

**Mobile Application for Traceability of Liquid Petroleum Gas  
Cylinders in Kenya**

**Submitted by:  
Brian Onjeri Wamwenje**



**A Research Thesis submitted to the Faculty of Information  
Technology in partial fulfilment for the requirement of the degree of  
Master of Science in Information Technology of Strathmore  
University**

**Submitted: 2025**

## Declaration

I declare that this research thesis, which I submit to Strathmore University for examination in consideration of the award of a Master of Science degree in Information Technology, has been composed solely by myself and that it has not been submitted, in whole or in part, in any previous application for a degree or professional qualification. Except where stated otherwise by reference or acknowledgment, the work presented is entirely my own. Furthermore, I took reasonable care to ensure that the work is original, and, to the best of my knowledge, does not breach copyright law.

Name: Brian Onjeri Wamwenje

Admission No: 094875

Signature: \_\_\_\_\_



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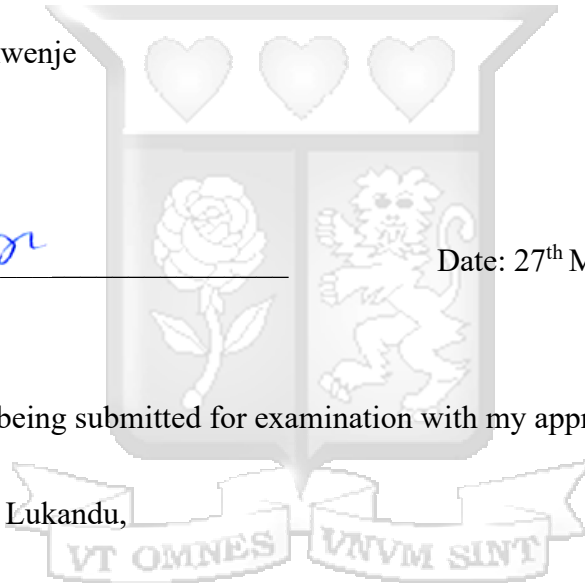
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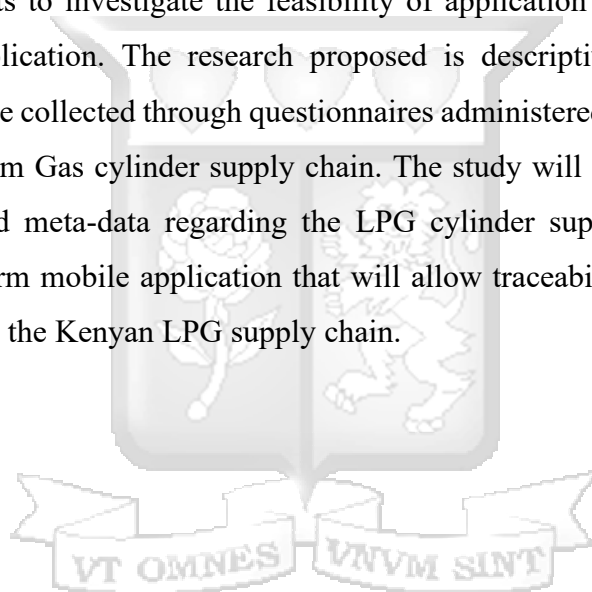
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## **Abstract**

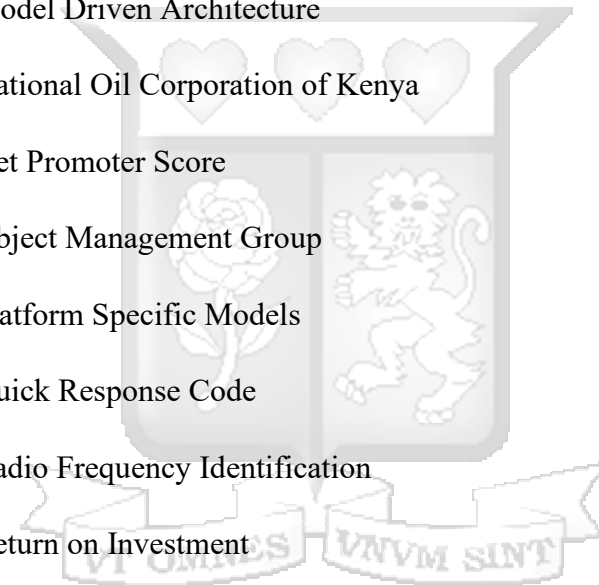
The introduction of the universal valve for Liquefied Petroleum Gas (LPG) cylinders in 2009 effectively lowered the entry barrier into the Kenyan LPG industry. The lower entry barrier coupled with poor visibility along the supply chain; resulted into the raise of illegal re-fillers; who preyed on other players' cylinders and consequently their brand equity. The illegal refilling business has been hugely characterised by incorrect weights of product and failure to adhere to safety regulations. This has resulted in a number of reported deaths and loss of property through fire. Consumers and traders have suffered losses attributed to incorrect weights. The research proposes to investigate the extent of cylinder traceability requirement in the Kenyan LPG cylinder space. The study attempts to investigate the feasibility of application and adoption of an LPG cylinder traceability application. The research proposed is descriptive, adopting a positivist paradigm. The data will be collected through questionnaires administered to different stakeholders in the Liquefied Petroleum Gas cylinder supply chain. The study will also capture data through structured interviews and meta-data regarding the LPG cylinder supply chain. The proposed solution is a cross platform mobile application that will allow traceability and authentication of LPG gas cylinders within the Kenyan LPG supply chain.



## Abbreviations and Acronyms

<b>2D</b>	-	Two Dimension
<b>3G</b>	-	Third generation of mobile telecommunications technology
<b>4G</b>	-	Fourth generation of mobile telecommunications technology
<b>AFNOR</b>	-	French Standardization Agency
<b>API</b>	-	Application Programming Interface
<b>APICS</b>	-	American Production and Inventory Control Society
<b>APK</b>	-	Android Package Kit
<b>BPM</b>	-	Business Process Modelling
<b>DB</b>	-	Database
<b>DFD</b>	-	Data Flow Diagram
<b>DNA</b>	-	Data Not Available
<b>DSDM</b>	-	Dynamic Systems Development Method
<b>EAC</b>	-	East African Community
<b>ERC</b>	-	Energy Regulation Commission
<b>EPRA</b>	-	Energy and Petroleum Regulatory Authority
<b>ERD</b>	-	Entity Relationship Diagrams
<b>FDD</b>	-	Feature-Driven Development
<b>FY</b>	-	Financial Year
<b>GIAI</b>	-	Global Individual Asset Identifier
<b>GLN</b>	-	Global Location Number
<b>GoK</b>	-	Government of Kenya
<b>GRAI</b>	-	Global Returnable Asset Identifier

<b>GTIN</b>	-	Global Trade Identification Numbers
<b>IoT</b>	-	Internet of Things
<b>JS</b>	-	JavaScript
<b>KNBS</b>	-	Kenya National Bureau of Statistics
<b>KPC</b>	-	Kenya Pipeline Company
<b>LPG</b>	-	Liquefied Petroleum Gas
<b>M2M</b>	-	Machine-to-Machine
<b>MDA</b>	-	Model Driven Architecture
<b>NOCK</b>	-	National Oil Corporation of Kenya
<b>NPS</b>	-	Net Promoter Score
<b>OMG</b>	-	Object Management Group
<b>PSM</b>	-	Platform Specific Models
<b>QR Code</b>	-	Quick Response Code
<b>RFID</b>	-	Radio Frequency Identification
<b>ROI</b>	-	Return on Investment
<b>SCM</b>	-	Supply Chain Management
<b>SCOR</b>	-	Supply Chain Operations Reference
<b>SDK</b>	-	Software Development Kit
<b>SSCC</b>	-	Serial Shipping Container Code
<b>TOB</b>	-	Traceable Object
<b>TOVE</b>	-	Toronto Virtual Enterprise Project
<b>TRU</b>	-	Traceable Resource Unit
<b>UI</b>	-	User Interface



- UX** - User Experience
- UML** - Unified Modelling Language
- WLPGA** - World LPG Association
- WP** - Windows Phone
- WSN** - Wireless Sensor Networks
- XP** - Extreme Programming



## Definition of Terms

**Apps store:**

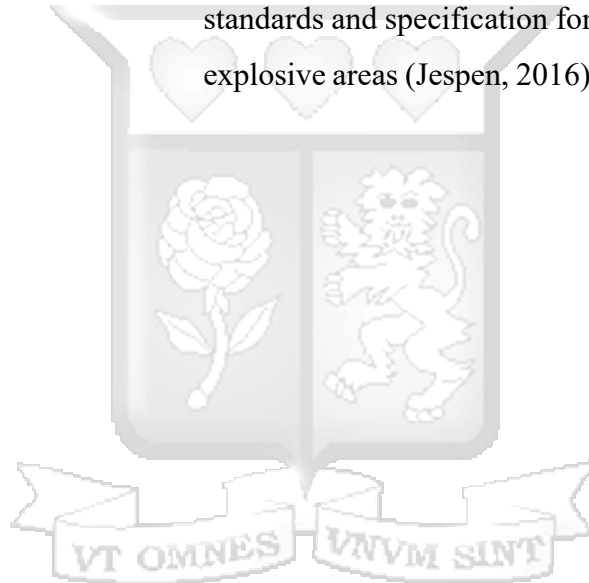
A virtual market place where users can search, purchase, download and install software applications and add-ons (Zhu et al., 2024).

**Common Back-End:**

The terms is a collective name for the application core business logic that is hosted in the server; including the database and associated procedures. (Li et al., 2020).

**ATEX standards:**

Refers to two European Directives 2014/34/EU (2014) and 1999/92/EC (1999) (ATEX directives). This define standards and specification for equipment used in highly explosive areas (Jespen, 2016) and (Părăian et al., 2020).

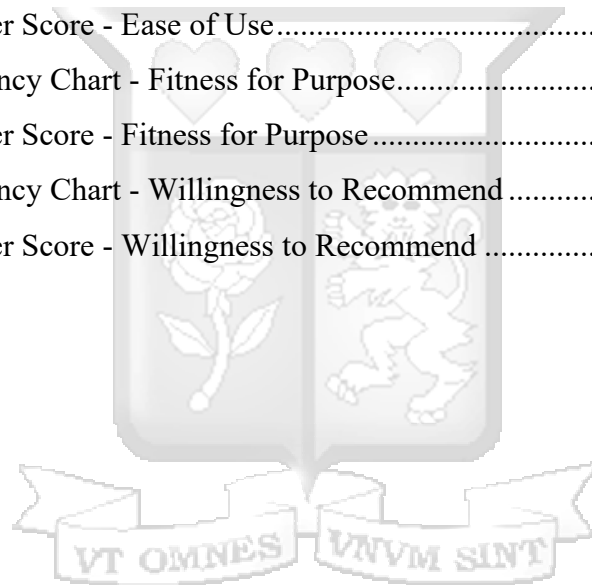


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## Chapter 1 : Introduction

### 1.1. Background to the Study

Liquefied Petroleum Gas (LPG) is a modern alternative fuel for use as a preferred alternative to the existing Kerosene and wood fuels (Raslavičius et al., 2014). This is because it reduces harmful emissions that form hazards on health and environmental degradation. The Kenya Government has deliberately fronted this as an alternative to existing kerosene and wood fuel solutions in the country (Ministry of Energy and Petroleum, 2023a). LPG is considered environmentally friendly because in the presence of excess oxygen, propane burns to form water and carbon dioxide.

The United Nations' Sustainable Energy for All (SE4All) 2011 initiative prioritizes access to clean forms of energy by 2030. In 2012 Kenya joined SE4All. At the time Kenyans relied heavily on dirty forms of energy for cooking such as wood, charcoal, kerosene or agricultural residue. Use of such fuels for cooking has proven to have a negative impact on user's health (Rahnema et al., 2017). The world bank projects that 23,000 lives are lost annual due to air pollution. Statistics also reveal that respiratory illness is responsible for approximately 40% of childhood fatalities (Rotich & Musyimi, 2024). Wood is not a sustainable fuel; it is a depleting resource as its demand outweighs the rate of replenishment (Imo, 2012). LPG alternative fuels such as wood and other fossil fuels are inefficient, negatively impact the environment and pose health risk to users. To curb this, the Government of Kenya as part of its strategic plan, targets to facilitate access to clean cooking fuels by all, by 2028. This strategic objective is etched into the country's vision 2030 blue print and embodied in the "Kenya National Cooking Transition Strategy 2024 – 2028", in alignment with the SE4All country action agenda (Ministry of Energy and Petroleum, 2024a).

The Vision 2030 further identifies flagship projects to be undertaken. Some of the critical energy projects are around investment into alternative clean energy. To this end the Government of Kenya (GoK) has made substantial investment toward enhancing the uptake of LPG in the country. The government has targeted to increase the average LPG consumption per capita from 6.59Kgs in 2022 to 10Kgs by 2027. This increase is also driven by a push to have at least 50% of public learning institutions using LPG over the period (Ministry of Energy and Petroleum, 2024b).

The increasing marketing space and poor regulatory enforcement has left both the Kenyan public and LPG marketers exposed. The country has seen an increase in illegal LPG cylinder refillers (Global LPG Partnership et al., 2019). Through the Energy Act of 2019 which replaced the LPG Regulations of 2009, the regulator prohibits distribution of unbranded gas cylinders with aim of improving accountability and traceability in the supply chain (Ministry of Energy and Petroleum, 2023b). The lack of enforcement has seen a continued presence of illegal LPG dealers; this continues to be a public safety challenge with millions at risk. A number of the leading LPG marketers have reportedly lost significant numbers of cooking gas cylinders (Business Daily, 2019). The illegals are able to thrive because none of the country's LPG cylinder players have a cylinder traceability system in place that will allow traceability of the cylinder across the supply chain to the end user (Muchiri, 2016).

Traceability can provide substantial benefits, and safe guard not only the lives of the Kenyan population but the investment done by legitimate business in the LPG cylinder business. Efficient traceability systems are critical in promotion of brand image and consumer safety. Such system reduce the potential production and distribution of defective products (Vazquez Melendez et al., 2024).

Limited regulations has lead to an erosion of LPG investment in Kenya due to growth of the black market LPG trade. Rogue LPG dealers have continued to engage in illegal handling of LPG products. This prevailing market condition has resulted in growing scepticism of the market and product by customers as a number of such traders engage in deceptive market practices. Public safety has been a major point of concern with increasing cases of fires due to faulty cylinders (Business Daily, 2019). The minimum number of cylinders required for one to be licensed as a brand owner by the Energy Regulatory Commission is 5,000. Industry players assert that this count is not adequate for a sustainable business.

Stock outs witness in the market, are caused by lack of cylinders to fill and supply back to the market (Karambu, n.d.; National Oil Corporation of Kenya, 2020). The Energy (Liquefied Petroleum Gas) Regulations 2009; that was replaced with the Energy Act of 2019, seeks to regulate handling and trading of LPG. Any LPG industry player needs to be commissioned by the respective LPG marketer. The act also requires those in the retail segment to have distributorship agreements in place with the LPG marketer. In June 2019, the Government of Kenya through the Energy and Petroleum Regulatory Authority (EPRA) abolished the mandatory interchange of LPG cylinders

(Energy and Petroleum Regulatory Authority (EPRA), 2019). EPRA sighted the exchange pool as a major reason to flat lining in LPG cylinder investment. This was due to the fact that averagely LPG markets lose visibility of approximately 90% of their cylinders..

Dealers in the industry are required to source product only from registered LPG marketers. The lack of traceability of cylinders within the Kenyan market has made implementation of this act and accompanying regulations difficult and unfeasible; putting consumers at risk and denying the country revenue. Regulatory framework and enforcement in Kenya's LPG industry has been under scored. There has been significant cases of unlicensed operations leading to public safety concerns and incidents. (Wachira, n.d.). LPG cylinders has been hit by cases of cross-filling; use of competitor cylinders to sell one's LPG. This has gone to the extent of rogue players re-branding other player's cylinders.

## **1.2. Problem Statement**

There is a need for LPG cylinder traceability to enable the regulator to monitor cylinders from source to destination. Allowing identification of illegal refilling stations and significantly curb the black market; all in an effort to enforce public safety (Energy and Petroleum Regulatory Authority (EPRA), 2024). The shortage is just one of the symptoms of illegal refilling; another major concern is public safety. The public is exposed to hazardous products due to failure by most illegal re-fillers to adhere to safety regulations and quality control standards. Cylinder management or traceability system would facilitate efficiency from operating stocks levels, cylinder turnaround time, and statistical re-ordering to attain optimum cylinder stock level , and enhance public safety in as far as LPG cylinders are concerned (Clean Cooking Alliance, 2021). EPRA ascertains that LPG markets have lost visibility on approximately 90% of their LPG cylinders(Energy and Petroleum Regulatory Authority (EPRA), 2019).

## **1.3. Research Objectives**

- i. To identify information requirements for tracking of LPG cylinders
- ii. To identify challenges in the traceability of LPG cylinders along the chain.
- iii. To analyse existing traceability frameworks and models.

- iv. To develop an application to enhance visibility and traceability of LPG retail products within the supply chain.
- v. To test the proposed system.

#### **1.4. Research Questions**

- i. What are information requirements for tracking of LPG cylinders?
- ii. What challenges impact traceability of LPG cylinders?
- iii. What are the current traceability framework and models that can be adopted in for LPG cylinder traceability?
- iv. How can an application be developed for LPG cylinder traceability?
- v. How can the system be tested?

#### **1.5. Justification for the Study**

According to a 2022 Kenya National Bureau of Statistics report, 68.5% of Kenyans use traditional fuels for cooking and only 31% of Kenyans use LPG as their primary cooking fuel (Ministry of Energy and Petroleum, 2023a). The Government has increased taxes on Kerosene in order to discourage its use. The LPG master plan asserts that Kenya Pipeline Company, in an effort to meet the projected demand for LPG, shall enhance capacity at the Mombasa refinery site by an estimated 15,000 metric tons.

Through various state agencies the Kenya Government is keen to enhance LPG handling capacity and storage in key towns across in the country. This will allow easy access to product by industry players. The government, in the 2016/16 budget allocated 3 billion shillings toward LPG market growth. To initiate the LPG growth programme, the Government has already allocated Sh. 3bn to show its commitment, in the 2016/17 budget. The Government through the Ministry of Energy and Petroleum will be procuring the 6kg cylinders, thereafter, facilitate distribution consumers through the National Oil Corporation. Through this programme, Kenya's annual LPG per capital consumption is targeted to increase from 2.8 to 5.0 by ensuring increased storage facilities: bottling and filling plants and expansion of marketing and distribution networks.

The standardization of cylinder valves in 2009 and subsequent creation of the LPG Cylinder Exchange Pool effectively lowered the market entry barrier and allow consumers to have ready

access regardless of the cylinder brand they had. The interexchange ability of LPG cylinder and the lack of regulatory enforcement allowed illegal players to thrive in the market. The exchange pool contributed to LPG marketers losing visibility over approximately 90% of their cylinders and saw the proliferation of illegal dealers (Energy and Petroleum Regulatory Authority (EPRA), 2019). This poor visibility is considered a major contributor to the artificial shortages seen in the market (National Oil Corporation of Kenya, 2020).

This raises concern on public safety, and product quality, not to mention loss of revenue to Government through taxation on LPG trading companies. The illegal players and/or illegal products only be address through product traceability solution; such a solution will allow all players all the way to the end consumer validate the authenticity of the source of the product. It will also isolate cases of illegal or sub-standard products for farther investigations.

#### **1.6. Scope**

The scope of this study will be confined to the use of a mobile phone application for product traceability by consumers of LPG cylinder products. The study will also look at the willingness of consumers and marketers adopting an LPG cylinder traceability system. The study will focus on a single LPG marketing entity's cylinder lifecycle and traceability. The results of such an entity can be generalized to other market players and/or used to develop a single shared traceability platform to be used by all LPG marketing entities. The study will cover a generic LPG cylinder refilling operation at the marketing entities factory; distribution models used in the Kenyan LPG cylinder business and consumer patterns. The study will address business intelligence needs of the marketer and/or regulatory authority.

#### **1.7. Scope Limitation**

The study will not fully address the distribution cycles and supply chain players. The scope will be confined to urban areas as guided by LPG infiltration rate. The study will not address the comparing and recording of the lot ID of the raw materials or components that are used in the production of the cylinder. LPG industry is required to adhere to safety regulations as guided by the ATEX standards. The standard prohibits use of active devices around the filling zones of the factory. As such the study will not address active location traceability. Cylinder manufacturing

operations will not be considered in the traceability touch points; owing to the fact that there is currently only one integrated LPG cylinder manufacturer and marketer in the country; with a significant number of players in the industry importing cylinders from overseas manufacturers.



## Chapter 2 : Literature Review

### 2.1. Introduction

Traceability is defined as the ability to capture and maintain the identity of an object through the objects life cycle. Traceability is not only concerned in capturing the instantaneous attributes of an asset but is also concerned with the assets journey through its life cycle (Kumar et al., 2024). Product traceability is not a quality certification but a mean to guarantee quality through predefined handling channels. (Chivunga & Tempest, 2021) assert that Mobile enabled services are critical for Africa's development. Africa continues to experience growth in mobile phone access; creating an opportunity for creative solutions to its issues.

#### 2.1.1. Mobile Penetration in Kenya

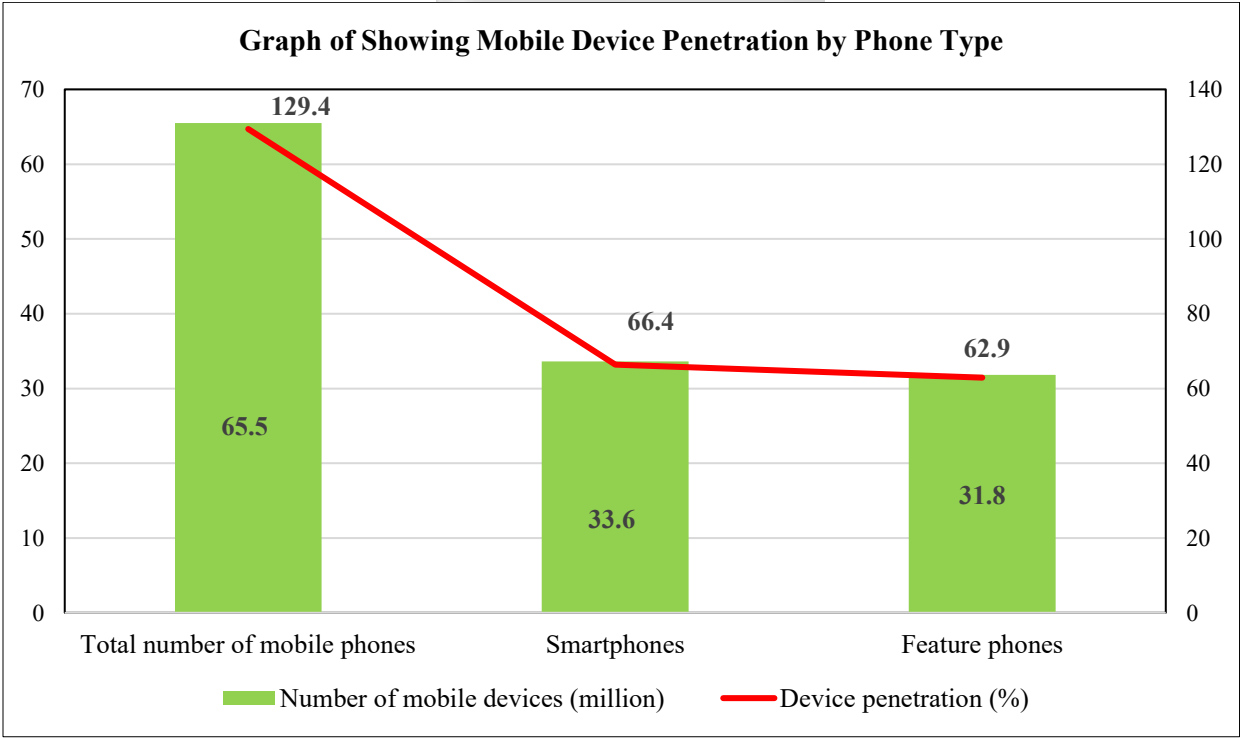
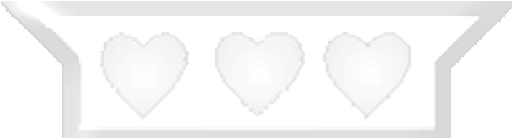
According to the Communications Authority of Kenya; as at 30 June 2024, mobile penetration stood at 133.7% with 68.9 million subscribers representing a 3.5 million growth in subscribers since 30 June 2023. The authority also observed that the mobile Internet/data market performed well, with 52.5 million subscriptions as at 30 June, 2024 up from 49.3 million as at 30 June 2023 this is represented in Table 2.1 (Communications Authority of Kenya, 2024).

Table 2.1: Mobile Telephony Subscriptions as at June 2024

(Communications Authority of Kenya, 2024)

Operator\FY	2019/20	2020/21	2021/22	2022/23	2023/24
Safaricom PLC	36,587,136	41,373,138	42,534,682	43,928,399	68,892,777
Airtel Networks Kenya Limited	15,307,422	17,327,290	17,046,982	18,074,576	20,293,643
Telkom Kenya Limited	3,441,362	4,009,758	3,422,345	2,522,887	1,478,668
Finserve Kenya Limited	1,696,312	1,495,535	1,397,416	1,501,749	1,452,867
Jamii Telecommunications Limited	DNA	DNA	272,392	411,549	590,108
Total	57,032,232	64,205,721	64,673,817	66,439,160	92,708,063
*DNA - Data Not Available					

According to Safaricom Limited, Kenya’s largest mobile telecommunication’s company, mobile data revenue grew by 18.0% Year on Year, in the financial year 2024 to KES. 63.24 billion driven by an increase in data consumption and a growth in smartphone penetration. As of the financial year 2024, smartphone penetration grew from 20.3 million the previous financial year to 22.9 million. This jump represented a 12.9% growth (Safaricom PLC, 2024). Figure 2.1 illustrates the rate of mobile device penetration in Kenya as at 31 March 2024. Kenya has a fairly high rate of smartphone penetration, pointing to the possibility that mobile applications could be an excellent channel for mass market solutions/initiatives. At 129.4% mobile penetration, mobile phone platforms have great reach.



(Safaricom PLC, 2024)

Figure 2.1: Mobile Penetration Rate by Device Type

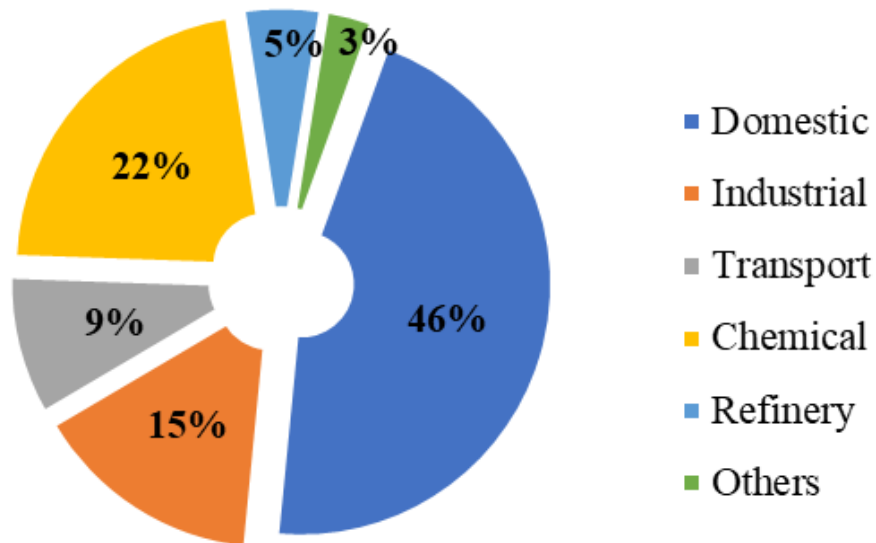
### **2.1.2. Liquefied Petroleum Gas Industry**

LPG is composed of two molecules in varying ratios; butane and propane. Both are alkane gases produced as output of crude oil refining. The two gases are highly flammable. This makes LPG a clean fuel. In Africa adoption of LPG is heavily influenced by government policy (Odongo, 2019). LPG industry is largely driven by the private sector. It has the a huge potential for employment and entrepreneurship at all levels of the value chain (Norad, 2020). Government policy never the less is a catalyst for any private sector initiative.

### **2.1.3. Global Liquefied Petroleum Gas Industry**

According to World Liquid Gas Association (WLPGA), 2024 global LPG demand stood at 358 million tonnes against a global production of 359 million tonnes; compared to a global demand of 342 million tonnes in 2023. It puts that domestic consumption of LPG accounted for 45% of total global demand in 2023. In the same year, demand in Africa grew by 5% (World Liquid Gas Association (WLPGA), 2024).

Global LPG consumption grew by approximately 8% in 2021. This growth is driven by increase demand for LPG in various sectors. It is projected that in the decade to 2030, focus on clean cooking backed up by supporting government policy and sustainability goals will be significant contributor to strong market growth. Two factors that impacts the LPG market penetration and growth is advancement in renewable energy sector and an unreliable supply chain in a number of markets. World LPG Association further asserts that in the coming years LPG markets will continue to grow driven by favourable government policy and adoption in vehicle. (WLPGA, 2022).



(WLPGA, 2022)

Figure 2.2: Global LPG Consumption by Sector 2022

#### 2.1.4. Liquefied Petroleum Gas Industry in Kenya

Nairobi and environs account for 60% of the Kenyan LPG market. The LPG market is concentrated in urban areas; rural Kenya accounts for only 1% of the market share. This distribution in market share is heavily influenced by availability of alternative cheaper fuels mainly firewood. In urban areas the impact LPG distribution cost are also lower due to sizable supply batch size due to demand and high population density. Consumer education and distribution efficiency are key to increasing LPG consumption across the country. In Kenya LPG is largely supplied in cylinders LPG; 6Kg cylinder also referred to as the ‘meko’ is the most popular (Getgas Kenya, 2016). Kenya’s LPG consumption as grown by a factor of three (3) over the last decade (WLPGA, 2022).

