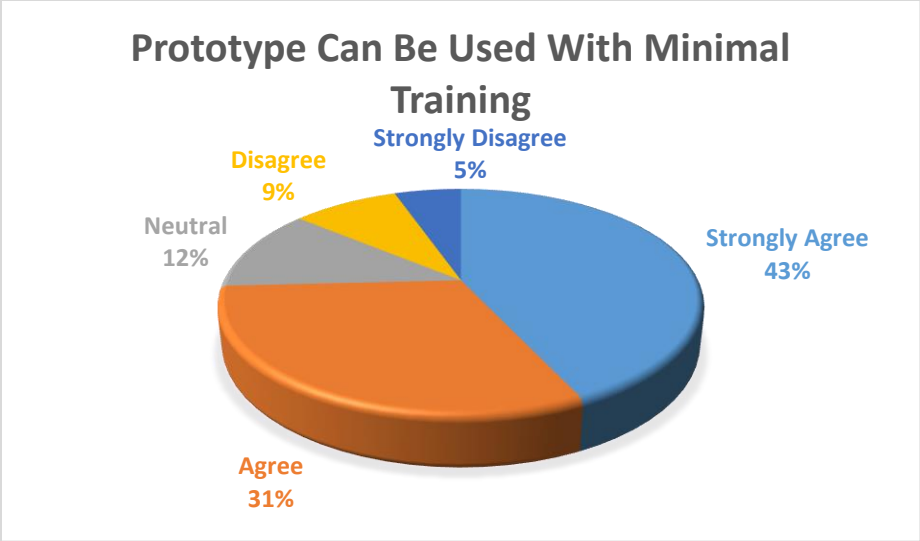

Figure 5.4: Prototype can be used with minimal training

5.9.5.2 Convenience

As shown in figure 5.16 below, 66% of the respondents strongly agreed that the prototype is convenient. 28% agreed, while 4% were neutral to that notion. Only 2% disagreed with the statement with none of the respondents strongly disagreeing with it.

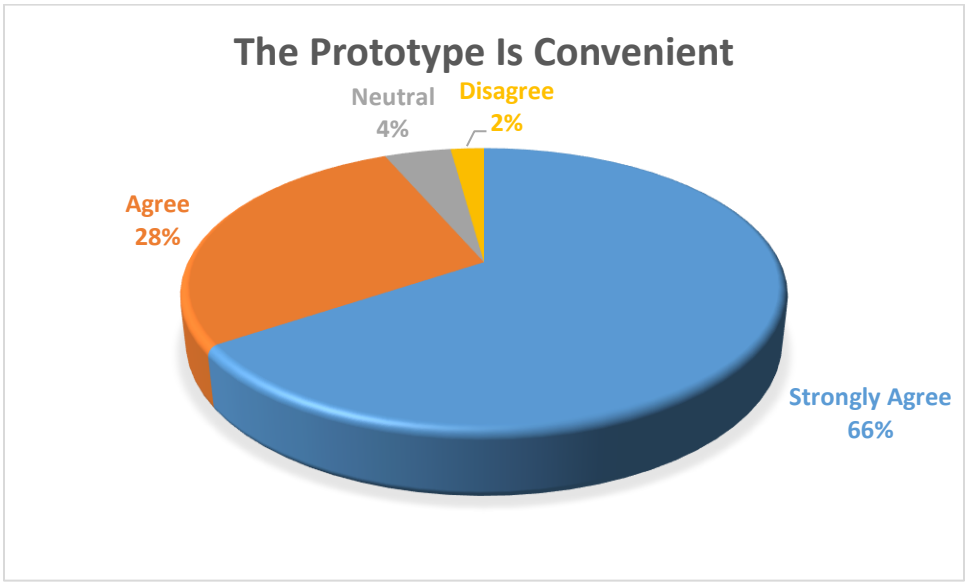

Figure 5.5: Prototype is convenient

Chapter Six: Discussions

6.1 Introduction

The findings obtained during the research formed the building blocks on which the prototype for price and advertisement update and display on retail store shelves was designed and developed. The prototype was tested against the requirements and functionalities gathered during the research to gauge its usefulness and adoptability. This chapter analyzes the findings in relation to the research objectives and extent to what the findings agree with the literature review.

