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# A Mobile application for tracing and verification of the authenticity of filled liquefied petroleum gas cylinders

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**A Mobile Application for Tracing and Verification of the Authenticity of  
Filled Liquefied Petroleum Gas Cylinders**

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091573

Submitted in partial fulfilment of the requirements for the Degree of Master of  
Science in Mobile Telecommunication and Innovation (MSc. MTI) at Strathmore  
University

Faculty of Information Technology  
Strathmore University  
Nairobi, Kenya

June, 2017

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08/06/2017

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## **Dedication**

I dedicate this dissertation to the Almighty God, my family, classmates, mentors, friends, my dissertation supervisor Dr. Vincent Omwenga and the entire Strathmore University fraternity for their support throughout the dissertation period.

### **Acknowledgements**

I would like to acknowledge the Almighty God for granting me favour to pursue this Master's program. I acknowledge Safaricom Academy in conjunction with @iLabAfrica and Strathmore University for believing in me by giving me the opportunity, training and support I needed to attain this Masters. I also wish to thank my dissertation supervisor Dr. Vincent Omwenga for his guidance and tenacious support. Fourthly, I express my special thanks to my father, Erickson Mutua and my brother, Alex Mwendwa for their encouragement during the time I was doing my master's degree. Finally I acknowledge James Wachira for his love and endless support.

## **Abstract**

Tracing and verification of the authenticity of filled Liquefied Petroleum Gas (LPG) cylinders has been marked with numerous challenges especially in the Sub-Saharan region. With an increase in LPG consumption, numerous sales points have sprouted in residential estates which even sell unbranded cylinders. Some traders involved in the illegal refilling and branding of cylinders use cylinders that do not meet the quality standards of the Kenya Bureau of Standards, thus compromising consumers' safety. Consequently, unlicensed gas operators are gaining an unfair advantage as they do not incur the cost of purchasing cylinders. Consumers end up paying the same for genuine and illegal products in spite of the non-compliance on safety checks, cylinder re-validation, gas specifications, quantity and value added tax remittance.

This research used document survey and an online questionnaire that was distributed to 96 LPG consumers to provide a detailed study of the characteristics of the authenticity of a filled LPG cylinder, methods and technology currently used to trace and verify the authenticity of filled LPG cylinder and how a mobile application for tracing and verification of the authenticity of filled LPG cylinder can be designed, developed, tested and validated. The data collected from the 96 respondents was analysed using Google analytics tools and the results used to obtain the system requirements and design of an Android mobile application for tracing and verifying the authenticity of filled Liquefied Petroleum Gas cylinders. Agile software development methodology was used which allows faster iteration and more frequent user feedback. The Android application was integrated with an analytical back-end for LPG manufacturers, distributors and retailers that present a summary of LPG supplies made. Testing and validation was done on the final prototype by the potential users and developer of the application. Users stand to benefit by using the mobile application to ensure their safety by verifying the authenticity of gas cylinders anytime and from anywhere.

**Keywords:** Authenticity, Filled Liquefied Petroleum Gas Cylinders, Tracing, Verification, Android.

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### **List of Abbreviations/Acronyms**

<b>BOC</b>	- British Oxygen Company (UK)
<b>DOE</b>	- Department of Energy
<b>GPS</b>	- Global Positioning System
<b>ICC</b>	- Import Commodity Clearance Certificate Mark
<b>ISO</b>	- International Organization for Standardization
<b>LPG</b>	- Liquefied Petroleum Gas
<b>M2M</b>	- Machine to Machine
<b>OS</b>	- Operating System
<b>PS</b>	- Philippine Standard Certification Mark
<b>QR Code</b>	- Quick Response Code
<b>RFID</b>	- Radio Frequency Identification
<b>SMS</b>	- Short Message Service
<b>TW</b>	- Tare Weight
<b>UK</b>	- United Kingdom
<b>URL</b>	- Uniform Resource Locator
<b>US</b>	- United States

## **Chapter 1: Introduction**

### **1.1 Background of the Study**

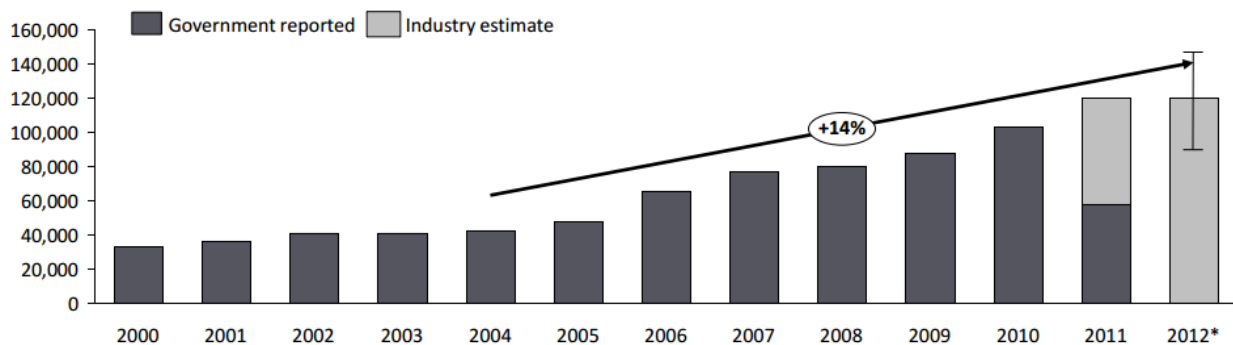
Liquefied Petroleum Gas (LPG) is used as fuel for thousands of applications; in commercial business, industry, transportation, farming, power generation, cooking, heating and for recreational purposes. It is actually a mixture of hydrocarbon gases. It includes butylene, propylene, butane as well as propane, which is present in substantial part. It is a flammable mixture and one needs to be highly cautious when dealing with it. Propane and butane gases that become liquid under pressure and can then be stored in pressurized containers. Propane is preferred where the climate is cold and butane where it is warm. LPG has a high energy per unit volume and is convenient to use. Its calorific value per unit volume is about 2.5 times larger than that of natural gas such as methane (Mahendran & Sumathi, 2015).

This research focuses on the use of LPG in cooking which basically means it is fuel used for the preparation of principal meals. Other types of fuel used in the preparation of meals include coal, wood, oil and gas (Mehta, 2016). Charcoal is a solid residue that consists mainly of carbon and is obtained by the destructive distillation of wood in the absence of air. Wood refers to all wood in the rough that is used for fuel. Kerosene is medium oil that is distilled between 150°C and 300°C. It is used as an illuminant and as a fuel and is often referred to as burning oil, vaporizing oil, power kerosene or illuminating oil. Electricity is an electric current used as a source of power. Gas is a combination of hydrocarbons which are gaseous under conditions of normal temperature and pressure, but are liquefied by compression or cooling to facilitate storage, handling and transportation (Fwiggins, 2011). Gas manufacturers package the gas in cylinders, hand it over to distributors who distribute to retailers from whom customers buy from.

However, to determine the authenticity of filled LPG cylinders, tracing and verification of the same is important. Authentic in this case means that the origin of the filled LPG cylinder is undisputed or genuine whereas Tracing means the manufacture should be able to track on whose hands the gas cylinders are throughout the supply chain to avoid illegal use of gas cylinders. Verifying is making sure or demonstrating that something is true, accurate or justified. In this case, for customers to have confidence in the product, they should verify the authenticity of filled LPG cylinders by scanning the QR code which is generated by manufacturers and placed on the

cylinders. To scan the QR code, customers use the mobile application which should inform them of the status of LPG before purchase.

With the cost of electricity ever rising, it is becoming increasingly difficult for many urban homes in Kenya to use it for cooking. Kerosene is also not a very good option due to its inefficiency, the mess it brings to the kitchen and again it is not widely and easily available in most areas, just like charcoal (Jhingran, 2016). All these factors have made LPG the most reliable, affordable and efficient means of cooking in many urban and some rural Kenyan homes. LPG is a clean heat generating source of energy and has been assigned a global warming factor of zero by the United Nations International Panel on climate change (WHO, 2016). With the current high demand of LPG, the sale of cooking gas is another lucrative business idea that small business people can consider. Cooking gas is among products whose market is yet to be fully exploited in Kenya despite of its growing demand. Figure 1.1 shows the total volume of LPG consumed in Kenya between the years 2000 and 2012.



**Figure 1. 1 Total Volume of LPG Consumed, Kenya 2000-2012 (Dalberg, 2013)**

Looking at Figure 1.1, it is fair enough to project that the total volume of LPG consumed from 2012 to 2016 has been rising. Data from the Kenya National Bureau of Statistics show that in the last quarter of 2014, the use of LPG actually rose by nearly 50%. This trend was attributed to an increase in disposable income and changing lifestyles among consumers.

The country has been experiencing unstable supply of services, pricing in the gas industry and inflation that has resulted in a high cost of living in most parts of the country. Consumers of this commodity have been airing complaints about non-authentic cylinders with everyone wanting to access quality gas cylinders in order to avoid hazards that come with such (Okoth, 2016). Furthermore consumers have found themselves in situations where they cannot tell whether a

cylinder is genuine or not. This has left many stranded having to walk for miles at times in the wrong direction in search of a gas vendor they can trust. Consumers in such situations have been forced to rely on luck and maybe bumping into someone who will give them authentic information as to the location of a trusted vendor.

This study aims at the development of a mobile application for tracing and verifying the authenticity of filled LPG cylinders. It outlines the design requirements of the mobile application, a gas manufacturer QR code (Quick Response Code) generator and a QR code reader that is used by consumers and retailers to verify the authenticity of the product. The backend dashboard is to be used by the manufacturers, distributors and retailers in providing their services. The manufacture generates the QR code from the backend and stores the data in tables on the database. Details stored in the table include serial number of the cylinder, date of manufacturing, weight of the filled LPG cylinders, the name of the manufacturer, date issued to the distributor, the name of the distributor, the address, the contacts and number of cylinders issued to the distributor.

Distributors and Retailers have different modules each of their own where they update the date they receive the filled LPG cylinders, the number of filled LPG cylinders they receive, the weight of each, from who they receive them, the date they issue them and to whom they issue them. The customers, distributors and retailers use the front-end android application which is a QR code scanner to check against what is stored by the manufacturer on the database. For example, if the status gives a flag such as ‘suspicious’ it means the status of the filled LPG cylinder is questionable.

## **1.2 Problem Statement**

LPG business in Kenya has been chaotic characterized by illegal imports, unlicensed and unsafe filling operations, cylinder cross-filling, re-branding of competitor cylinders and above all, under-filling of cylinders.

## **1.3 Research Objectives**

### **1.3.1 General Objective**

The purpose of this study was to develop a mobile application for tracing and verifying the authenticity of filled LPG cylinders using an Android device.

### **1.3.2 Specific Objectives**

- i. To analyze the characteristics of an authentically filled LPG cylinder.
- ii. To analyze the technologies available to support tracing and verification of LPG cylinders.
- iii. To investigate how tracing and verification of filled LPG cylinders is currently done in Kenya.
- iv. To design, develop and test an Android mobile application for tracing and verifying the authenticity of filled LPG cylinders.
- v. To validate the effectiveness of the mobile application for tracing and verifying the authenticity of filled LPG cylinders.

### **1.4 Research Questions**

- i. What are the characteristics of an authentically filled LPG cylinder?
- ii. Which technologies are available to support tracing and verification of LPG cylinders?
- iii. How is tracing and verification of filled LPG cylinders currently done in Kenya?
- iv. How can the new solution be designed, developed and tested?
- v. Does the system handle tracing and verification of LPG cylinders problem through the optimised solution?

### **1.5 Justification of the Study**

The study should be useful to LPG manufacturers, distributors, retailers and consumers. Consumers prefer to be sure of their safety and would use the mobile application to verify the authenticity of the gas cylinder anytime and from anywhere. Retailers would use the application to check if the filled LPG cylinders are genuine so that they can gain the trust of their customers. Distributors and retailers stand to benefit from the basic book keeping that comes with the system. The gas manufacturer QR code generator would also come in handy to a manufacturer when it comes to accountability. Moreover, gas manufacturers stand to benefit by using the application as some form of advertising which they can use to build a better relationship with their customers.

### **1.6 Scope of the Study**

QR technology was used in this research to develop an application for tracing and verifying the authenticity of Liquefied Petroleum Gas to a wide segment of population. The application was designed to run on Android platform with an intention to reach a large population since most

Kenyans use Android smartphones. The application has a frontend which is the mobile application and a backend, the administrator side. Lastly, the research was done in Nairobi.

### **1.7 Limitations of the Study**

First, Internet connection must be available for users to get results after scanning the QR code. Second, the mobile application targeted users of Android phones. This however leaves out users using phones running on other platforms.

### **1.8 Conclusions**

This research aims at coming up with an Android mobile application for tracing and verifying the authenticity of filled LPG cylinders. A gap still exists in Kenya where LPG business has been chaotic characterized by illegal imports, unlicensed and unsafe filling operations, cylinder cross-filling, re-branding of competitor cylinders and under-filling of cylinders. In the next chapter, a review was conducted on what other researchers have done to help deal with the challenges that face tracing and verification of the authenticity of filled LPG cylinders.

## Chapter 2: Literature Review

### 2.1 Introduction

This chapter covers what has already been done by other researchers. However, there are very few papers done in this particular area. Despite the little literature available, some papers have been reviewed. The areas discussed include characteristics of an authentically filled LPG cylinder, methods currently used in tracing and verification of LPG cylinders, and technologies available to support tracing and verification of LPG cylinders. Lastly, it discusses the adoption of QR technology using mobile phones in Kenya.

### 2.2 Characteristics of an Authentically Filled LPG Cylinder Identifiable by a Customer

The identification of the gas contents of any cylinder is given by the label on the cylinder and is qualified by the color(s) of the cylinder and the cylinder outlet (Liquigas Malta, 2013). The label in this scenario, refers to the brand imprinted on the cylinder that represents the different gas manufacturing companies such as K-Gas, Total among others.

#### Cylinder Seals

In the realization that some LPG cylinders were being filled illegally plus in an unregulated manner, Liquigas Malta cautioned consumers to verify their LPG cylinder seals prior to use. The agency immediately suspended the supply of its cylinders to a number of distributors after acquiring evidence of illegal and unregulated refilling of LPG cylinders at a third party site. Liquigas advised its clients to confirm that their LPG cylinder seals are genuine, explaining that genuine seals have an injection point on top, between the words “Liquigas” and “Malta,” in addition to a square profile rim as shown in figure 2.1 (Liquigas Malta, 2013).

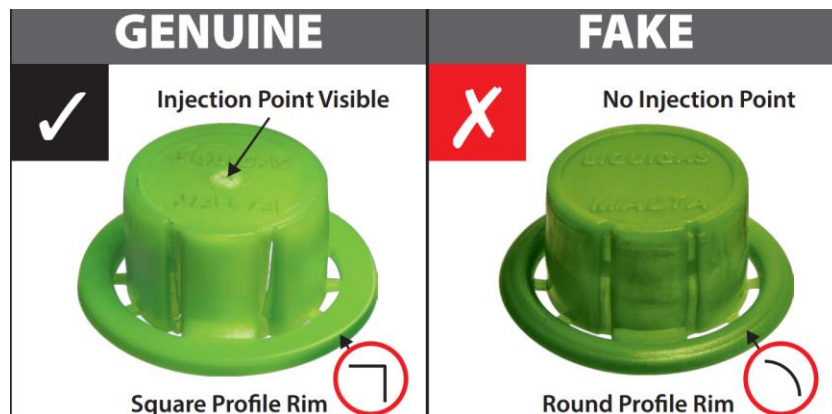


Figure 2. 1 Genuine and Fake Seals (Liquigas Malta, 2013)

### **Date of Manufacture**

Unlike Liquigas Malta, Shakti argued that all cylinders are required to come with a date of manufacturing which should not exceed the specified limit by the manufacturer (Shakti, 2014).

### **Cylinder Condition**

Contrary to Shakti's view, the consumer welfare advises consumers to purchase LPG cylinders that are in good condition. Gouges, dents and corrosion on the cylinder might be an indicator of ingenuity. The cylinder should also not be welded since it might be a health hazard to the consumer due to gas leaks (Consumer Welfare, 2015).

### **Trusted Brand**

The consumer welfare also pinpoints that an authentically filled LPG cylinder has to bear branding from a licensed LPG gas manufacturer. The consumer welfare agrees with Liquigas Malta that the cylinder normally has a seal with brand name on the valve. It also has markings on the cylinder body indicating the LPG brand manufacturer name, the weight of the contents, PS or ICC markings and country of manufacturer if imported (Consumer Welfare, 2015). On the collar of the cylinder, it has a serial number of the gas cylinder.

### **Weight**

Lastly, the consumer welfare states that weight manifests the right LPG contents. Check the LPG tank prior to buying by always looking for the Department of Energy (DOE) required weighing scale at LPG outlets or stores (Consumer Welfare, 2015). To determine the net content of LPG:

- i. Look for the tare weight (weight of the empty tank) of the LPG you are shopping for. TW is indicated on the tank's shoulder.
- ii. Weigh the filled LPG tank.
- iii. Deduct the tare weight from the weight of the filled LPG tank.