## 2.2. Liquefied Petroleum Gas Frameworks

### 2.2.1. Regulatory Framework

The Kenyan LPG industry is regulated by the Energy Regulation Commission (ERC). There are two key regulations that, legislate the industry; The Energy Act 2006 and Energy (Liquefied

Petroleum Gas) Regulations 2009; replaced by the Energy Act 2019. The regulations prohibit LPG product traders from buying LPG from unlicensed persons. There have been challenges in the implementation due to lack of traceability systems and enforcement capability. The Energy Act 2006 implies the need for trace ability (The Energy Act 2006, 2006). The Act requires LPG marketers and traders to establish and validate their LPG suppliers. The law prohibits traders from buying LPG from unlicensed persons (Republic of Kenya, 2019). The act ends at authentication of stakeholders but fails to propose product traceability as a means to verify the authenticity of the products handled by concern stakeholders.

### **2.2.2. Traceability Framework**

The operation scope, within which one desires to implement a traceability solution, influences the applicable traceability framework. Multiple traceability framework allows for application of different framework depending on the key requirement at a given point. Three important traceability frameworks can be identified (Xu et al., 2021). In defining traceability framework variation a key determinant is the nature of information required at a given stage and the corresponding refresh frequency.

Status traceability framework is concern with operations level. It focuses on period relevant information on a given Supply Chain management (SCM) system and its operational context (Mohamad Hashim et al., 2023). Typical system status information includes transferred stock values, safety stock, lot size, lead time, production capacity, work in progress and so on. The values are directly managed and logged in the system (Islam & Cullen, 2021). Status traceability is applicable to LPG cylinder traceability in that it facilitates the tracing of traceable objects along the supply chain.

Performance traceability framework a systems capability to generate progress report against a given plan. Historical data must be logged to allow trend analysis and variance reporting. Performance is periodic and may be both quantity and/or quantity. Typical performance tracing information focuses on deviations from a given plane; its form of time series analysis between plan/budget and actual (Riaz et al., 2024).

Goal Traceability framework is concerned with the end result. The framework seeks to establish and highlight the necessary conditions and resources to facilitate as desired system's goal.

Such a traceability framework is impactful in reducing operational cost and maintaining predication in a supply chain management system. (Oost, 2022).

### **2.3. Traceability and Related Concepts**

Traceability is the capability to identify the historical location or procedure performed on an asset through logging. (Wang et al., 2012). Traceability can be assessed from two perspectives. The first, is the capability to uniquely locate an asset across a supply chain network. Second is the capability to uniquely define the input products that are required to manufacture a given product. (Wang et al., 2012). Traceable Object (TOB) is uniquely identifiable asset that can be monitored and logged across a supply chain (Wang et al., 2012).

#### **2.3.1. Importance of Product Traceability**

Research shows that companies considered that being able to demonstrate traceability did confer some competitive advantage (Malik et al., 2021). Improved visibility into the processes applied to a product and the ability to show customers, and/or competent authorities, enhanced information as a proof of product quality are a key benefit of product traceability in some industries. Such information should be guaranteed to justify a higher price for the quality product . Improving and ensuring quality and safety of products is core to product traceability functionality (Silvestri et al., 2023).

#### **2.3.2. Information System and Traceability**

Töyrylä (1999) asserts that, “technical enablers include the computerization of data processing and the use of automatic identification in data collection.” The need to ensure “Long-term availability of data” and “the frequency, quickness and accuracy of the information collection” address directly data persistence and recording responsibilities of information systems. The correlation between information systems and traceability is encapsulated in the need for fast response times, especially during data retrieval and the choice of data to retrieve (Rajput, 2024). On a manufacturing shopfloor there is a need to define traceability activities as mapped to the process control system used on the shopfloor (Harkonen et al., 2024).

### 2.3.3. Development of a Traceability Model

Construction of generic models helps the consistency of different views or dimensioning of a product within its respective lifecycle (Gräßler & Pottebaum, 2021). Such a model should consider different entities and attributes necessary for traceability. Consideration should be given to various processing stages and the resources required in each stage, including timestamps and location (Sabri & Abdellatif, 2013). Figure 2.2 illustrates the key consideration in a product centred traceability approach.

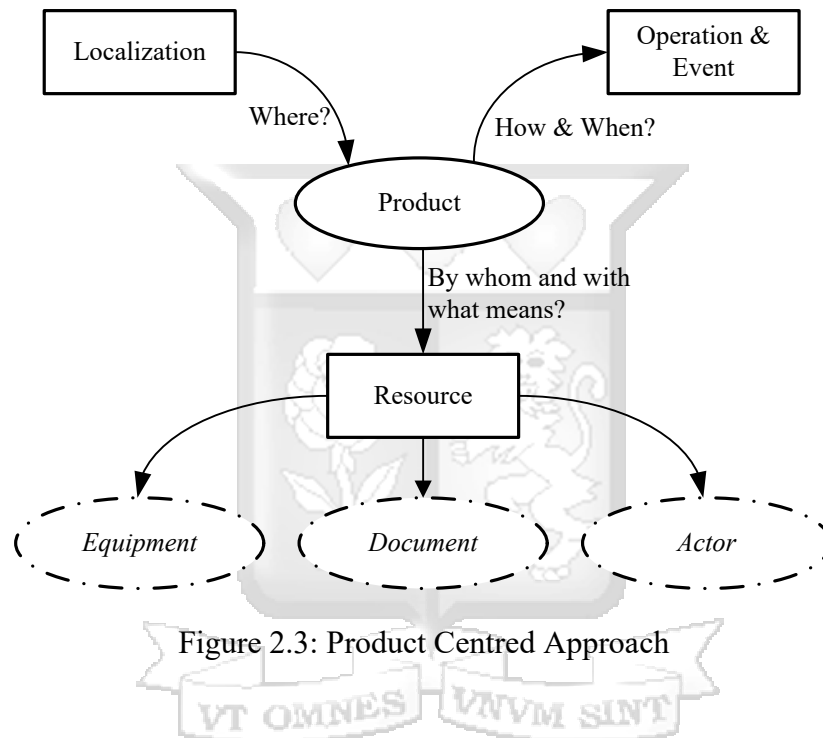
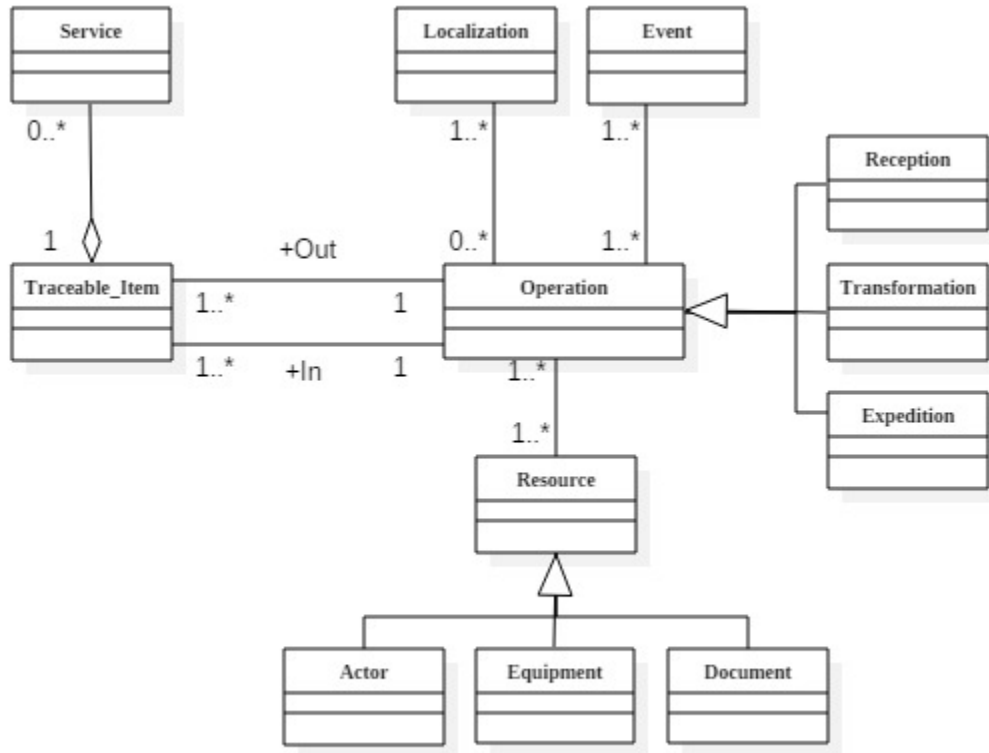


Figure 2.3: Product Centred Approach

In a data model centred item, the item can be uniquely referenced for example using tags and serialization etc. The critical step is to identify what we need to trace. A proposed traceability methodology advanced in the TOVE project (Toronto Virtual Enterprise) hinges on two concepts to be traced; the Traceable Resource Unit (TRU) and its associated basic actions / events. The TRU is unique within the given traceability view or adopted perspective. The basic action cannot be broken down into sub-actions/events (Sanabria et al., 2022). Such a model highlights the interaction and touch points between the item and its environment. A supply chain cycle can be subdivided into five major processes as guided by Supply Chain Operations Reference model (SCOR); prepare, procurement, production, distribution and reverse distribution (Sabri & Abdellatif, 2013). For our LPG cylinder scenario source represents an operation similar to this.

For a traceability model to capture the entities required for traceability, assigning of attributes, actions and geography is critical. Actions represent the interaction of the traceable object with its immediate environment in reference to defined business process (Sabri & Abdellatif, 2013).



(Sabri & Abdellatif, 2013)



Figure 2.4: UML Diagram Presenting the Skeleton of Generic Traceability Model

### 2.3.4. Traceability Data Models

Based on the traceability model, various data models that address the traceability requirements can be built (Sabri & Abdellatif, 2013). Through literature review we were able to identify the following traceability data models.

#### 2.3.4.1. Traceable Item Data Model

In this traceability data model, the traceable object is seen as a tangible object identifiable by its attributes. The traceable material object has a unique identification (Sabri & Abdellatif, 2013).

#### **2.3.4.2. Resource Data Model**

The term resource here is adopted to encompass resources applied during the objects lifecycle (Sabri & Abdellatif, 2013). It formalizes the following concepts. Class "Actor" is an individual/entity specifically identified, according to a hierarchical structure, an actor is empowered to work on a particular type of equipment and perform some type of tasks. Class "Equipment" represents all material resources involved in a lifecycle of a product; it can be a machine, transport or storage means or e.g. computer equipment. Located through the package localization, its availability status and its diagnosis allows it to participate actively in the lifecycle of products. The "Document" class provided information on all Documentary Resources used for the accomplishment of the various tasks undergone by traceable objects. May include delivery note, invoice, sales order etc.

#### **2.3.5. Localization Data Model**

Localization model, tries to answer the question relating to the identification of different locations through which traceable objects pass, throughout their lifecycle (Sabri & Abdellatif, 2013). For case of LPG cylinder location can be production unit, distributor etc.

#### **2.3.6. Operation & Event Data Model**

There exists causal links between operation and event, for example a loading operation associated to a sales order processing event. This data model inspired by the discrete event simulation, formalize the relationships between the cause (Event) and its effect (Operation) (Sabri & Abdellatif, 2013). Events main be scheduled or random.

### **2.4. Liquefied Petroleum Gas Cylinder Traceability Technology Overview**

For a secure LPG cylinder supply chain, new approaches and stronger leadership are necessary. Product traceability can only be informed by an adoption of shared/extended supply chain system leveraging on current technology (Shou et al., 2021).

#### **2.4.1. Trade Item Identification**

Manufacturers use different approaches to uniquely identify product items. One of such approaches is GTIN (Global Trade Identification Numbers); GTIN is a globally unique 14-digit number used to identify trade items, products, or services. It is simply a number not guided by any

standard. GTIN describes a family of GS1 (EAN.UCC) global data structures that employ 14 digits and can be encoded into various types of data carriers (Bar Code Graphics, n.d.).

The second is the Serial Shipping Container Code (SSCC) is an 18-digit number used to identify logistics units. In order to automate the reading process, the SSCC is often encoded in a barcode, generally GS1-128, and can also be encoded in an RFID tag. It is used in electronic commerce transactions. A third identification option is; The Global Location Number (GLN) is part of the GS1 systems of standards. It is a simple tool used to identify a location and can identify locations uniquely where required. This identifier is compliant with norm ISO/IEC 6523 (GS1, 2017).

Lastly are GS1 keys for assets identification; Global Returnable Asset Identifier (GRAI) is one of two GS1 Keys for asset identification. This GS1 Key is especially suitable for the management of reusable transport items, transport equipment, and tools and can identify these returnable assets by type and if needed also individually for tracking and sorting purposes. The other GS1 Keys for assets identification are Global Individual Asset Identifier (GIAI), Companies can apply a GIAI on any asset to uniquely identify and manage that asset. This could be a computer, desk, vehicle, piece of transport equipment, or spare part, as just a few examples (GS1, 2017).

#### **2.4.2. Radio-Frequency Identification technology**

Radio-frequency identification (RFID) is a technology that allows the electronic decoding and reading of tag identity by a suitable reader device through use radio frequency. The tags comprising of a transponder, contains electronic identification details. RFID tags are classified as either active or passive (Esposito et al., 2022). Passive tags are energized by the probing radio waves of a reader that is in reasonably proximity to the stage. Active tags are self-powered not relying on the reader to supply the required power. The advantage of RFID is that it does not require direct contact or line-of-sight scanning (Pandey et al., 2023).

The data is used to notify a programmable logic controller that an action should occur (Wu et al., 2020). The action could be logging movement of the object or in the case of our study, LPG cylinder movements. This has been greatly used to inform E-Pedigree systems. RFIDs are easy to conceal or incorporate in other items. For example, researchers at Bristol University successfully

glued RFID micro-transponders to live ants in order to study their behaviour (Tsioras et al., 2022). This trend towards increasingly miniaturized RFIDs is likely to continue as technology advances.

### **2.4.3. Quick Response (QR) Code**

The term QR is an abbreviation for “Quick Response”. As the name suggests, this is a two-dimensional bar code that allows encoding of data that can be quickly read by applicable scanners or devices with embedded cameras. A QR is a pictorial representation of square patterns on a contrasting background (Ren & Zhang, 2022). With increased popularity of QR codes, majority of mobile phones widely have capability to recognize QR codes using built-in camera (Tiwari, 2016). QR code is seen as an improvement to the barcode system which has a limitation in terms of information capacity. A barcode can only hold a maximum of 20 alphanumeric characters (Tiwari, 2016). QR Code is considered 2D as it contains information in both the vertical and horizontal directions, whereas a bar code contains data in one direction only (Ren & Zhang, 2022). QR codes variations are based on the arrangement of the contrasting square dots. The module refers to the black and white dots that make up QR Code. Version 1 has 441 modules ( $21 \times 21$  modules) while version 40 has 31,329 modules ( $177 \times 177$  modules). A QR Code variation has a determined capacity that defines the size of the data to be stored and the parity check level (Tiwari, 2016).

The QR code generation has two components, the encoding and decoding. Encoding entails actual translation of readable text/data into a QR image; where as decoding entails the reading of the coded data. (Tiwari, 2016). The symbol versions of the QR Code range from Version 1 to Version 40

### **2.4.4. Internet of Things (IoT)**

Internet of Things is a term used to reference a technological eco-system comprising of multiple devices with some form of basic compute capability and a modem, that connect to a backend system via the internet (Pai et al., 2020). The backend system facilitates the management of the device remotely via the Internet. This technological phenomenon has accelerated real time data collection and system interaction with the real world. The result has been reduced human system interaction leading to improved system data integrity (Chen et al., n.d.). In the study, IoT

technology is critical in allowing accurate, real time communication of product movement data across the supply chain.

#### **2.4.5. Approaches to System Development**

System development approach is a critical factor in the success of a system. Approach is critical in ensuring quality of the system to be produced is guaranteed. There are two major approaches to system developments that is, structured and object oriented system development (Al-Saqqa et al., 2020). Structured approach refers to a conventional monolithic system methodology; such are more suited to technically interlaced systems. On the other hand object oriented system development is a more recent soft systems approach that is viewed as more relevant to human and social systems (Al-Saqqa et al., 2020). Agile Development is an umbrella term for several iterative and incremental software development methodologies. The most popular agile methodologies include Extreme Programming (XP), Scrum, Crystal, Dynamic Systems Development Method (DSDM), Lean Development, and Feature-Driven Development (FDD).

#### **2.5. Review of Mobile Application Development Process**

There are millions of smartphone applications in various application stores globally. With new applications launch daily this is a substantial attraction to organisations to invest (Mehra et al., 2021). The mobile application development sector has embraced conventional development approaches, but continue to advance new approaches that overlay industry standards and expectations. The reality is that the software development methodology varies depending on the industry, project or advancement in technology (Raji et al., 2020). The development of a mobile application is an initiate that has multiple stages. Generally, it involves the system requirement specification, assembling of teams and sprint plannings, general project management etc. The choice of approach and path is heavily dependent on the resources and feature specification. Agile software development methodology is a highly practiced approach used by many developers. The approach allows for scalable delivery of the application and allows room for cost-effective project management. Agile allows for a shorter path to value realisation and by extension concept validation, as the developers start with an MVP and build on to encapsulate the entire feature set (Alrabaiah & Medina-Medina, 2021).

### 2.5.1. Types of Mobile Application

Mobile applications can be grouped into three broad categories; the native application, which is distinctively developed from the ground up purely for use on a mobile client. The web application generally uses browser capabilities to launch and execute. The third category is the hybrid, which is a mix of the capability and approach of the previous two. (Mahmud & Abdullah, 2015). According to Mahmud and Abdullah (2015) mobile web application is an application in which the user interacts with the system via a user interface on the web browser.

Native mobile application is devices and/or platform specific. Development of native application is skill dependant. Native applications offer more more customization options and flexibility in feature development and user experience as compared to web applications. Native mobile applications are also faster and in some cases can function offline.

Hybrid applications combine characteristics of a both a web and native application. In hybrid application much of the system logic is hosted in the backend and clients from either platform access the core system via API (Mahmud & Abdullah, 2015).

### 2.5.2. Mobile Application Characteristics

Mobile application development is dependent on the characteristics of a mobile application. One such characteristics is the mobile platform; the choice of platform impacts the programming language and tools that can be used (Mahmud & Abdullah, 2015). A mobile software development process should maintain the balance between market-oriented and technical activities (Al-Saqqa et al., 2020). A developer's view of the difference between mobile platforms is represented in table 2.2.

Table 2.2: Differences between Mobiles Platforms from a Development Point of View

(Latif et al., 2016)

OS	Company	Programming Language	Development Environment	Application Store
Android	Google	JAVA	Android Studio, Android SDK	Google Play Store
iOS	Apple	Objective-C/Swift	Xcode	Apple App Store
Windows phone	Microsoft	Visual C#, C++	Visual Studio	Window Phone Market
BlackBerry OS	RIM	JAVA, C, C++, Qt	BlackBerry Plug-in for Eclipse	BlackBerry Apps World

## 2.6. Review of Traceability Management Systems

Traceability systems vary in feature, functionality and deployment depending on the desired use case and context of operation (Corallo et al., 2020). A traceability system is viewed as a management information system that enable the reconstruction or recording of the life cycle of the subject item, either fully or partially. Hierarchical traceability model should be viewed as a tree with nodes indicating the relationship of products and components (Varrà et al., 2021). Virtual digital shadow of actual products can be employed in presenting the hierarchical product traceability structure. In such an approach the product is viewed based on the actions, state of the digital shadow in the system (Zhuang et al., 2021).

According to the Toronto Virtual Enterprise Project 'TOVE', a sound traceability system would allow tracing of the item and relevant history by use of Traceable Resource Units (TRU) and elementary actions (Lin et al., 2020).

Traceability systems are not limited to item tracking but must also include the basic actions associated with item movement for example check-out or check-in. These should be viewed as entities with sets of attributes, in the system (Omar et al., 2022). Dupuy (2004) proposed a structured supply chain system adopting a modular approach anchored on generic blocks linked together to cover the entire supply chain. The key consideration here was concept of event and function. In the model an event triggers a function that leads to an event (Ammar et al., 2015). Traceability data should be captured based on Business Process Modelling approach.

The French Standardization Agency (AFNOR) proposed in a review methodology with of a static and dynamic phase. A Static Phase where one models the system operation based on basic activities and sequence the system, with management consideration, to capture the require traceability data. The Dynamic Phase focuses on conceptualizing a robust system through related indicators; response time, level of accuracy etc, etc (Ammar et al., 2015).

Emrich, Ganz, Werth, and Loos (2010) assert that extensible semantic context model may be employed for business data traceability. The model would be based on event driven changes for key touch points (Emrich et al., 2010). An advanced traceability system in supply chain is proposed by Parreño-Marchante, Alvarez-Melcon, Trebar, and Filippin (2014). The system incorporates Web services used to integrate traceability data logged using RFID technology with auxillary information capture via a Wireless Sensor Networks (WSN) infrastructure. The system integrates information collected along the entire supply chain, from the producer to the consumer (Parreño-Marchante et al., 2014).

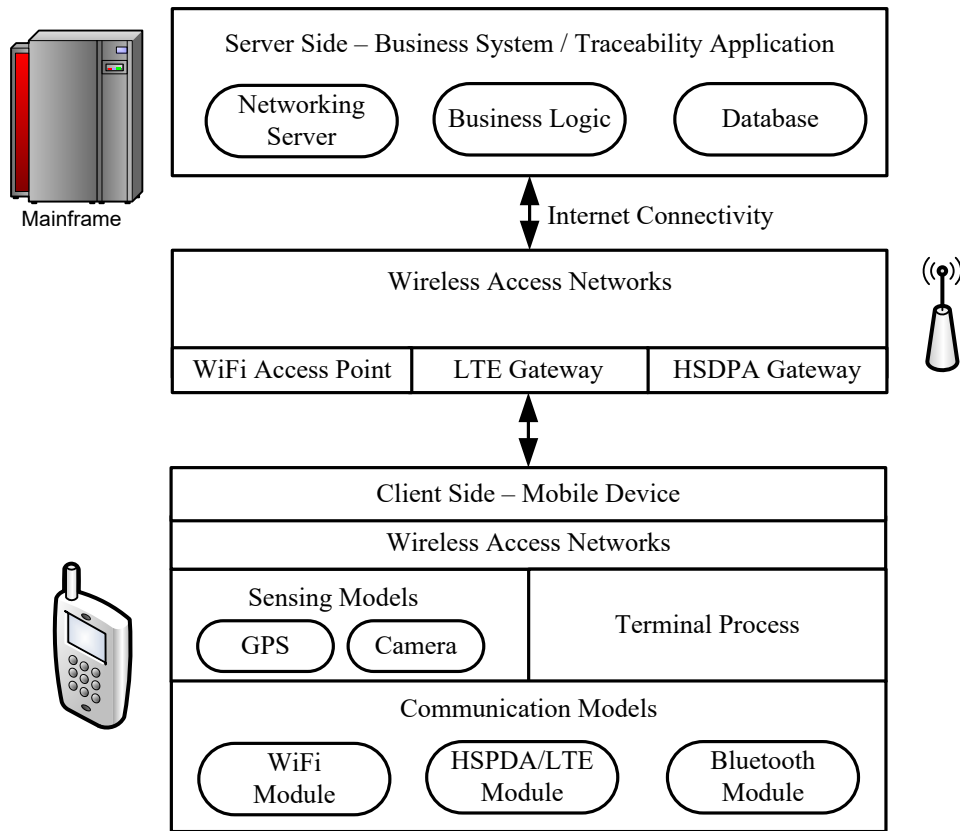
### **2.6.1. Cylinder Traceability**

AGA is a leading company in Nordic and Baltic countries. AGA specializes in gas products and services. AGA was the first gas company to introduce electronic Individual Cylinder Control. The electronic cylinder control offers you full overview of your cylinder business, providing you with vital information about the exact quantity of gas cylinders, which type of gas they contain and their location within the company. You can also keep track of the cylinder and gas origin as well as expiration dates (AGA, 2015).

In 2012, BOC a leading gas product and services company launched a pioneering tracking system that will enable the entity operate the most effective and fully integrated cylinder tracking system available in the market today. The system is based on use of 1D barcode tags affixed on the cylinders. The system is main used by the company for internal controls and operations (BOC, 2012).

## **2.7. Proposed Architecture for Liquefied Petroleum Gas Cylinder Traceability**

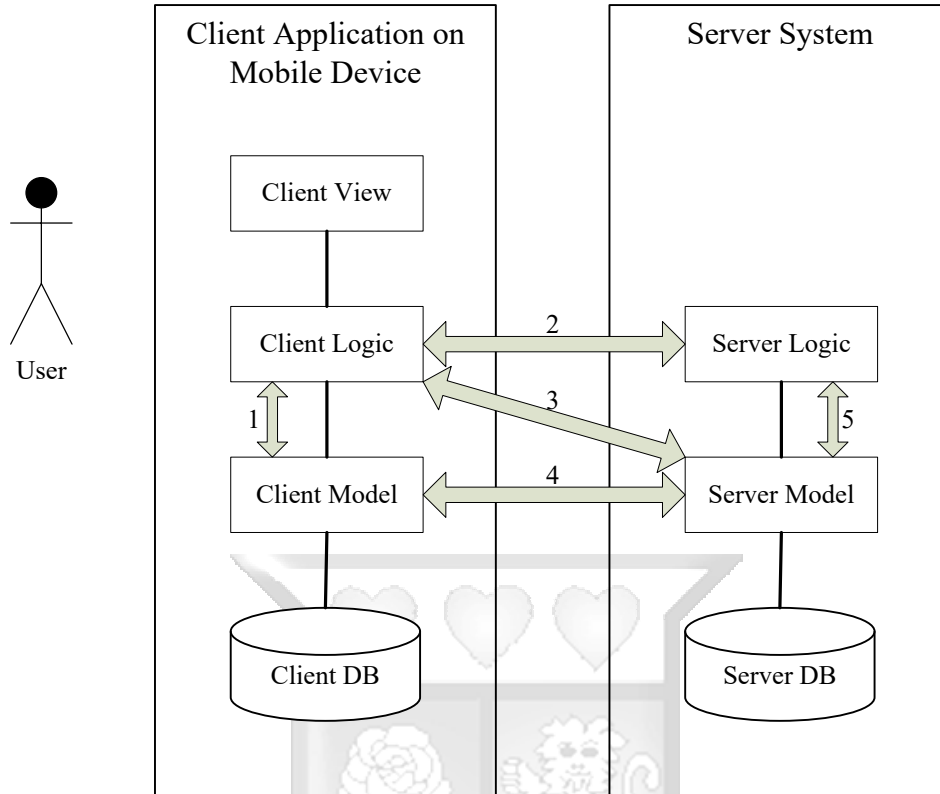
Software architecture plays a key role in overcoming the resource limitation while providing required quality of services (Muccini et al., 2020). Traceability mobile application architecture is a form of a server – client architecture with a network connectivity layer in between.



(Hu et al., 2015)

Figure 2.5: Proposed Physical Architecture of the Conventional Traceability Mobile Application System

In the proposed architecture the client application will be three categories. The Client View is the user interface a user interacts with, and Client Logic performs business process logic for example input data validation rules. The Client Model contains entity-type classes which manage data for a specific mobile user and tend to be temporarily stored. In the server system, there are two components. Server Logic runs business process logics that invoke public methods of Server Model and can be reused by multiple mobile users. The server system does not have a view layer. The server provides functionality to the client system only (La et al., 2011).



(La et al., 2011)

Figure 2.6: Mobile Application Eco-System

There are five interaction paths in the proposed architecture. Path 1 is an interaction between Client Logic and Client Model. This is applicable to functionalities which are invoked on the client system without relying on the server system; does not require any communications with server system. Similarly, on the server system equivalent interaction is facilitated through Path 5.

Path 2 is an interaction between Client Logic and Server Logic. This is applicable to the case that the functionality of Client Logic is fulfilled with the support of the Server Logic. Path 3 is a direct interaction between Client Logic and Server Model, without going through Server Control. This is applicable to the case that the Client Logic needs to update the objects in Server Model efficiently so that network overhead is reduced. Path 4 is an interaction between Client Model and Server Model. This is useful to synchronize the states of two corresponding objects to maintain the states consistency.

One of the key challenges in defining the proposed mobile application architecture is in the positioning of the business logic within the architecture. There are three possible solutions; business logic allocated only to the client, only to server, and balanced between the client and the server. Another important decision is whether Client Model is necessary (La et al., 2011).

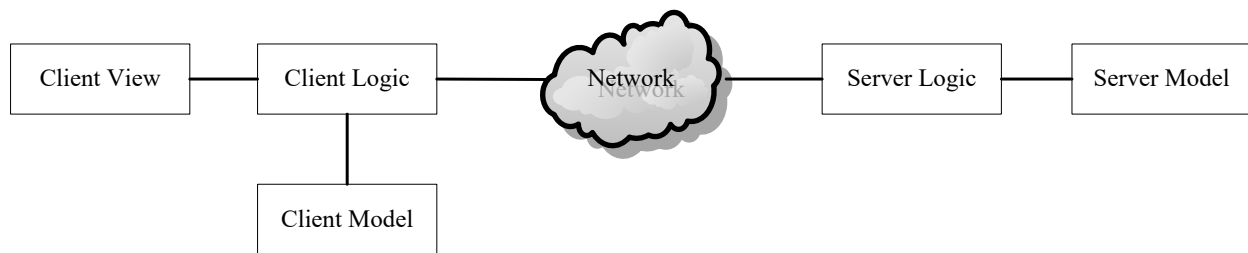


Figure 2.7: Proposed Pattern of Mobile Application Architecture

In proposed pattern of mobile application architecture factors in both Client Logic and Server Logic, and also a Client Model. This configuration would suitable in our proposed multiplatform solution as there exists a high coupling/dependency between each pair of Logic and Model.

The proposed architecture is will involve 3 layers, the mobile device layer, the back-end server that holds the business logic, and the cylinder identification system. The cylinder identification system is an automatic identification system that allows manufacturers and business to read the tagged cylinders along the process line. The data from this system is feed into the server and analysed against defined business logic. The mobile layer provides a query interface for the end-user (consumer) to interact with the backend server that carries the business logic and data.