6.2 Data currently being used for price and advertisement display

The first objective in section 1.3.1 was to identify the data and currently used in price and advertisement display in retail store shelves. From the findings of the study, it was determined that most of the respondents use the product name, quantity or weight, price, discounts with a select few going further to add other attributes like colour and barcode. This showed that retail stores were very much interested in a clear way of product information display but also a way of undertaking extra marketing initiatives such as discounts and offers that would increase their revenues.

6.3 Challenges facing price and advertisement display

The second objective was to analyse the challenges that currently plague retail stores in their price and advertisement information update and display endeavours. The study found out that the retail stores face challenges such as high costs brought about by frequent printing of new paper labels and the manual labour needed to put up the new labels. This process was also found to be very time-consuming requiring to be done at when the store is closed or not busy. They also faced high error rates and issues of discrepancies between shelf and checkout counter prices caused by updates not being carried out universally across all retail store departments. The problem of enticing customers and moving near-expiring products was another area that respondents felt that current systems did not address effectively. The literature review discusses current methods of price display and how they fall short in addressing the challenges that retail stores in the country currently face.

6.4 Price and advertisement display methods and technologies

The third objective was to analyze the methods and technologies currently being used for price and advertisement display in retail store shelves in the country. Research findings showed that a majority of the retail stores rely on paper based methods with a few using digital media in a limited capacity. The literature discussed electronic media that is being used in retail stores in technologically advanced countries and how though applicable, still does not meet all the challenges that face retail stores in Kenya, particularly on the costs front.

6.5 Prototype for real-time product and advertisement update and display in retail stores

The fourth objective was to develop a prototype for real-time product and advertisement update and display in retail stores in Kenya. Research findings showed that respondents felt that an automated system would not only make it easier to update prices on the shelves, but it would also be faster more accurate and lower costs in the long run compared to current systems. The prototype would also enable integration with other systems in the retail store to facilitate advertising where there are cross-sell and up-sell opportunities thus providing a way of enticing customers and boosting sales at no extra cost. The literature review discusses e-ink technology and shows how it will be used to achieve a system capable of carrying out the required tasks.

6.6 Advantages of the Prototype as Compared to the Current System

The ESL tag based prototype provides a real-time price and advertisement display platform, which the current system cannot do. It also enables remote monitoring of all the ESL tags with information on what they are currently displaying and their status thus improving accuracy. The prototype also provides a new revenue stream for retail stores where they are able to carry out advertising and discount offers on the tags to boost their revenues. It also boost the image of the retail store with a technologically forward store likely to have more customers. It also helps drive green initiatives, with reduced use of paper helping with saving the environment.

6.7 Disadvantages of the Prototype

Though the use of ESL tags saves costs in the long run the initial cost of investment can be high and off-putting with the risk of inevitable gains not being clear to retail store owners. As with all electronic components, they are bound to be unforeseen failures and breakdown with the equipment, which can cripple operations until a component, is replaced.

Chapter Seven: Conclusion, Recommendations and Future Work

7.1 Conclusion

Price, offer and advertisement display in retail stores in Kenya remains a cumbersome task. With all stores still using paper label on their shelves, the process involves a lot of moving parts, which do not always coordinate with each other. From price updates coming from the vendors to retails stores updating their stock pricing, point of sale system pricing, to the actual printing of paper labels and physically replacing the old ones with the new. Not only is this approach inefficient and tedious, it leaves a lot of room for error, errors which have occurred in various retail stores bringing with them bad press and customer dissatisfaction.

As highlighted in the questionnaires, most of the users of the current system agree that the current process of price, offer and advertisements update is quire time consuming. They are aware of the problems that come about due to the inefficiencies of the current processes and wish for a solution that provides them with a much more streamlined process to carry out these tasks.