Example

Weight of Filled LPG Tank	24.0 kg
Tare Weight (TW)	<u>-13.0 kg</u>
Correct Net Content	11.0 kg

## **Gas Leakages**

Examine the safety cap for any cracks. Remove safety Cap and inspect for leakage from the valve (IndianOil, 2015). Each time there is a gas leak, there is an increased chance of fire and explosion, as well as the likelihood of carbon monoxide poisoning. LPG can leak because of faulty coupling. Due to the fact that LPG is heavier than air, it settles down and fills the surrounding like a liquid. In the case of Papua New Guinea Liquefied Natural Gas (PNG LNG), it goes up in the air as it is lighter. When the gas concentration rises above roughly 2% in the air, it becomes explosive (Joshi, 2011). In most instances, gas leakages can go un-noticed for a long time as some are odourless and colourless. It is therefore vital to be on the lookout for gas leaks prior to buying LPG (Amuzuvi, 2016).

### **2.3 Characteristics of an Authentically Filled LPG as Proven by the Manufacturer**

For a company to qualify as a trusted LPG manufacturer, it must be licensed and must comply with desirable industry practices. Consequently, one crucial characteristic of an authentically filled LPG cylinder is the proof that the manufacturer has followed the proposed good practice guideline. The guide focuses on the management of LPG cylinders right through the life cycle. There are six fundamental sections: Selection of LPG cylinder, Cylinder Design, Manufacturing, Filling, Maintenance, Repair and Requalification, Cylinder Scrapping (Calor Gas, 2010).

#### **Selection of LPG Cylinder**

LPG cylinders have for many years been made from metal in different valve types and with different sizes. Currently, aside from aluminium, there has been the development and introduction of light weight steel which give several benefits over metal cylinders. With various types of cylinders now available in the market it is crucial to choose the right one for a business. This will greatly depend on the precise application, budget, environment and market conditions where it will be used (Calor Gas, 2010).

#### **Cylinder Design**

LPG is a highly flammable product that is normally stored under pressure. Any leakage of LPG from its container has a capability to cause fire and injury. For this cause, cylinders chosen ought to be designed and manufactured in accordance to recognised codes and standards (Xydias, 2012).

## **Manufacturing**

Manufacturers should be licensed to ISO 9001 and should show their potential to making cylinders that meet quality standards. Moreover, manufacturers should have the certifications to produce to particular codes and standards. It is also crucial that manufacturers observe the necessities of the design code and production specifications by designating an independent inspection authority during and after production to prove compliance (Tyler, 2014).

## **Cylinder Filling**

Filling of LPG cylinders is a crucial activity that needs to be done only by trained and competent workers in a facility modelled mainly for cylinder filling. The right specifications and amount of LPG should be filled. Scales used for weighing ought to be serviced regularly and examined for fill accuracy and tolerance prior to and during cylinder filling operation (Marinas, 2015).

## **Maintenance, Repair and Periodic Requalification**

The physical condition of LPG cylinders can decline with poor handling and use of improper distribution equipment. Therefore, it is important to check and then segregate cylinders with defects or damage for suitable action when they are brought into the filling facility for refilling. Only qualified contractors with well-equipped workshops and manned by competent workers should handle repairs. The result for temptation to save on expenses by ignoring maintenance, repair and test is a declining asset base and greater safety risks to customers (Hahn, 2016).

## **Cylinder Scrapping**

Cylinders beyond the economic value of repair compared to the cost of new cylinders should be processed for scrap. They should be emptied before being scrapped and made completely unsuitable for further service. The serial numbers of scrap cylinders should be saved on record, along with motives for scrapping, as well as details of the buyer of scrap cylinders. The record is useful to track sources of recycled scrap cylinders in case they turn up in the plant (Dong, 2016).

## **2.4 Methods Currently Used in Tracing and Verification of LPG Cylinders**

### **Study from Malaysia**

In Malaysia, Radio frequency identification technology is used to track cylinders using permanent RFID tags. The RFID tags incorporate information about the cylinder's weight, serial number and date of manufacture. RFID readers are attached in the position of the filling line to know and verify

eligibility of refilling and reissue depending on the manufacture date. Authentic LPG cylinders are then issued to filling stations while the rest are mandatorily rerouted for additional re-inspection (Zou, 2008).

### **Study from Kenya**

In Kenya, plans for having tracking devices on LPG cylinders have been in place since 2012 with no noticeable progress. According to an article on the Nation Newspaper on 16th April 2012, there were proposed plans linked to National Oil Corporation of Kenya's stock control system modeled on GPS technology to give real time tracking of LPG cylinder movement. The plan never saw the light of day (Karambu, 2012).

### **Study from United States**

In the US, M2M low energy consumption devices are installed on the cylinders to screen key parameters which consist of GPS positioning and motion, temperature, pressure or filling degree tilt and effect. The device is designed to send data periodically through a network which gathers the data and stores it in servers (Cabrera, 2015).

### **Study from UK and Ireland**

In the UK and Ireland, BOC LPG manufacturers have an online portal that traces cylinder(s) with its serial number. Every cylinder has a peculiar barcode which is scanned for every delivery and return. On return to any of BOC gas store or agent, the BOC cylinders are removed from the buyer's account who had been issued the cylinder (Calder, 2016).

## **2.5 Technologies Available to Support Tracing and Verification of LPG Cylinders**

Internationally, the technology behind tracing and verification of LPG cylinders has grown in leaps and bounds.

### **2.5.1 Radio Frequency Identification Technology**

RFID technology uses a peculiar microchip that is embedded with a protective case to withstand harsh conditions. RFID reader, which is a radio signal initiator and receiver, listen to signals sent back from RFID tags. A trigger on the RFID reader is pulled to read and give a peculiar identification code enabling tracking of an asset. Functional tags have a power source like a battery and can send the signal to the reader since it does not need to be within the line of sight of the reader (Zou, 2008).

### **2.5.2 Machine to Machine Devices**

M2M devices are connected to the cylinder's valve picking up measurements of temperature to check if the cylinder can withstand temperature levels, measuring the filling levels to guarantee accurate filling of cylinders, GPS positioning and measuring the number of times the cylinder suffers impact as well as raising an alarm if it exceeds the threshold (Qiu, 2014). An M2M network that covers the region where the devices are is used to enable sending of data to other devices for storage (Hauff, 2014).

### **2.5.3 Bar Codes**

A barcode is a machine readable image of lines and spaces that is placed on an item to uniquely distinguish it. The code makes use of vertical bars and spaces to represent numbers and symbols. A bar code reader, used to scan bar codes, uses a laser beam sensitive to the reflection of the lines and spaces converting it to digital data that is usable to a computer (Ewing, 2016).

### **2.6 QR Code Technology**

A QR code is a matrix barcode readable by smartphones and mobile phones with cameras. They are sometimes referred to as mobile codes, 2d codes or 2d barcodes.

Tan Jin Soon states that QR code commonly appears like a small white square with black geometric structures, although colored and branded QR codes are currently being employed. QR codes can keep much more information compared to a regular barcode. The information encoded within a QR code can be a phone number, a V-card, a URL, an SMS message or any text. The reason they are known as QR is their ability to permit high speed decoding of contents. In 1994, Denso-Wave, a Toyota subsidiary developed QR codes (Soon, 2008).



**Figure 2. 2 QR Code (Ashford, 2010)**

According to Ashford, most significantly, QR codes are a timely way to join the virtual to the physical, to deliver useful content, usually at the time of need. QR codes are a low-threshold technology. Low fee, simple to use, and simple to implement, they are a technology that offers a lot of bang for the buck, when implemented wisely (Ashford, 2010).

**Table 2. 1 Comparison among Barcode, QR Code and RFID (Lotlikar, 2013)**

<b>Attribute</b>	<b>Barcode</b>	<b>QR Code</b>	<b>RFID</b>
Line of Site	Required	Required	Not required (in most of the cases)
Read Range	Several inches to feet	Several inches to feet	Passive RFID -Up to 30 feet Active RFID -Up to 100s feet
Identification	Most barcode only identify only type of item (not uniquely)	QR code can identify each item uniquely (Limited up to certain value)	It can uniquely identify each item
Read\Write	Only read	Only read	Read Write
Technology used	Optical (laser)	Optical (laser)	RF(Radio frequency)
Automation	Most barcode Scanners need humans to operate	QR scanners need humans to operate	Fixed scanners don't need human labor
Updating	Cannot be Updated	Cannot be Updated	New information can be written on old tag
Tracking	Manual tracking required	Manual tracking Required	No need of tracking
Capacity of Information	Very less	Less	More than QR and Barcode
Ruggedness	No	No	Yes
Reliability	Wrinkled and smeared tags won't work	Wrinkled tags may work 30% data recoverable	Nearly flawless read rate
Data capacity	<20 characters with linear	up to 7,089 characters	100s to 1000 characters
Orientation Dependent	Yes	No	No

### 2.6.1 Implementing QR Codes on Mobile

When implementing code scanners or generators there exist some approaches to go about it but as Zapper (2007) maintains, the best way is to use a library that is already built and integrate it into your application. The following steps are required to do this:

#### i. Scanning

If one needs to scan, they initiate an intent and do a call to the class that holds the scanning method which takes one parameter to dictate how the information will be relayed back to the developer. The information can be obtained in full, unprocessed QR contents, or can only be visible. After the class is launched and the code read, the results are returned to the next class as shown in the Figure 2.3. The last class gets the information and decides whether to display, send or store them.

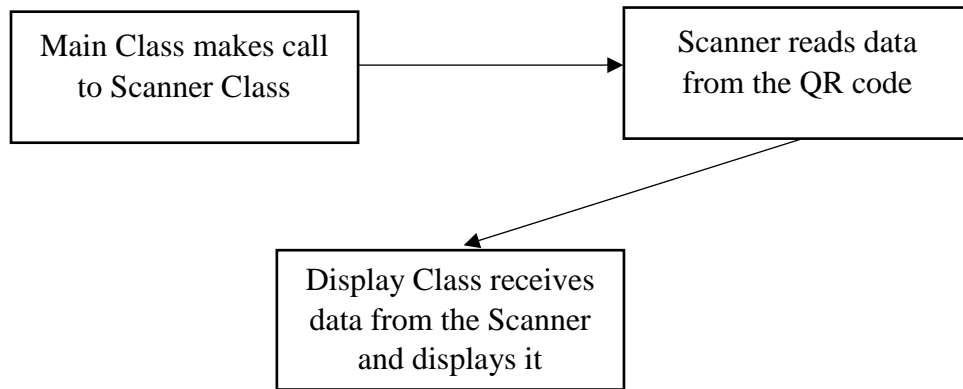


Figure 2. 3 Scan Process (Zapper, 2007)

#### ii. Generate

Zapper (2007) gives the steps shown in Figure 2.4 for adding the QR code generator to an application.

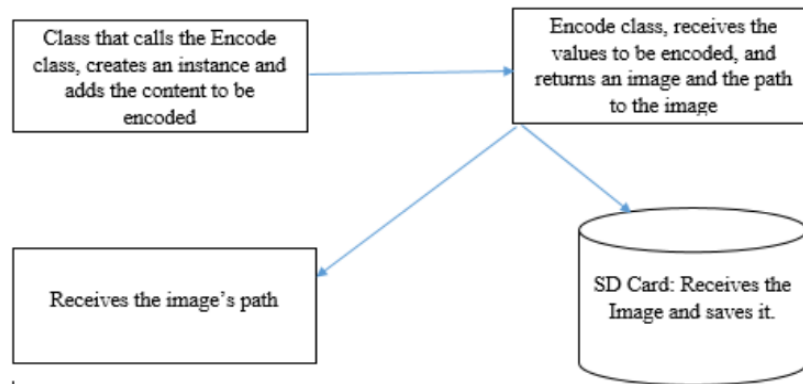


Figure 2. 4 QR Code Generation Process (Zapper, 2007)

Just like the scanner the generator is saved in a class called the Encode class which require the variable to be encoded into the code. The size of the code is automatic depending on the phone being used but the developer can specify the size they prefer. The Encode method returns an image which is saved and the path returned by the class. After the image has been created, the developer can either send it or store it to be used later.

### **2.6.2 Why QR Code**

The speed of decoding the QR code can be made 20 times faster than that of other matrix symbols. QR codes are cost effective. By making the relationship between the character type and the saved data peculiar for special use, QR Code can be easily encrypted. With the use of web analytics and peculiar codes for various placements, marketers can get some valuable facts about how well campaigns are going, as well what works and what does not (Asare, 2015).

To correct distortion in symbols, QR Code has alignment patterns arranged at a regular interval within the range of the symbol that make the distorted symbols readable. QR Code has a linking functionality which enables one symbol to be represented in several symbols by dividing it. This allows the entire information to be edited and submitted to the computer regardless of what order the symbols had been read by the reader (Peng, 2014).

### **2.6 Gaps and Limitations**

According to The Times of India City (2016), it was decided not to proceed with the RFID technology piloted in 2011 in India since it was not a success considering that cylinders still found a way into the open market. The use of RFID is very expensive and also hard to implement because of absence of regulatory standards (Kaur et al., 2011). Bar codes are handicapped because they can be easily duplicated, causing the integrity of the physical location of cylinders unreliable (Hyster, 2012).

M2M technology is difficult to implement. Many M2M devices are less visible, but more pervasive and, therefore, bring about issues related to privacy. Considering the use of M2M for LPG tracing and verification, huge quantity of information can be generated. Without suitable safeguards, experience has already proven in some countries, that privacy implications can cause serious concerns for an M2M service (OECD, 2012).

Online verification bridges the gaps and limitations of Barcodes, RFID, M2M and the manual process because it is affordable, fast and the fact that it cannot be forged. However, currently, no unified system for online verification exists for tracing and verification of the authenticity of filled LPG cylinders. To fill the gaps and limitations that exist, this research maximized on the advantages of online verification and QR code technology to improve the process of tracing and verification of authenticity of filled LPG cylinders.

## **2.7 Conclusions**

Previous researchers have used bar codes, RFIDs and M2M to track and verify if LPG cylinders are authentic or not. However, this study makes use of QR codes to achieve the same because with this technology, smartphones and mobile phones with cameras can be used to read the codes. The next chapter explains the methodology that was be used in this research.

## Chapter 3: Research Methodology

### 3.1 Introduction

This chapter describes the methods used for conducting this research and their viability with the aim of answering the research questions. The methodology that was used in this study was Agile software development methodology.

### 3.2 Agile Software Development Methodology

Agile model trusts that each project requires to be tackled distinctly and the existing methods should be customised to best fit the project requirements. In agile, the tasks are divided into small time frames to give particular features for a release. Iterative approach is embraced and a functioning software build is released after every iteration. Every build is progressive in terms of features, the ultimate build supports all the features needed by the customer (Zhang, 2007).

Agile methods appropriately suited this research because it provides the ability to create and respond to change. Moreover, it encourages participation of users enabling creation of what users want leading to creation of better solutions. Figure 3.1 exhibits the stages of Agile development that were followed to attain the set objectives for this research. These phases include planning, requirements analysis, design, building and testing.

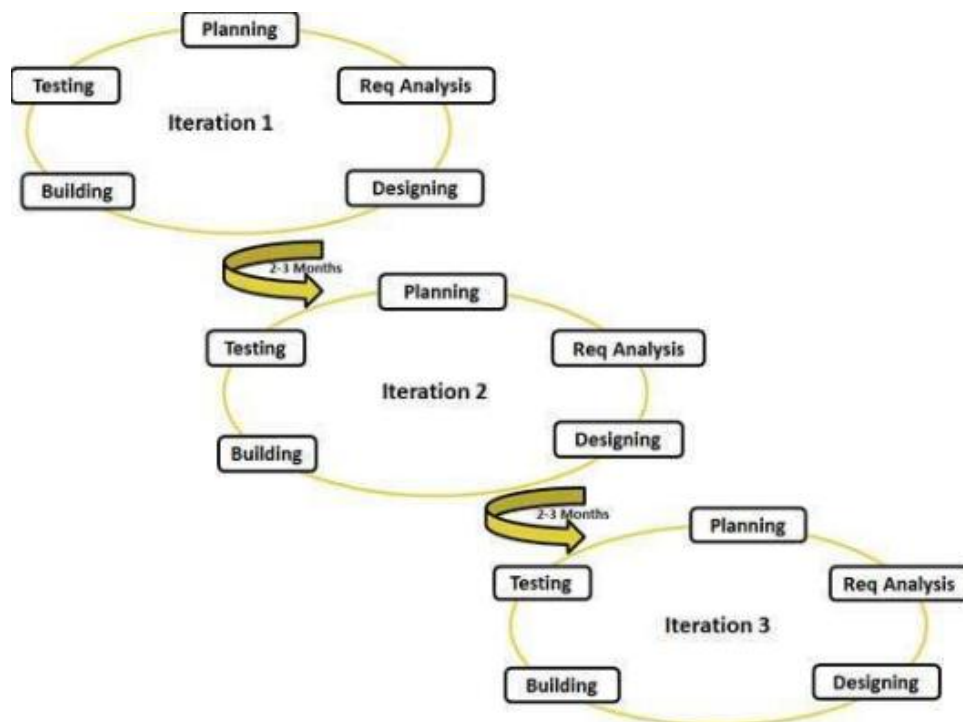


Figure 3. 1 Agile Software Development Methodology (Steljes, 2012)

### **3.2.1 Planning Phase**

This is the first phase of Agile methodology where planning of how the whole process was undertaken. Planning was used to identify what resources were needed to build the system.