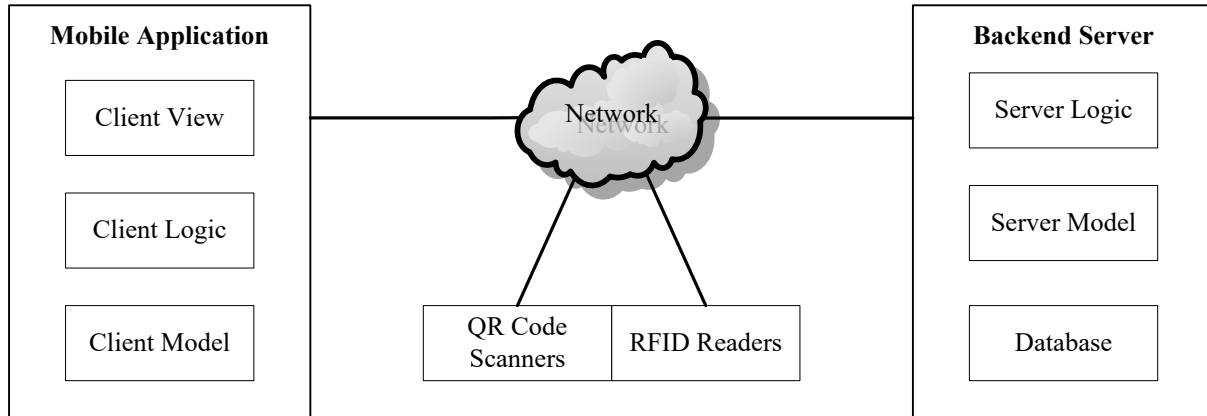
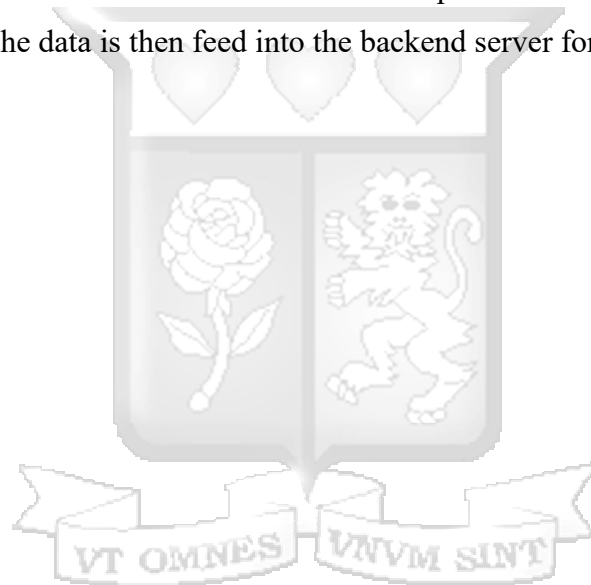


Figure 2.8: Proposed System Architecture

QR code scanners and RFID readers are to be used to provide tracking data for the cylinders along the process flow. The data is then feed into the backend server for logic tests and logging.



## Chapter 3 : Research Methodology

### 3.1. Introduction

The study will explore the challenges faced in LPG cylinder traceability in Kenya, through administration of questionnaires to different stakeholders in the cylinder supply chain. The interaction will seek to establish the key consideration for the stakeholder(s) within the Kenyan LPG industry, in regards cylinder traceability. Core to the study will be establish the main touch point that would define a complete traceability loop (Sargent, 2020).

The researcher will seek to profile the target population and sampling frame required for conclusive evaluation. The researcher will analysed the questionnaire response to determine the core functional requirements and/or key consideration for the development of a LPG cylinder traceability mobile application. The researcher will ensure that adequate control is embedded in the study to ensure validity and reliability of the study findings. The outcome of the analysis of the response received from the questionnaires will for the system requirements of the proposed LPG cylinder traceability mobile application. Using the system requirements, the research will proceed to develop a system design which will then be implemented to realize the proposed LPG cylinder traceability mobile application. The research will also consider appropriate avenues for utilization and dissemination of results. The entire study will be conducted within ethical limits as defined.

### 3.2. Research Design

Research design is the plan that provides the logical structure that guides the investigator to address research problems and answer research questions (Muratovski, 2021). The research will adopt a positivist paradigm. It will seek to describe relationship and interaction of key players and touch points in the LPG cylinder supply chain network in Kenya. The solution will be informed by the facts on how transparency and traceability of LPG cylinders can be achieved. The data collected will seek to model the flow and change of custody of LPG cylinders in supply chain. The study will be descriptive as it shall seek to describe a phenomena or characteristics of a particular group of subjects being studied. This will be achieved through both survey and qualitative research.

### 3.3. Target Population and Sampling frame

The target population in this study will be restrictive. Stratified Sampling will be used so as to partition the population into groups based on their interaction with the process. The study will have a total of four strata. The population is categorized into three groupings. The first category will be LPG marketing companies; companies that import and package LPG cylinder products for local consumption. The defunct Energy Regulatory Commission (the Commission) was mandated under section 80 of the Energy Act 2006 to license any person conducting the business of Liquefied Petroleum Gas (LPG) in Kenya. The Energy Regulatory Commission (ERC) was replaced by the Energy and Petroleum Regulatory Authority (EPRA) (Republic of Kenya, 2019). EPRA was established under the Energy Act, 2019. EPRA's is responsible for the economic and technical regulation of energy; including LPG (Energy and Petroleum Regulatory Authority, 2024a). The authority is charged with responsibility of licensing companies trading in LPG products.

EPRA's seeks to promote transparency, accountability, and efficiency in the petroleum sector; this has been fostered by the development and enforcement of a robust regulatory framework anchored on stakeholder engagement. EPRA has sub-divided the petroleum value chain into three segments; upstream, midstream and downstream. Upstream operations related to exploration, extraction and development petroleum sources. Such operations are undertaken in the early stages of the petroleum value chain. This study focuses on the midstream and downstream segments which look at the market and where the LPG cylinder is prevalent (Energy and Petroleum Regulatory Authority, 2024c).

According to the 2022 Kenya Demographic and Health Survey (2022 KDHS) 76% of Nairobi residents use clean fuel and technologies for cooking, heating and lighting; this represents approximately 21% of the Kenyan population (Kenya National Bureau of Statistics (KNBS), 2022a). The 2022 KDHS study further states that 24% of the Kenyan population use clean fuels and technology for cooking. Urban areas reported a higher uptake of clean cooking fuels represent approximately 59% of the population compared to 6% percent of the population in rural areas (Kenya National Bureau of Statistics (KNBS), 2022b).

As at 02<sup>nd</sup> December, 2024 EPRA listed a total of 112 companies licensed to engage in storage and wholesale of LPG cylinders (Energy and Petroleum Regulatory Authority, 2024b). For purpose of this study a sample size 5 LPG marketing firms representing 6% of the population will be adopted. The next critical category will be; the reseller. These are entities that move the products

from the refilling plants to the markets, provide the products to the end users and in some cases other resellers. It observed that in Kenya, LPG is commonly used in urban areas, with Nairobi accounting for approximately 60% of the market (KNBS, 2017). KNBS farther estimates that there are about 10,000 LPG resellers. The Energy & Petroleum Regulatory Authority through a publication on its website lists the number of LPG retails as 6,183 as at 21<sup>st</sup> July, 2020 (Energy & Petroleum Regulatory Authority, 2021). 1,000 resellers within the Nairobi region will be sampled under the study, representing approximately 10% of the market in Nairobi and environs.

The final and core target population for this study is the consumers. These are individuals who use LPG cylindered products. The study hopes to achieve a sample about 3,000 consumers. The sample will be a build-up of the 1,000 resellers, who for the purposes of this study will also be assumed to be LPG consumers.

The study will be conducted in Nairobi and the surrounding counties. The assumption made is that the Nairobi and environs is a good representation of the national stage. Table 3.1: Proposed Sample Population, represents the sample frame.

Table 3.1: Proposed Sample Population

Details	Proposed Count	Population Representation	Criteria
LPG Re-fillers	5	6%	At least 3 staff with excellent background knowledge of the re-filler's operations.
Resellers	1,000	6%	The study will sample retails across various estates in Nairobi and environs.
Consumers	3,000	~	General cylindered LPG product users.

### 3.4. Data Collection

The data will be collected in the through questionnaires and structured interviews, identified LPG industry players. The interviews will be conducted on a one to one basis, while the

questionnaires will be both manually administered as well using online portals. The questionnaire will contain four sections; section one will be used for collection of biodata. Section two to four, will be partitioned among the different stakeholders in the supply chain, who are LPG marketer, retailer/distributor and lastly the consumer. The proposed questionnaire is attached as appendix A. The questionnaire will be partly administered online.

### **3.5. Data Analysis**

The study will utilize both qualitative data analysis and quantitative data analysis. The data collected will provide an understanding into the process flow and possible areas for LPG cylinder traceability improvement. The analysis will identify main players in the supply chain and identify areas of visibility lapse with the chain. The data analysis will shade more light on systemic control failures in current LPG cylinder traceability solutions deployed by players along the supply chain. The analysis will be critical in establishing key data capture and/or control points and features for the proposed mobile application system by looking correlating scores and statistical weights. In the case of interviews, qualitative data analysis is going to be employed to identify common patterns within the responses and critically analysing them in order to achieve research aims and objectives.

### **3.6. Research Quality Aspects Validity and Reliability**

Validity in qualitative research means “appropriateness” of the tools, processes, and data. Reliability refers to the repeatability of process and findings. The two aspects will be addressed by an expansive sample list. Unbalanced observations will be minimised through the use of regression. The study will seek to establish a line of best fit to guide our sample data as a revalidation.

### **3.7. System Requirements Analysis**

Systems analysis involves the collection of authentic data, understanding the processes involved. The major output is to isolate problems and generate solutions with high efficacy. The study will seek to understand and map both the upstream and downstream LPG cylinder supply chain. Identifying key data capture and control points along the chain. The study will also seek to establish the bottlenecks of LPG cylinder traceability. A key aspect of the system analysis will be

to establish the applicable data models and isolate the manual process in the supply chain flow. The study will employ the following techniques during system analysis; questionnaires, observation, interview, use case analysis and data models.

### **3.8. System Design**

System design is dictated by the user requirement and optionally a review of the legacy system. The design includes detailed documentation of the system's architecture, data structures and processes. The system design also clarifies the hardware and operating system platform the system will employ. The study will employ the following tools and techniques in the design of the system; Flowchart, Data flow diagram (DFD), Structured English, Decision table, and Decision tree. The outcome of the system design process will include DFD, Entity Relationship Diagrams (ERD) Database schema and class diagrams. A cross-platform mobile application approach will be used in the study.

#### **3.8.1. Model Driven Approach**

The proposed mobile application design is based on Model Driven Architecture (MDA) approach. This model offers more control over the development process. It allows for agility in the development process; proving a better option in accommodating variable constraints (Sebastián et al., 2020). As demonstrated by various quantitative and qualitative studies, MDA practices have proved to increase effectiveness and efficiency in software development. It's steady adoption is driven by the convergence of software development and business intelligence (N. Korongo et al., 2022). MDA is centred on models, as opposed to code; this facilitates significant reduction in technical complexity and development costs.

A core benefit of the MDA approach is that the mobile application development is defined by modelling activities without focus on low-level technical aspects for example system architecture, messaging etc (Shamsujjoha et al., 2021).

The model can either be classified as a Platform Independent Model (PIM) or a Platform Specific model (PSM); the key differentiator the level of definition on how the system utilises a given platform. A Platform Independent Model is platform agnostic while a Platform Specific model includes definitive platform requirements (Latif et al., 2016). Lastly is the model

transformation. Model transformation facilitate the development of platform antagonistic systems; by enabling translation of development languages (Thu & Nwe, 2017).

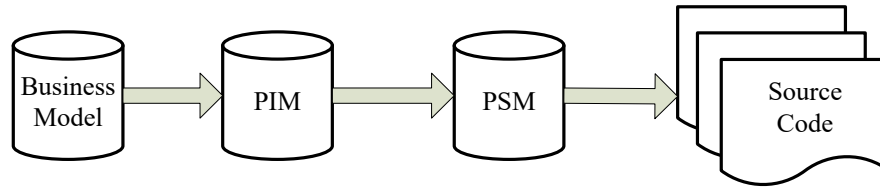


Figure 3.1: Key Models Model Driven Architecture

Transformation of a model involves the transformation of the entities of the model. This is achieved in a two-step approach. The first step is to identify the correlation between the concepts of source and target models in their meta-models; this would indicate the existence of a transformation function applicable to all instances of the source meta-model. The second step is to apply the transformation of the source model to automatically generate the target model by a program called transformation engine or execution (Shamsujjoha et al., 2021).

### 3.9. System Implementation

The system implementation will involve the development of a prototype. The prototype will be used in a conference pilot room test to assess the functionality of the proposed design. Once successful the system will undergo a User Acceptance test using a focus group to validate user expectation. The implementation will adopt an Agile Development approach, to allow deployment of functionalities in a staggered approach.

### 3.10. Utilization of Results

The findings of this study will be used in the development of a mobile application for cylinder traceability in Kenya. For effective utilization of the results of this study dissemination or diffusion of the findings is needed. Rogers Theory of Diffusion asserts that results of a study must have good characteristics for adoption. The results of the study should demonstrate relative advantage of the study recommendation in addressing cylinder traceability challenges through the

use of the proposed mobile application. The study results should equally be feasible within the Kenyan LPG industry context. The study results must be presented in its simplest form to allow easy understanding across board; this is best captured in presentation of a trial design.

### **3.11. Dissemination of Results**

A key output of the study should be to target specific findings and recommendations to different audiences in formats that are appropriate, relevant and accessible for each. The research shall endeavour to identify and categorize the different audiences by their interest in the LPG supply chain in Kenya, their challenges and the impact to the research findings. For all participants the researcher will share the study findings particular to the LPG markets as a form of industry validation. This will be done through interactive meetings and presentations.

### **3.12. Ethics Considerations**

It is important from the onset to highlight the relevance of ethical issues. Special consideration needs to be given to ensure that individuals are aware and give consent for collection of data using the application. The data to be collected include geo-location data, contact details, and projected usage count. Ethical issues will arise such data is collected and used without the consumers knowledge or consent.

## Chapter 4 : Data Analysis and System Design

### 4.1. Introduction

A core component of the study was to identify information requirements for tracking of LPG cylinders in Kenya. The study sort to map the possible route to market approaches and touchpoints used by the LPG marketers, and avenues customers acquire the product in the market. To address this requirement of the study a survey conducted. The Survey was administered to collect primary data from sampled LPG stakeholder. The stakeholders were categorized into three (3) categories; LPG marketers, distributors/agents/retailers, and consumers. Each category of respondents had a differentiated questionnaire. The questionnaires had questions covering aspects of LPG cylinder sourcing by the LPG marketers, cylinder SKUs, the preferred route to market, adoption asset tagging for LPG cylinders in their business, and the extent of traceability systems employed in their operations. For consumers the survey went farther to question the choice of cylinder SKU, the affinity of the respondents to use an LPG cylinder traceability solution, the level of smart phone penetration among the respondents, and frequency of use of LPG cylinder products. The survey was conducted using online questionnaires; Microsoft Forms.

### 4.2. Data Analysis and Findings

#### 4.2.1. Survey Information

##### 4.2.1.1. Response Rate

A total of 3,056 respondents participated in the survey, representing a 76% response rate. The forms from the 3,056 respondents has been used in the analysis. Table 4.1 represents the response rate of the survey.

Table 4.1: Response Rate

<i>Description</i>	<i>Target</i>	<i>Response</i>	<i>Percentage</i>
LPG Marketers	15	21	140%

Distributors / Retailers	1,000	386	39%
Consumer	3,000	2,649	88%
Total	4,015	3,056	76%

**4.2.1.2. Respondents’ Ownership of Smart Phones**

For the survey results, it was observed that 81% of responded own smartphones as represented in table 4.2.

Table 4.2: Smartphone Penetration Rate

<i>Description</i>	<i>Count</i>	<i>Percentage</i>
Own Smart Phone	2,146	81.0%
Basic Phone	503	19.0%
Total	2,649	100%

The following a graphical representation of the Smartphone penetration level. Smartphone penetration rate is a key consideration in validation of the choice of a mobile application for traceability of LPG cylinders within the Kenyan LPG space.

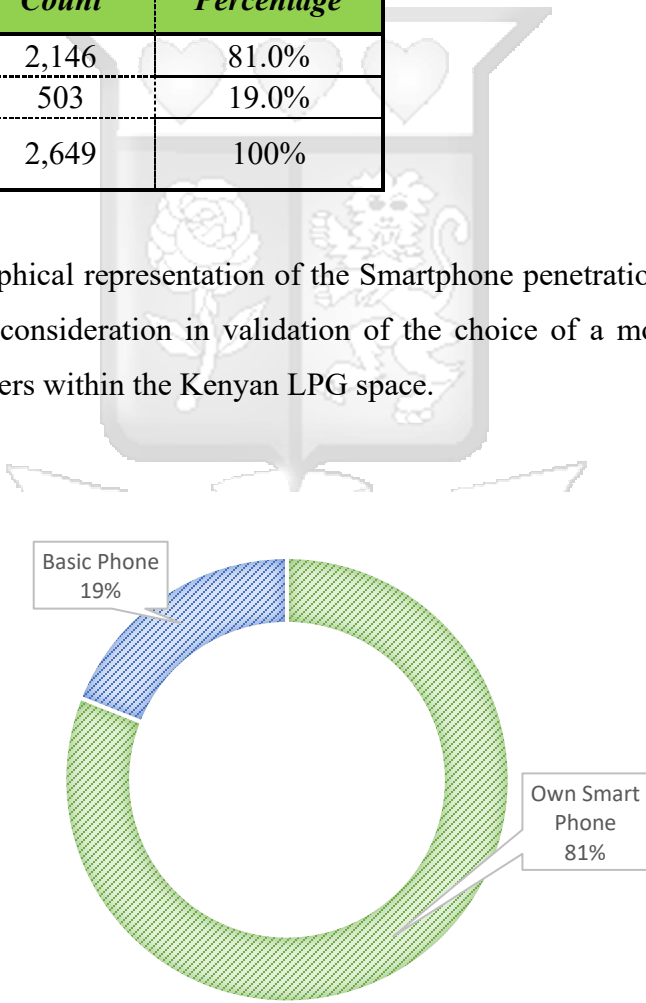


Figure 4.1: Smartphone Penetration Rate

#### 4.2.1.3. Source of LPG Cylinder

Traceability of LPG cylinders requires an understanding of the source of the cylinder by the legal owner or supplier in the market. We sort to under the sourcing approaches by players in the upstream supply chain; these looked at LPG marketers and retailers. From the survey responses received LPG marketers surveyed acquired their LPG Cylinders through purchase and manufacturing. From the twenty-one respondents, sixteen confirmed to acquire LPG Cylinder through purchase. The remaining five manufacture their own LPG cylinder.

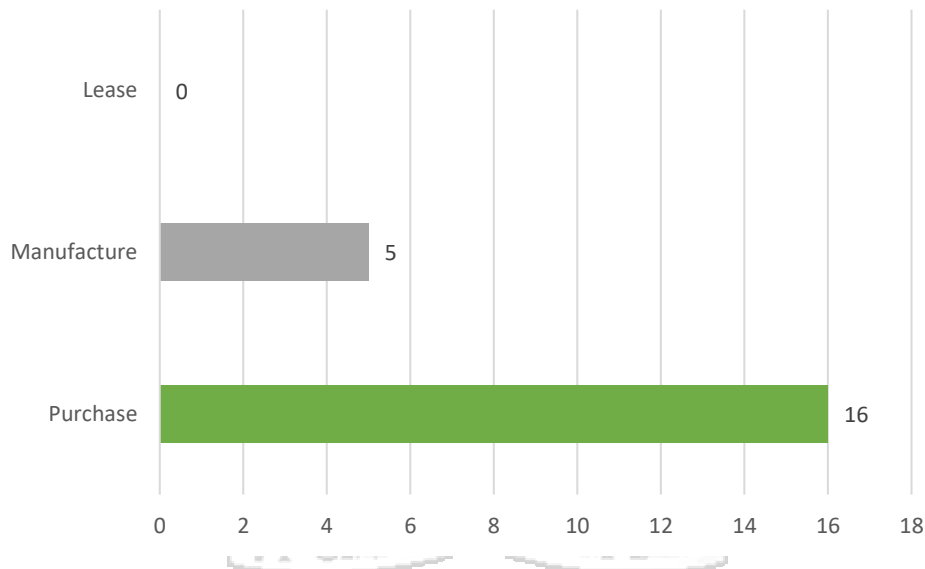


Figure 4.2: Source of LPG Cylinders - LPG Marketers

A closer analysis of the data relieved that some of the respondents represented views of similar organizations. The analysis of the data by unique organization showed that of the LPG marketer companies sampled majority acquire LPG cylinder through purchase, only one company was observed to acquire cylinders through manufacturing; this is represented in table 4.3

Table 4.3: LPG Cylinder Sourcing Approach by Company Surveyed

<i>Company</i>	<i>Respondents Count</i>	<i>Acquisition Approach</i>
Proto Energy Limited	5	Manufacture
M-Gas Kenya Limited	2	Purchase
Total Energies	3	Purchase
Rubis Energy Kenya	3	Purchase
Ola Energy Kenya	2	Purchase
Vivo Energy Kenya	2	Purchase
Hashi Energy	1	Purchase
Oryx Energies Kenya	1	Purchase
Lake Gas Limited	2	Purchase
Total	21	

From the survey results eight of the nine LPG marketing companies surveyed, acquire LPG cylinder through purchasing.

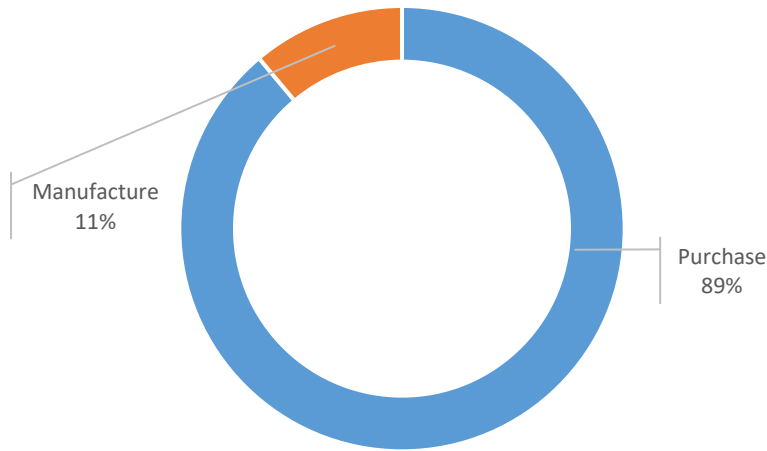


Figure 4.3: LPG Cylinder Sourcing Approach by Company Surveyed

The distributors and retailers bridge the gap between the LPG marketer and the consumer. This segment is largely responsible for the movement of LPG cylinders in the market place. Analysis of the results revealed the below distribution of LPG cylinder sourcing approaches among sampled distributors and retailers.

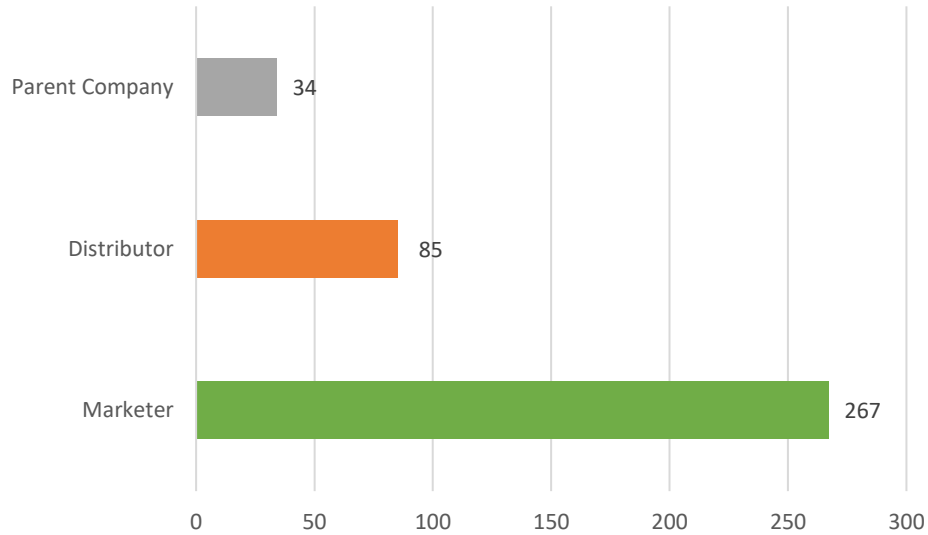


Figure 4.4: Source of LPG Cylinders - Distributors/Retailers

A total of 386 respondents were classified as distributors and/or retailers. Out of this number it was observed that majority get their LPG cylinders directly from LPG marketers. A total of 119 respondents confirmed that they get their cylinders from parties other than the LPG marketer.

#### 4.2.1.4. LPG Cylinder Sizes Traded

Observation of the traded LPG cylinder SKU was to confirm level of differentiation in route to market for LPG cylinder based on SKU. The survey assessed this on three different levels; the marketer, distributor/retailer and the consumer.

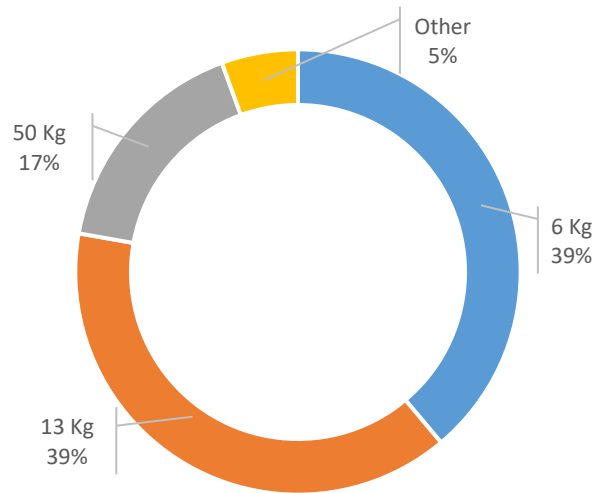


Figure 4.5: LPG Cylinder SKU Trade Distribution - LPG Marketers

Of the response received it was noted that all LPG markets trade with the 6 Kg and 13 Kg SKU. This implies that the market demand and uptake for these two SKUs is high. The same data is correlated by the response received from retailers on the distribution of SKU traded in; this is illustrated in the following graph.

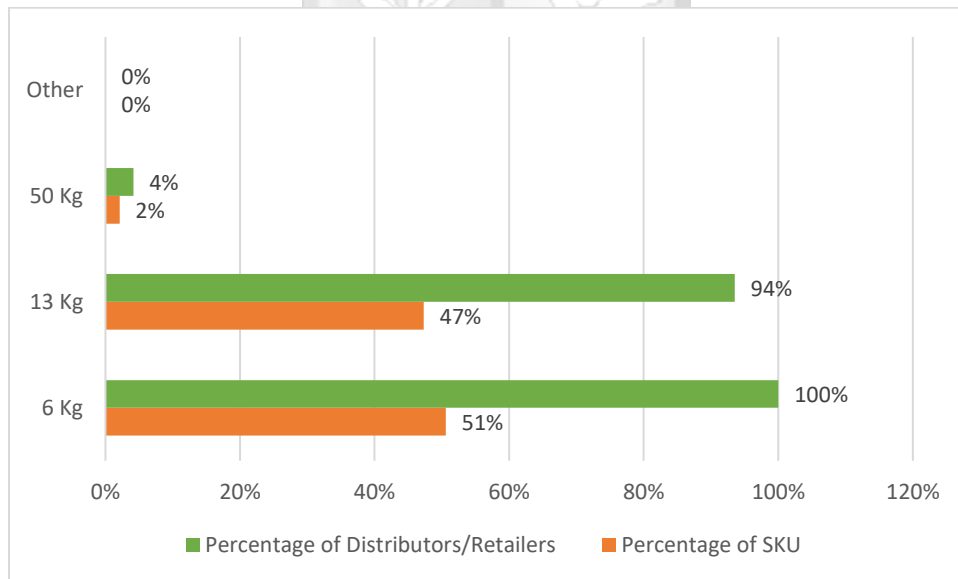


Figure 4.6: LPG Cylinder SKU Trade Distribution - Distributors/Retailers

From the analysis of response received, it was observed that the 6 Kg and 13 Kg accounted 98% of SKUs traded by the sampled respondents. It was also observed that all distributors/retailers

sampled trade in the 6 Kg SKU, with 94% trading in the 13 Kg. Only mere 4% of respondents trade in other SKUs as compared to the 6 Kg and 13 Kg.

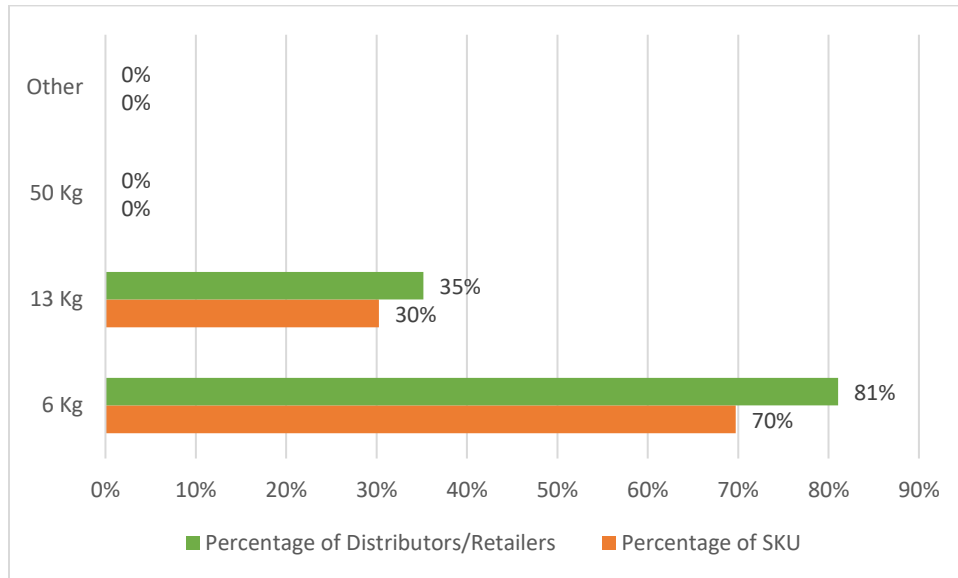


Figure 4.7: LPG Cylinder SKU Trade Distribution - Consumers

The survey analysis observes that consumers sampled only use the 6 Kgs and 13 Kgs SKU of LPG cylinders. The 6 Kg is by far the most preferred SKU of LPG cylinders.

#### 4.2.1.5. LPG Cylinder Route to Market

The study sort to establish a high-level understanding of the degree of complexity in the route to market employed by the different LPG marketers. The following is an illustration of the findings. It was observed that the results indicated a heavy adoption of hybrid approach of using both company and third-party owned depots.