This research takes advantage of existing ESL technology to provide a solution that not only computerizes the process of price display on the retail store shelves, but also provides a platform to display offers and advertisements. These advertisements can provide vendors with an in-store platform to up-sell or cross-sell their products as well introduce new products by advertising them on their well know products. All the revenue generated from these advertisements helps the retail stores achieve a return on investment for the ESL infrastructure much faster than they would have were they to rely on the eventual cost cuts brought about by use of ESL tags in place of paper labels.

7.2 Recommendations

The price and advertisement update and display prototype was of great importance to retail store operations. However, the researcher noted that more could be done in regard to what the ESL tags can do to enhance both operations as well as customer experience while shopping at the retail store. If equipped with weight or temperature sensors, the tags can not only help with stock keeping by informing store keepers when a re-order level has been reached based on the weight of products on the shelf but can also be used to send out alerts for products whose temperatures shouldn’t go beyond a certain point. With advancement in display technology, tags can also have

communication chips such as NFC to enable them transmit information to shoppers' mobile devices about the products.

7.3 Future Work

The researcher intends to expand the application to suit various types of ESL tags to provide versatility depending on the environment the tags will be used. Tags of different sizes, display technologies and communication technologies will be handled by the same system to ensure a centralized control location for all the display media. Finally, the researcher will also look into how the technology can be applied in various other sectors in ways that can improve efficiency of operations.

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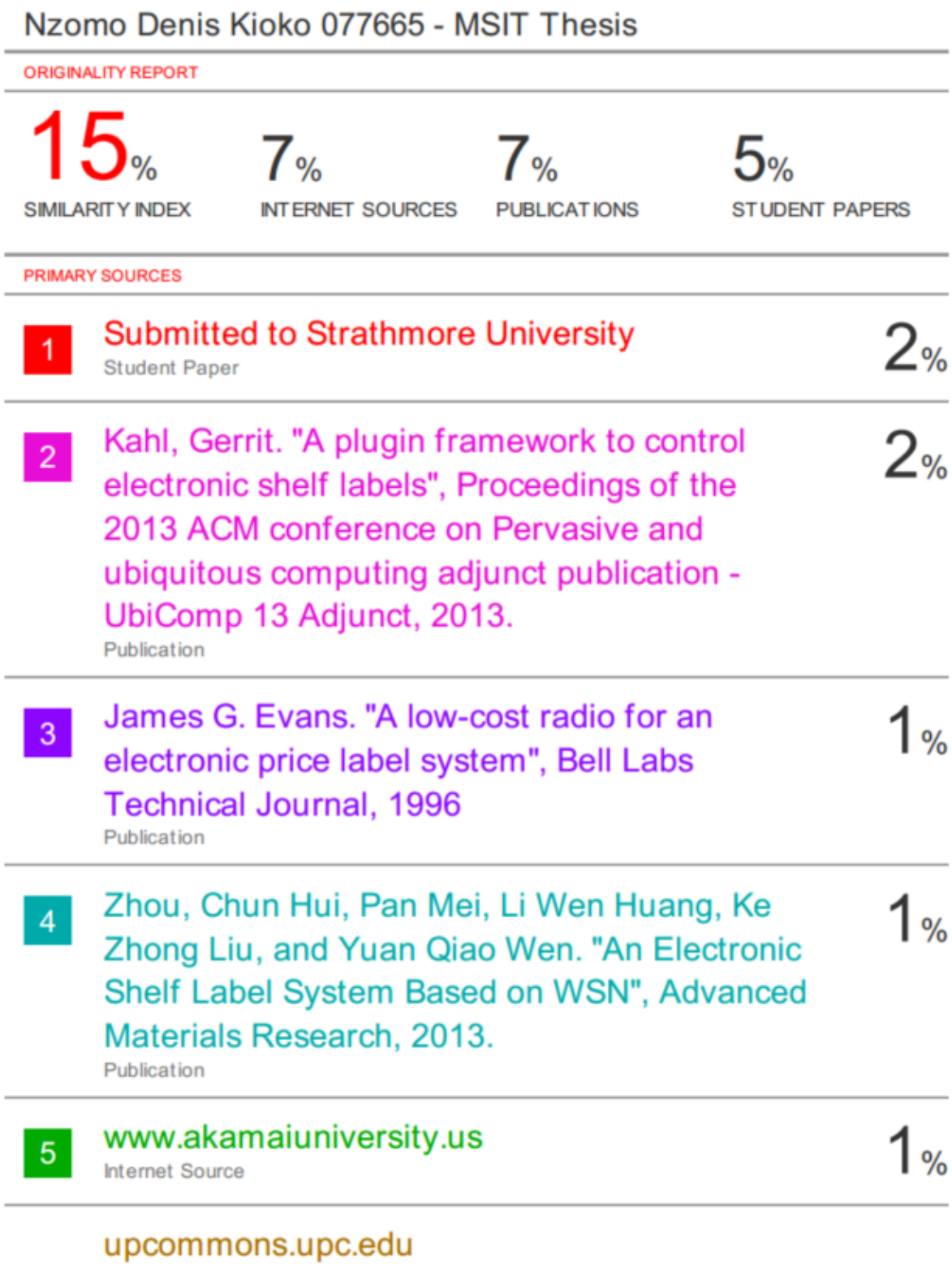
Appendices