### **3.2.2 Requirements Analysis Phase**

This phase deals with specification of what the system requires to meet the needs of end users (Ramesh, 2006). Both primary and secondary sources of data that were used include questionnaires, observation and document survey. This research made use of quantitative research through questionnaires and the problem quantified through numerical data. 96 individuals who would actually like to use the new system or think the new system is a fit idea were identified (Creswell, 2014). The user requirements questionnaire was distributed electronically by use of Google forms so as to reach a large population.

Qualitative research was done through non-participant observation which was carried out to support the data provided through questionnaires. The objective of qualitative research is to gain a heightened comprehension of the problem that exists through sincere reporting, direct experience and quotations of real conversations. It was used to get an understanding of the current platforms and processes of tracing and verifying the authenticity of filled LPG cylinders. These methods were used because they have a high chance of providing accurate data which comes in handy when trying to understand the situation on the ground in addition to providing useful information in coming up with requirements of the application.

### **Target Population and Sampling**

This research mainly drew its findings from Nairobi County with the target population being the LPG consumers within the county. According to the GLPGP - Kenya Market Assessment Report of August 2013, the penetration of LPG in Nairobi was at 21% which is equivalent to 376, 560. This large number of target population leads to the necessity of choosing a sampling technique. In this case, random sampling technique was applied where the sample population was selected at random from the residents of Nairobi County.

Equation 3.1 shows the formulae that was applied to get the sample population meaning every person got an equivalent chance to be part of the sample population.

$$n = \frac{NZ^2 * 0.25}{[d^2 * (N - 1)] + (Z^2 * 0.25)}$$

n = Sample size

d = Precision level (mostly 0.10 or 0.5)

N = Total population

Z = Statistic for a level of confidence (for example 1.96 for 95% confidence level)

Equation 3.1 Random Sampling (Frerichs, 2013)

$$n = \frac{376,560 * 1.96^2 * 0.25}{[0.1^2 * (376,560 - 1)] + (1.96^2 * 0.25)}$$

$$n = 96.015766575$$

The questionnaires were disseminated to 96 respondents.

### **Data Collection**

Both primary and secondary data were used in this research. Primary data was collected using questionnaires and observation to determine the user requirements. The advantage of using primary data is the freedom to filter specific data in regards to the problem under study and the fact that there is no question about the quality of the data.

Secondary data was collected from books in the library and online books which hold information from work of past researchers with the objective of finding the gaps that need to be filled. The advantage of using secondary data is its availability and affordability.

### **Questionnaires**

A user requirements questionnaire was pre-formulated using Google docs and distributed via email to the chosen sample population (Appendix A). A questionnaire was used because of its ability to gather a lot of information from a large population (Burgess, 2001).

### **Data Analysis**

The reason for analyzing data is to acquire usable and useful information (Nasimoya, 2006). Descriptive analysis was applied in this research. Quasi-experimental research was done using an online survey which was a questionnaire sent and answered via mail. Google analytics was used to analyze the data collected and the qualitative data was represented in form of charts and graphs for clear inference of the results. This was then be used to make conclusions with regards to whether the new system would solve the problems in place and help improve information access and service delivery in the gas industry.

### **3.2.3 Designing Phase**

The approaches used in system design can either be object-oriented, data-oriented or process-oriented. Unlike data-oriented and process-oriented approaches which put weight on data and process respectively, object-oriented approach combines both processes and data into one entity called object (Joshi, 2013). Because of the above reason, object-oriented design (OOD) approaches was used to fine-tune the object requirements definition pinpointed in requirements analysis and to determine design specific objects.

System design aims at defining the architecture, components, modules, interfaces and data for a system to satisfy specified requirements (Waldo, 2006). The study made use of UML (unified modeling language), sequence diagrams, use-case and activity diagrams to design the system.

#### **Use Case Diagram**

Use Cases were used to pin point and divide the system actors and processes. Various manufacturers, distributors, retailers and customers interacting to make the LPG tracing and authentication solution a success were the actors of the proposed system. The Use Case was going to be depicted as text that outlines the effect the user was going to have on the system (Malan, 2001).

#### **System Sequence Diagram**

The System Sequence Diagram was used to breakdown all the Use Cases and summarize them. It illustrated the order of events that an external actor was going to generate, how those actions followed each other and any other interaction with external systems (Zhang, 2007).

#### **Entity Relationship Diagram (ERD)**

An Entity Relationship Diagram was used during database design. Entities, attributes and relationships between entities were identified and represented in the (E-R) Diagram.

#### **Design Class Diagram**

The Design Class Diagram was used for standard conceptual formation of the software semantics. The design class diagrams included classes which incorporated methods, objects and interactions of the system (Fowler, 2006).

### **3.2.4 Building Phase**

This phase involves converting the designs into an actual application. The QR code scanner was an Android application which was developed on Android Studio using Zxing library and Java in xml. The Web backend dashboard used PHP and HTML5. PHP is preferable due to its fast speed and platform independence (Sakshay, 2013). HTML5 is the markup language that was used to structure and present content in the web backend dashboard. MySQL was used as the relational database management system. The reason MySQL was preferred for this research is the fact that it is open source and can work across platforms. The QR code generator in the backend was developed using a PHP QR Code library known as QRLIB. The system was implemented using phased changeover strategy. Therefore the application was installed in a few android phones then users gave feedback and any suggested changes were made before the release of the application to the public. Since agile methodology allows iteration when a change is required to be made, the application was implemented and released module by module.

### **3.2.5 Prototype Testing and Validation**

This phase involves ensuring that the needed functionalities are working as required with regards to the set objectives. Various testing approaches were used. Unit testing was used to test each module, Integration testing for the integrated modules, System testing involved the entire system, Audit testing ensured there were no errors and finally Load testing was done to measure the amount of time the application took to process a request. Compatibility test was carried out to make sure that the web and mobile applications are compatible with existing platforms. To validate if the developed mobile application solved the problems faced in the gas industry, Alpha acceptance testing checked if end user requirements were met and Beta acceptance testing checked if the system worked on different android phones (Briand, 2002).

## **3.3 Research Quality Aspects**

### **Validity**

The study was carried out in such a manner to ensure that the set questions yielded valid results. Content validity was applied to ensure accuracy by examining the test content systematically to check if it includes the selected sample of the behavior domain to be measured. A pilot study similar to the main study was conducted to measure the validity of the research. The initial idea and research questions were inspected and the system was implemented as close as possible to the

actual application that users tracing and verifying the authenticity of filled LPG cylinder would adopt. Survey questions were given to respondents and their responses analysed to determine whether the new solution was valuable to the users. To come up with the degree to which the content domain related to the construct, content validity that was selected matches the test content.

### **Reliability**

Reliability ensures that the results are consistent such that even if the same study was to be done after a given period of time or if repeated then the same results would be achieved regardless of the changes. This research used Inter-rater reliability to determine if the information gathered was done in a trustworthy way. Reliability was achieved by issuing questionnaires to respondents after every one week and correlation between the two was the same. With this, the researcher got a go ahead therefore refining the questions by relying on the feedback acquired from the pilot test.

### **3.4 Ethical Considerations**

The study had the intention of ensuring that all the respondents acted at will and that they were not coerced. Any private data the respondents chose to share remained private and was only used for analysis purposes. The study also ensured that the solution proposed worked for people who chose to use the service (Ceridwen, 2003).

### **3.5 Conclusions**

This chapter has discussed the steps that were taken to come up with the mobile application for tracking and verifying the authenticity of filled LPG cylinders. It explains how the objectives of this research were achieved. The next chapter expounds on the requirements analysis.

## Chapter 4: Requirements Analysis and System Design

### 4.1 Introduction

This chapter covers the requirement analysis, system analysis and system design in detail. In requirements analysis, the researcher explains the findings that result from the research that was carried out. Google forms analysis tools were used to do the analysis of the responses from the online questionnaire. Graphs and charts were used to represent the responses received from respondents because they give a clear visual and improve understanding of the results. Results from the data collected were used to answer the research questions as well as providing the requirements needed to come up with the system design for the application. The sample size for this research was 96 respondents. In system analysis, system design and architecture, design diagrams used include use-case diagram together with their descriptions, sequence diagram, design class diagram and entity relationship diagram.

### 4.2 Results from User Requirements Questionnaire

The questionnaire was distributed to 96 respondents but 95 answered all the questions.

#### Respondents Period of Using LPG

82.3% of respondents have used LPG for more than 2 years, 12.5% had used it between 1 and 2 years while 5.2% had used it for less than 1 year.

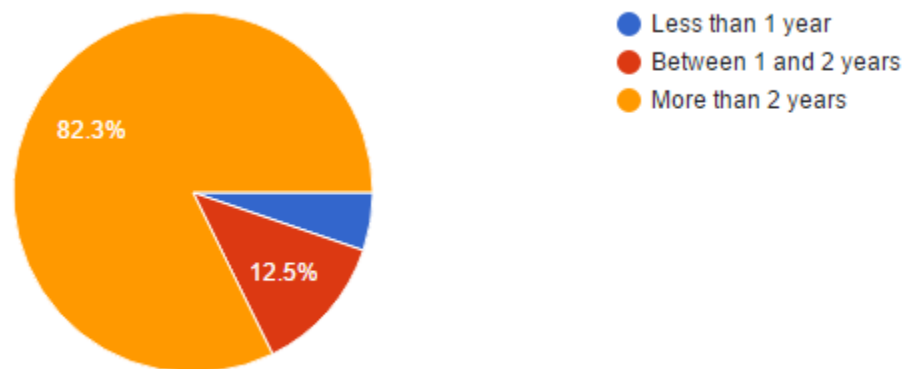


Figure 4. 1 Respondents Period of Using LPG

### Capacity of LPG Respondents Use

The findings show that 53.1% respondents use 6kg LPG cylinders, 36.5% use 13kg, 9.4% use 3kg and 1% use 50kg LPG cylinders.

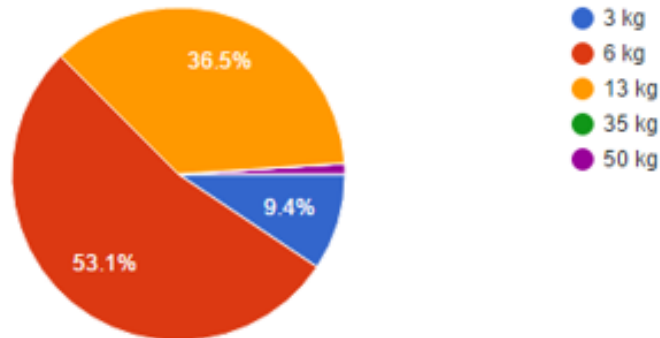


Figure 4. 2 Capacity of LPG Respondents Use

### Purchase Point Preference

58.3% respondents purchase their LPG from retailers, 31.3% from authorized dealers and 10.4% from distributors.

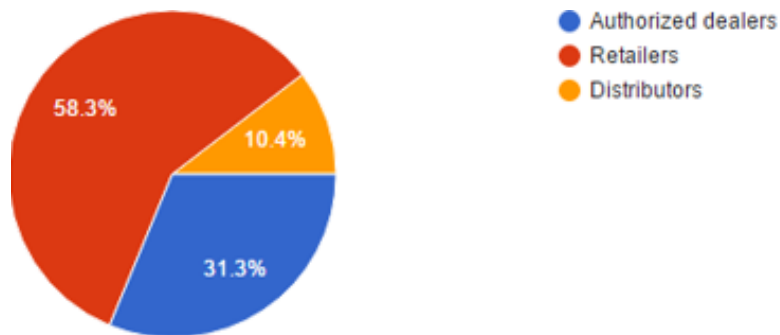


Figure 4. 3 Purchase Point Preference

### Characteristics that Respondents Use to Consider the Authenticity of Filled LPG cylinder

Figure 4.4 show the characteristics that respondents consider in identifying the authenticity of filled LPG cylinder as the brand, date of manufacture and weight.

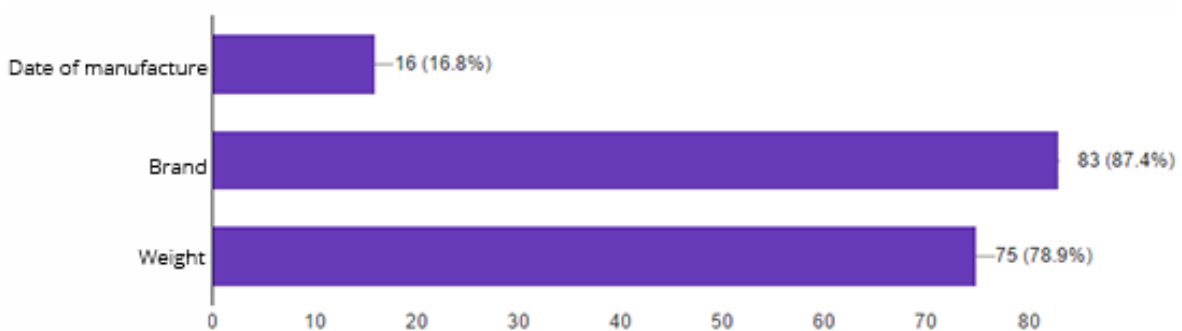
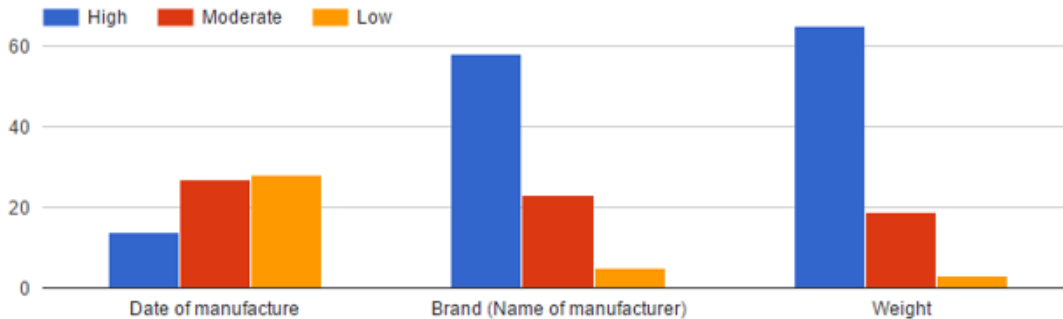


Figure 4. 4 Characteristics Respondents Check for in a Filled LPG cylinder

### Importance Attached to the Characteristics on Figure 4.4

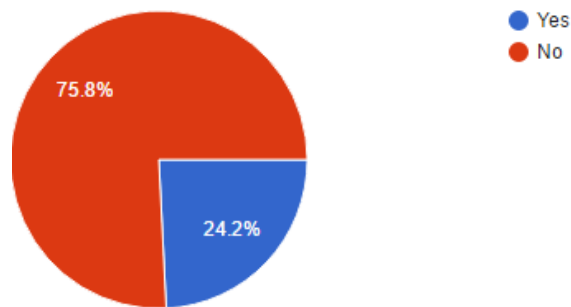
Figure 4.5 show that most respondents consider weight to be very important when checking the authenticity of a filled LPG cylinder followed by the brand and finally the date of manufacture.



**Figure 4. 5 Importance Attached to the Characteristics on Figure 4.4**

### Sources of Gas

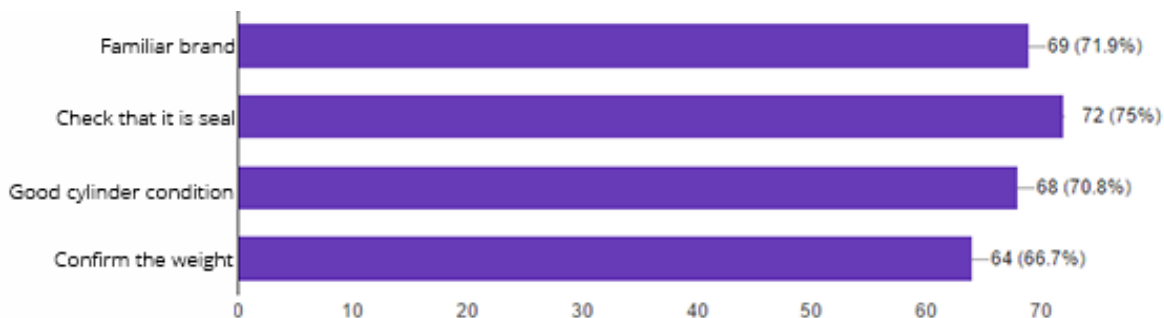
Findings from the questionnaire show that 75.8% did not know the source of the gas they use while 24.2% did know.