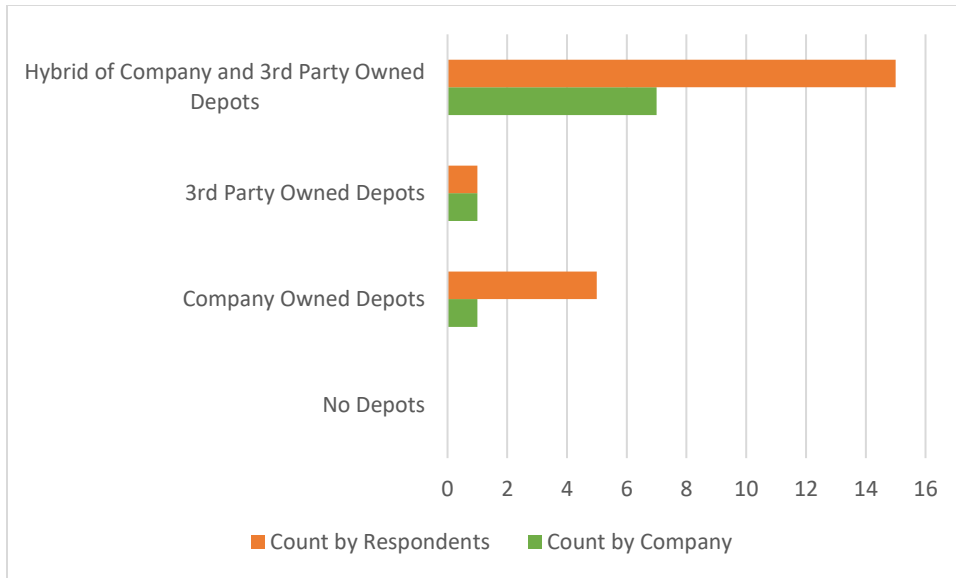


Figure 4.8: LPG Cylinder Route to Market Model Approach

#### 4.2.1.6. Tagging of Cylinders

The survey sort to under the level of infrastructure already in place in regards to LPG cylinder traceability. The survey was limited to the LPG marketers are the legal proprietors of the LPG cylinder. Below is an illustration of the observed analysis of results.

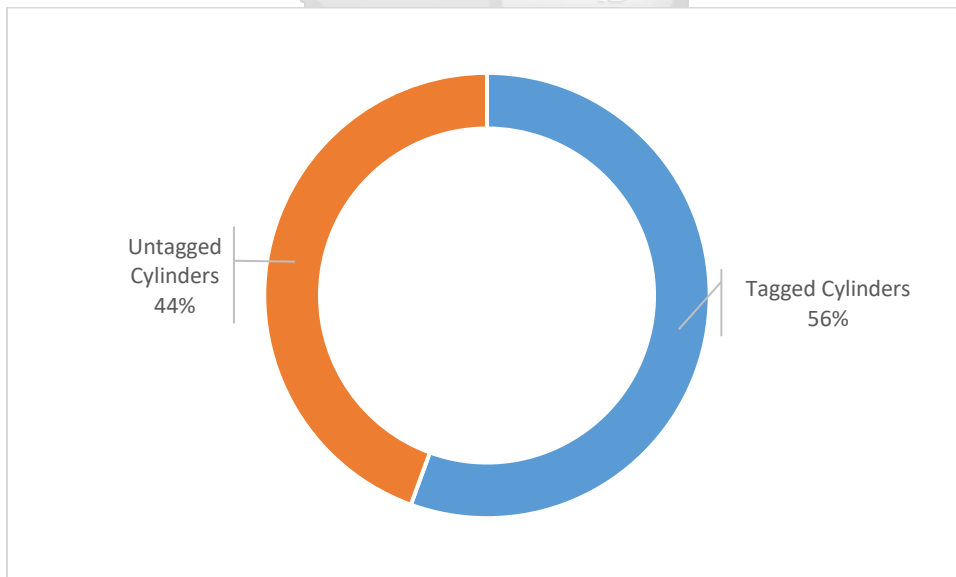


Figure 4.9: Cylinder Tagging Adoption by LPG Marketer

#### 4.2.1.7. Cylinder Traceability Capabilities

As part of establishing the level of already deployed cylinder traceability infrastructure by LPG marketers was to understand their cylinder traceability capabilities. The study sort to identify the number of LPG marketers with cylinder traceability systems and the extent of the traceability within their eco-system. It was noted that majority of the LPG marketers had no elaborate form of a cylinder traceability system, with 66% of the companies polled indicating that they had no cylinder traceability system in place.

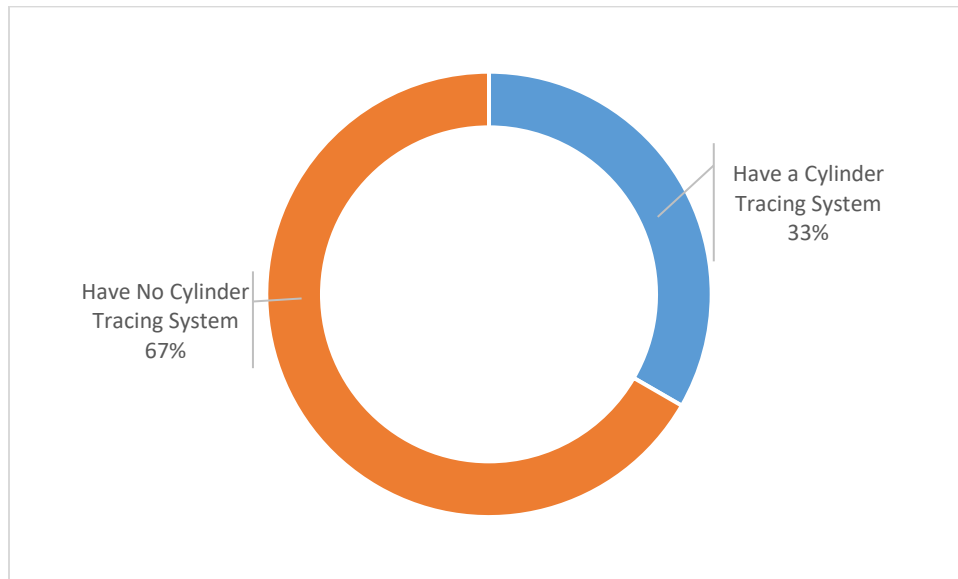


Figure 4.10: Presence of a Cylinder Traceability System by Company

For both instance of response, the researcher was intent on understanding the level of traceability each of the polled LPG marketers was capable of achieving. The study sought understand the tracing capabilities of each player based on three levels or locations where the cylinder maybe located in at a given instance; own stores, distributor/retailers, and with the consumer; the following is an illustration of the findings of the study.

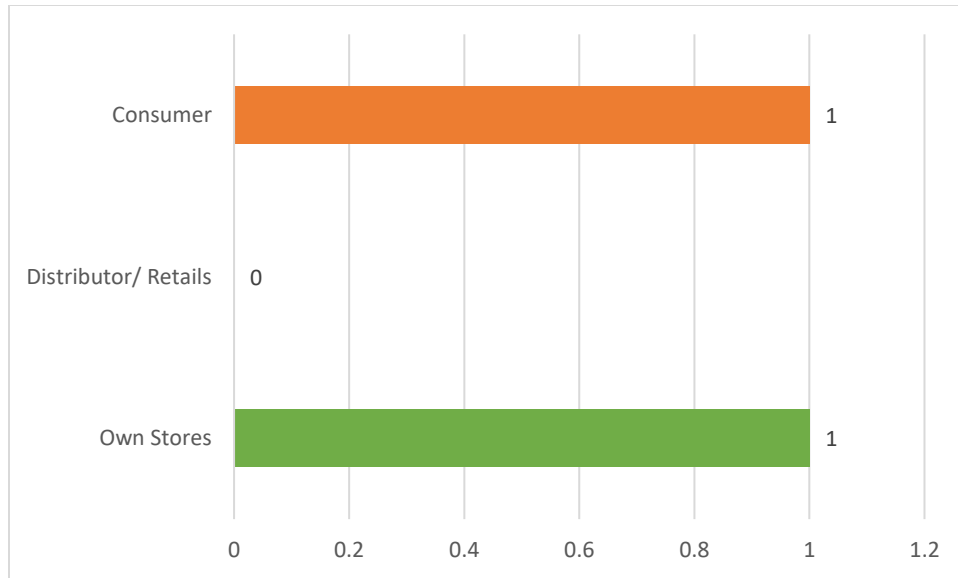


Figure 4.11: Tracing Capability by Company

Out of the nine companies polled it was observed that only two had some form of elaborate cylinder tracing system. One could only automatically trace the cylinders are their own stores. During follow-up questions it was noted that majority of the players could only trace cylinders to their filling plant as this is a legal requirement. The traceability is predominantly manual, a user maintains a list in a log book by hand. Only one company could trace cylinders to the consumer level.

#### 4.2.1.8. Consumer Behaviour

The consumer is the final leg of the supply chain and a critical actor in the LPG cylinder traceability flow. This is the actor that has the most to benefit from an elaborate LPG cylinder traceability system. The study sort to understand aspect of the consumer behaviour to allow the researcher to understand the possible use case and scope of the proposed system. First was to understand how consumers generally acquire or receive their ordered LPG cylinder. As illustrated in the following diagram it was noted that 89% of the respondents confirmed to have their cylinders delivered by the retailer. 21.8% confirmed to collect their cylinders from the retail outlet. Interestingly there are 4.8% of respondent who assert that their cylinders are delivered individuals; in such cases the respondents could not associate the delivery with an established retailer shop.

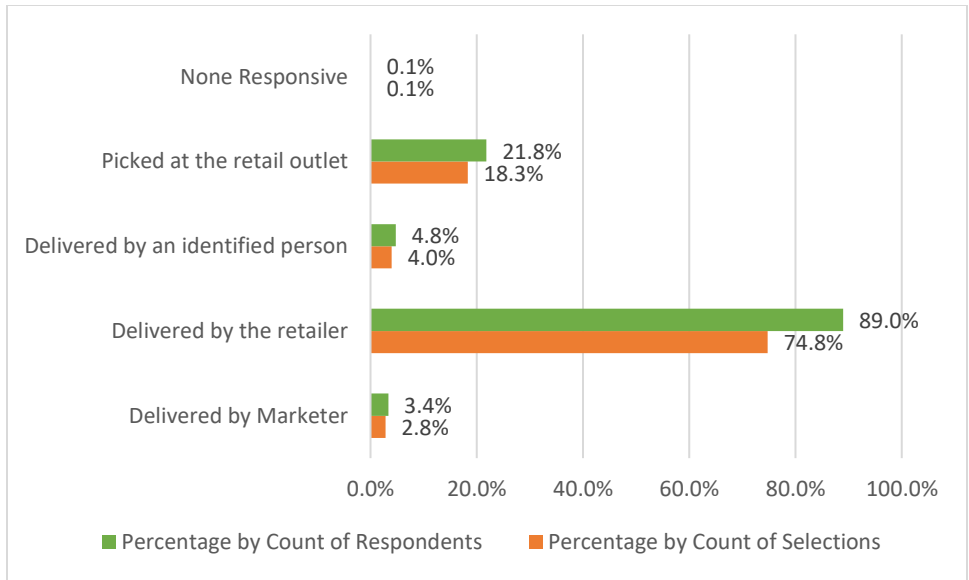


Figure 4.12: LPG Cylinder Consumer Delivery Channel

The survey also sort to understand the level of need for a cylinder traceability system exposed to the consumers. Analysis of the results indicated that 86% of respondents had experienced supply of suspicious cylinders.

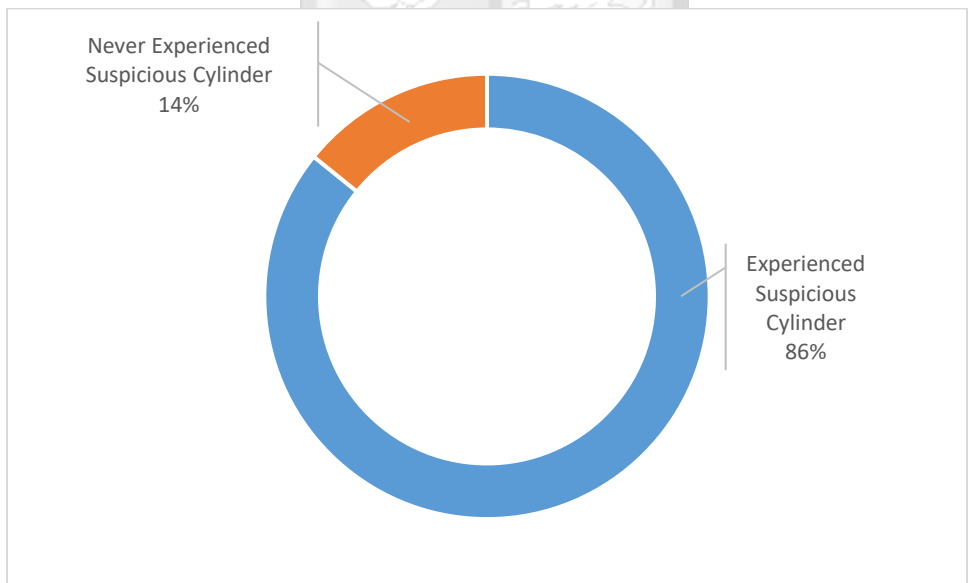


Figure 4.13: Suspicious Cylinder Experience by Consumer

For respondents that polled in the affirmative for receipt of suspicious cylinders the study sort to understand the nature of suspicion. This is parameter is to help the research design as system that would answer the areas of concern for the consumer in addressing their cylinder traceability requirements. Respondents were allowed to pick a maximum of three options.

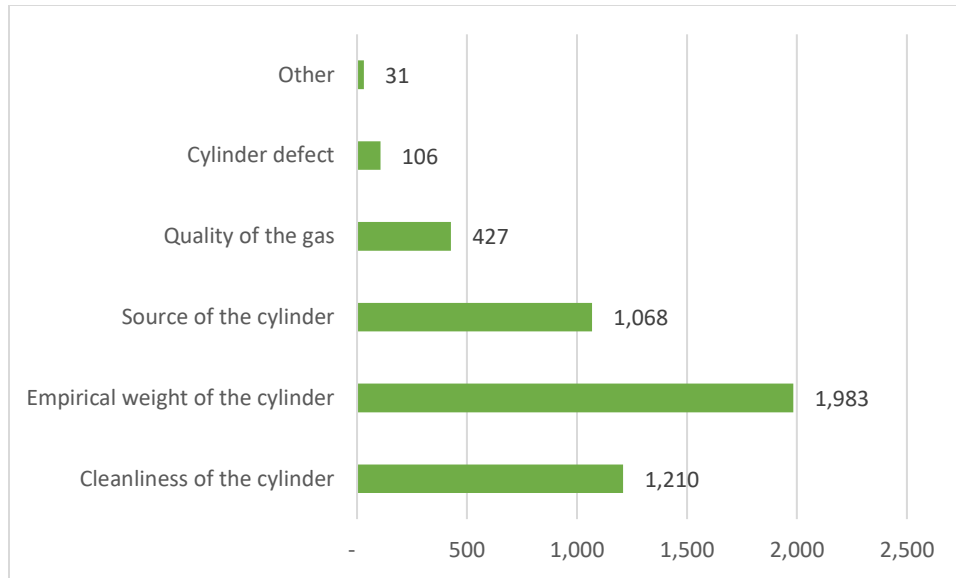


Figure 4.14: Consumer Reasons for Suspecting LPG Cylinder

From the analysis of the survey results the top three reasons for suspicion of LPG cylinder is discrepancy in the empirical weight of the cylinder, the cleanliness of the cylinder and the potential source of the cylinder in that order.

#### 4.2.2. Interpretation of Results

Based on the results presented, it is apparent that there is a need for an LPG cylinder traceability system. Majority of the users sampled confirmed to having received LPG cylinder that were suspect. Based on the survey the suspicion is driven largely by three reasons; all of which point to the suspicion that the consumer is not getting value for money. The interpretation is that the consumer is likely the main beneficiary of a traceability system.

The results also pointed out to the existence of some elements of cylinder traceability. However the extent or capability of the same is shallow. This points to a possible attempt predominantly to adhere to legal requirements that require a LPG marketers cylinders to be uniquely identifiable and traced by filling date and station. A few of the LPG marketers have attempted to implement an LPG cylinder traceability system but are still unable to meaningfully use it. The most advanced entities can only trace cylinders to their shops or outlets but not beyond. Only one company was observed to have capability to trace cylinder to their consumers. This company was noted have a completely different model where the LPG cylinder is purely handed

by its staff from filling to consumer houses and back. As such they have a less complicated ecosystem compared to the majority of the industry. It is the researchers view that such a model though expensive is partly deployed to help curb LPG cylinder traceability challenges currently experienced in the market.

The fact that the study confirmed a high mobile penetration rate affirms that a mobile application would be a choice solution for a LPG cylinder traceability system in Kenya. The solution would offer value to both the consumer and the marketers. For consumers the solution will ensure value for money and peace of mind as a consumer would be able to verify the source of the cylinder and hence confirm it is a genuine product. The LPG marketer on the other hand will have better visibility of the market as it would them to map the route to market all the way to the consumer. The prevalent model adopted across the industry is the user of third-party outlets and agents. Ownership of the actual client, the consumer, remains with the third-party agents. The fact that most distributors and/or retailers sampled acquire their cylinders from the LPG marketing companies directly indicates a shift away from a distributorship model to one where the LPG marketers are seeking to remove the middleman.

#### **4.2.3. Summary of Data Analysis and Findings**

The survey findings puts fourth a strong case for an LPG cylinder traceability mobile application in Kenya. The benefits would not only support compliance but ensure value for money for consumers and return on investment for the LPG marketing companies that make substantial investment into the purchase of cylinders to serve their choice markets. From the analysis of collected data, key considerations emerged that give guidance on critical design consideration. The following are key consideration in the design of the system:

- a. From the survey analysis a majority of the LPG marketers, purchase their cylinders from third-parties hence there is no need for the system to explore traceability from acquisition of the cylinder.
- b. A suitable LPG cylinder traceability system for the Kenyan context should being from mapping of the acquired cylinder into the system.
- c. The analysis of data has pointed to the fact that majority of the distributors acquire LPG cylinders through marketers. This points to a trend of marketers tilting towards elimination of

the middleman ostensibly to reduce risks around cylinder management. This infers the need for LPG markets to have visibility over their agents and the movement of cylinders in the distributors customer.

- d. The survey results analysis asserts that the 6kg and 13kg LPG cylinder are the most popular for the retail segment. Other SKU though traded in lower volumes does not feature prominently amongst consumers implying suitability in the business-to-business segment where traceability may not be a challenge. The proposed system should hence be designs based on the retail SKUs.
- e. The analysis of results asserted that the LPG cylinder eco-system is predominantly built on a depot distribution model. Majority of the marketers have opted for a hybrid depot model; mix of both company owned and third-party owned depots. This implies that the traceability system needs to take into account third-party entities in the supply chain.
- f. From the analysis of results cylinder tagging uptake is fair with approximately half of the LPG marketers adopting tagging of cylinders. These points to the growing demand for cylinder tracking albeit with limitations in functionality. The system design needs to consider integration to pre-existing tracking infrastructure particularly for cylinder tagging.
- g. Over 90% of consumers sampled indicated that the acquire their LPG cylinder products through the retailer; either by delivery or self-collect. This implies that the retailer is a critical cog in the supply chain and the traceability system must encompass the retail as a key actor.
- h. The analysis of result demonstrated the need for the system to give comfort to the consumer on the source of the cylinder. This will require the system to be able to furnish the consumer with relevant details about a cylinder in question, for example; filling plant where it was filled before the current delivery, and date the cylinder was filled, the retailer the cylinder was sold to.

#### **4.3. Requirements Analysis**

The proposed system design is based on the identified and implies requirements. Requirements are classified into two categories.

### 4.3.1. Functional Requirements

Functional requirements define a functionalities or features that the implemented system or its components should be able to execute. The requirements are defined by the research objectives. The following is a tabular representation of the core functional requirements of the proposed system.

Table 4.4: System Functional Requirements

ID	Requirement
FR01	User is able to install the mobile application on their phone
FR02	User can create a profile in the application
FR03	Authorized user is able to register an LPG cylinder in the system
FR04	Store the LPG cylinder details in a database
FR05	Allow authorized users to view registered cylinder details
FR06	Authorized user should be able to update cylinder status
FR07	Store cylinder status transaction update in a database
FR08	Allow authorized users to view cylinder status history
FR09	Allow a user to query cylinder status history
FR10	Allow users to validate cylinder status
FR11	Provide report of individual cylinder life cycle

### 4.3.2. Non-Functional Requirements

Non-functional requirements provide a criteria for evaluating the system useability. These provide the requirements for the system's accessibility and usage. The following is a tabular representation of the core non-functional requirements of the proposed system.

Table 4.5: System Non-Functional Requirements

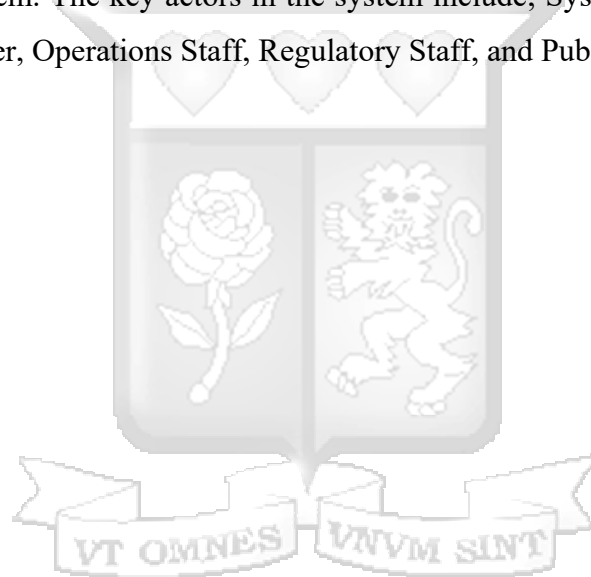
ID	Requirement
TR01	The system should be reliable
TR02	The system should be user friendly to allow elementary level users navigate
TR03	The system should be customizable i.e., should be easy to modify to suit the changing needs
TR04	The system should be scalable to cope with changing requirements
TR05	The System should be able to capture and log GPS coordinates where transactions are performed

#### 4.4. Process Modelling

Software modelling allows for the representation of a system definition, design, and architecture. The process will allow for the definition of the system design in differentiated levels of details.

##### 4.4.1. Use Case Modelling

Use cases models facility the identification and representation of proposed functionality of the proposed mobile application system. The modelling highlights the discrete instances of interaction between a user and the system. Figure 4.15 shows the interactions in the proposes LPG cylinder traceability system. The key actors in the system include; System Administrator, Retail Staff, Operations Manager, Operations Staff, Regulatory Staff, and Public User.



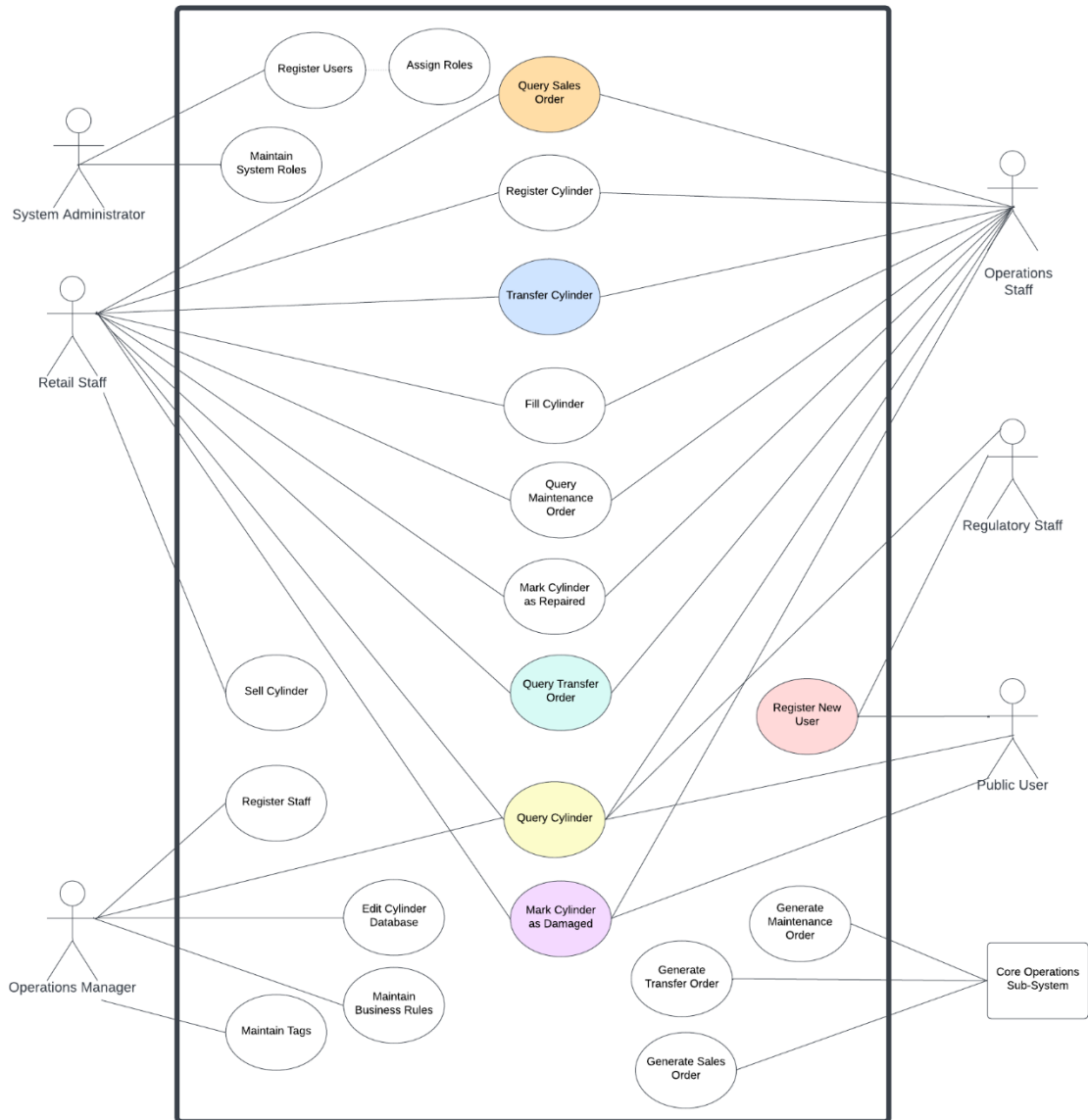


Figure 4.15: Use Case Diagram for an LPG Cylinder Traceability System

The core identified use case a described in a greater detail in the following tables. The details include the pre-condition required for the use act and the resultant condition once the use case is executed in a given instance. Further a happy-path and alternative process flow is defined.

Table 4.6: Register Cylinder Use Case Description

Use Case ID	UC01
Title	Register Cylinder
Description	A user wishes to register a new cylinder into the system so that it can be traced in the system.
Actor(s)	Operations Staff
Pre-Conditions	User must have launched the mobile application, and has the role of operations staff assigned to them
Post-Conditions	The cylinder record is saved in the database
Main success Scenario	<ol style="list-style-type: none"> <li>1. User clicks on the register cylinder icon</li> <li>2. User keys in all the cylinder details and associated tag</li> <li>3. User clicks on complete</li> <li>4. Cylinder record is captured and stored in database</li> </ol>
Alternative flow of events	<ol style="list-style-type: none"> <li>1. System declines data entered and returns an error message</li> </ol>

Table 4.7: Fill Cylinder Use Case Description

Use Case ID	UC02
Title	Fill Cylinder
Description	A user wishes to update a registered cylinder from empty to filled so that the cylinder is identifiable as full in the system
Actor(s)	Operations Staff
Pre-Conditions	User must have launched the mobile application, and has the role of operations staff assigned to them
Post-Conditions	Cylinder status is changed from empty to filled
Main success Scenario	<ol style="list-style-type: none"> <li>1. User clicks on the fill cylinder icon</li> <li>2. User keys in the shift / filling order details</li> <li>3. User enters cylinder that have been filled</li> <li>4. Cylinder record is captured and stored in database as fill cylinders</li> </ol>
Alternative flow of events	<ol style="list-style-type: none"> <li>1. System declines data entered and returns an error message</li> </ol>

Table 4.8: Transfer Cylinder Use Case Description

Use Case ID	UC03
Title	Transfer Cylinder
Description	A user wants to transfer a cylinder to another user so that there is a change of custody of the identified cylinder
Actor(s)	Operations Staff, Retail Staff
Pre-Conditions	User must have launched the mobile application, and has the requisite role assigned to them

Use Case ID	UC03
Post-Conditions	Custody transfer is recorded against the identified cylinder
Main success Scenario	<ol style="list-style-type: none"> <li>1. User clicks on the transfer cylinder icon</li> <li>2. User keys in the transfer order details</li> <li>3. System populates the order details</li> <li>4. User captures the cylinders to be transferred against that order</li> <li>5. User confirms transfer by clicking on the submit button</li> <li>6. User_2 receives a transfer request</li> <li>7. User_2 approves the transfer request</li> <li>8. Custody of transferred cylinder change and record is updated in the database</li> </ol>
Alternative flow of events	<ol style="list-style-type: none"> <li>1. System declines data entered and returns an error message</li> <li>2. User_2 rejects the transfer request; not change of custody is done; record is achieved</li> </ol>

Table 4.9: Sell Cylinder Use Case Description

Use Case ID	UC04
Title	Sell Cylinder
Description	A user wants to transfer a cylinder to consumer so that there is a change of custody of the identified cylinder to an unidentified actor
Actor(s)	Retail Staff
Pre-Conditions	User must have launched the mobile application, and has the requisite role assigned to them
Post-Conditions	Custody transfer is recorded to an unidentified actor
Main success Scenario	<ol style="list-style-type: none"> <li>1. User clicks on the transfer cylinder icon</li> <li>2. User keys in the sales order details</li> <li>3. System populates the order details</li> <li>4. User captures the cylinders to be transferred against that order</li> <li>5. User confirms transfer by clicking on the submit button</li> <li>6. Custody of transferred cylinder change and record is updated in the database</li> </ol>
Alternative flow of events	<ol style="list-style-type: none"> <li>1. System declines data entered and returns an error message</li> </ol>

Table 4.10: Mark Cylinder Damaged Use Case Description

Use Case ID	UC05
Title	Mark Cylinder Damaged
Description	A user wants to mark a cylinder as damaged so that the cylinder is not allowed to participate in the normal process flow
Actor(s)	Operations Staff, Retail Staff, Enforcement Staff

Use Case ID	UC05
Pre-Conditions	User must have launched the mobile application, and has the requisite role assigned to them
Post-Conditions	Cylinder is marked as damaged in the system
Main success Scenario	<ol style="list-style-type: none"> <li>1. User clicks on the Damaged cylinder icon</li> <li>2. User captures the cylinder identity</li> <li>3. User captures attributes of the damage</li> <li>4. User confirms the record by clicking on the submit button</li> <li>5. Cylinder is marked damaged in the system</li> </ol>
Alternative flow of events	<ol style="list-style-type: none"> <li>1. System declines data entered and returns an error message</li> </ol>

Table 4.11: Mark Cylinder Repaired Use Case Description

Use Case ID	UC06
Title	Mark Cylinder Repaired
Description	A user wants to mark a damaged cylinder as repaired so that the cylinder is allowed to participate in the normal process flow
Actor(s)	Operations Staff
Pre-Conditions	User must have launched the mobile application, and has the requisite role assigned to them
Post-Conditions	Damaged cylinder is marked as repaired in the system
Main success Scenario	<ol style="list-style-type: none"> <li>1. User clicks on the Repaired cylinder icon</li> <li>2. User captures the damaged cylinder identity</li> <li>3. User confirms the record by clicking on the submit button</li> <li>4. If cylinder is repairable, cylinder is marked as repaired in the system</li> <li>5. If cylinder is not repairable, cylinder is marked as write-off in the system</li> </ol>
Alternative flow of events	<ol style="list-style-type: none"> <li>1. System declines data entered and returns an error message</li> </ol>

Table 4.12: Query Cylinder Use Case Description

Use Case ID	UC07
Title	Query Cylinder
Description	A user wants to trace a cylinder so that he/she can know its last capture and the current status and custodian of the cylinder
Actor(s)	All users
Pre-Conditions	User must have launched the mobile application, and has the requisite role assigned to them
Post-Conditions	Cylinder details are displayed on the user's screen

Use Case ID	UC07
Main success Scenario	<ol style="list-style-type: none"> <li>1. User clicks on the Query cylinder icon</li> <li>2. User captures the cylinder identity</li> <li>3. User confirms the cylinder to query by clicking on the query button</li> <li>4. System displays available details on the queried cylinder</li> </ol>
Alternative flow of events	<ol style="list-style-type: none"> <li>1. System declines data entered and returns an error message</li> </ol>

Table 4.13: Update Cylinder Details Use Case Description

Use Case ID	UC08
Title	Update Cylinder Details
Description	A user wishes to edit the details of a registered cylinder so that the amended details are visible in the system
Actor(s)	Operations Manager
Pre-Conditions	User must have launched the mobile application, and has the requisite role assigned to them
Post-Conditions	Cylinder details are updated in the database
Main success Scenario	<ol style="list-style-type: none"> <li>1. User clicks on the Update Cylinder icon</li> <li>2. User enters the identifier of the cylinder to be updated</li> <li>3. System populates the cylinder details</li> <li>4. User enters the new details where applicable</li> <li>5. User commits the changes</li> <li>6. Cylinder record is updated in the database</li> </ol>
Alternative flow of events	<ol style="list-style-type: none"> <li>1. System declines data entered and returns an error message</li> </ol>

#### 4.4.2. Sequence Diagrams

Sequence diagrams are design representation artifacts used to illustrate the interaction between actors and associated objects during the execution of a use case. The following are sequence diagrams for the main use cases in the LPG cylinder traceability system.