Appendix A: Turnitin Originality Report



Nzomo Denis Kioko 077665 - MSIT Thesis

ORIGINALITY REPORT

15%	7%	7%	5%
SIMILARITY INDEX	INTERNET SOURCES	PUBLICATIONS	STUDENT PAPERS

PRIMARY SOURCES

1	Submitted to Strathmore University Student Paper	2%
2	Kahl, Gerrit. "A plugin framework to control electronic shelf labels", Proceedings of the 2013 ACM conference on Pervasive and ubiquitous computing adjunct publication - UbiComp 13 Adjunct, 2013. Publication	2%
3	James G. Evans. "A low-cost radio for an electronic price label system", Bell Labs Technical Journal, 1996 Publication	1%
4	Zhou, Chun Hui, Pan Mei, Li Wen Huang, Ke Zhong Liu, and Yuan Qiao Wen. "An Electronic Shelf Label System Based on WSN", Advanced Materials Research, 2013. Publication	1%
5	www.akamaiuniversity.us Internet Source	1%
	upcommons.upc.edu	

Appendix B: User Requirements Questionnaire

A Prototype for Real-time Price Display on Shelves in Retail Stores Questionnaire

Dear Respondent,

I am a student at Strathmore University pursuing a course in Maters of Science in Information Technology. I am currently conducting a study on **A Prototype for Real-time Price Display on Shelves in Retail Stores**.

You have been selected to form part of this study. I kindly request you to complete the questionnaire below. The information requested is needed for academic purposes only and will be treated in strict confidence.

Kind Regards,

Denis Kioko

SECTION A: Demographic Information

(Please select the appropriate response by ticking [✓] *in the box)*

A1. Which Retail Store do you work for? {Please tick [✓] one}

- □ Nakumatt
- □ Tuskys
- □ Naivas
- □ Uchumi
- □ Other, please Specify …….

A2. What is your role in the Retail Store? {Please tick [✓] one}

- □ Pricing
- □ Marketing
- □ Management
- □ System Administration

SECTION B: Data Used in Price and Advertisement Display

B1. What data and information do you display on your retail store price labels? {Please tick [✓] all that apply}

□ Product Name

□ Weight

□ Size

□ Price

□ Barcode

□ Discounts/Offers

□ Colour

B2. Where do you get this information? {Please tick [✓] all that apply}

□ Product Managers

□ Internal Pricing

□ Other …….

SECTION C: Challenges Facing Price and Advertisement Display

C1. What approaches do you use for in-store advertising, offers and discounts in your retail store? {Please tick [✓] all that apply}

□ Paper Labels

□ Cardboard Banners

□ Brand Ambassadors

□ Other …….