**Figure 4. 6 Sources of Gas**

### Details Respondents Check When Buying LPG

Respondents check if the cylinder is sealed, confirm that the brand is familiar, ensure that the cylinder is in a good condition and weigh to confirm the weight is the one indicated on the cylinder.



**Figure 4. 7 Details Respondents Check When Buying LPG**

### Operating System of Respondent's Mobile Phones

Results from the questionnaire show that 86.5% respondents own Android phones while the other operating systems share the rest of the percentage (13.5%).

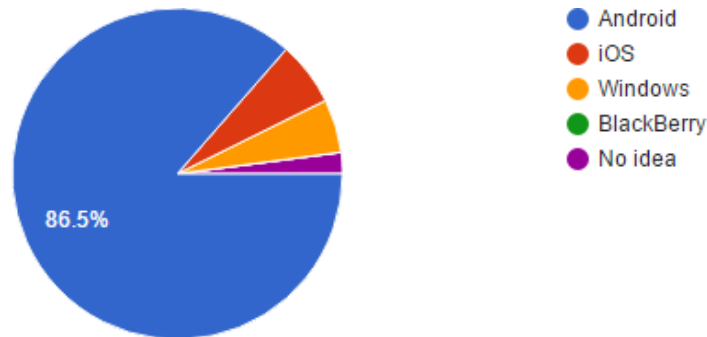


Figure 4. 8 Operating System of Respondent's Mobile Phones

### Technologies Respondents are Familiar With

Figure 4.9 shows that the respondents are familiar with bar codes, QR codes, RFIDs and M2M. However, 14.7% had no idea of these technologies.

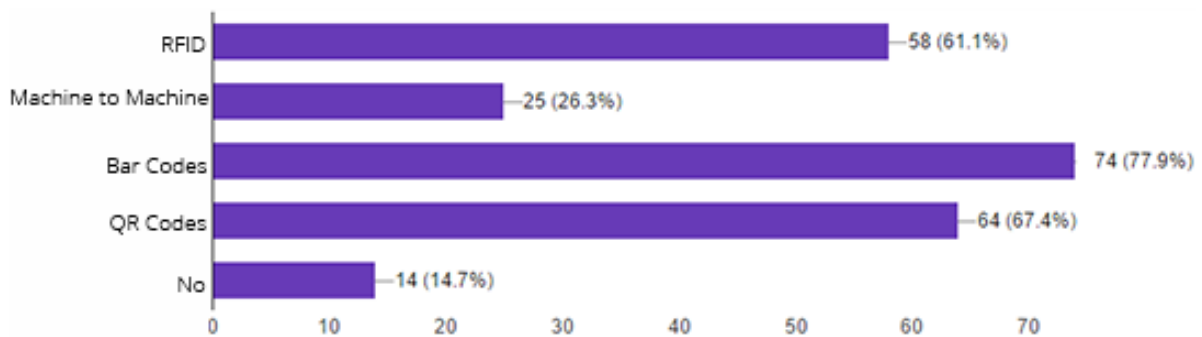


Figure 4. 9 Technologies Respondents are Familiar With

### Respondent's Capability to Use a Mobile Phone

Figure 4.10 shows that respondents are capable of accessing the internet, downloading an application, taking a picture and sending or receiving emails.

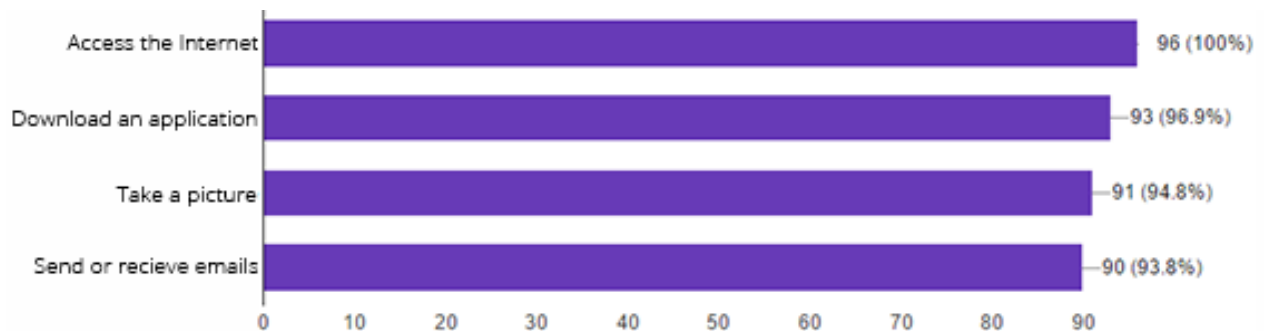
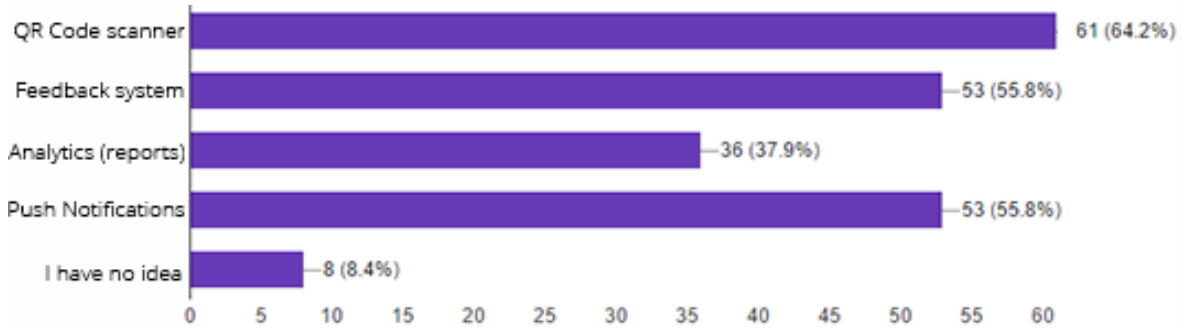


Figure 4. 10 Respondent's Capability to Use a Mobile Phone

### Features Respondents Would Like to See on the Proposed Application

Figure 4.11 shows that respondents would like features like QR code scanner, feedback system, notifications and analytics on the new application.



**Figure 4. 11 Features Respondents Would Like to See on the Proposed Application**

### 4.3 Requirement Analysis

The requirements for the mobile application for tracing and verifying the authenticity of filled LPG cylinder can be divided into functional and non-functional requirements.

#### 4.3.1 Functional Requirements

Functional requirements are the capabilities, functions and basic processes that the implemented application must be able to perform. They include: Verify LPG cylinder where all users should be able to request for verification of an LPG cylinder, get results, view verification reports by being able to retrieve a history of all the details of LPG cylinders they have scanned before and finally post a comment by getting a chance to give feedback about the services they get from the application.

Create account where manufacturers, distributors and retailers should be able to set a username and password in order to access the system. Login where all manufacturers, distributors and retailers should be able to login into their accounts using the correct username and password. Manage distributors where manufacturers should be able to add, edit and delete distributors, Manage cylinders where manufacturers should be able to add, edit and delete LPG cylinders as well as generate a QR code for each cylinder, Logout where manufacturers, distributors and retailers should be able to logout of their respective accounts. Manage retailers where all distributors should be able to add, edit or delete retailers. Manage manufacturer where an

administrator should be in a position to add new users (manufacturers) to the system, edit or delete them.

#### **4.3.2 Non-Functional Requirements**

These are requirements that any system can perform without but are desirable qualities that make the system interactive and user friendly. They include:

Security - the back-end web application has an administrator who has authority over the usernames and passwords. Error reporting by keeping error logs for purposes of resolving issues.

Availability - the system should be available all the time.

Reliability – the system should be reliable to perform user tasks.

Scalability – the system should easily allow for future improvements and upgrades.

Integrity – the system should make sure that stored data is not altered or corrupted.

Performance – the system should have a reasonable response time when performing its functions.

#### 4.4 Use Case Diagram and Description

Figure 4.12 gives an illustration of the major interactions that the new system underwent with the various actors and other sub-systems. What follows are the Use Case Descriptions.

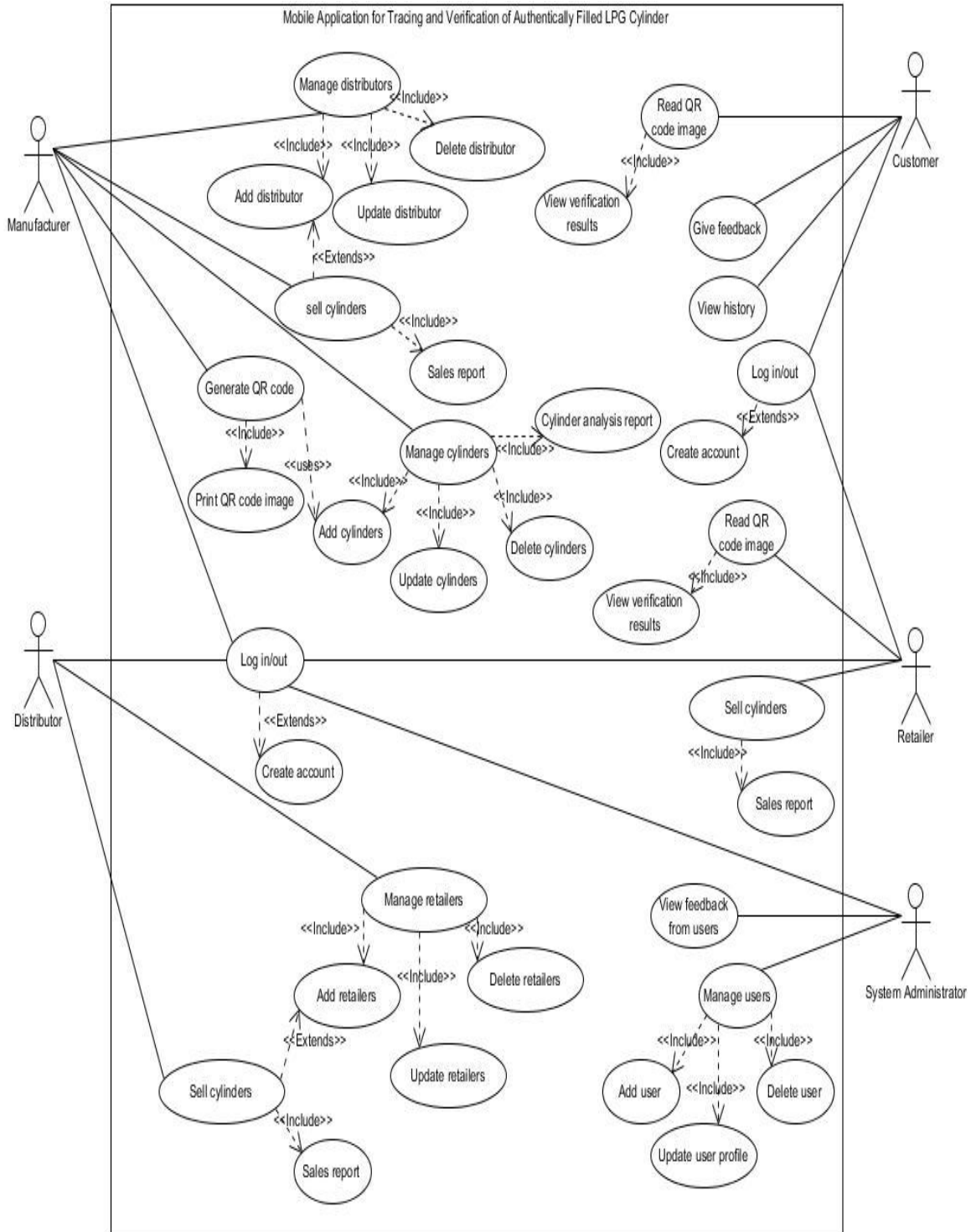


Figure 4. 12 Use Case Diagram

The following are the Use Case Descriptions:

**Table 4. 1 Verify Cylinders**

<b>Use Case: Verify Cylinders</b>	
<b>Primary Actors:</b>	Customer, Retailer, Distributor
<b>Stakeholders:</b>	Manufacturer
<b>Precondition:</b>	Need to verify a filled LPG cylinder. Presence of LPG cylinder to be verified.
<b>Post condition</b>	Verify LPG cylinder, view verification results that report whether the cylinder is genuine or counterfeit.
<b>Main success scenario</b>	
<b>Actor</b>	<b>System</b>
<ol style="list-style-type: none"> <li>1. User views the menu</li> <li>2. User selects scan.</li> <li>3. User reads QR code on the cylinder using the QR code scanner.</li> </ol>	3.1 System sends verification details to the user.
<p><b>Alternative Flow:</b> Menu selection</p> <p>At step 2, user selects feedback menu.</p> <ul style="list-style-type: none"> <li>• User gives feedback information.</li> </ul>	<ul style="list-style-type: none"> <li>• A message is sent to the administrator.</li> </ul>

**Table 4. 2 View Verification History**

<b>Use Case: View Verification History</b>	
<b>Primary Actors:</b>	Customer, Retailer, Distributor
<b>Stakeholders:</b>	Manufacturer
<b>Precondition:</b>	User has verified a cylinder before. Cylinder verification was successful.
<b>Post condition</b>	User views the history report.
<b>Main success scenario</b>	
<b>Actor</b>	<b>System</b>
User clicks on history menu.	Verification history available.

**Table 4. 3 Create Account**

<b>Use Case: Create Account</b>	
<b>Primary Actors:</b>	Manufacturer, Retailer, Distributor
<b>Stakeholders:</b>	
<b>Precondition:</b>	Need to manage cylinders, sales, distributors, retailers.
<b>Post condition</b>	Activation request sent.
<b>Main success scenario</b>	
<b>Actor</b>	<b>System</b>
User submits registration details.	Account created and activated.

**Table 4. 4 Login**

<b>Use Case: Login</b>	
<b>Primary Actors:</b>	Manufacturer, Retailer, Distributor
<b>Stakeholders:</b>	
<b>Precondition:</b>	Need to manage cylinders, sales, distributors, retailers. Manufacturer, distributor or retailer account successfully created.
<b>Post condition</b>	Manage cylinders, sales, distributors, retailers.
<b>Main success scenario</b>	
<b>Actor</b>	<b>System</b>
User submits login details.	User successfully logs in.

**Table 4. 5 Generate QR Code**

<b>Use Case: Generate QR Code</b>	
<b>Primary Actors:</b>	Manufacturer
<b>Stakeholders:</b>	
<b>Precondition:</b>	Manufacturer account successfully created. Manufacturer is logged into the system.
<b>Post condition</b>	Generate QR code.
<b>Main success scenario</b>	
<b>Actor</b>	<b>System</b>
Submit cylinder details.	Cylinder is added and QR code generated.

**Table 4. 6 Manage Sales**

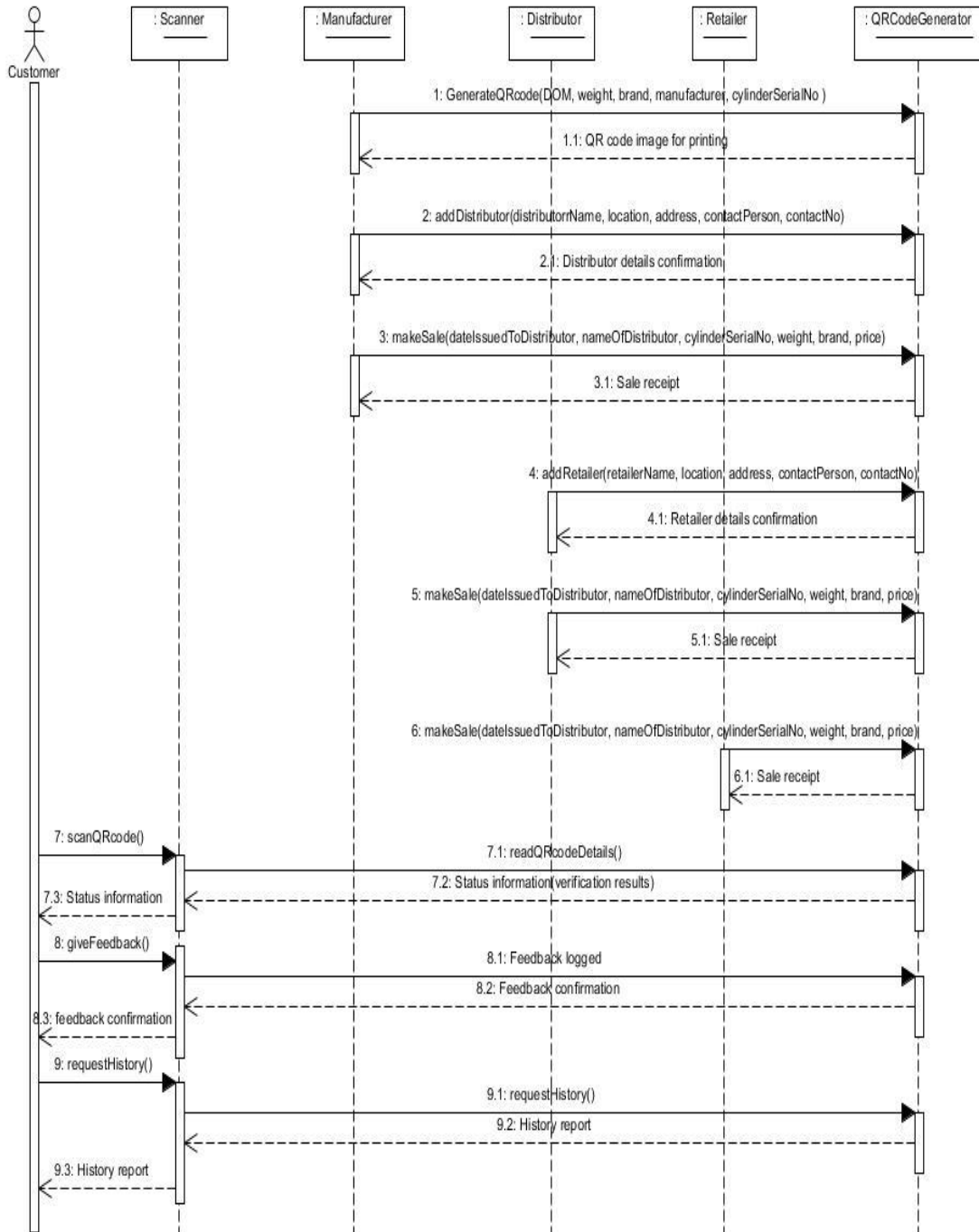
<b>Use Case: Manage Sales</b>	
<b>Primary Actors:</b>	Manufacturer, Distributor, Retailer
<b>Stakeholders:</b>	
<b>Precondition:</b>	Manufacturer, distributor or retailer account successfully created. Manufacturer, distributor or retailer is logged into the system.
<b>Post condition</b>	Create, update and delete sales.
<b>Main success scenario</b>	
<b>Actor</b>	<b>System</b>
Submit sales details.	Sales successfully added, updated or deleted. System returns a sales receipt.