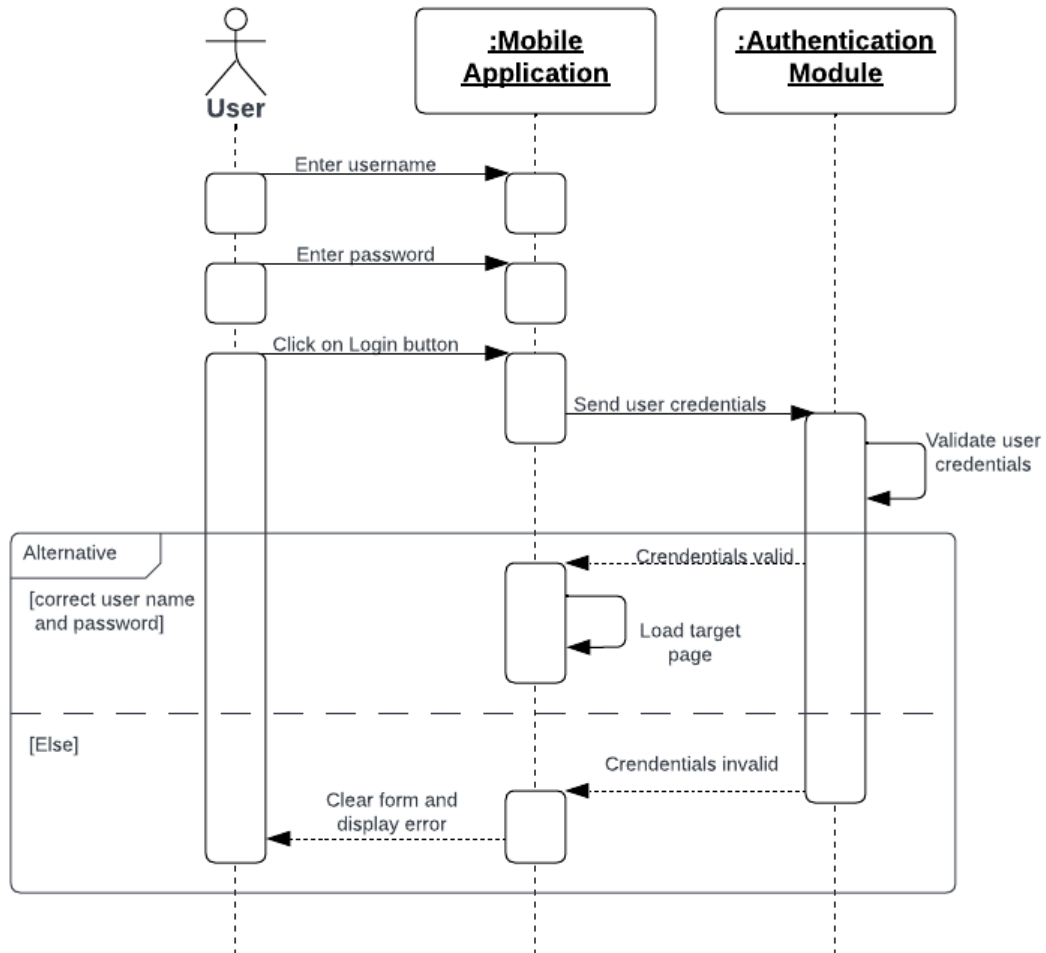


Figure 4.16: Login Sequence Diagram

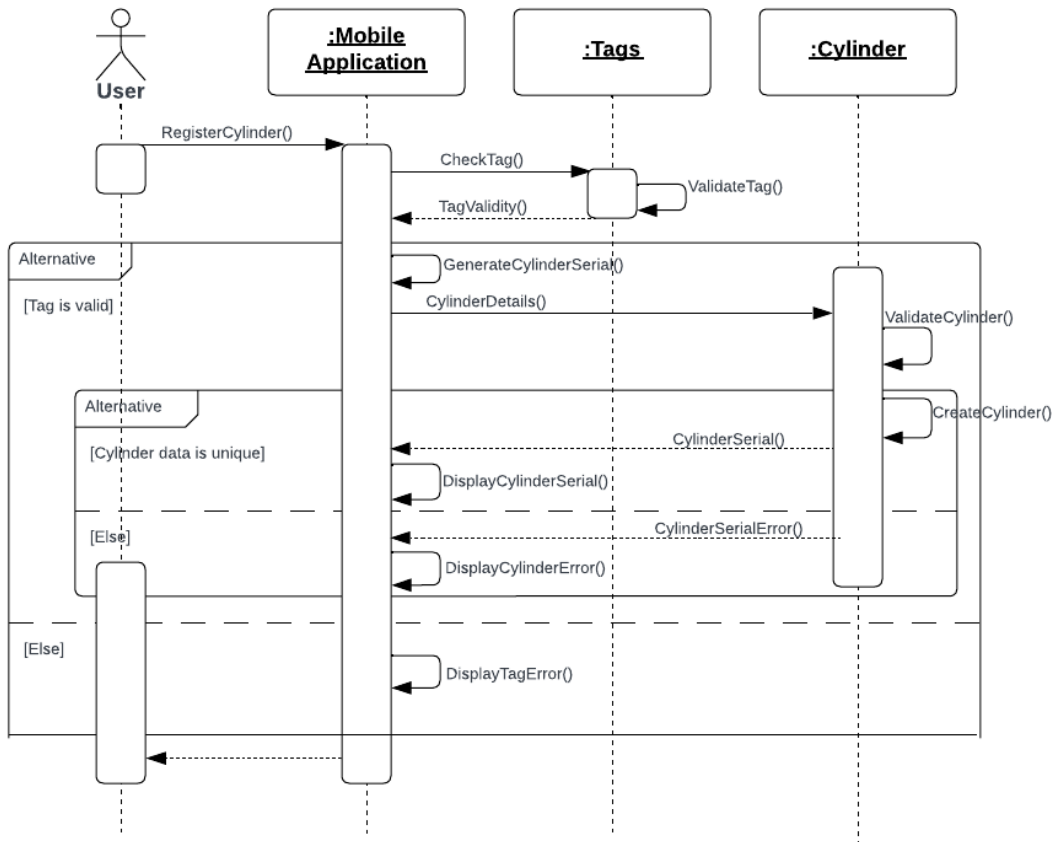


Figure 4.17: Register Cylinder Sequence Diagram



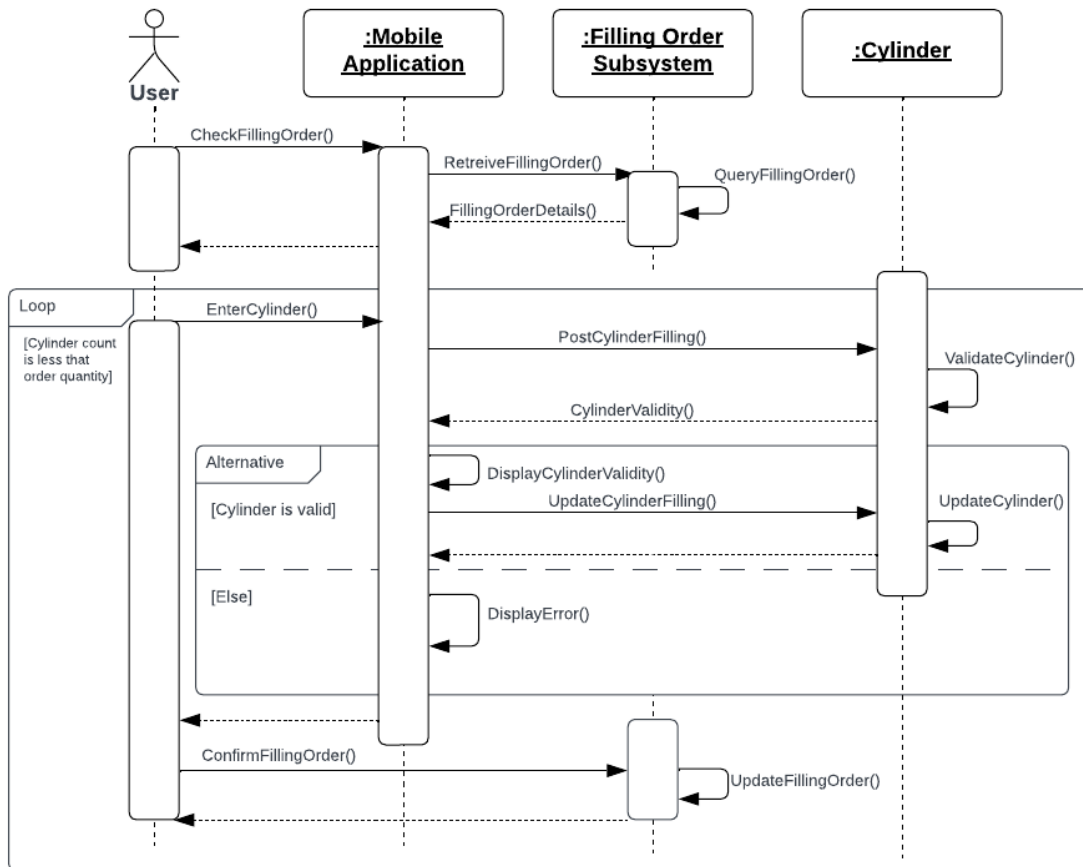


Figure 4.18: Fill Cylinder Sequence Diagram



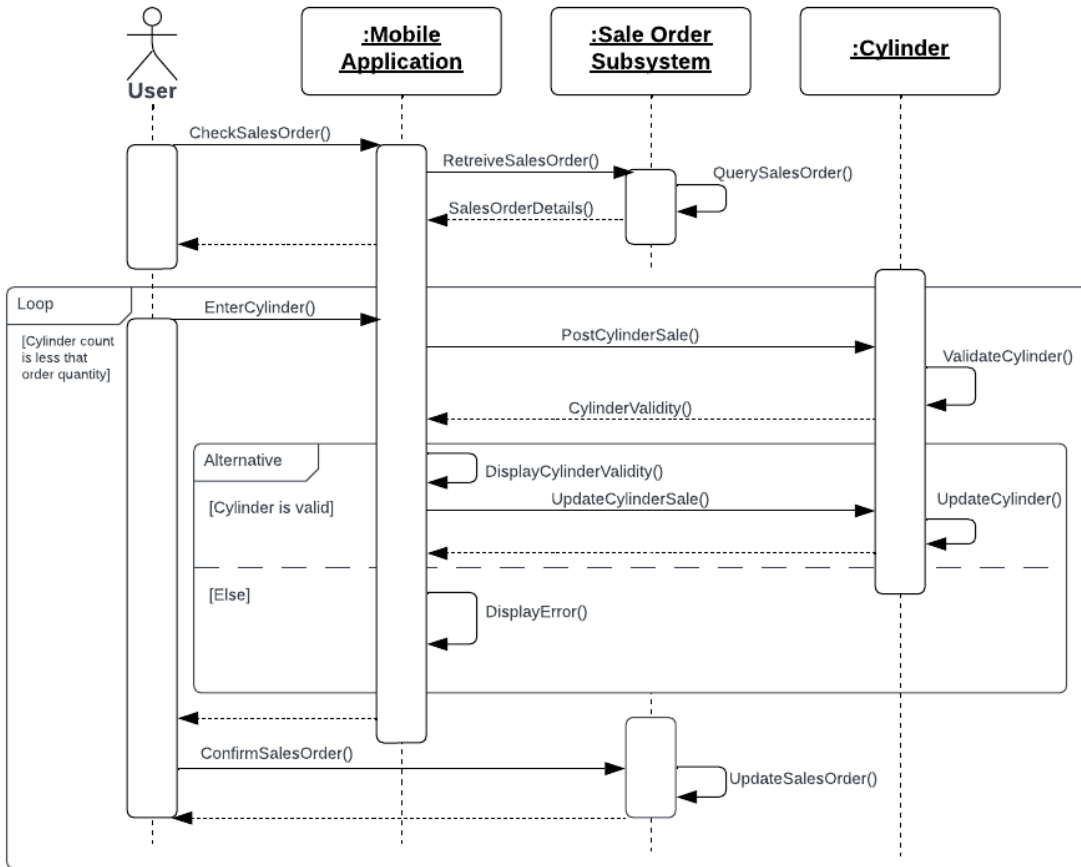


Figure 4.19: Sell Cylinder Sequence Diagram



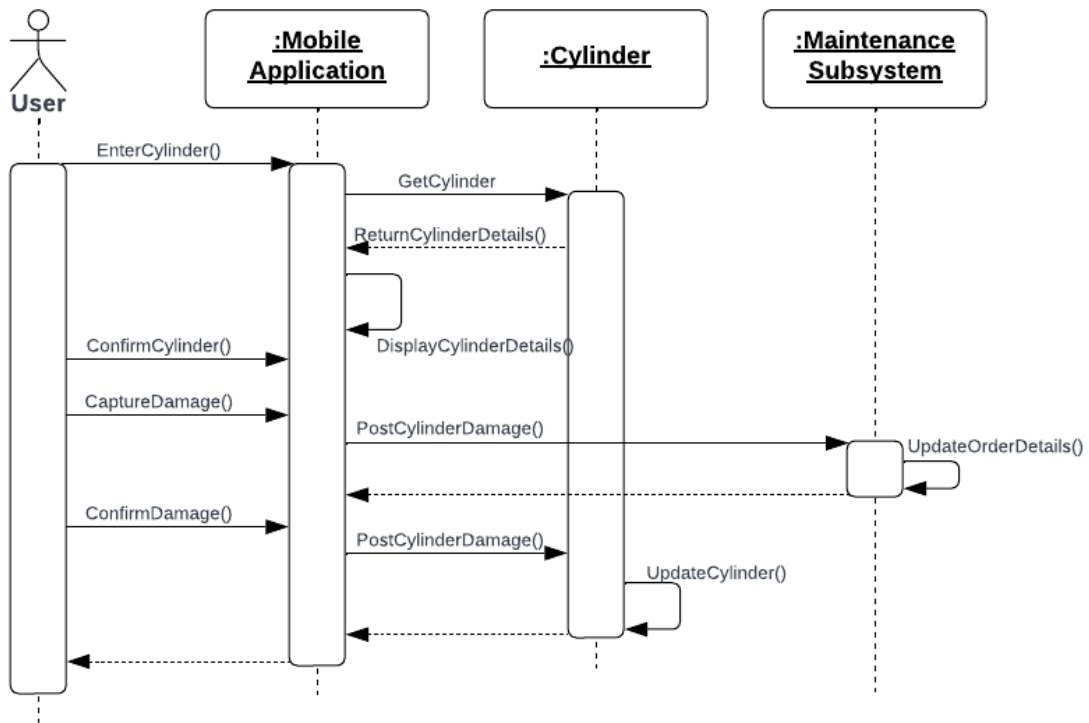
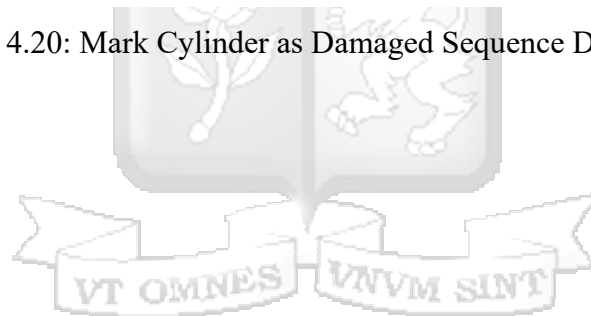


Figure 4.20: Mark Cylinder as Damaged Sequence Diagram



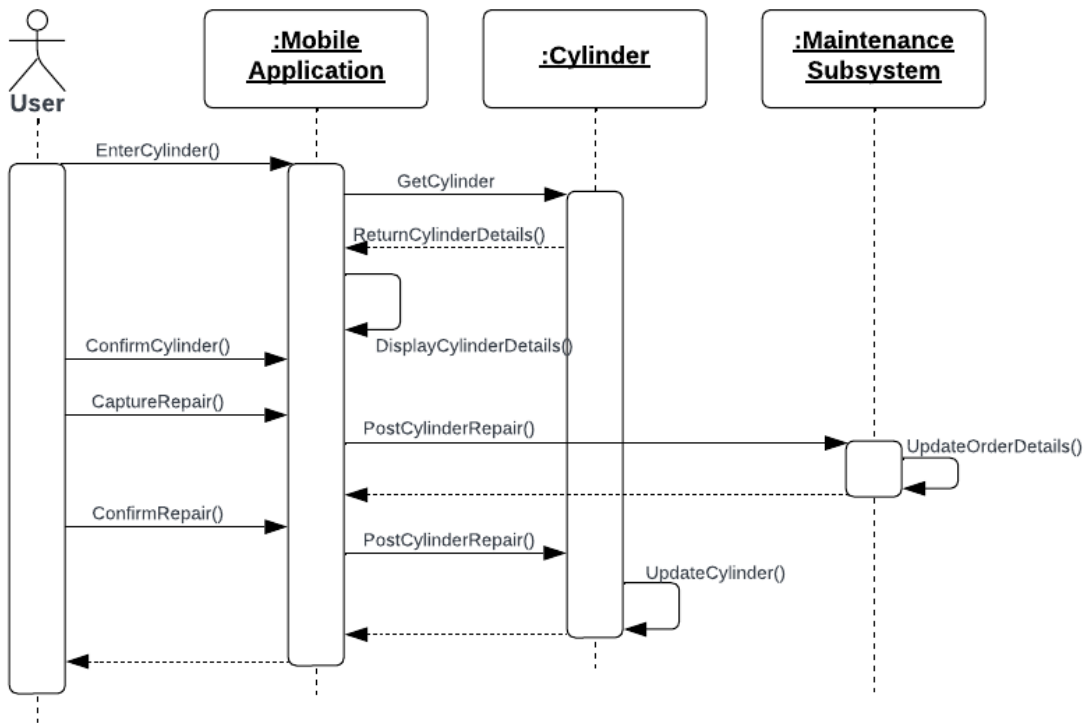


Figure 4.21: Mark Cylinder as Repaired Sequence Diagram

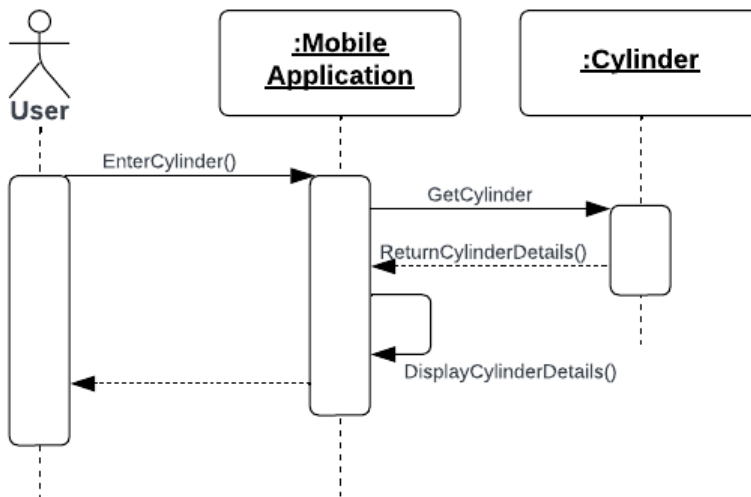


Figure 4.22: Query Cylinder Sequence Diagram

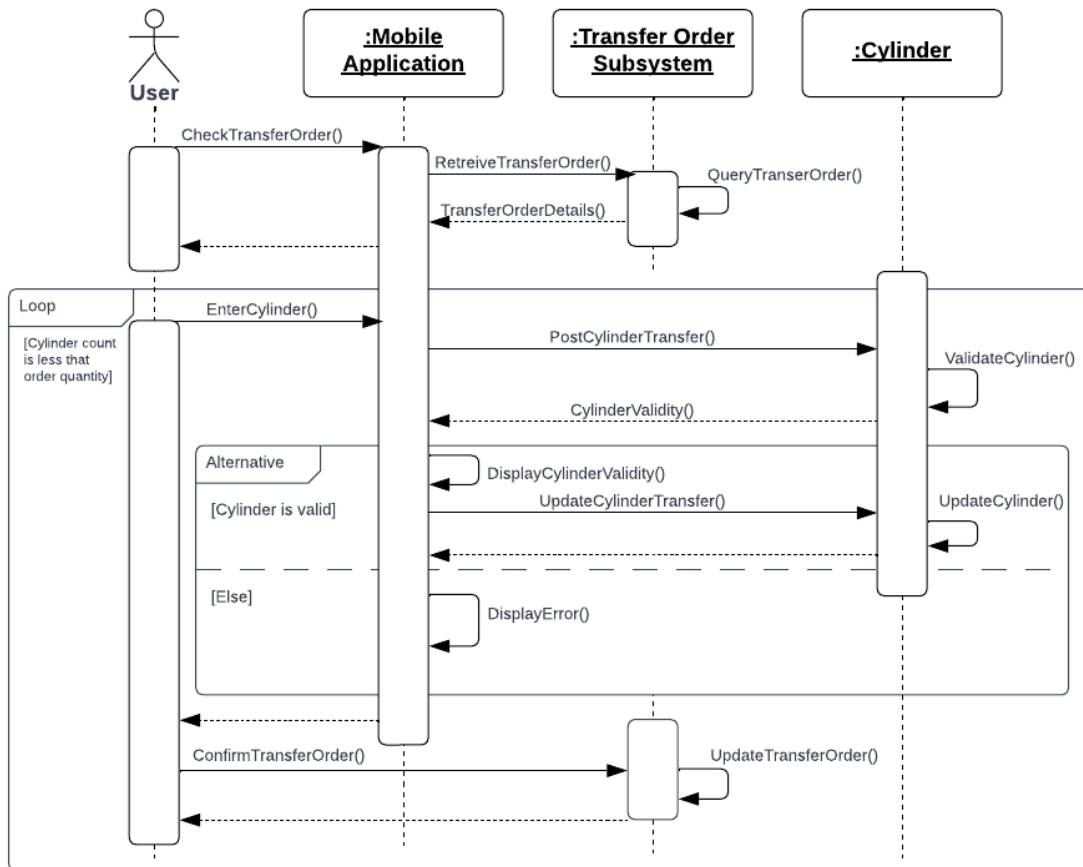
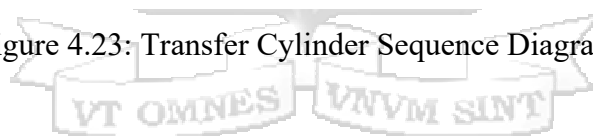


Figure 4.23: Transfer Cylinder Sequence Diagram



#### 4.4.3. Data Flow Diagrams

The following Data Flow Diagrams (DFD) illustrate the flow of data across the system landscape. The objective is to show the direction and purpose of flow and subsequently to give greater details in terms of inputs, output and relevant data stores. The Data Flow Diagrams for the proposed LPG Cylinder Traceability System are presented as follows in two levels. Level 0 illustrates the high level system view where as level 1 attempts to show case the detailed data flows in select processes.

### 4.4.3.1. Level 0 Data Flow Diagram

Figure 4.24 show cases the data flow across the LPG cylinder traceability system . It illustrates the flow of data between the core actors, core process and relevant data stores.

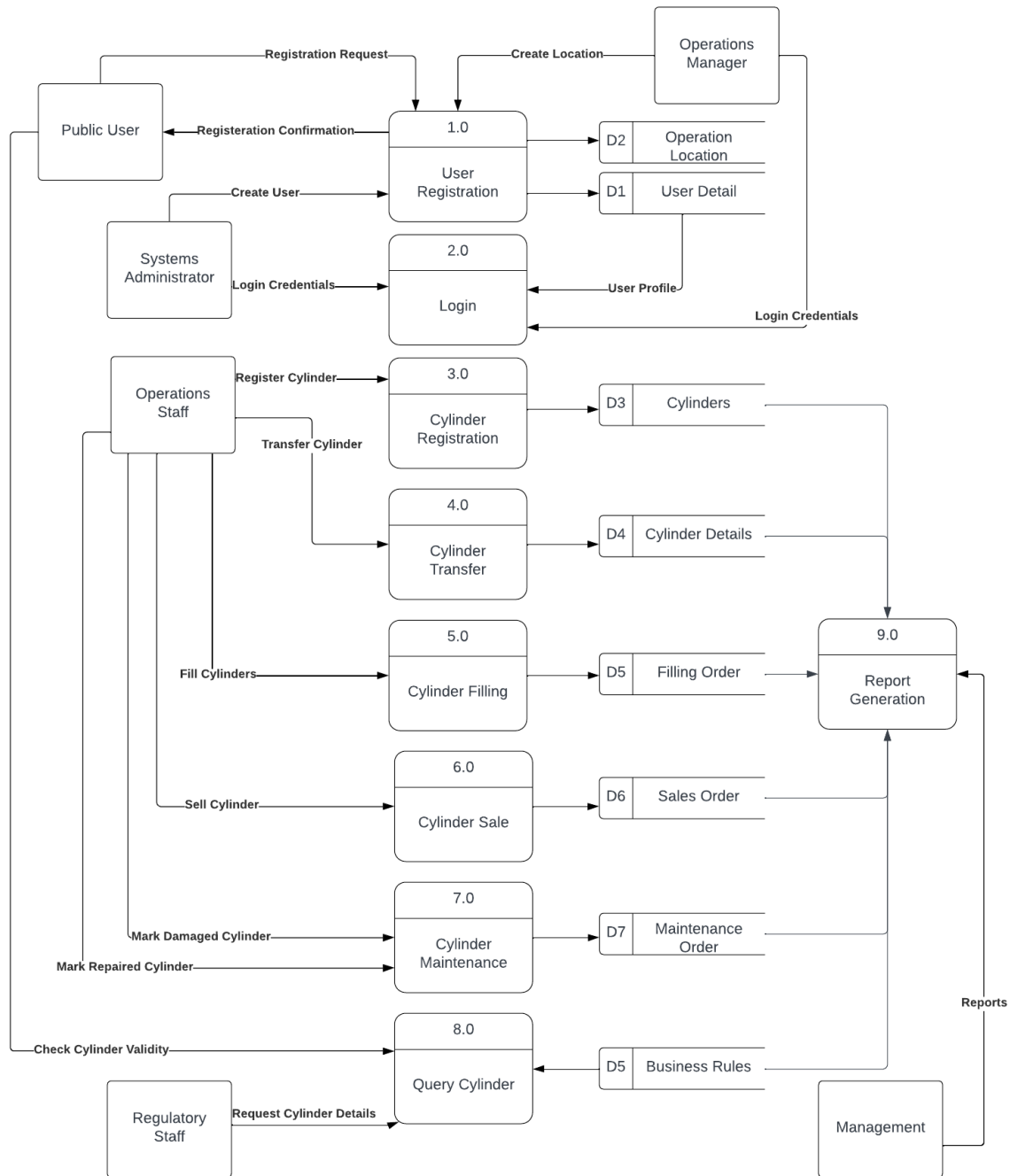


Figure 4.24: Level 0 DFD for LPG Cylinder Traceability System

#### 4.4.3.2. Level 1 Data Flow Diagrams

Level 1 Data Flow Diagrams for the proposed system illustrate the three critical process in greater details; the cylinder registration process, the cylinder transfer process and the cylinder details query process.