C2. Please rank the following challenges that face retails stores in order from 1 to 5 where 1 is most significant and 5 is not at all significant. {Please tick one option per challenge [✓]}

	Very Significant				Not at all Significant
	1	2	3	4	5
Costs	☐	☐	☐	☐	☐
Engaging and Enticing Customers	☐	☐	☐	☐	☐
Time consuming	☐	☐	☐	☐	☐
High Error Rate	☐	☐	☐	☐	☐
Moving nearly expired product	☐	☐	☐	☐	☐

C3. Please rate how you strongly agree or disagree with each of the following statements by ticking [✓] against the choice that best summarizes your opinion.

Statement	**Strongly Agree**	**Agree**	**Neutral**	**Disagree**	**Strongly Disagree**
a) Price and product information update and display is easy to do with current procedures?					
b) The current process for price and product information update and display is efficient.					
c) The current process of updating prices and product information is user friendly.					
d) The current process of updating price information is accurate and error free.					
e) The current process integrates seamlessly with other processes in the retail process					

SECTION D: What Technology Do You Currently Use

D1. What do you currently use to display prices and advertisements on retail store shelves? {Please tick [✓] one}

□ Paper labels

□ Electronic Media

□ Other, please specify …….

SECTION E: Real-Time Price and Advertisement Display Prototype

E1. Do you think an Electronic Shelf Label application for real-time price and advertisement update is necessary? {Please tick [✓] one}

□ Strongly Agree

□ Agree

□ Neutral

□ Disagree

□ Strongly Disagree

Appendix C: Interview Questions

Introduction

Dear Respondent,

I am a student at Strathmore University pursuing a course in Maters of Science in Information Technology. I am currently conducting a study on **A Prototype for Real-time Price Display on Shelves in Retail Stores**.

You have been selected to form part of this study. I kindly request you to provide answers to the interview questions below. The information requested is needed for academic purposes only and will be treated in strict confidence.

Kind Regards,

Denis Kioko

Section A: Personal information

Interviewee: ……. Location: …….

Medium: ……..…. Date: ……

Section B: Please answer the following questions in as much detail as possible

1. What is the current procedure for changing or updating price and product information in the retail store?

   ……

   ……

   ……

2. How do you carry out the process of creating offers and sales promotions in the current system?

   ……

   ……

   ……

3. Which parties are involved in the price and product information change procedure?

……

……

4. What are the challenges you are currently facing stores in the price and product information update process?

……

……

……

5. What is the current process for detecting discrepancies between shelf and till prices in the retail store?

……

……

……

6. Are all the systems involved in the price update and product information change located within the premise of the retail store?

……

……

……

7. In your opinion, what functionality should the prototype have in order to improve the process of;

a. Price and product information update.

……

……

b. Offers and Advertisement management for products on sale in the retail store.

……

……

8. Any Comments

……

……

Thank you for taking the time to complete this questionnaire. If you wish to receive information on the conclusions of the research, please include your email address below.

……

Appendix D: System Usability Questionnaire

Dear Respondent,

I am a student at Strathmore University pursuing a course in Maters of Science in Information Technology. I am currently conducting a study on **A Prototype for Real-time Price Display on Shelves in Retail Stores**.

You have been selected to form part of this study. I kindly request you to complete the questionnaire below. The information requested is needed for academic purposes only and will be treated in strict confidence.

Kind Regards,

Denis Kioko

Section A: Prototype Accuracy and Usability

1. This question is practical and aims at testing the accuracy of the prototype. Kindly use the prototype to carry out a hundred price and advertisement update tasks. (How many updated accurately and on the first try?)

   ……

2. Please rate how you strongly agree or disagree with each of the following statements by ticking [✓] against the choice that best summarizes your opinion.

Statement	**Strongly Agree**	**Agree**	**Neutral**	**Disagree**	**Strongly Disagree**
a) The user interface is very user friendly, easy to understand and navigate.					
b) I can use the prototype with minimal user training.					
c) Using the prototype for price and advert updates is faster than with current system					
d) The prototype provides a convenient way of product offer and advertisement update.					
e) Would you use this system in place of the current process?					
f) How likely are you to recommend this system to other users for a similar use case					

3. Any comments or suggestions on further improvements you would wish to have in terms of functionality of the prototype.

……

……

Thank you for taking the time to complete this questionnaire. If you wish to receive information on the conclusions of the research, please include your email address below.

……