**Table 4. 7 Logout**

<b>Use Case: Logout</b>	
<b>Primary Actors:</b>	Manufacturer, Distributor, Retailer
<b>Stakeholders:</b>	
<b>Precondition:</b>	Manufacturer, distributor or retailer is logged into the system.
<b>Post condition</b>	Logged out of the account.
<b>Main success scenario</b>	
<b>Actor</b>	<b>System</b>
User clicks on logout option.	User successfully logs out.

## 4.5 Sequence Diagram

The sequence diagram shows the flow of information between the main entities in the system. Figure 4.13 depicts how users interact with the system, how they send and receive feedback to and from the system.



**Figure 4. 13 Sequence Diagram**

### 4.6 Entity Relationship Diagram

An entity relationship diagram is a conceptual representation of the database design. Entities, attributes and relationships are identified and represented in Figure 4.14.

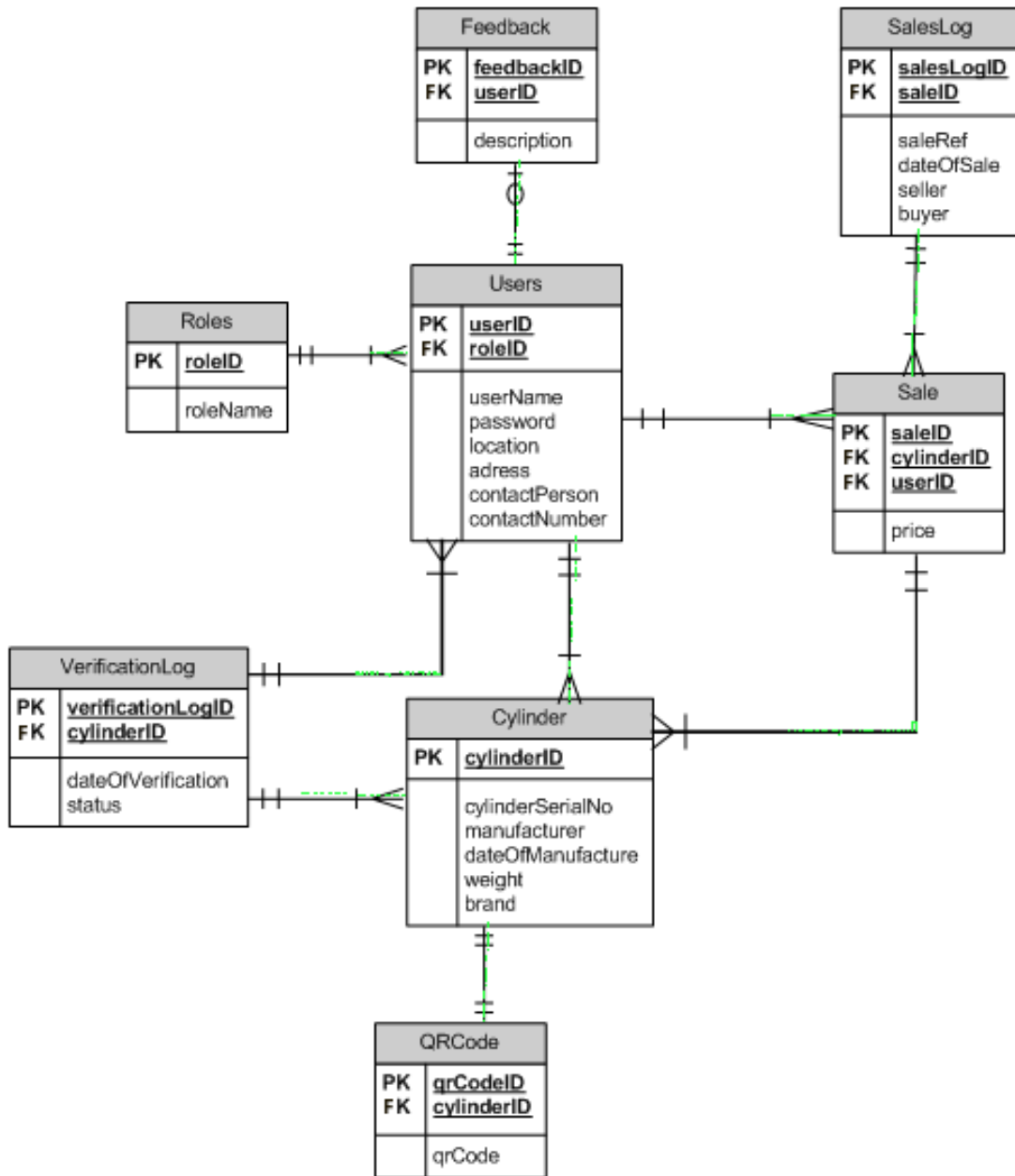


Figure 4. 14 Entity Relationship Diagram

## 4.7 Database Schema

### Users Table

This table contains all the users of the system. Such users include system administrator, manufacturer (LPG refillers), distributors, retailers and users.

Table 4. 8 Users Table

Column Name	Data Type	Index
userID	Integer(10)	Primary key
roleID	Integer(10)	Foreign key
username	Varchar(30)	
password	Varchar(100)	
address	Varchar(100)	
contactPerson	Varchar(50)	
contactNumber	Varchar(30)	

### Roles Table

Roles table determines the user level of all the users identified in the users table.

Table 4. 9 Roles Table

Column Name	Data Type	Index
roleID	Integer(10)	Primary key
roleName	Varchar(30)	

### Cylinders Table

Once a manufacturer adds a cylinder, the details of the cylinder are saved in the cylinders table and a QR code is generated for each cylinder.

Table 4. 10 Cylinders Table

Column Name	Data Type	Index
cylinderID	Integer(10)	Primary key
cylinderSerialNo	Varchar(50)	
Manufacturer	Varchar(50)	
dateOfManufacture	Varchar(50)	
Brand	Varchar(50)	
Weight	Varchar(10)	

## Sales Table

All sales are stored in this table. Each sale is associated with the user who made the sale.

Table 4. 11 Sales Table

Column Name	Data Type	Index
saleID	Integer(10)	Primary key
cylinderID	Integer(10)	Foreign key
userID	Integer(10)	Foreign key
Price	Varchar(50)	

## SalesLog Table

SalesLog table stores all the sales that have ever been made, whether they were made by a manufacturer to a distributor, by a distributor to a retailer or by a retailer to a customer.

Table 4. 12 Sales Log Table

Column Name	Data Type	Index
salesLogID	Integer(10)	Primary key
saleID	Integer(10)	Foreign key
cylinderID	Integer(10)	Foreign key
saleRef	Varchar(50)	
dateOfSale	Varchar(50)	
Seller	Varchar(50)	
Buyer	Varchar(50)	

## Verification\_Log Table

This table keeps a log of all successful verifications done. Each verification is associated to the user who requested it.

Table 4. 13 Verification Log Table

Column Name	Data Type	Index
verificationLogID	Integer(10)	Primary key
cylinderID	Integer(10)	Foreign key
userID	Integer(10)	Foreign Key
dateOfVerification	Varchar(50)	
Status	Varchar(50)	

## Feedback Table

Feedback table stores all user comments.

Table 4. 14 Feedback Table

Column Name	Data Type	Index
feedbackID	Integer(10)	Primary key
userID	Integer(10)	Foreign key
Description	Varchar(50)	

## 4.8 Design Class Diagram

Figure 4.15 is a design class diagram that shows all interactions between classes, their corresponding methods and attributes.

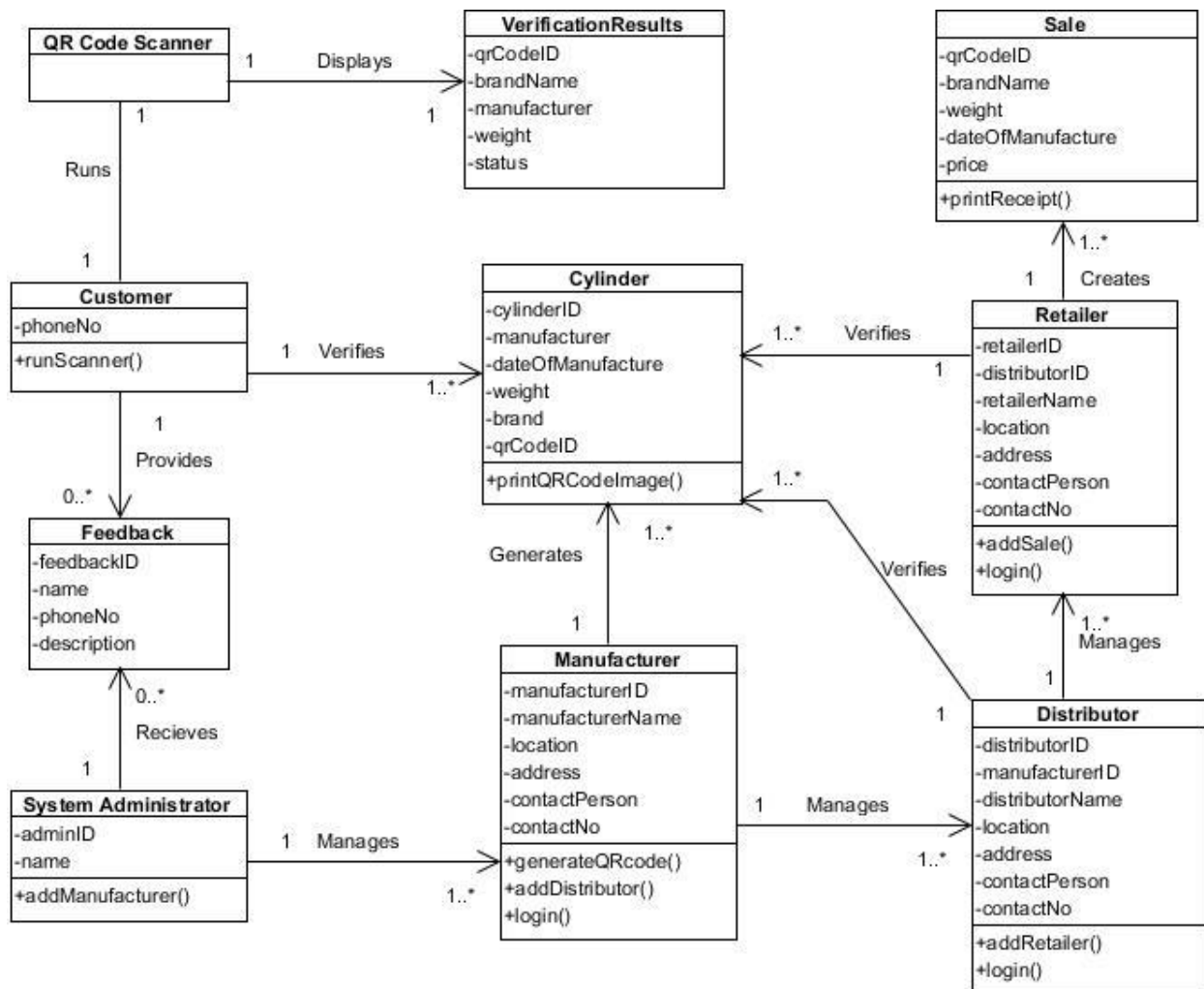
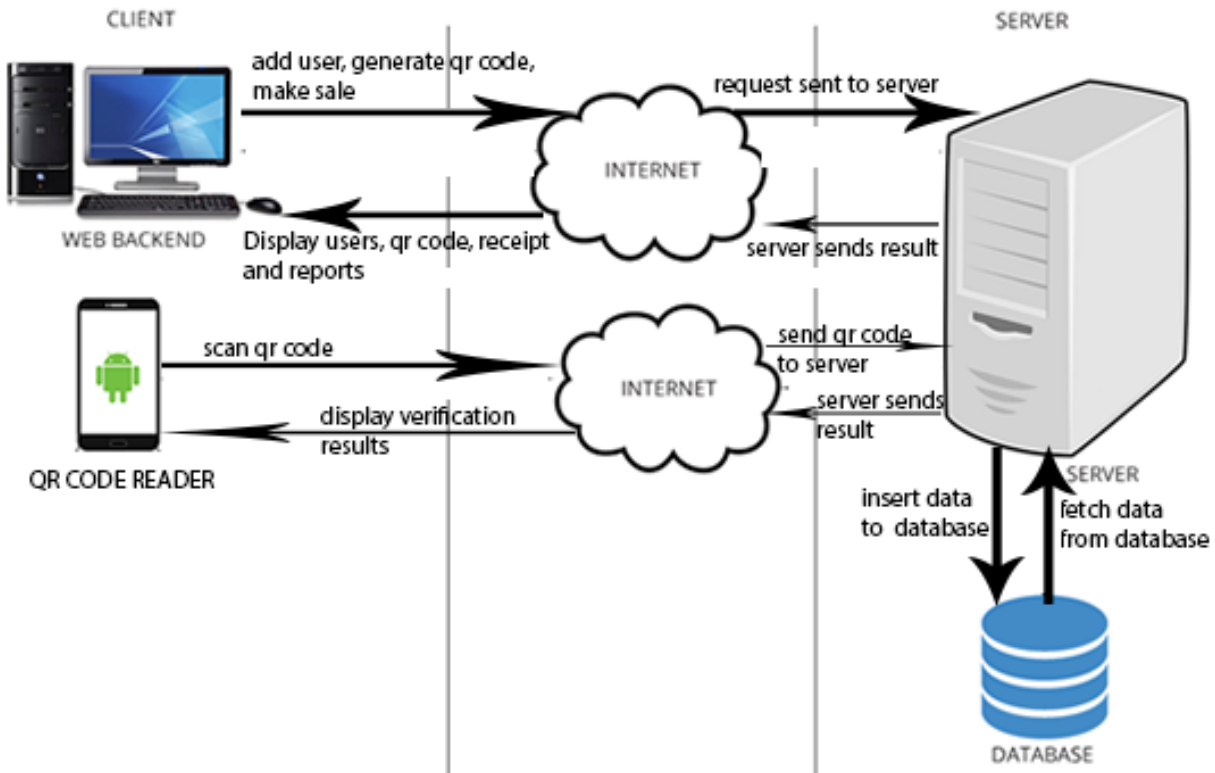


Figure 4. 15 Design Class Diagram

## 4.9 System Architecture

The client-server architecture was adopted for the development of the system. A client-server architecture acts as a distributed model that divides tasks between resource providers known as servers and service requestors known as clients. Figure 4.16 shows a client server architecture of the application for tracing and verification of the authenticity of filled LPG cylinder.



**Figure 4. 16 Client Server Architecture**

The manufacture adds cylinders and generates the QR code from the backend and stores the data in tables on the database. The researcher proposes that the manufacturers use aluminum tags to print the QR codes and place them near the cylinder valve. Using aluminum tags means the stickers are firm enough such that a valid sticker cannot be used multiple times since it cannot be removed from one cylinder and placed on another. Also, the serial number of each cylinder is used to generate its QR code that means there is no inter-changing of stickers. Placing the sticker on the top part of the cylinder next to the valve ensures that they do not wear out since this part is safe from scratches. The custom application hides the address of the verification server by issuing tokens to the client application that will be used to access the service.