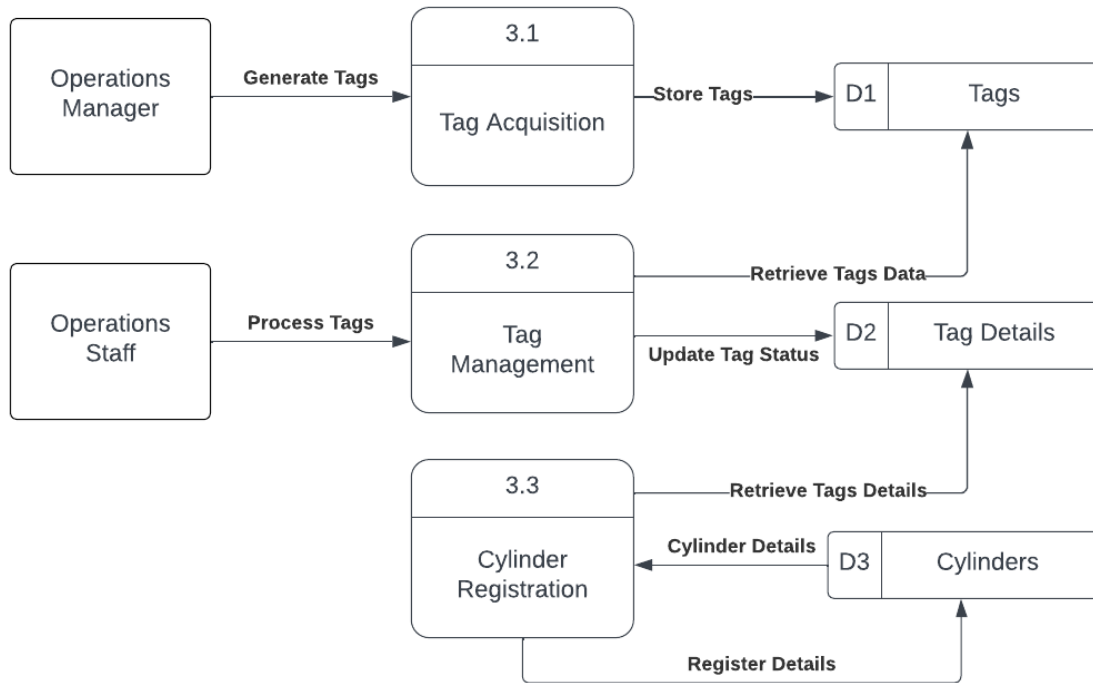


Figure 4.25: Level 1 DFD for Cylinder Registration process



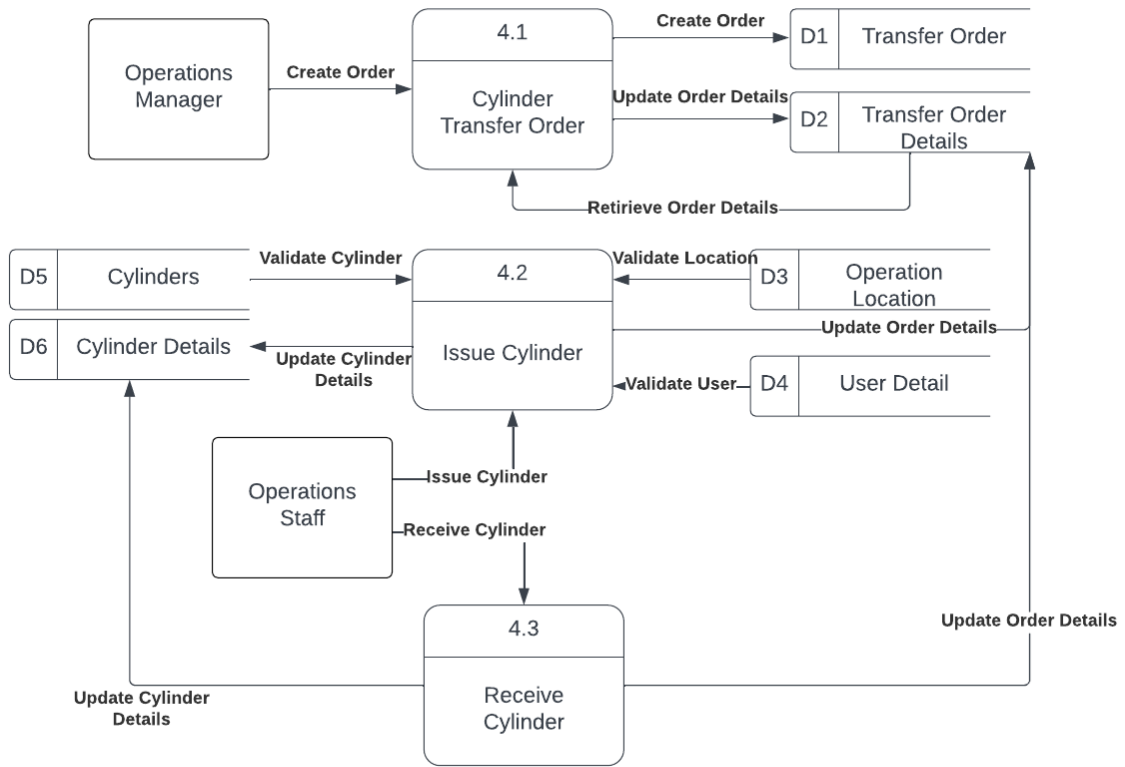
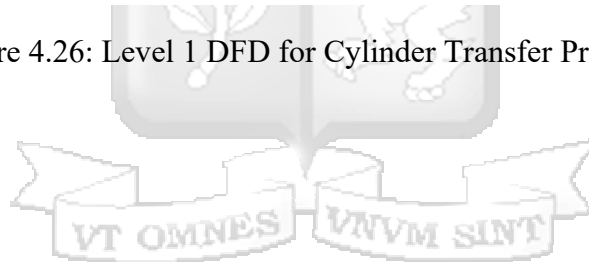


Figure 4.26: Level 1 DFD for Cylinder Transfer Process



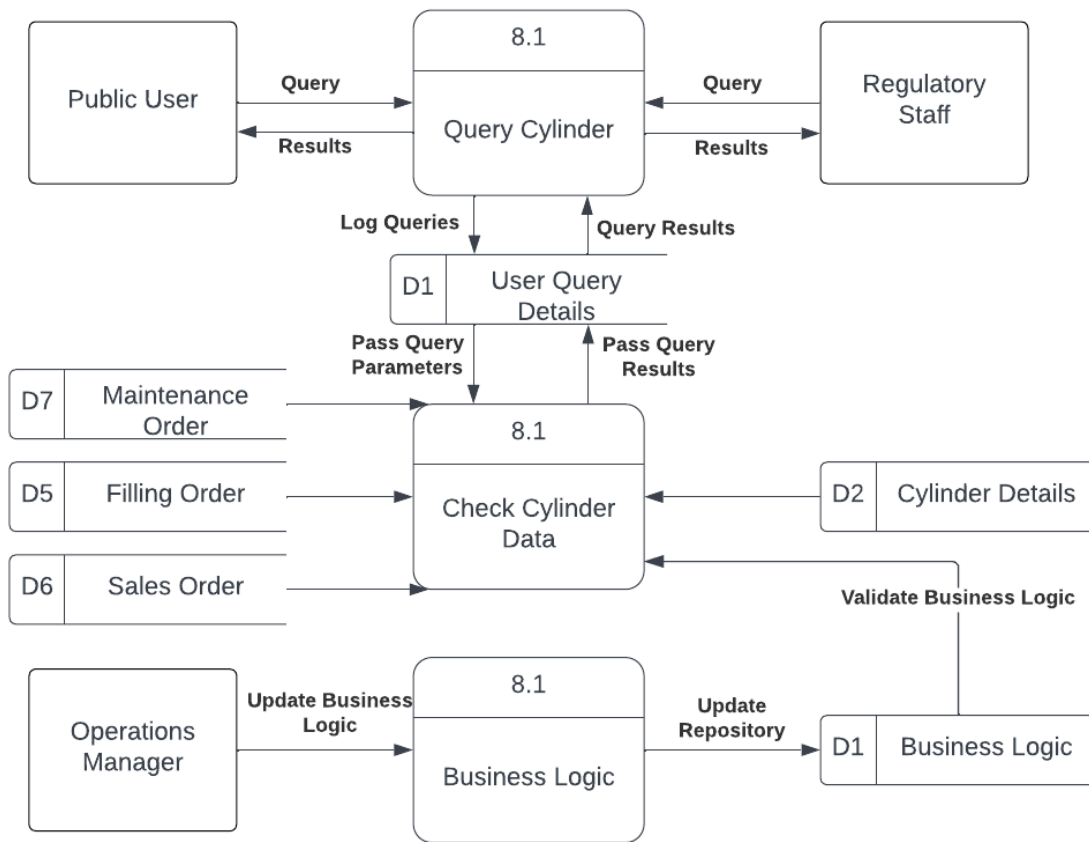


Figure 4.27: Level 1 DFD for Cylinder Details Query Process

## 4.5. Control Modelling

Control models are models that illustrate the control flow between components or sub-systems of a given system.

### 4.5.1. Conceptual Model and Entity Relationship Diagram

Conceptual models and entity relationship diagrams are a special class of control models that showcase the select problem domain. The diagram provide clarity on the direction of the envisaged system as the show the conceptual classes and the relations there of. The following is the Entity Relationship Diagram for the proposed LPG Cylinder Traceability system.

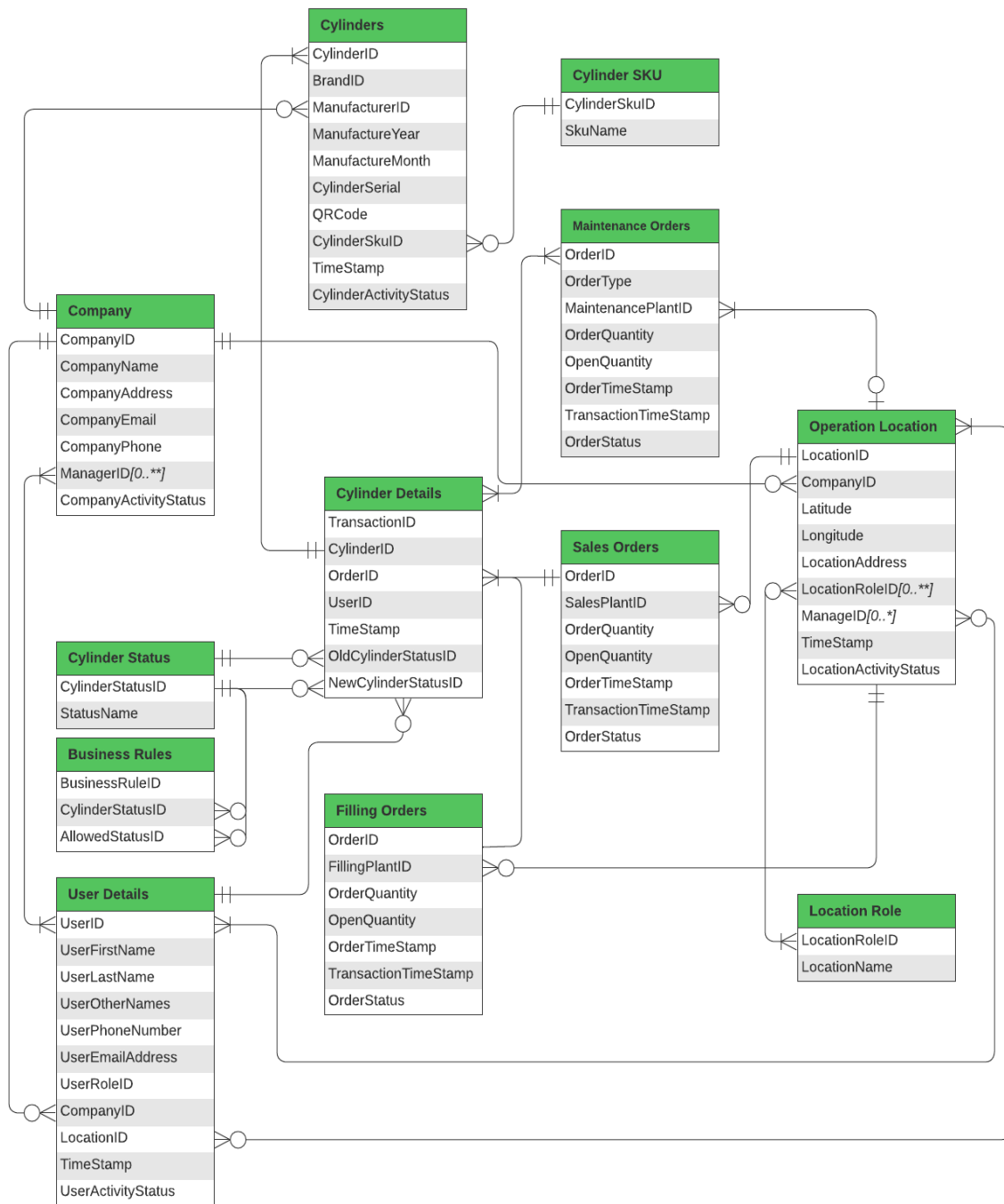


Figure 4.28: ERD for Proposed LPG Cylinder Traceability System

#### 4.5.2. Database Schema

A database is a collection of interrelated data files or structures. A database schema defines the relations between tables in a database. It highlights the associated items that are related to one another in a given relation.

The core tables in the system database are the user details table which stores all user credentials, the cylinder database that stores the attributed of a registered cylinder. Changes to a cylinder are stored in the Cylinder details page. The system includes critical tables, used as staging tables for supplementary systems that would be required to interface to the LPG cylinder traceability system, these include; the Filling Order, Sales Order, Maintenance Order, and Transfer Order tables.

Table 4.14: System Database Schema - Company Table

Field	Type	Size	Null	Key	Default	Extra
CompanyID	int(5)	4 Bytes	NO	PRI	(NULL)	auto_increment
CompanyName	char (65)	66 Bytes	NO		(NULL)	
CompanyAddress	char (65)	66 Bytes	NO		(NULL)	
CompanyEmail	char (65)	66 Bytes	NO		(NULL)	
CompanyPhoneNumber	int(12)	4 Bytes	YES		(NULL)	
ManagerID	int(5)	4 Bytes	NO	MUL	(NULL)	
CompanyActivityStatus	int(1)	4 Bytes	NO		(NULL)	
DateModified	datetime	8 Bytes	NO		CURRENT_TIMESTAMP	

Table 4.15: System Database Schema - Registered Cylinder Table

Field	Type	Size	Null	Key	Default	Extra
CylinderID	char(10)	8 Bytes	NO	PRI	(NULL)	
BrandID	int(5)	4 Bytes	NO	MUL	(NULL)	
ManufacturerID	int(5)	4 Bytes	NO	MUL	(NULL)	
ManufactureYear	int(4)	4 Bytes	NO		(NULL)	
ManufactureMonth	char	4 Bytes	NO		(NULL)	
CylinderSerial	int (7)	8 Bytes	NO		(NULL)	
QRCode	char(6)	8 Bytes	NO		(NULL)	
CylinderSKU	int (2)	4 Bytes	NO		(NULL)	
TimeStamp	datetime	8 Bytes	NO		CURRENT_TIMESTAMP	
CylinderActivityStatus	int(1)	4 Bytes	NO		0	

Table 4.16: System Database Schema - Cylinder Details Table

Field	Type	Size	Null	Key	Default	Extra
TransactionID	int (10)	8 Bytes	NO	PRI	(NULL)	auto_increment
CylinderID	char(10)	8 Bytes	NO	MUL	(NULL)	
OrderID	int (8)	8 Bytes	NO	MUL	(NULL)	
UserID	int(5)	4 Bytes	NO	MUL	(NULL)	
TimeStamp	datetime	8 Bytes	NO		CURRENT_TIMESTAMP	
OldCylinderStatusID	int(1)	4 Bytes	NO	MUL	(NULL)	
NewCylinderStatusID	int(1)	4 Bytes	NO	MUL	(NULL)	

Table 4.17: System Database Schema - Order Table

Field	Type	Size	Null	Key	Default	Extra
OrderID	int (8)	8 Bytes	NO	PRI	(NULL)	
FillingPlantID	int(5)	4 Bytes	NO	MUL	(NULL)	
OrderQuantity	int (5)	4 Bytes	NO		(NULL)	
OpenQuantity	int (5)	4 Bytes	NO		(NULL)	
OrderTimeStamp	datetime	8 Bytes	YES		(NULL)	
TransactionTimeStamp	datetime	8 Bytes	NO		CURRENT_TIMESTAMP	
OrderStatus	int(1)	4 Bytes	NO		(NULL)	

Table 4.18: System Database Schema - Location Table

Field	Type	Size	Null	Key	Default	Extra
LocationID	int(5)	4 Bytes	NO	PRI	(NULL)	auto_increment
CompanyID	int(5)	4 Bytes	NO	MUL	(NULL)	
Latitude	Decimal(8,6)	8 Bytes	NO		(NULL)	
Longitude	Decimal(9,6)	8 Bytes	NO		(NULL)	
Address	char (65)	66 Bytes	NO		(NULL)	
LocationRoleID	int(2)	4 Bytes	NO	MUL	(NULL)	
ManagerID	int(5)	4 Bytes	NO	MUL	(NULL)	
TimeStamp	datetime	8 Bytes	NO		CURRENT_TIMESTAMP	
LocationActivityStatus	int(1)	4 Bytes	NO		(NULL)	

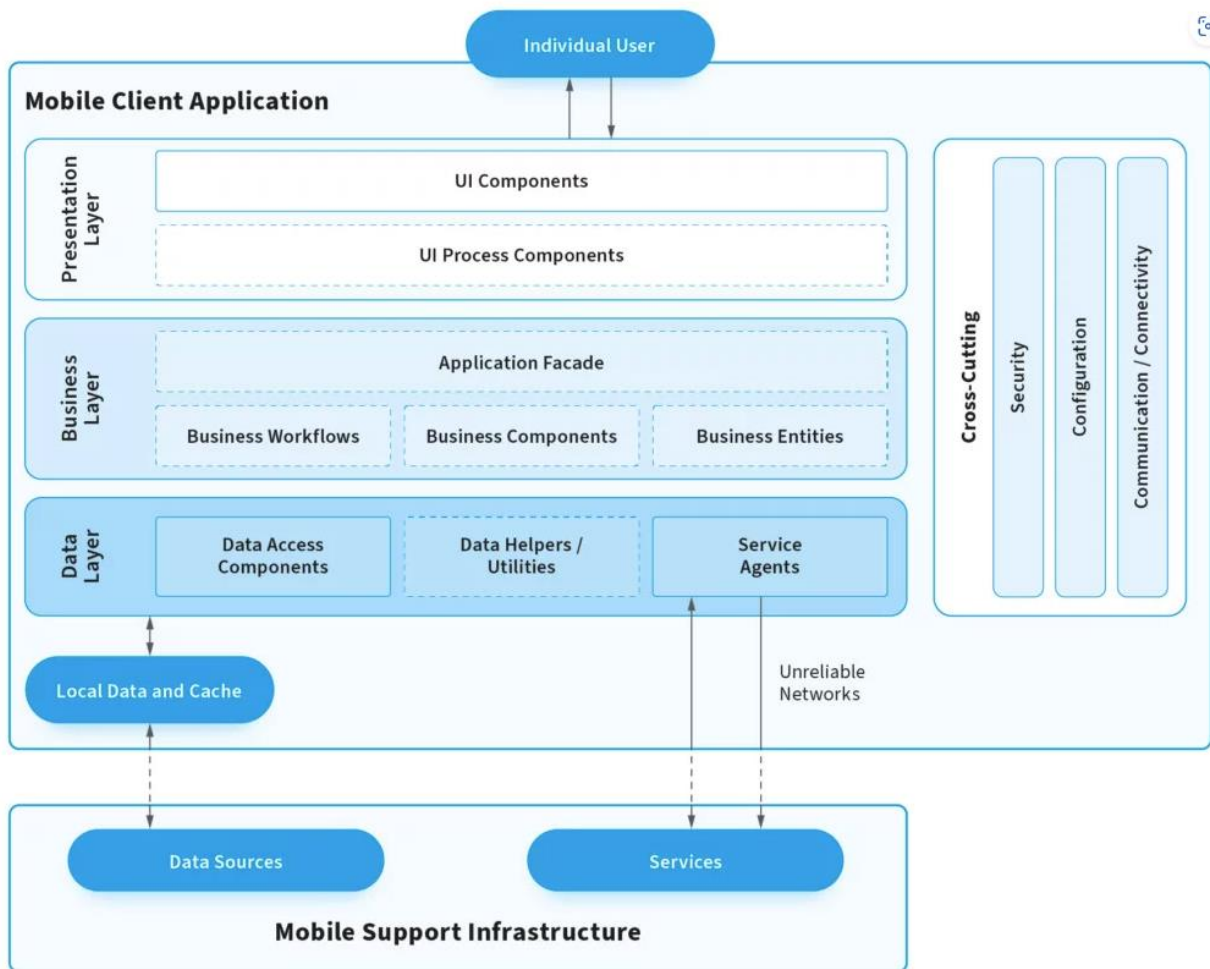
#### 4.6. Proposed System Architecture

The system architectural design showcases a birds eye view of the proposed system. It provides an illustration of the major system components including their individual set of interfaces, and the mode of interactions between the system components. This definition of components and

their interactions; formulates a set of rules, techniques, and patterns to develop the LPG cylinder traceability system.

#### 4.6.1. High Level System Architecture

Mobile applications ideally comprise of three layers; the data layer, the business layer and the presentation layer.



(Application Architecture for a Mobile App: IOS, Android, Hybrid – NIX United, n.d.)

Figure 4.29: High Level System Architecture

##### 4.6.1.1. Presentation Layer

The presentation layer is concerned with process and components that allow a user to interact with the application. The presentation layer has two main components: the user interface (UI) and the user experience (UX). The user interface looks at the design questions while the user

experience is interested in the manner in which a customer interacts with the application – this is driven by the user requirements.

#### **4.6.1.2. Business Layer**

The business layer defines the data flow and processing rules. It defined the operation performed on the data. Data integrity and logging is performed within the business layer. The layer can be hosted; on the application client or on the system backend; in some instance you may have a hybrid of the two.

#### **4.6.1.3. Data Layer**

This is the critical backend component that includes all data storage and associated procedures. The layer has two perspectives; persistence and network. Persistence addresses data access with data sources via API whereas network covers communication, routing and error reporting elements of the eco-system.

#### **4.6.2. LPG Cylinder Traceability System Architecture**

The LPG Cylinder Traceability application architecture is a three tier client server architecture. This approach creates a separation between the application server and the database server. The system administrator and Operations manager will have a web access to the system for configurational use case/functionality. All users will interface the system via the proposed Android mobile application. Being a public facing system, the system will have an application load balance in front of it to manage fluctuating load created by unpredictable user requests and ensure highest service uptime. The application server sits behind a firewall. There is a firewall between the application server and the database server to as an added security layer secure all connection to the database. This will limit direct access to the database.

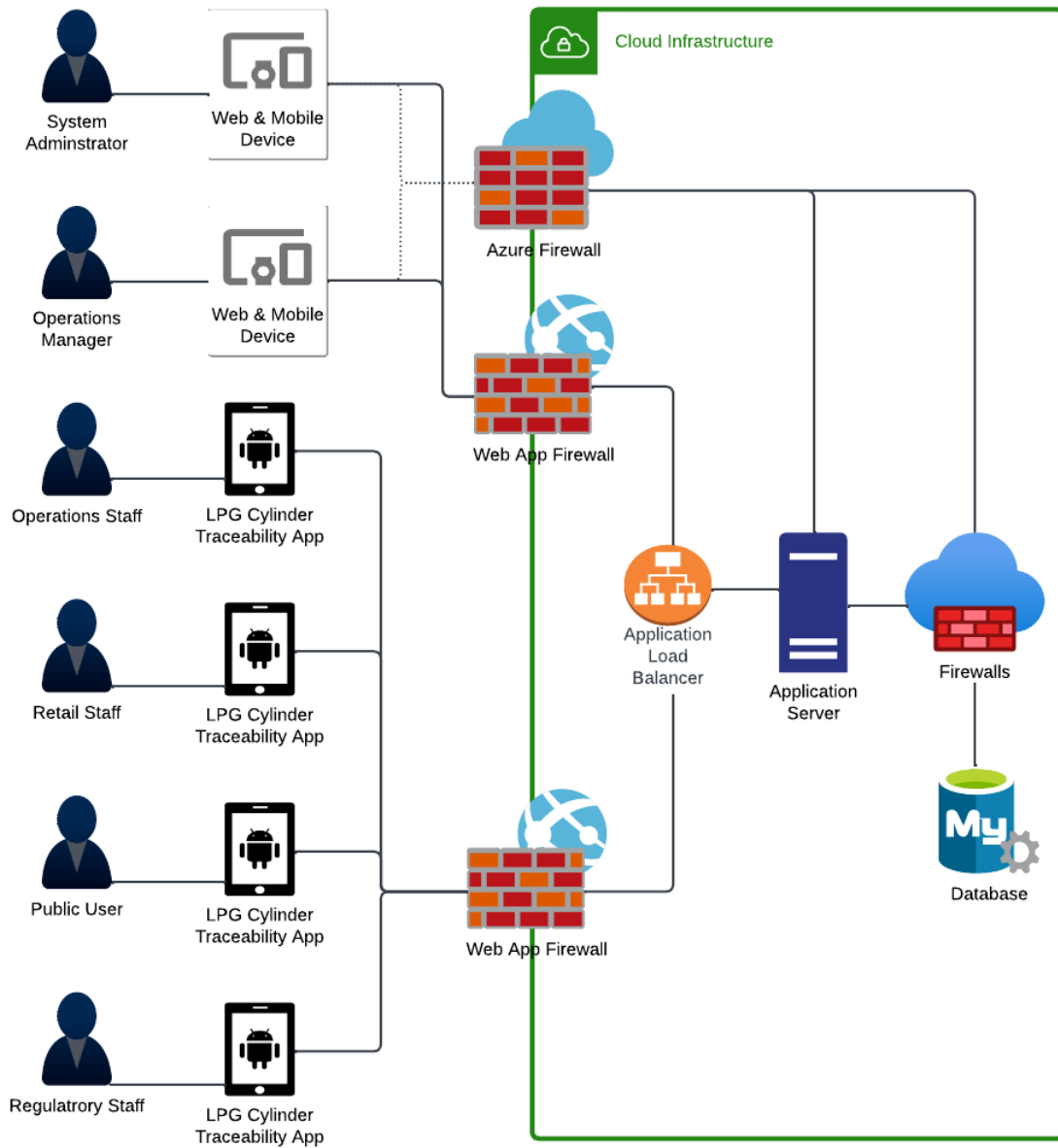


Figure 4.30: LPG Cylinder Traceability System Architecture

#### 4.7. Mobile Application Wireframes

Mobile application wireframes for the LPG Cylinder Traceability system were developed by defining the target user flow and then defining the various screens and lastly using design patterns to standardize the screens. The targeted user flow are as illustrated below.

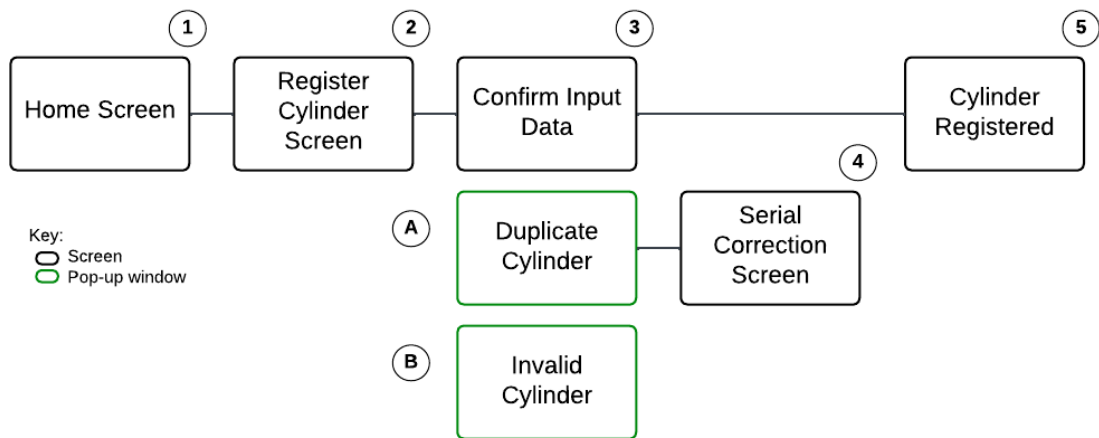


Figure 4.31: Target User Flow - Cylinder Registration Process

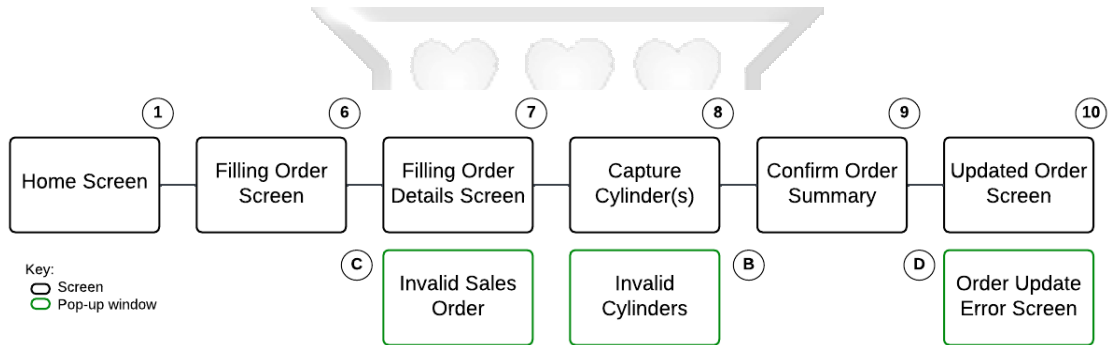


Figure 4.32: Target User Flow - Cylinder Filling Process

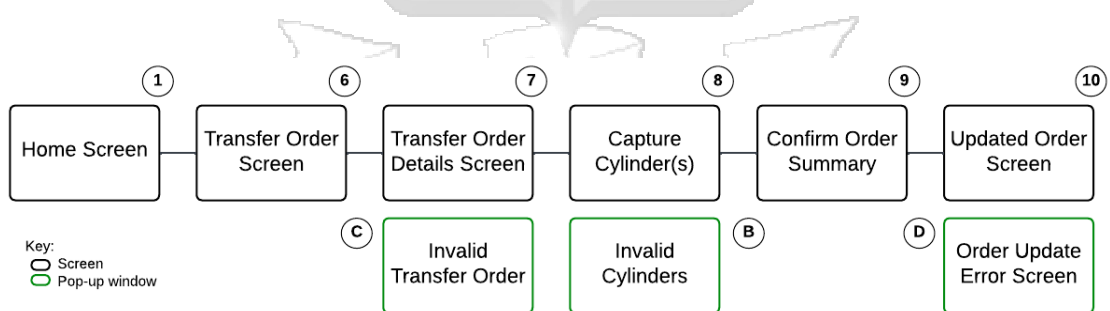


Figure 4.33: Target User Flow - Cylinder Transfer Process

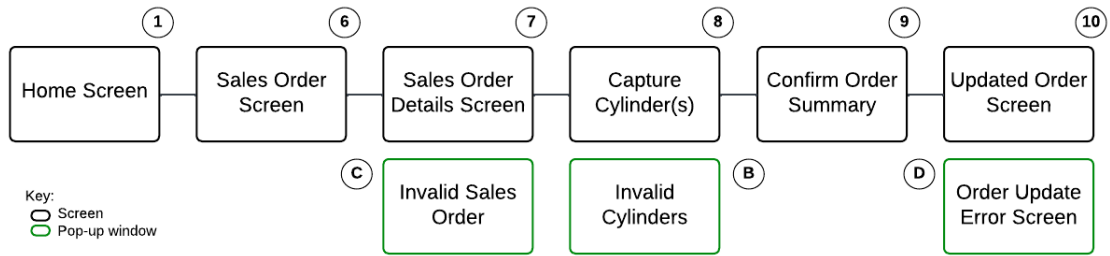


Figure 4.34: Target User Flow - Cylinder Sales Process

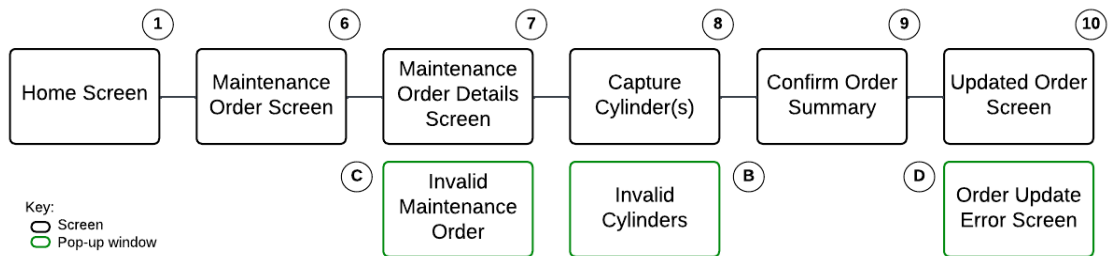


Figure 4.35: Target User Flow - Cylinder Maintenance Process

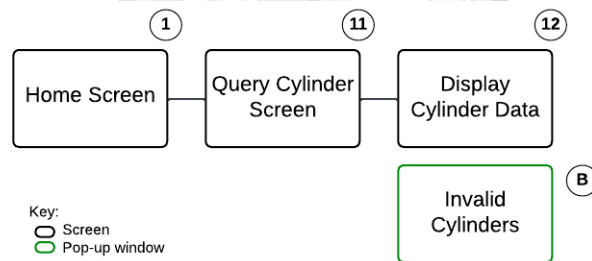


Figure 4.36: Target User Flow - Cylinder Query Process

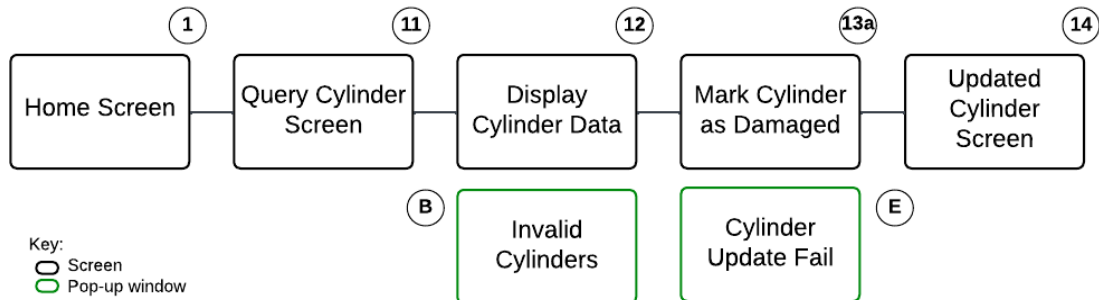


Figure 4.37: Target User Flow - Damaged Cylinder Process

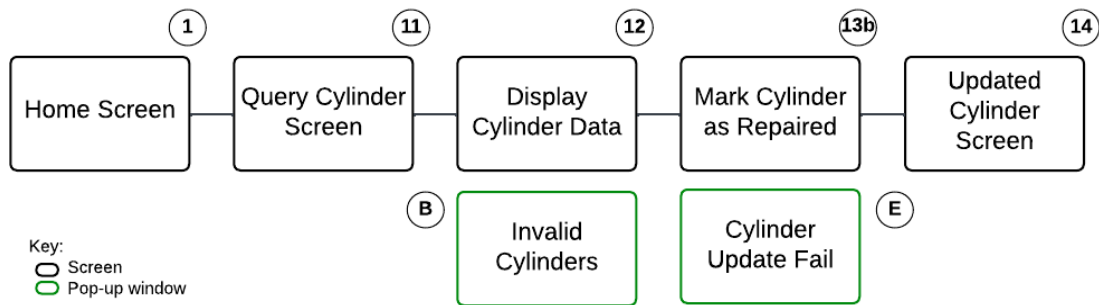


Figure 4.38: Target User Flow - Repaired Cylinder Process

The target user flows as illustrated revealed a total design requirement for fourteen (14) screen and about five (5) pop-up message screens. The identified screens are as tabulated in the following table.

Table 4.19: Mobile Application Screen Index

Screen Index	Screen Name	Purpose of the Screen	Data Input
1	Home Screen	The default landing page depending on user role	n/a
2	Register Cylinder Screen	Screen to register new cylinders in the system	Cylinder identification parameters; manufacturer, month and year of manufacture, cylinder serial number, tare weight of the cylinder and assigned tag
3	Confirm Input Data	Screen to display captured cylinder details	Confirmation
4	Serial Correction Screen	Screen to edit the cylinder identification parameters	Edit options for register cylinder screen
5	Cylinder Registered	Confirmation information of the updated cylinder registrations	n/a
6	Capture Order Screen	Screen to capture order reference to be queried for task execution	Order ID, Order Type
7	Display Order Details Screen	Display of queried order details	Confirmation

Screen Index	Screen Name	Purpose of the Screen	Data Input
8	Captured Cylinder Screen	Capture cylinders against a given order	Cylinder tag; scan or key in
9	Confirm Order Summary Screen	Display the details of the cylinders captured against the order	Confirmation
10	Updated Order Screen	Display order update status	
11	Query Cylinder Screen	Capture Cylinder identifier	cylinder tag; cylinder parameters / photo
12	Display Cylinder Data Screen	Display the details of the cylinder against the query	n/a
13a	Mark Cylinder as Damaged	Mark a displayed cylinder as damaged	Confirmation
13b	Mark Cylinder as Repaired	Mark a displayed cylinder as repaired	Confirmation
14	Updated Cylinder Screen	Display the updated cylinder status screen	n/a

Table 4.20: Mobile Application Pop-up Index

Pop-up Index	Pop-up Screen Name	Purpose of the Pop-up	Data Input
A	Duplicate Cylinder	Display details of existing cylinder in the system with similar identification parameters	Option to edit cylinder data or remove
B	Invalid Cylinder	Display an error message for an invalid cylinder as per the business rules defined for each process	Option to edit cylinder data or remove
C	Invalid Order	Display an error message for an invalid order	Acknowledge and revert to previous screen
D	Order Update Error	Display error encountered when updating order details	Acknowledge and revert to previous screen
E	Cylinder Update Error	Display error encountered when updating a cylinder status	Acknowledge and revert to previous screen

The targeted user flow allowed the generation of the indexed screens. The following are mock-ups of the mobile application interface based on the identified and indexed screens. The wireframe designs have been done using Figma an online mobile wireframe design software.

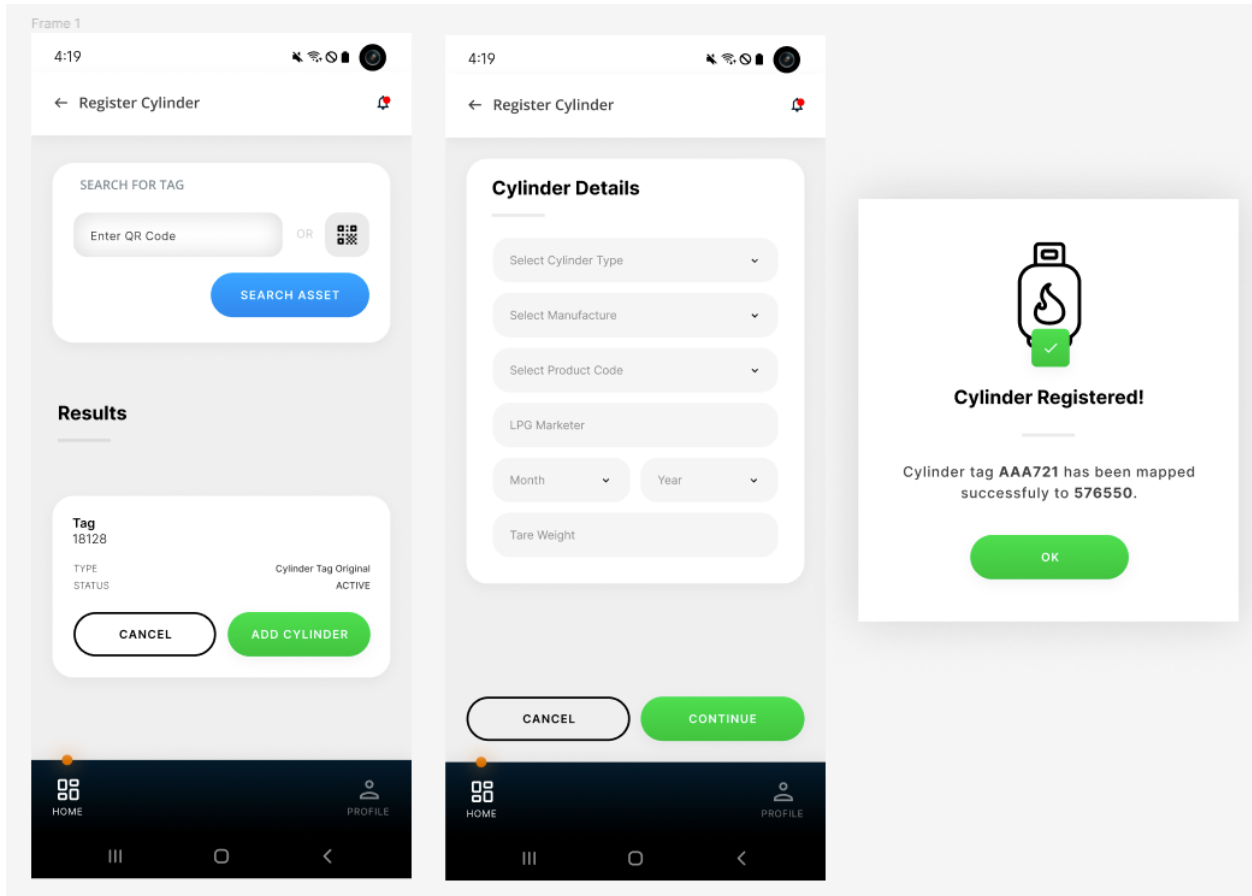


Figure 4.39: Cylinder Registration Wireframes

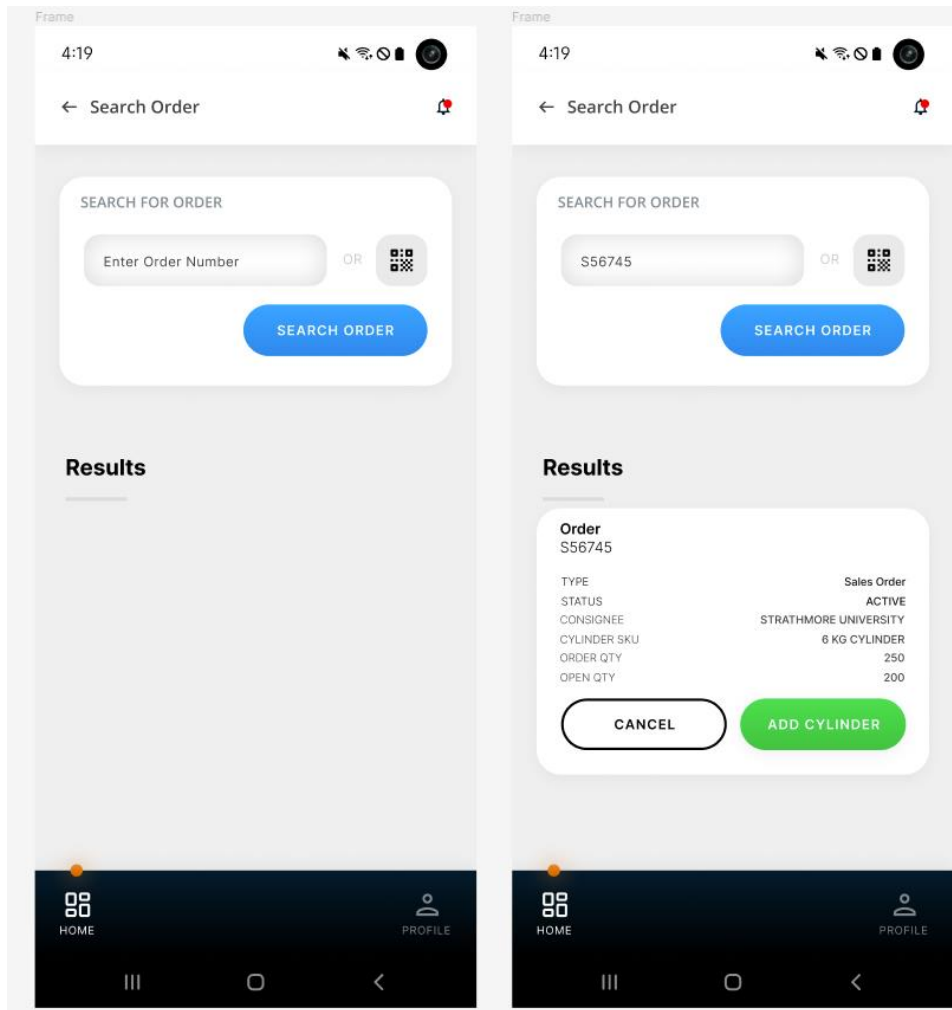


Figure 4.40: Search Order Wireframes

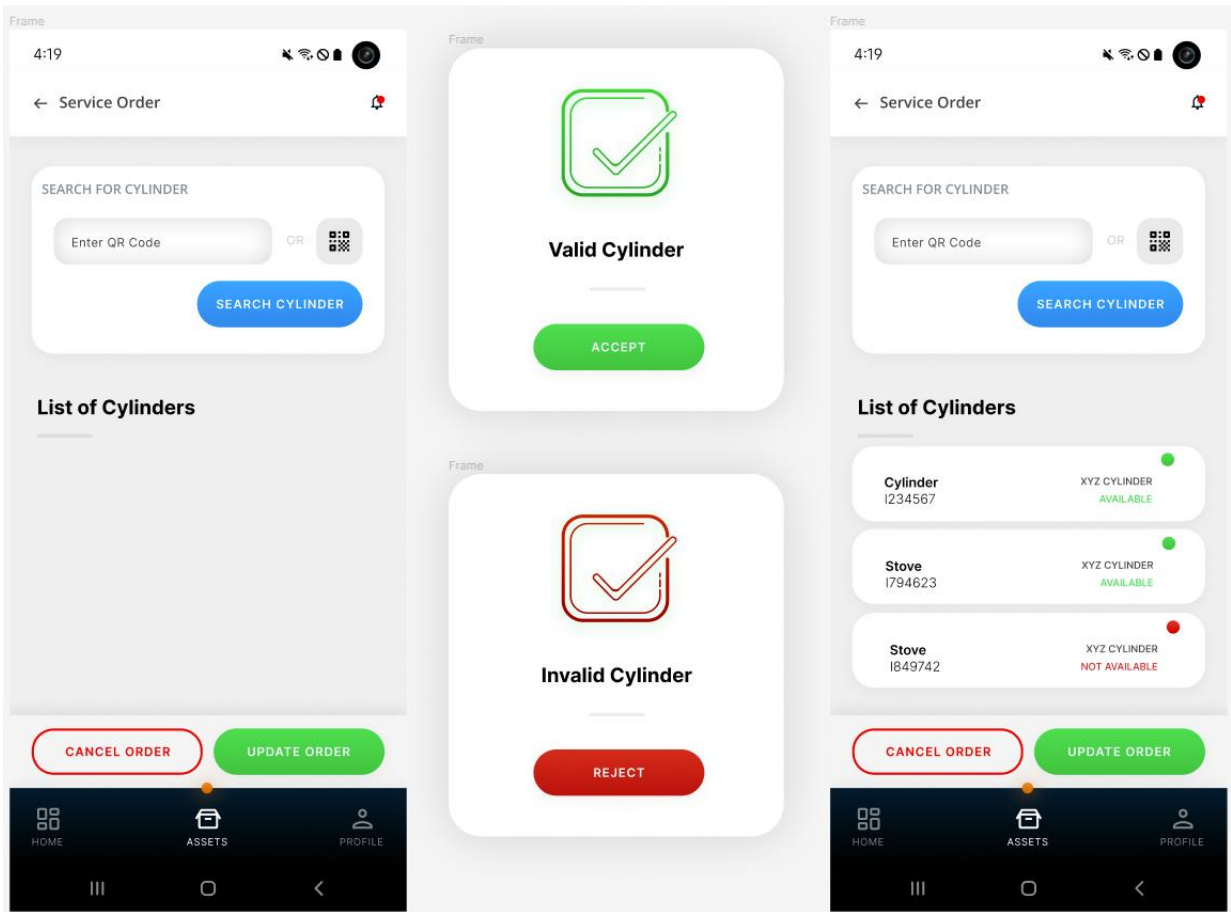


Figure 4.41: Service Order Wireframes



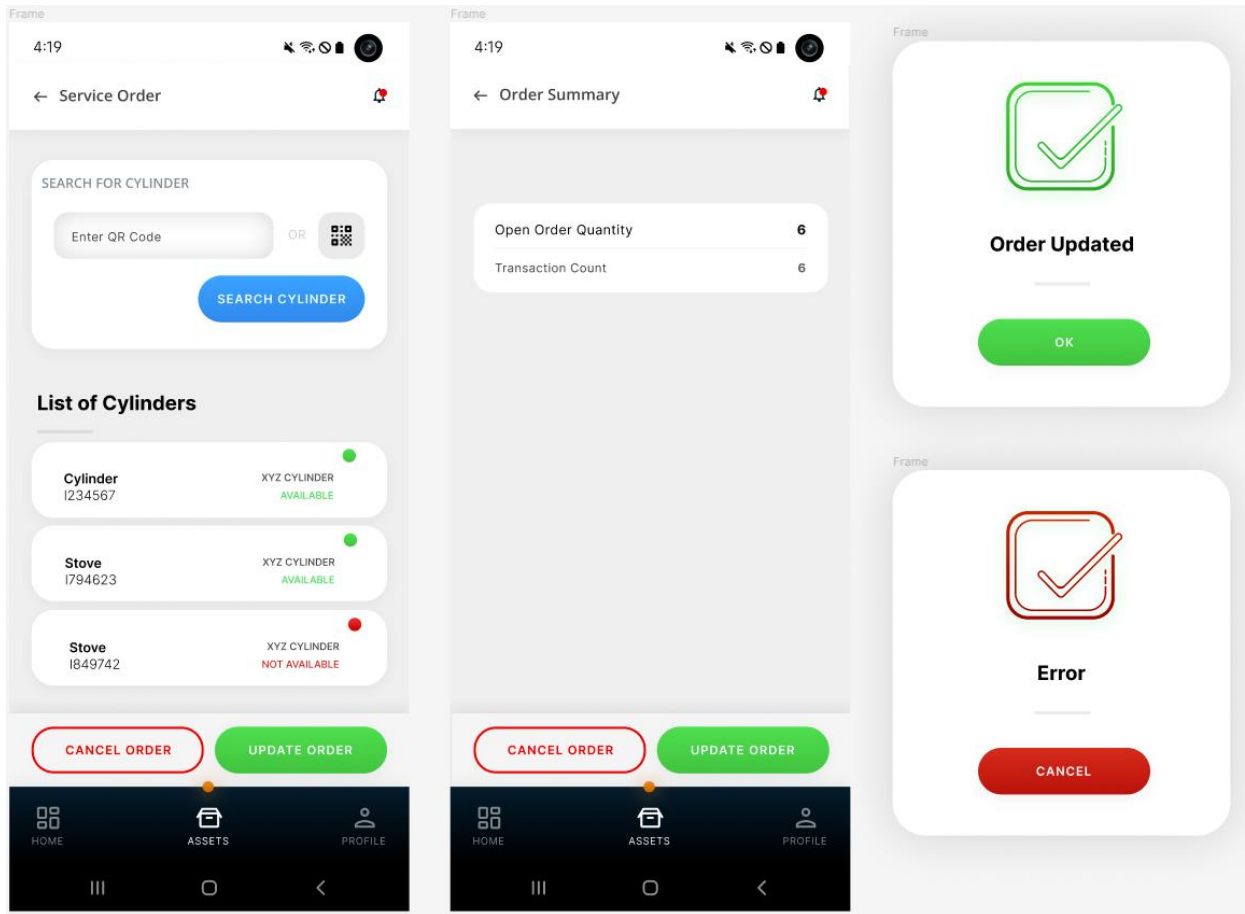


Figure 4.42: Serviced Order Update Wireframes



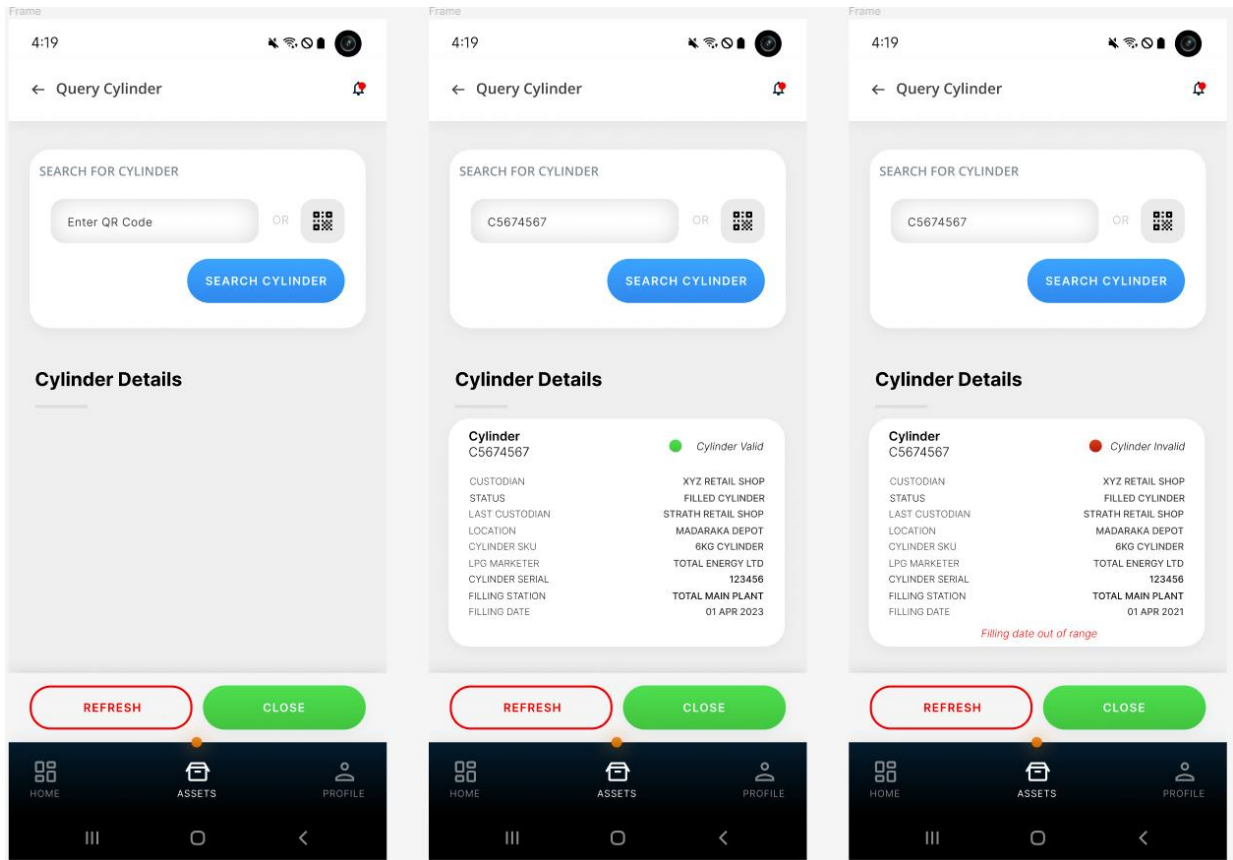
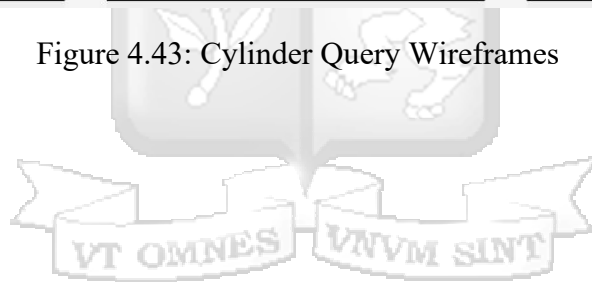


Figure 4.43: Cylinder Query Wireframes



## Chapter 5 : System Implementation and Testing

### 5.1. Introduction

The proposed LPG cylinder traceability system as articulate in the system and architecture design in chapter four (4) was developed into a prototype. The system was implemented following agile methodology. The system was tested to ensure it satisfies the stipulated user requirements; both functional and non-functional requirements.

### 5.2. System Implementation Environment

The implementation environment was a sum total of the structure defined during architectural design based on the interpretation of the study and system analysis. The idea was to construct system elements capable of satisfying the stakeholder requirements and system requirements defined in the earlier stages of this study. The development of the system was done using Flutter. Flutter is a software development kit developed by Google. Flutter uses Dart programming language and allows development of applications across multiple platforms from a single codebase. The system was developed across a mobile (Android) and web platform; using Google's Firestore Database as the database engine.

#### 5.2.1. Mobile Application Prototype

A core component of the system is the mobile application. The choice to build an Android based mobile application was informed by its popularity among the target market. The LPG cylinder traceability system is developed for the Kenyan markets space where Android is the leading mobile phone OS. Other than the fact that Flutter SDK is an open source tool, the use of Flutter in the development of Android application is reported to boost application performance (*Flutter Performance Profiling* | Flutter, n.d.). Flutter utilizes practices such as lazy loading, advanced widget building, image caching and hot reload framework to ensure high performance and better user experiences.

The system was tested on Android Studio and on an Android mobile device. The development utilized some of the native Flutter libraries including the QR Code scanner library, location library among others.

### **5.2.2. Web Application**

The system also entails a thin web application. The application was developed using Flutter. This offers the advantage of unified codebase with the mobile application. Similar to the mobile application, web development using Flutter offers a rapid development capability with features like hot reloads and consistent UI across platforms. This allows simplified maintenance process and offers app-centric experiences.

### **5.2.3. Database**

The system was built on a NoSQL database system due to the desire for flexibility and scalability for handling diverse and rapidly changing data. NoSQL was particularly preferred due to its flexible data models, fast query capability and ease of use for developers. Firebase database was adopted for the system.

## **5.3. System Functionality Summary**

The LPG cylinder traceability system allows one to register a cylinder into the system for purposes to tracking its movement through a defined iterative life cycle. Cylinder registration entails capturing the cylinders identifying attributes creating a system instance that is mapped to an easy to read (scannable) tag. The cylinder is referenced and tracked across the landscape using the mapped tag. The system ensures that the cylinder process flowed is compliant with the defined business rules. Business rules define the movement through the cylinder life cycle using cylinder status; it defines the possible new status allowed give the current status. The system allows users to query a given cylinder and validate if the cylinder is valid or not based on business rules embedded in the application logic. One of the foundation questions the system had to address was how to ensure that cylinders are uniquely identified in the system.

## **5.4. Major System User Interfaces**

A simulation of the system was done to demonstrate its functionality and user journey. The simulation entailed data entry into the system and resultant interfaces as follows.

### 5.4.1. Mobile Application Splash Screen

The mobile application has as simple splash screen as shown below.

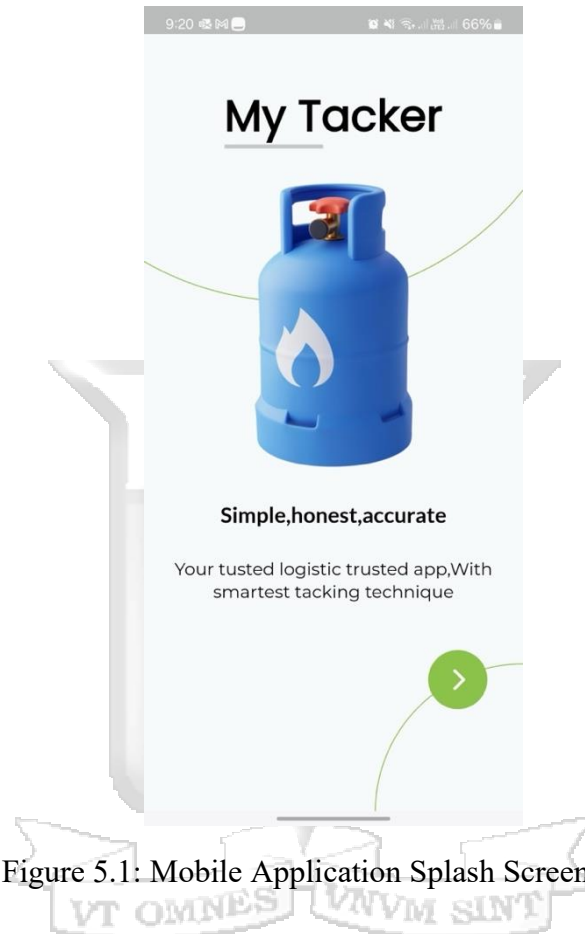


Figure 5.1: Mobile Application Splash Screen

The prototype application is secured and requires a validated email to log in. In the event that an email address is not verified in the system then the user is assigned the customer role and can only query a cylinder. A verified user is allowed to access the full system capability based on roles. Users are uniquely identified using their email addresses.