In this application, the Android application is the client side which consists of the QR code scanner. Users interact with the application by capturing the unique identifier of the LPG cylinder. With the use of an Internet connection, the application verifies with a central database if the filled LPG cylinder is genuine or counterfeit. In this case, all manufactures maintain a central database of LPG cylinders from which the application gets the verification information.

Among the feedback received by the application will be the status which will indicate whether the filled LPG cylinder is authentic or not. For example, if the status gives a flag such as ‘suspicious’ it means the status of the filled LPG cylinder is questionable. The Android application also collects feedback from users as well as keeping a record of the history of all LPG cylinders verified before. A system administrator is responsible for the application server and can manage data for secondary reporting.

#### **4.10 User Interface Flow Diagram**

This section shows the user interface flow diagrams which include mobile application wireframes and web application wireframes.

#### **Mobile Application Wireframes**

The following figures are the various wireframe designs for the mobile application.



**Figure 4. 17 QR Code Scanner Wireframe**

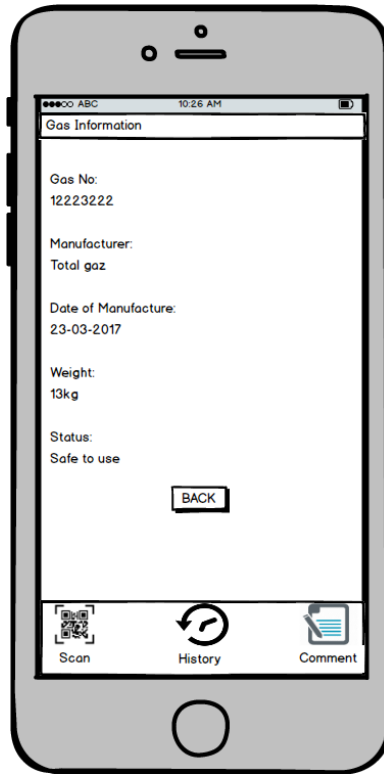


Figure 4. 18 Verification Results Wireframe

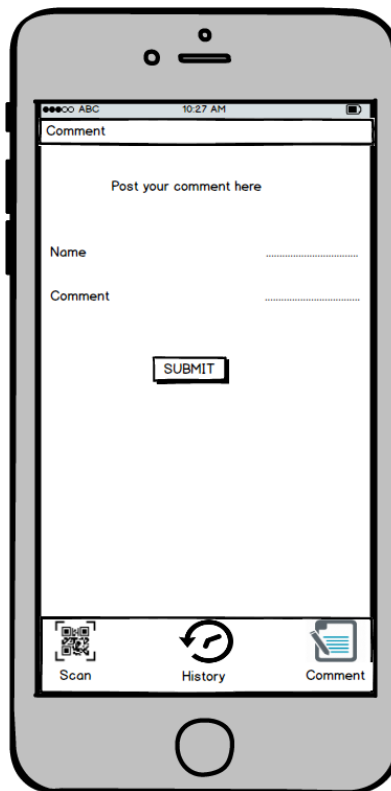


Figure 4. 19 User Feedback Wireframe



Figure 4. 20 Verification History Wireframe

### Web Application Wireframes



Figure 4. 21 Web Login Wireframe

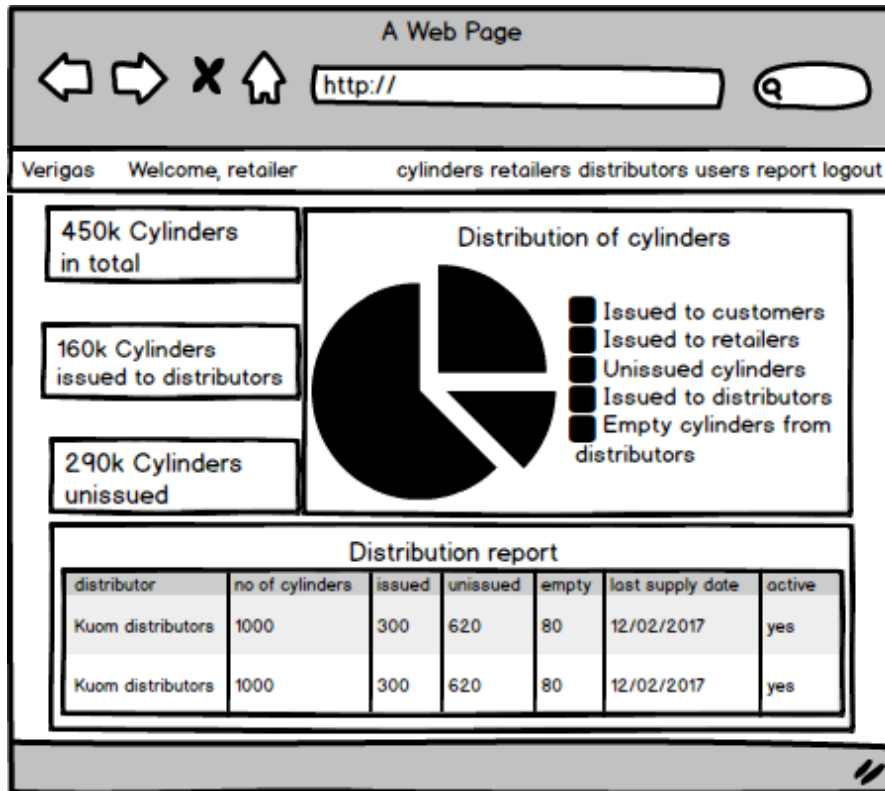


Figure 4. 22 Manufacturer Dashboard Wireframe

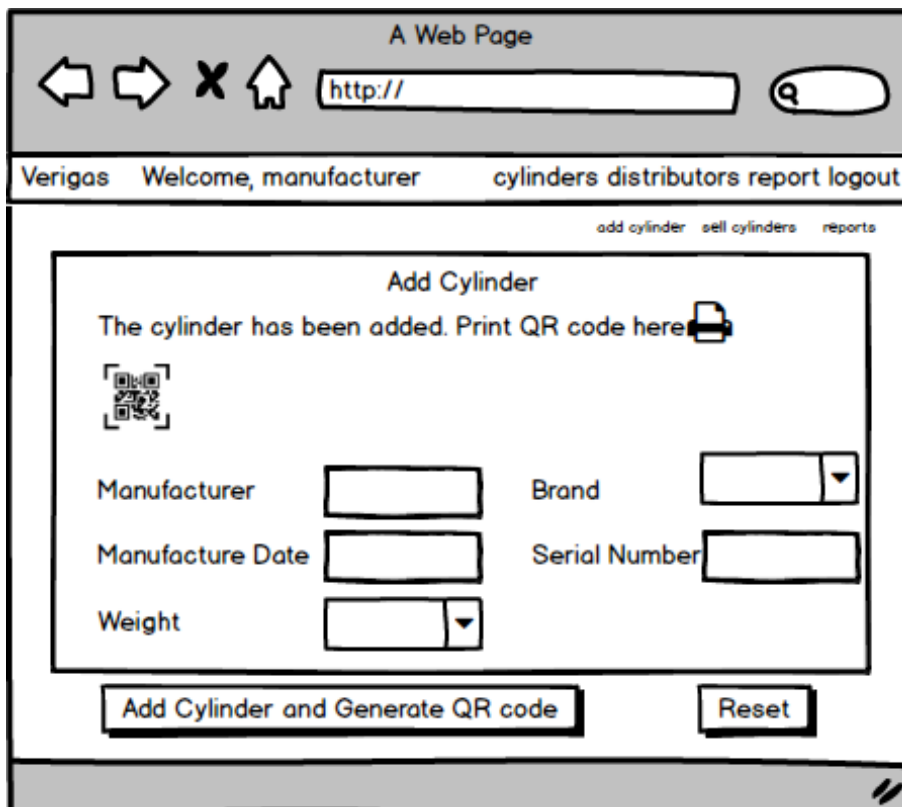


Figure 4. 23 Add Cylinder and Generate QR Code Wireframe

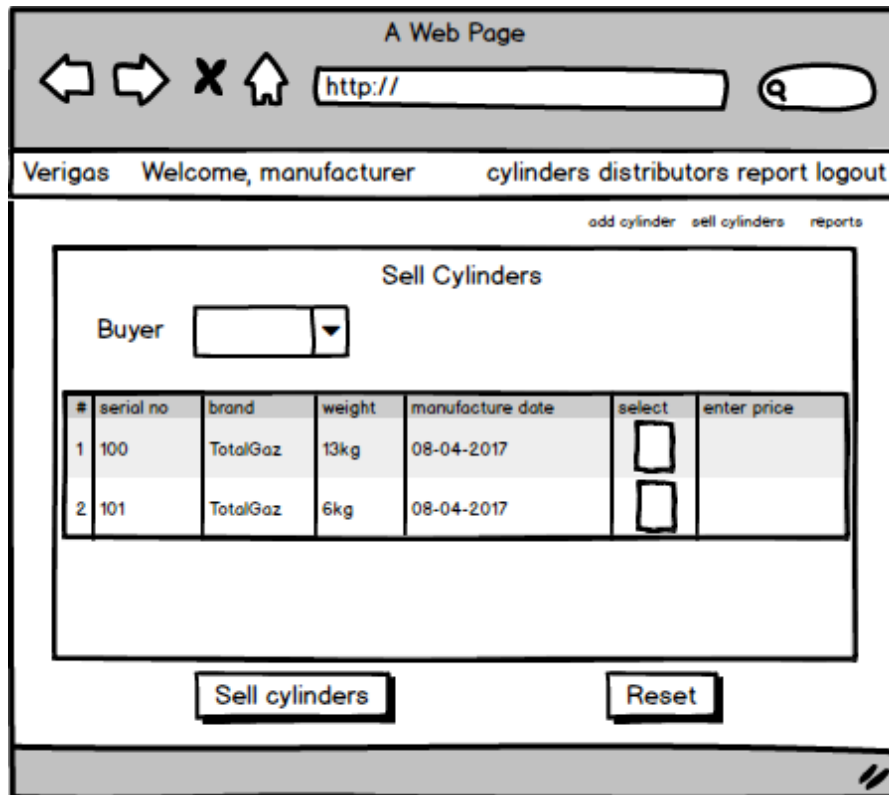


Figure 4. 24 Sell Cylinders Wireframe

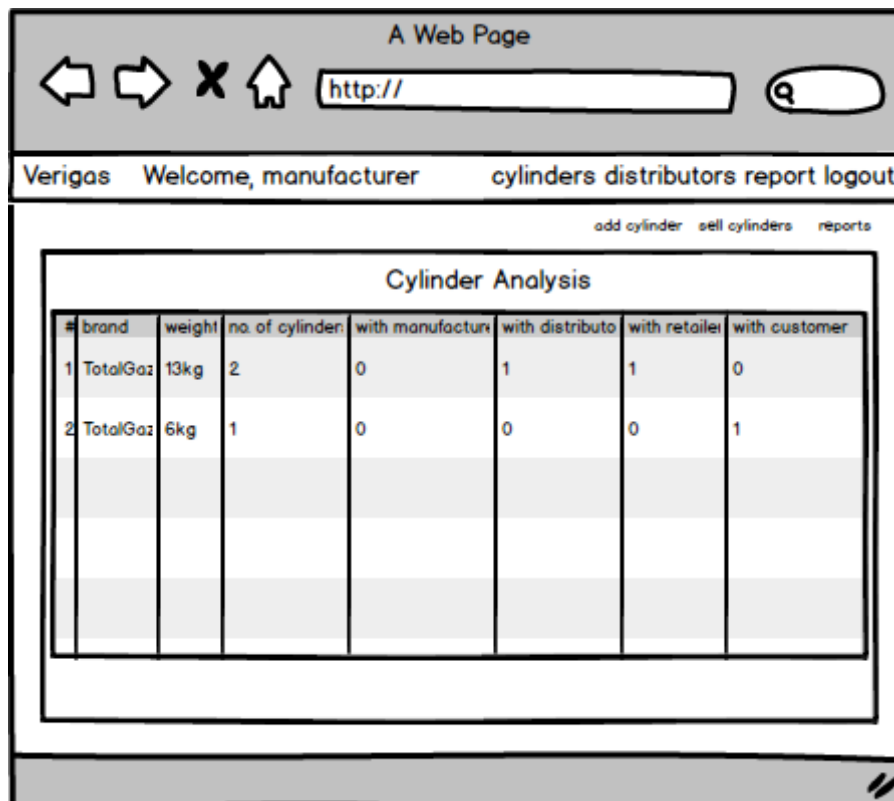


Figure 4. 25 Cylinder Analysis Wireframe

#### **4.11 Conclusions**

Data collected from the respondents was analysed and used to come up with informed conclusions. The proposed solution should be built for Android platform to begin with, features like QR code scanner, feedback system and comprehensive reports should be offered. Parameters to be used to check the authenticity of filled LPG cylinder include serial number, brand, weight, manufacturer and date of sale to customer.

System analysis and design helped to fine-tune the object requirements definition pinpointed in requirements analysis and to determine design specific objects. It was useful at defining the architecture, components, modules, interfaces and data for the system to be developed which helped satisfy the requirements. The next chapter explains the prototype building and testing.

## **Chapter 5: Implementation, Testing and Validation**

### **5.1 Introduction**

This chapter focuses on prototype building, testing and validation of the proposed system. Implementation part involves exploring various modules of the system, how implementation was done and how they function. Testing and validation involves functional testing and usability testing to check if the system fulfilled the objectives of the proposed solution.

### **5.2 System Implementation**

Agile software development methodology was used to develop this project. Initial requirements were identified and captured as executable specifications. Since there was active participation of stakeholders, requirements changed all through the project so that the working versions were modified to meet the evolving needs of stakeholders.

The system, named Verigas has a front-end and a back-end. The front-end is an Android mobile application which was developed using Java in xml. The back-end is a web application developed using PHP. HTML5 is the markup language that was used to structure and present content in the web backend dashboard. MySQL was used as the relational database management system.

The manufacture adds cylinders and generates the QR code from the backend and stores the data in tables on the database. The researcher proposes that the manufacturers use aluminum tags to print the QR codes and place them near the cylinder valve. Using aluminum tags means the stickers are firm enough such that a valid sticker cannot be used multiple times since it cannot be removed from one cylinder and placed on another. Also, the serial number of each cylinder is used to generate its QR code that means there is no inter-changing of stickers. Placing the sticker on the top part of the cylinder next to the valve ensures that they do not wear out since this part is safe from scratches.

In this application, the Android application is the client side which consists of the QR code scanner. Users interact with the application by capturing the unique identifier of the LPG cylinder. With the use of an Internet connection, the application verifies with a central database if the filled LPG cylinder is genuine or counterfeit. In this case, all manufactures maintain a central database of LPG cylinders from which the application gets the verification information. Among the feedback received by the application will be the status which will indicate whether the filled LPG cylinder is authentic or not. For example, if the status gives a flag such as ‘suspicious’ it means the status

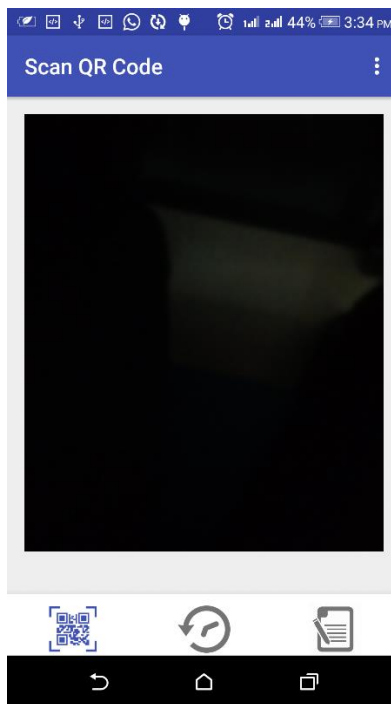
of the filled LPG cylinder is questionable. The Android application also collects feedback from users as well as keeping a record of the history of all LPG cylinders verified before. A system administrator is responsible for the application server and can manage data for secondary reporting.

### 5.2.1 Verigas Mobile Application

This application is designed to run on Android mobile phones and requires a camera and Internet connection.

#### QR Code Scanner

Figure 5.1 represents the main activity of the Verigas mobile application. To verify a filled LPG cylinder, the user focuses the phone camera on a QR code image which scans the image and returns verification results.



**Figure 5. 1 QR Code Scanner**

## Verification Results

Figure 5.2 shows a sample of verification results that a user gets once they scan the QR code image on the LPG cylinder.

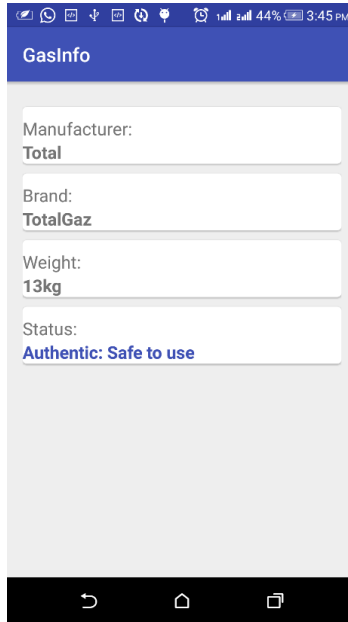


Figure 5. 2 Verification Results

## Authentication History

This is a record of all the scanned QR code images done by the user as shown in figure 5.3. The user can review the history by clicking on each record to get all the details about that particular scanned QR code image.

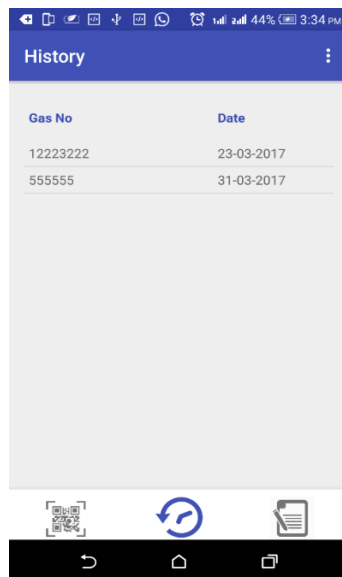
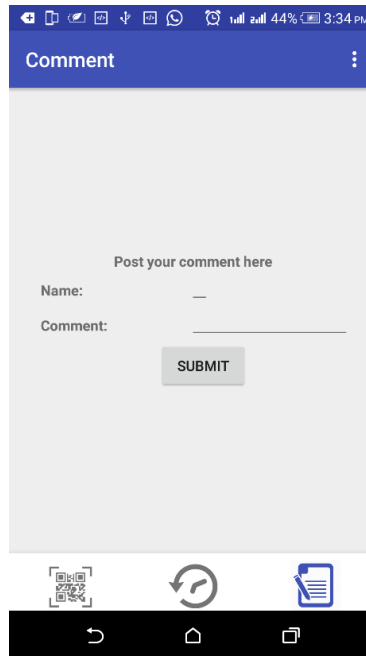


Figure 5. 3 Verification History

## Feedback

Figure 5.4 shows an activity where a user can leave a comment or complain for the admin.



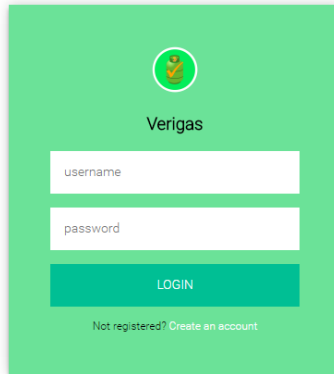
**Figure 5. 4 Feedback Page**

### 5.2.2 Verigas Web Application

The web application was designed to be used by manufacturers, distributors and retailers. Manufactures use it to add distributors, add cylinders so that they generate QR codes for each one of them, sell the cylinders to distributors such that they get a receipt for cylinders sold and get reports such as cylinder analysis and sales reports. Distributors use it to add retailers, sell the cylinders to retailers, get a receipt for cylinders sold and get reports as well. Retailers use it to sell cylinders to customers, get a receipt for goods sold and get reports.

## Login

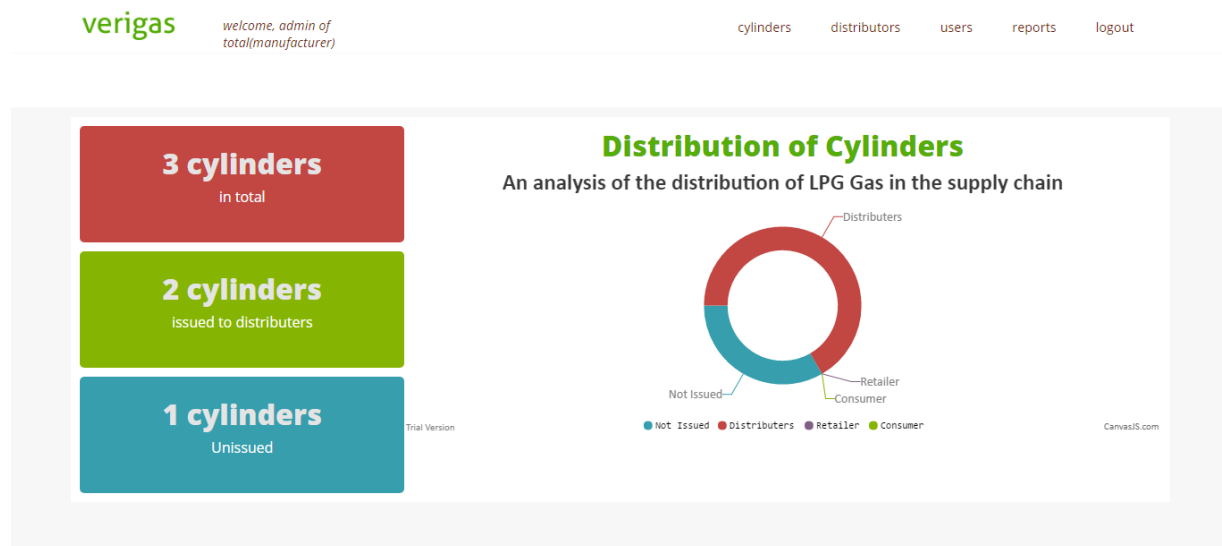
Figure 5.5 shows the login page where all users enter their username and password to gain access to Verigas web application. If the username and password match with what is saved in the database, then access is granted otherwise access is denied. This authentication is done to prevent unauthorised access.



**Figure 5. 5 Web Application Login Page**

## Dashboard

Figure 5.6 shows a dashboard that acts as a control panel for all the components of the web application.



**Figure 5. 6 Web Application Dashboard**

## Add Cylinder

Figure 5.7 shows the page where a manufacturer adds a cylinder into the system by entering the name of the manufacturer, the manufacturing date, the weight, the brand and the serial number of the cylinder. The serial number is then used to generate a QR code unique to that particular cylinder. Once the QR code is generated, it can then be printed for tagging on the cylinder.

The screenshot shows the 'Add Cylinder' page in the Verigas system. The page header includes the Verigas logo, a welcome message for 'admin of total(manufacturer)', and navigation links for cylinders, distributors, users, reports, and logout. Below the header are icons for 'add Brand', 'add cylinder', 'view cylinders', 'Sell cylinders', and 'Receipts'. The main content area features a green heading 'Add Cylinder' and a message: 'The Cylinder has been added. Print QR Code here' with a printer icon. A QR code is displayed on the left. The form contains the following fields: 'Manufacturer' (with 'Total' entered), 'Brand' (a dropdown menu), 'Manufacture Date', 'Serial Number', and 'Weight'. At the bottom, there are two buttons: a green 'Add Cylinder & generate qr code' button and a red 'Reset' button.

Figure 5. 7 Add Cylinder

## All Cylinders

Figure 5.8 shows a list of all the cylinders that have been added to the system by the manufacturer.

The screenshot shows the 'All Cylinders' page in the Verigas system. The page header is identical to Figure 5.7. The main content area features a green heading 'All Cylinders' and a table with the following data:

No.	Serial Number	Brand	Manufacture Date	Weights Available(in KGS)	Edit
1	111	TotalGaz 13kg	2017-04-08	13kg	<a href="#">edit</a>
2	112	TotalGaz 13kg	2017-04-08	13kg	<a href="#">edit</a>
3	113	TotalGaz 6kg	2017-04-08	6kg	<a href="#">edit</a>

Figure 5. 8 All Cylinders

## Add Distributor

Figure 5.9 shows the page where a manufacturer adds a distributor by entering the name of the company of the distributor, the address, contact person, location and phone or landline number that can be used to reach them.

The screenshot shows the 'Add Distributors' page. At the top, there is a header with the Verigas logo, user information 'welcome, admin of total(manufacturer)', and navigation links for 'cylinders', 'distributors', 'users', 'reports', and 'logout'. Below the header, there are two buttons: 'add Distributor' and 'view distributors'. The main content area is titled 'Add Distributors' and contains a form with the following fields: 'Distributors', 'Address', 'Contact Person', 'Location', and 'Phone'. At the bottom of the form, there are two buttons: 'Add distributor' and 'Reset'.

Figure 5. 9 Add Distributor

## Sell Cylinders

Figure 5.10 shows the sell cylinders page. The user needs to choose to whom they wish to sell the cylinders, select all the cylinders they want to sell and enter all their prices then click on sell cylinders button.

The screenshot shows the 'Sell Cylinders' page. At the top, there is a header with the Verigas logo, user information 'welcome, admin of total(manufacturer)', and navigation links for 'cylinders', 'distributors', 'users', 'reports', and 'logout'. Below the header, there are five buttons: 'add Brand', 'add cylinder', 'view cylinders', 'Sell cylinders', and 'Receipts'. The main content area is titled 'Sell Cylinders' and contains a form with a 'Buyer' dropdown menu and a table with the following columns: '#', 'Serial', 'Brand', 'Weight', 'Manufacture Date', 'Select', and 'Enter Price'. The table contains three rows of data. At the bottom of the form, there are two buttons: 'Sell Cylinders' and 'Reset'.

#	Serial	Brand	Weight	Manufacture Date	Select	Enter Price
1	111	TotalGaz 13kg	13kg	2017-04-08	<input type="checkbox"/>	
2	112	TotalGaz 13kg	13kg	2017-04-08	<input type="checkbox"/>	
3	113	TotalGaz 6kg	6kg	2017-04-08	<input type="checkbox"/>	

Figure 5. 10 Sell Cylinders

## Sale Receipt

Figure 5.11 shows a receipt that a user gets after making a sale. It records the receipt no, date of sale, the buyer, the seller as well as the serial number, the brand, the weight and amount of each cylinder sold.

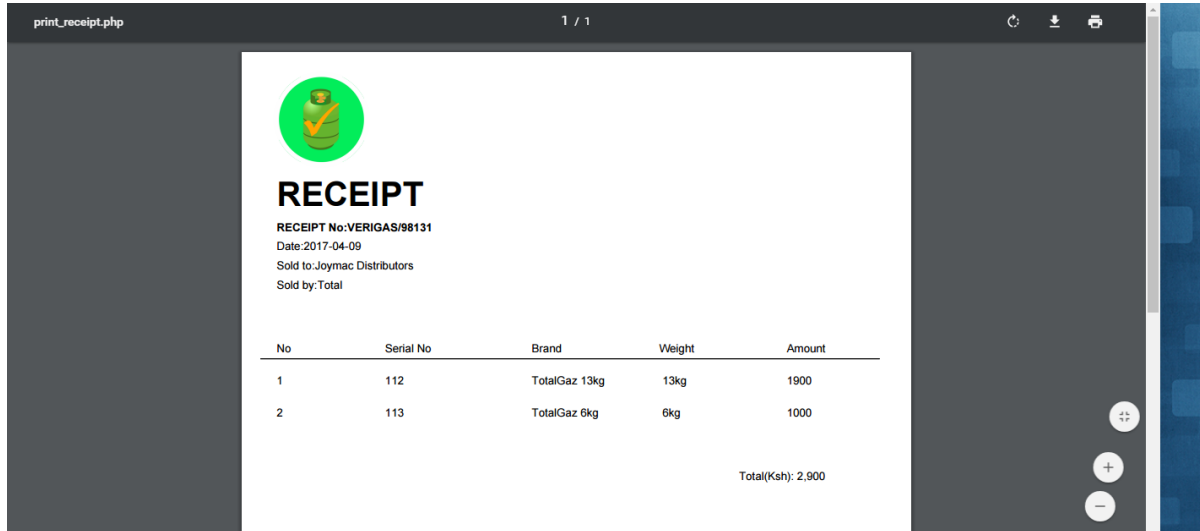


Figure 5. 11 Sale Receipt

## Cylinder Analysis Report

Cylinder analysis report gives a record of the distribution of cylinders. It record the number of cylinders with manufacturers, distributors, retailers and those with customers based on the brand and weight as shown in figure 5.12.

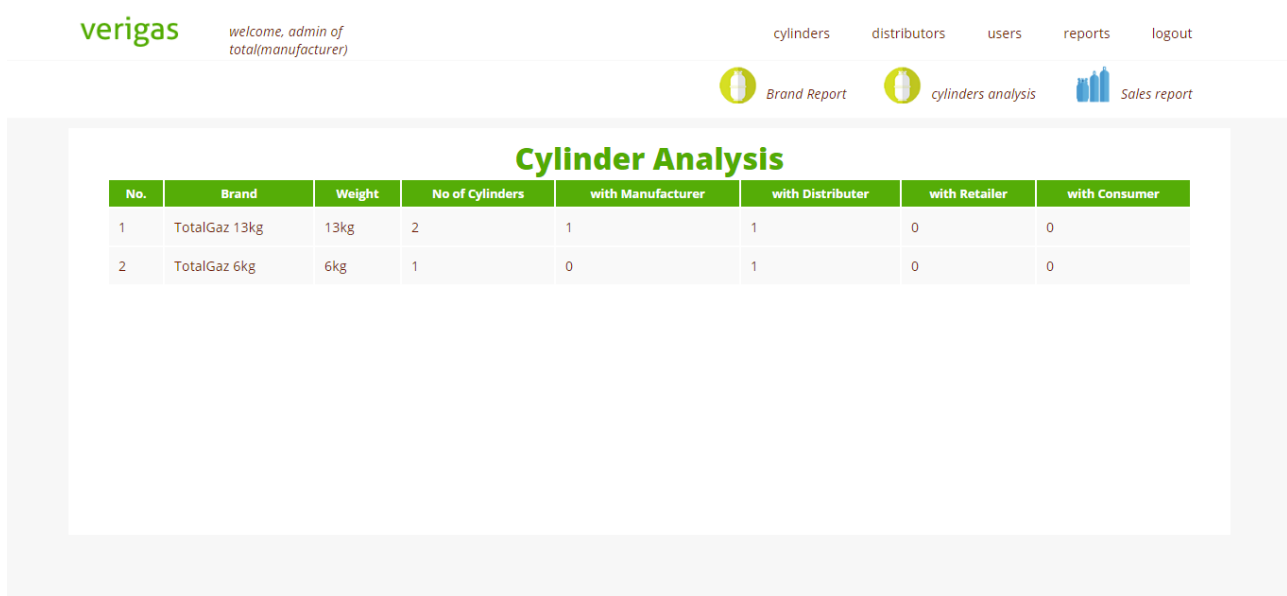


Figure 5. 12 Cylinder Analysis Report

## Sales Report

This report contains a list of all the sales that have been made by a user.



**Figure 5. 13 Sales Report**

## 5.3 System Testing

Since Agile software development methodology was used to implement the proposed system, Agile testing was applied. Agile testing is an approach where a software program is tested for performance issues or bugs within the context of an agile workflow. Agile testing was continuously applied during development of the software to make sure that during each iteration the features are well implemented.

### 5.3.1 Compatibility Testing

Compatibility test was carried out to make sure that the web and mobile applications are compatible with existing platforms.

#### Web Browser Compatibility Testing

The web application was tested against the existing web browsers which are commonly used.

**Table 5. 1 Web Browser Compatibility Test**

Browser Type	Compatibility
Firefox (Versions 8.0 and above)	Yes
Google Chrome (All versions)	Yes
Internet Explorer (Versions 4 and above)	Yes

### Android Platform Compatibility Testing

The mobile application was tested against existing Android versions.

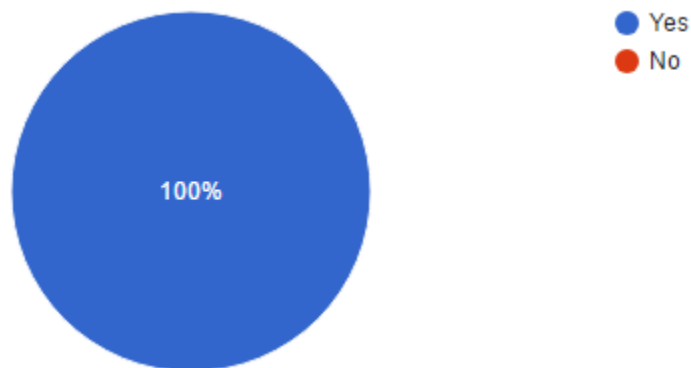
**Table 5. 2 Android Platform Compatibility Test**

Android Platform	Compatibility
Android 10 (2.3.3)	Yes
Android 11 (3.0)	Yes
Android 12 (3.1)	Yes
Android 13 (3.2)	Yes
Android 14 (3.3)	Yes
Android 15 (4.0.3)	Yes
Android 16 (4.1.2)	Yes
Android 17 (4.2)	Yes
Android 19 (4.4)	Yes
Android 21 (5.0)	Yes

### 5.3.2 Usability Testing Results

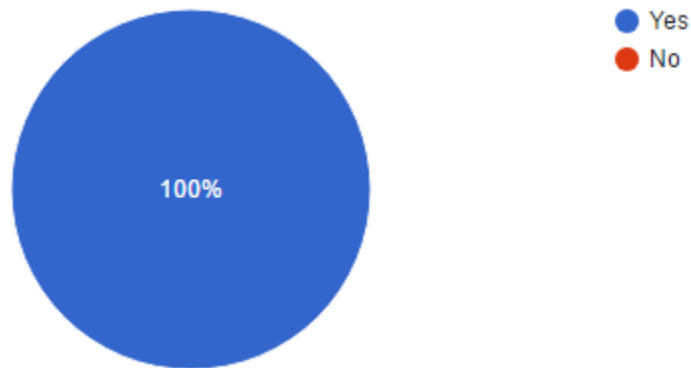
The usability and validation questionnaire was prepared using google forms then it was distributed to 8 respondents via mail and the data analysed using google analytics.

All the participants were able to generate a QR code as shown in figure 5.14.



**Figure 5. 14 Generating a QR Code**

There was 100% success in scanning the QR code as shown in figure 5.15.



**Figure 5. 15 Scanning a QR Code**

None of the participants encountered any problems during generation, scanning and getting of verification results.

None
None
N/A
No

**Figure 5. 16 Problems Encountered When Using the Application**

Figure 5.17 shows some of the features that users thought they were interesting.

The whole thing
Being able to scan the cylinder and get feedback about the gas
QR Code Scanner
Ability to be able to know a genuine gas cylinder
scanning the qr code
report on the lpg gas
QR code scanner
QR code generator

**Figure 5. 17 Features That Interested Users Most About the Application**

Figure 5.18 displays some of the comments and suggestions given by the respondents.

Excellent work, would use it anytime
it is an awesome application
This is a great app. Promoting security in house holds.
Develop it on other platforms.
great work
Excellent work!Keep up
This application is very useful.
It is an amazing application.

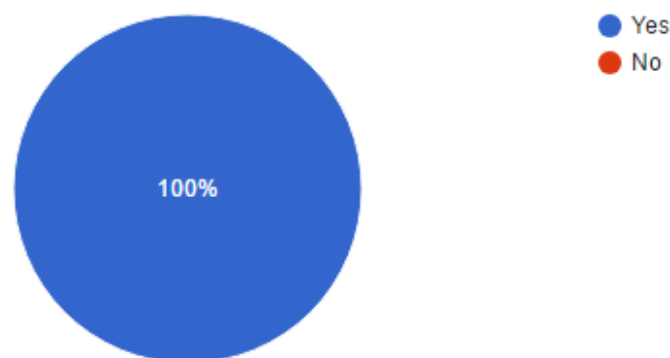
**Figure 5. 18 Comments, Suggestions or Recommendations about the Application**

### 5.4 Validation

Validation was carried out so as to check whether the implemented system addressed the challenges that existed as far as tracing and verification of the authenticity of filled LPG cylinders is concerned.

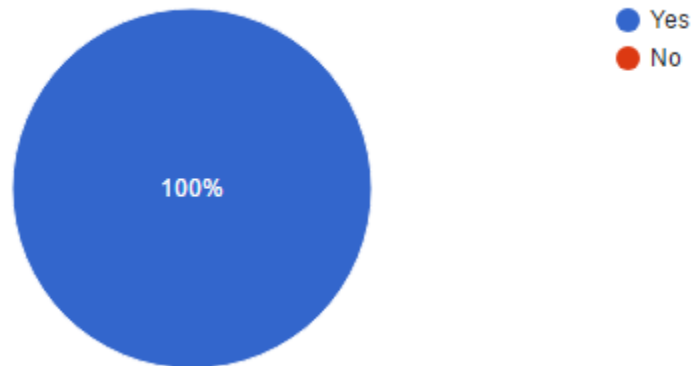
#### 5.4.1 Validation Results

All the participants confirmed that the functionalities provided by the application helped solve the problems faced during tracing and verification of the authenticity of filled LPG cylinders.



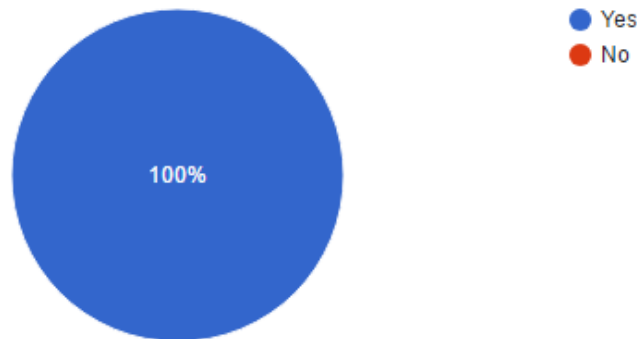
**Figure 5. 19 Ability of the Application to Solve Problems When Tracing and Verifying the Authenticity of Filled LPG Cylinder**

All the participants were satisfied with the solution.



**Figure 5. 20 Satisfaction with the solution**

All the participants confirmed that they would recommend the application to other customers and LPG manufacturers to adopt the application.



**Figure 5. 21 Determination Whether a User Can Recommend Other Consumers and LPG Manufacturer to Adopt the Application**

## 5.5 Conclusions

The requirements identified during requirements analysis phase gave essential information which was used during the implementation phase. The design gave information on how the system implementation was done. All the research objectives were also considered so as to make sure that the system implemented met the user requirements of potential users. The entire system was implemented based on the objectives.

## **Chapter 6: Discussions**

### **6.1 Introduction**

This chapter explains the research findings and achievements, reviews how the research objectives were achieved and also reviews the solution that was developed by mentioning its advantages and limitations. Findings obtained from this study formed the basis on which a mobile application for tracing and verification of the authenticity of filled LPG cylinder was developed.

### **6.2 Findings and Achievements**

In order to develop a suitable solution, the research findings were used to help identify the most appropriate technology. The literature review showed that technologies that support tracing and verification of LPG cylinders include RFID, Bar code, Manual verification, M2M and QR code. RFID technology is expensive and hard to implement because of absence of regulatory standards (Kaur et al., 2011). Bar codes on the other hand can be easily duplicated hence they are unreliable. M2M is difficult to implement, since it generates a huge quantity of information, its privacy implications can cause serious concerns (Hyster, 2012).

The questionnaire was distributed to 96 LPG consumers within Nairobi, 95 respondents answered all the questions while 1 respondent answered only part of the questionnaire. 82.3% of respondents had used LPG for more than 2 years, 12.5% had used it for between 1 and 2 years while 5.2% had used it for less than 1 year. 53.1% respondents use 6kg LPG cylinders, 36.5% use 13kg, 9.4% use 3kg and 1% use 50kg LPG cylinders. 58.3% respondents purchase their LPG from retailers, 31.3% from authorized dealers and 10.4% from distributors.

Characteristics that respondents consider in identifying the authenticity of filled LPG cylinder include the brand, date of manufacture and weight (Consumer Welfare, 2015). Most respondents consider weight to be very important when checking the authenticity of filled LPG cylinder followed by the brand and finally the date of manufacture. 75.8% do not know the source of the gas they use while 24.2% know. Respondents check if the cylinder is sealed, confirm that the brand is familiar, ensure that the cylinder is in a good condition and weigh to confirm the weight is the one indicated on the cylinder before purchasing LPG.

86.5% respondents own Android phones while the other operating systems share the rest of the percentage (13.5%). Respondents are familiar with bar codes, QR codes, RFIDs and M2M.

Respondents are capable of accessing the internet, downloading an application, taking a picture and sending or receiving emails. Respondents wanted features like QR code scanner, feedback system, notifications and analytics to be included on the new application.

Since manual verification was used in Kenya according to the results from the questionnaire, there was need for an automated system that could effectively achieve the same. To fill the gaps and limitations of the aforementioned technologies, QR code technology was adopted to come up with a mobile application and a unified web back end system for online tracing and verification of the authenticity of filled LPG cylinder. The mobile application was developed to be used by customers who have access to a mobile phone running on Android operating system which is data enabled and with a camera.

### **6.3 Review of Research Objectives in Relation to the Mobile Application**

In reference to section 1.3, the first objective was to analyze the characteristics of an authentically filled LPG cylinder. According to the findings from the questionnaire, it was seen that respondents check the brand name, the weight, the date of manufacture, the seal and cylinder condition. These findings are in line with the literature review as discussed in section 2.2.

The second objective was to investigate the methods currently used for tracing and verification of filled LPG cylinders in Kenya. According to the answers in the questionnaire, Kenyans trace and verify LPG cylinders manually clearly indicating the need for automation of this process. From the review of literature on section 2.4, it is evident that the literature review is in harmony with findings from the study.

The third objective was to analyze the technologies available to support tracing and verification of LPG cylinders. Results from findings show that almost all respondents are conversant with RFIDs, Bar Codes, QR Codes, and M2M technologies. These technologies are in line with the literature review because they consist of technologies discussed in section 2.5.

The fourth objective was to design, develop and test an Android mobile application for tracing and verification of the authenticity of filled LPG cylinder. Findings showed that users wanted to see features like QR code scanner, feedback system, analytics and notifications on the proposed application. The application developed was in harmony to the technology discussed in the literature review on section 2.6 which is QR technology.

The last objective was to validate the developed mobile application. The literature review focused on regression, usability and smoke testing to do the testing and validation. To test and validate the developed application, the usability testing and validation questionnaire in Appendix B was used. All the participants did not face any problems generating, scanning the QR code and getting verification details therefore the application proves to be reliable. Easy to find core functionality, responsiveness and usefulness were rated excellent.

#### **6.4 Advantages of the Application Compared to the Current System**

Compared to the manual tracing and verification of LPG cylinders used in Kenya, the proposed solution offers a web back-end that provides a platform for data manipulation and representation. The application offers confidence of legitimacy, it does not cost the user anything to use it for verification, it is easy to use and requires very little time to trace and verify the LPG cylinders. The application provides real-time online access to information on LPG cylinders at any time and from anywhere.

#### **6.5 Limitations of the Application**

The mobile application was only designed for LPG cylinder tracing and verification. Secondly, it is only useful to smartphone users whose phones run on Android operating system. Thirdly, for one to use the application, Internet connectivity is required.

## **Chapter 7: Conclusions, Recommendations and Future Work**

### **7.1 Introduction**

In this chapter, conclusions, recommendations and future work are discussed. As for the conclusions, all the objectives are reviewed briefly by looking at how the research questions were answered. In recommendation, the researcher gives some recommendations to users and stakeholders of the system. Future work entails something that was not implemented in the system but can be implemented in the future.

### **7.2 Conclusions**

This research found out that the characteristics that customers look for to determine if a filled LPG is genuine or counterfeit include the brand, intact seal, weight and sometimes the cylinder condition. A review of the methods currently used and the technologies that support tracing and verification of the authenticity of filled LPG cylinder concluded that those technologies include RFID, Bar code, Manual verification, M2M and QR code. The study exposes the fact that there are challenges within the gas industry specifically those of tracing and verifying whether a filled LPG cylinder is authentic or not.

The challenges identified led to the development of a mobile application with a web back end for tracing and verification of the authenticity of filled LPG cylinder using one of the available studied technology. Agile software development methodology was used to develop the system because it allows for iterative build in terms of features such that the final build supports all the features needed by the customer. Testing and validation was done using a questionnaire that was distributed to 8 respondents.

### **7.3 Recommendations**

To the customers, verifying filled LPG cylinders before purchasing saves them a lot financial losses due to hospital bills in case of incidents of explosions resulting from counterfeit LPG. Therefore, my recommendations is to LPG manufacturers to adopt this system by generating unique QR codes for each LPG cylinder so that the details are saved to a central database from whose data customers, retailer and distributors can validate an LPG cylinder before taking it with them. Secondly, so as to increase the adoption of the system, public awareness should be effectively conducted. To use the application, a user only needs to download it for free.

#### **7.4 Future Work**

The researcher has seen that the proposed solution can be expanded in the future. First, this platform can be used in targeted marketing where manufacturers can offer similar or related products to the user, the user can get suggestions to the nearest gas depots, pricing of different brands, availability and make requests for delivery of the gas cylinders to their desired location. Secondly, manufacturers will get more precise analytics to help them make informed business decisions for example, they can know the demand and supply of different regions to determine marketing and supply channel strategies to apply thus increasing their returns. Thirdly, in order to expand the market to more users, the same application will be developed for other platforms like iOS, Windows among others.

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## **Appendices**

### **Appendix A: Questionnaire**

Dear Respondent,

I am a Masters student in the Faculty of Information Technology, Strathmore University conducting a research entitled A MOBILE APPLICATION FOR TRACING AND VERIFICATION OF THE AUTHENTICITY OF FILLED LIQUEFIED PETROLEUM GAS CYLINDERS. You have been selected to be part of this study. Your participation in filling out this questionnaire will be highly appreciated. The information requested is for academic purpose only and will be treated with high level of confidence.

Your cooperation is highly appreciated. Thank you.

Kind Regards,

Carolyne Wanza

\*Required

#### **Section A: Respondent detail**

A1. Please choose ONE option to indicate for how long you have used LPG (cooking gas)\*

- Less than 1 year
- Between 1 and 2 years
- Above 2 years

A2. Please choose ONE option to indicate the capacity of LPG (cooking gas) you use\*

- 3 kg
- 6 kg
- 13kg
- 35 kg
- 50kg

A3. Please choose ONE to indicate where you buy your LPG (cooking gas)\*

- Authorized dealers
- Retailers

- Distributors

**Section B: Characteristics of an authentically filled LPG cylinder**

B1. Please tick (√) ALL characteristics that you consider in identifying an authentically filled LPG cylinder by (Choose ALL that apply)\*

- Date of manufacture
- Brand
- Weight

B2. Please rank the importance attached to the characteristics when checking the authenticity of filled LPG cylinder using the scale (High, Moderate, Low)\*

	<b>High</b>	<b>Moderate</b>	<b>Low</b>
<b>Date of manufacture</b>	○	○	○
<b>Brand</b>	○	○	○
<b>Weight</b>	○	○	○

**Section C: Current methods of tracing and verifying the authenticity of filled LPG cylinders in Kenya**

C1. Do you know the source of the gas you use? (Choose ONE)\*

- Yes
- No

C2. What do you check for when buying cooking gas? (Choose ALL that apply)\*

- Confirm that the brand is familiar
- Check if it is sealed
- Ensure that the cylinder is in good condition
- Confirm the weight

**Section D: Technologies available to support tracing and verification of LPG cylinders.**

D1. What operating system does your mobile phone run on? (Choose ONE)\*

- Android
- iOS
- Windows
- BlackBerry
- No idea

D2. Are you aware with these technologies? (Choose ALL that apply)\*

- Radio Frequency Identification Technology (RFID)
- Machine to machine (m2m)
- Bar codes
- QR codes
- None

**Section E: Application for tracing and verifying the authenticity of filled LPG cylinders**

E1. Are you capable of doing the following using a mobile phone? (Choose ALL that apply)\*

- Access the internet
- Download an application
- Take a picture
- Send or receive email

E2. What features would you like to see on the application for tracing and verifying the authenticity of filled LPG cylinders (Choose ALL that apply)\*

- QR Code scanner
- Feedback system
- Analytics
- Push Notifications
- I have no idea

**Thank you for your time.**

**Appendix B: Usability Testing and Validation Questionnaire**  
**LPG Tracing and Verification System**

\*Required

**Section A: Usability Testing**

A1. Were you able to generate a QR code? (Choose ONE)\*

- Yes
- No

A2. Were you able to scan a QR code? (Choose ONE)\*

- Yes
- No

A3. Were you able to get verification results? (Choose ONE)\*

- Yes
- No

A4. If any of your answer above is ‘No’ please list the problems you encountered?\*

.....

.....

.....

A5. How would you rate the whole application? (Choose only ONE per row)\*

	<b>Poor</b>	<b>Fair</b>	<b>Good</b>	<b>Very Good</b>	<b>Excellent</b>
<b>Navigability</b>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
<b>Easy to learn and use</b>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
<b>Easy to find the core functionality</b>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
<b>Responsiveness</b>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
<b>Useful and satisfying</b>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

A6. What feature interested you most? \*

.....

A7. Any comments, suggestions or recommendations about this application? \*

.....  
.....

**Section B: Validation**

B1. Do the functionalities provided by the application solve the problems faced during tracing and verification of the LPG cylinders? (Choose ONE)\*

- Yes
- No

B2. Are you satisfied with solution provided by the application as far as tracing and verification of LPG is concerned? (Choose ONE)\*

- Yes
- No

B3. Would you recommend other consumers and LPG manufacturer to adopt the application? (Choose ONE)\*

- Yes
- No

**Thank you for your time.**

## Appendix C: Turnitin Report

The screenshot displays a Turnitin report interface. At the top, the document title is "Dissertation2" by "WANZA CAROL". The Turnitin logo is visible on the right, along with a similarity score of "15% SIMILAR" and a status of "-- OUT OF 0". Below the header, the document title is "A Mobile Application for Tracing and Verification of Authentically Filled Liquefied Petroleum Gas Cylinders". The author's name is "By Mutua Carolyne Wanza". At the bottom, it states "A Dissertation Submitted in Partial Fulfilment of the Requirements for the Award of a Master of Science Degree in Mobile Telecommunication and Innovation (MSc. MTI)". The right side of the report area is a solid grey rectangle, likely representing a redacted or missing image or content.

**Figure C. 1 Turnitin Report**