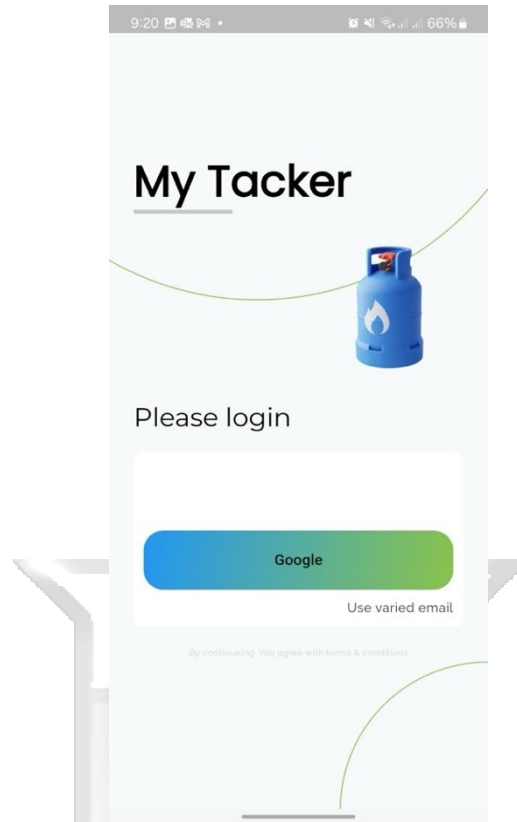


Figure 5.2: Mobile Application Login Screen

The email address are stored in the system and retrieved during authentication. When a user is authenticated; user will be directed to a landing page depending on whether or not the email address used to logged in is verified or not. The below method is always called as long as a user has been authenticated.

```
bool isVerified = userSnapshot.data!.get("isVerified") ?? false;  
  
return GetMaterialApp(  
  debugShowCheckedModeBanner: false,  
  themeMode: ThemeMode.system,  
  darkTheme: RTheme.darkTheme,  
  theme: RTheme.lightTheme,  
  home: isVerified ? MainScreen() : CustomerScreen(name:  
user.displayName ?? 'User'),
```

Figure 5.3: Code Snippet – Role Selection on Authentication

## 5.4.2. Mobile Application Home Screen

On successful authentication the application home screen is launched. The application home screen is as displayed below. A verified user will have access to a number of functionalities in the system depending on the role.

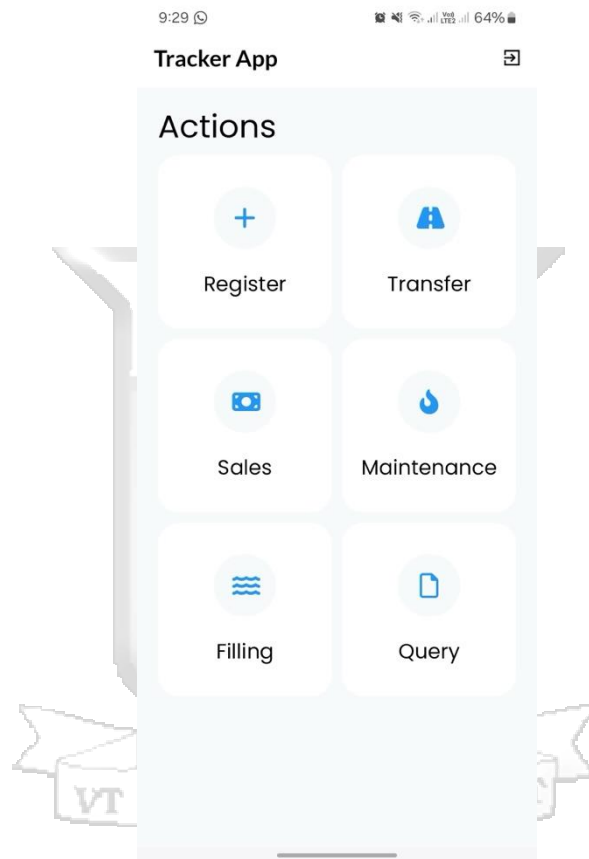


Figure 5.4: Mobile Application Home Page

An unverified user will have access only to cylinder query application. This is designed to cater for the public good component of the system. One of the features of the system is allow the public check the validity of the LPG cylinders sold to them.

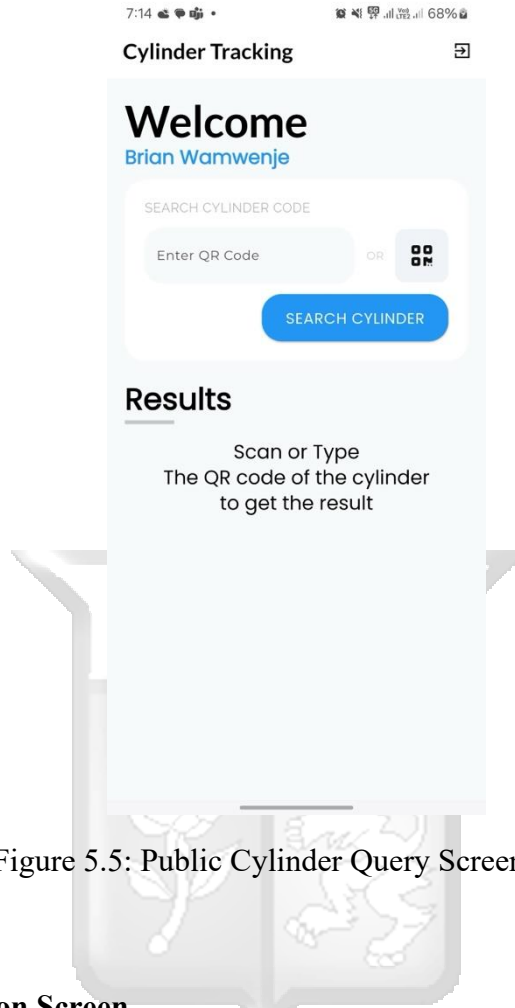


Figure 5.5: Public Cylinder Query Screen

#### 5.4.3. Cylinder Registration Screen

The cylinder registration feature is activated by the clicking on the Register Cylinder icon on the home screen of the mobile application. This launches the Scanner dialogue box as a prelude into the Register cylinder screen. The scanner window allows the user to capture the QR code affixed to the cylinder and there after the cylinder details.

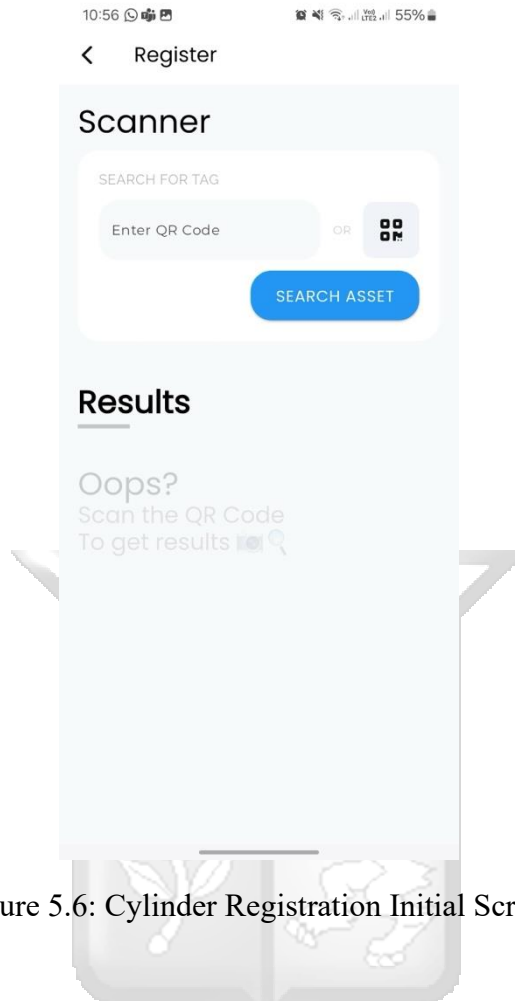


Figure 5.6: Cylinder Registration Initial Screen

One has to first capture the affixed QR code tag details using the scanner for the registration process to begin. If the QR code which should be a unique attribute exist in the system then the application will display the details of the attached cylinder in the 'Results' section of the screen. If not then the application will allow the user to input the predefine identifying parameters of the given cylinder.

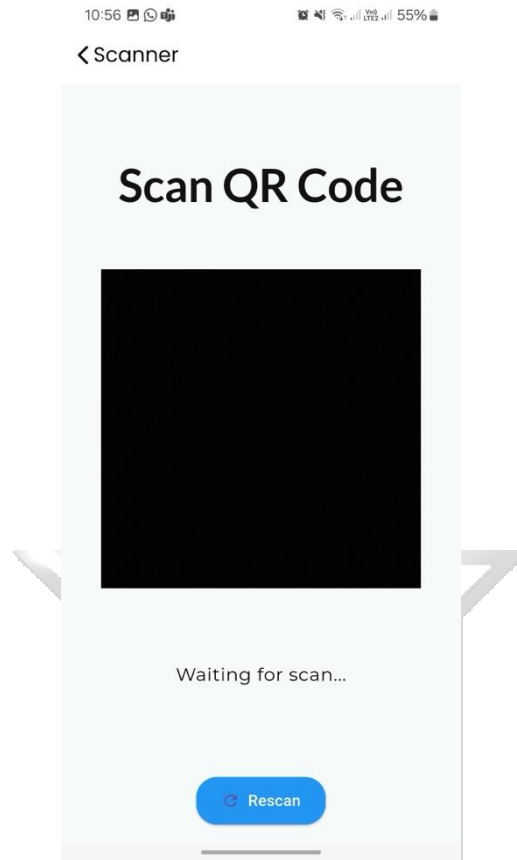


Figure 5.7: QR Code Scan Screen

The scanner utilizes the barcode scanning library in Flutter. For unique scan the application automatically transitions the user to the 'Cylinder Details' screen. The screen allows the user to capture attributes that are legally required to be engraved and/or painted on the surface of the cylinder. The reason for this is to allow the system generate a unique serial number in addition to having all the identifier parameters for a given cylinder. During cylinder details capture the location details are automatically captured.

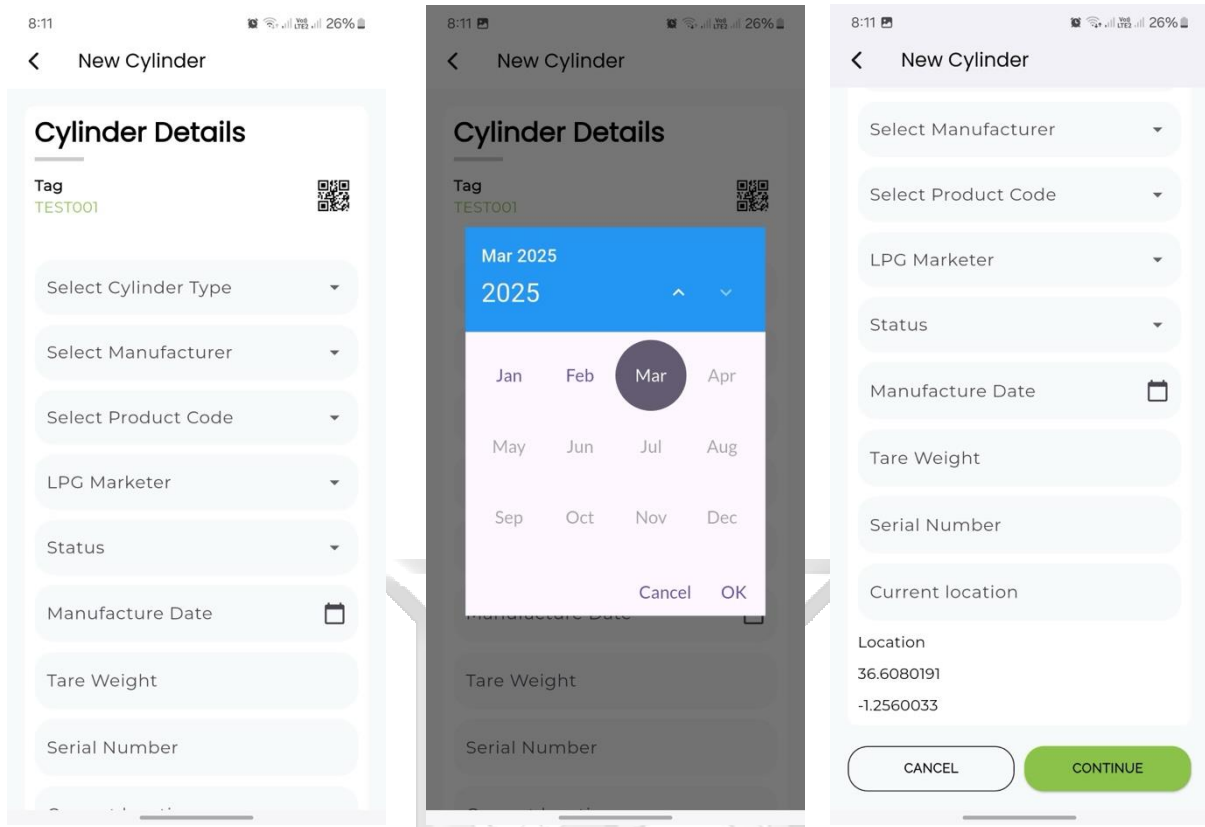


Figure 5.8: Cylinder Registration Screen

One of the challenge to LPG cylinder traceability in Kenya is the lack of a unique identifier to track LPG cylinder. The developed system uses the collected data to generate a unique cylinder serial that is then used in the traceability application.

```

Future<String> generateSerialNumber() async {
  if (selectedYear.value == null ||
      selectedMonth.value == null ||
      selectedManufacturer.value == null |
      selectedLpgMarketer.value == null |
      serialController.text.isEmpty) {
    return "Error: Missing required values!";
  }
  if (serialController.text.length != 6) {
    return "ERROR: Serial number must be exactly 6 digits!";
  }
  int yearInt = int.tryParse(selectedYear.value!) ?? 2023;
  String yearCode = String.fromCharCode(65 + (yearInt - 2023));

  Map<String, String> monthCodes = {
    'January': 'A',
    'February': 'B',
    'March': 'C',
    'April': 'D',
    'May': 'E',
    'June': 'F',
    'July': 'G',
    'August': 'H',
    'September': 'I',
    'October': 'J',
    'November': 'K',
    'December': 'L'
  };
  String monthCode = monthCodes[selectedMonth.value] ?? "XX";
  String lpgCode = lpgCodes[selectedLpgMarketer.value] ?? "00";

  String serial = serialController.text;

  int correctionValue = await cylinderData.getCylinderCount();
  int cylinderLength = correctionValue + 1;
  return
"$yearCode$monthCode$manufacturerCode$lpgCode$serial$cylinderLen
gth";
}

```

Figure 5.9: Code Snippet – Unique Cylinder Serial Code Generation

The system generates a thirteen-character alphanumeric code that uniquely identifies the cylinder. This is achieved by a combination of cylinder markers and identifiers enforced in law

and regulatory standards to generate a unique serial number. The following is a decode view of the system serial number ‘AB12345678900’.

Table 5.1: Cylinder Serial Encoding

Serial Characters	Character Label	Encoding Option
A	Year of manufacture	Alphabetic representation from a defined start year
B	January	Alphabetic representation
12	Cylinder Manufacture	Indexed from the Cylinder Manufacturers' table.
34	LPG marketer	Indexed from the LPG Marketers' table.
567890	Cylinder Serial Number	Serial number of the cylinder
0	Corrective digit	Assigned by the system as a parity check for any duplication

#### 5.4.4. Order Query Screen

The life cycle of a cylinder is predominantly defined by four operations on the asset; transfer, filling, sale and maintenance. The Order Query Screen allows a user to query an order for purposes of attaching a cylinder to the order details during order execution. The orders are captured on the application dashboard (web) but can be queried and executed from the mobile application. The application handles the key orders types that reflect the cylinder life circle. The order handled in the prototype include sales order, transfer order, maintenance order, and filling order.

Sales orders act as documents that allow the transition of a cylinder from the LPG market and/or their partners to the customer. The key identifier for an order is an alphanumeric autogenerated order ID. The order ID starts with an initial alphabetic character to represent the individual order. Each order type is defined by a preset order model.

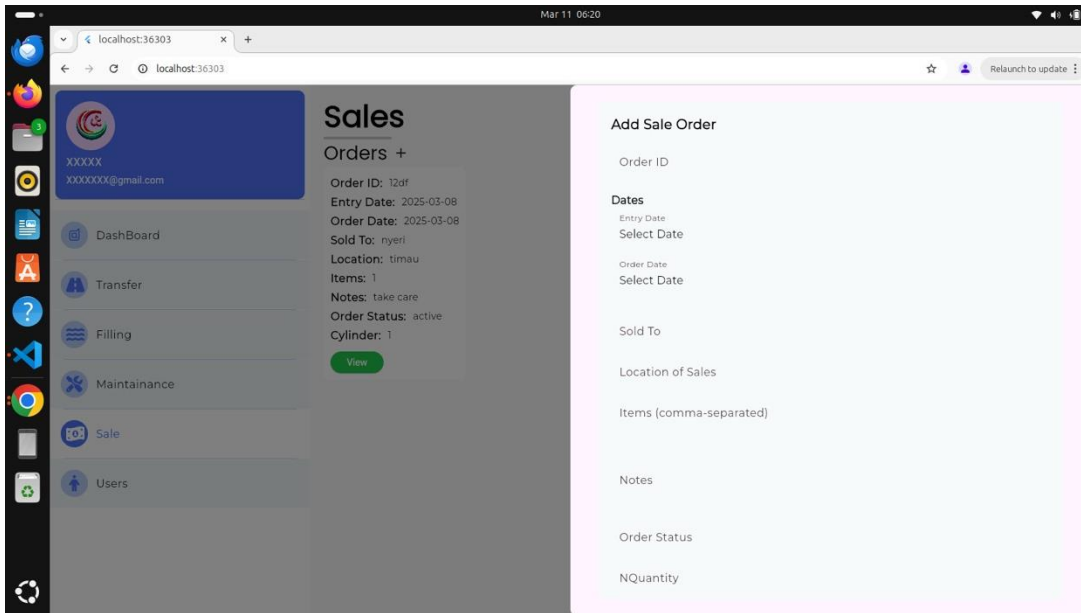
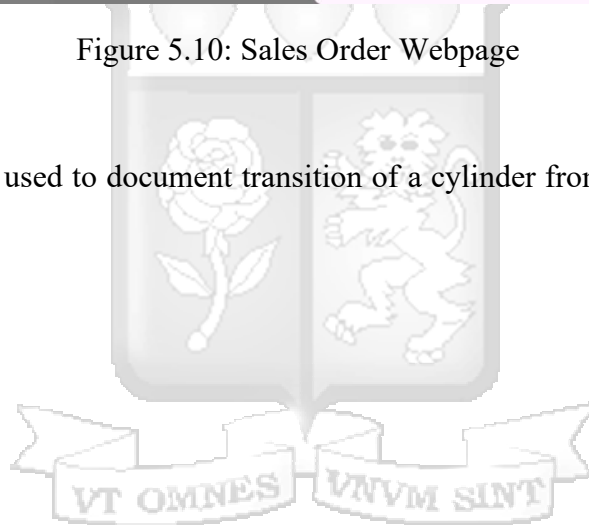


Figure 5.10: Sales Order Webpage

Transfer orders are used to document transition of a cylinder from one operating station to another.



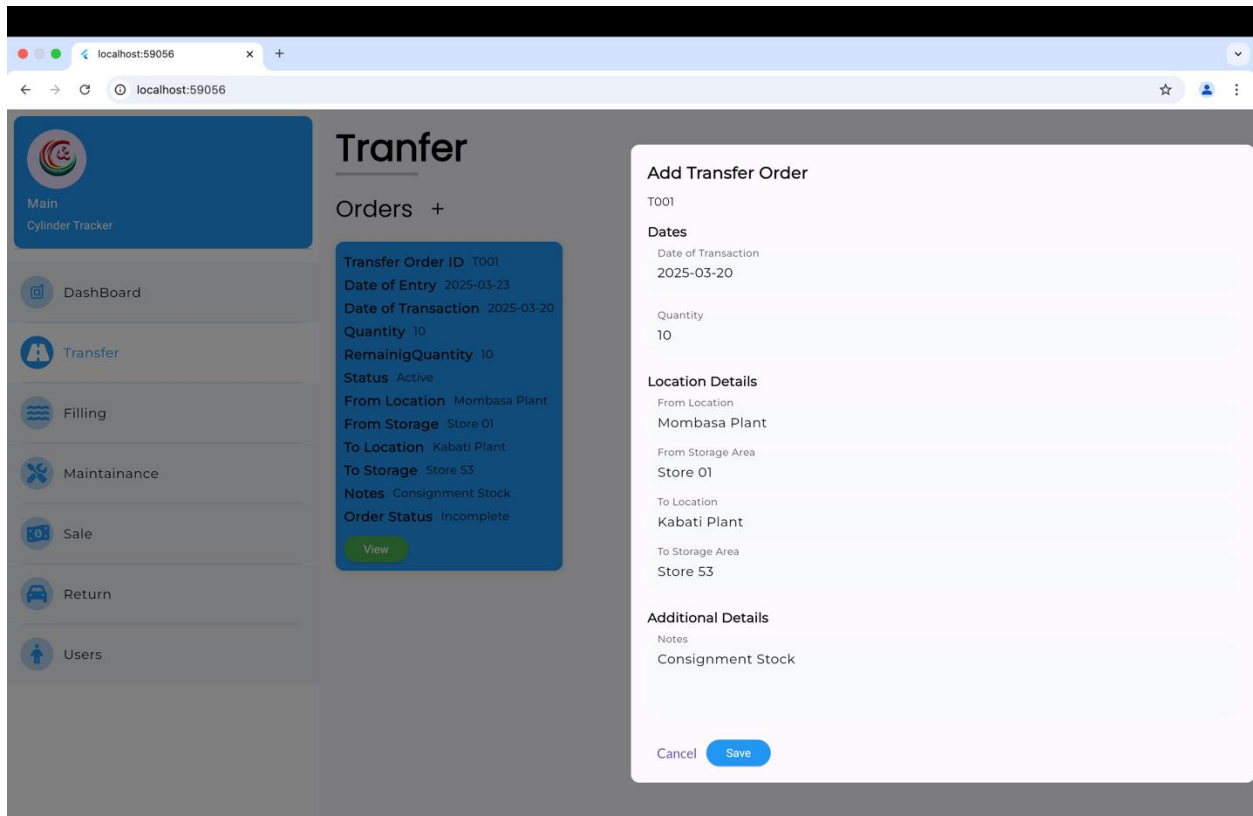


Figure 5.11: Transfer Order Webpage

Maintenance orders are used to capture record of damaged cylinder repair and effectively convert identified damaged cylinder into active cylinder for re-circulation into the market.

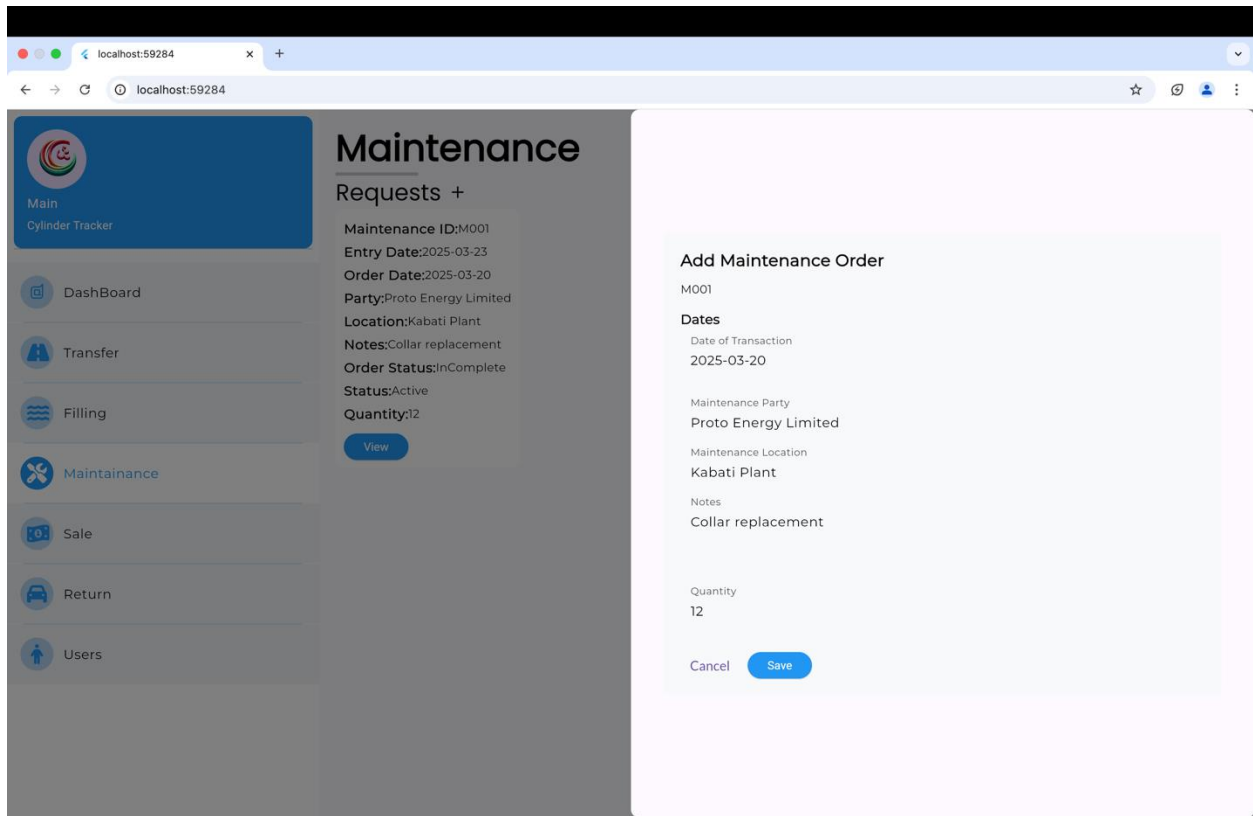


Figure 5.12: Maintenance Order Webpage

Once an active sales order is reference from the mobile application then user using a the standard QR code scanning feature in the application scans the cylinders sold under the order.

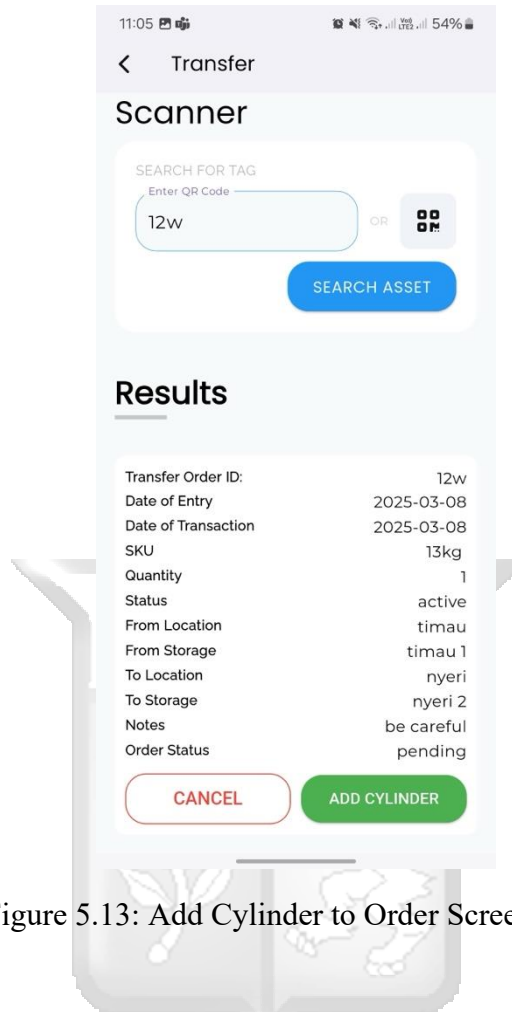


Figure 5.13: Add Cylinder to Order Screen

#### 5.4.5. Cylinder Query Screen

The cylinder query screen is a major screen that allows an authorized user to view the details of a particular scanned cylinder.

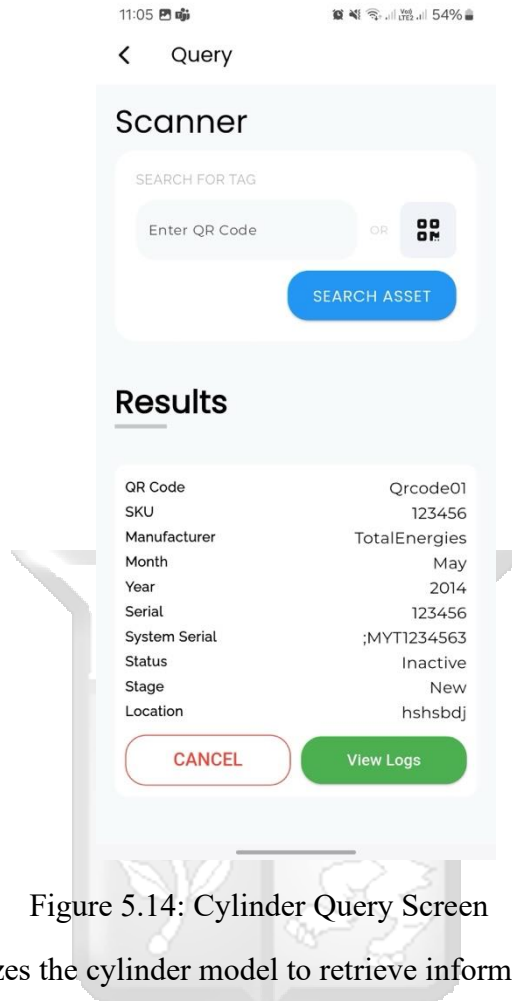


Figure 5.14: Cylinder Query Screen

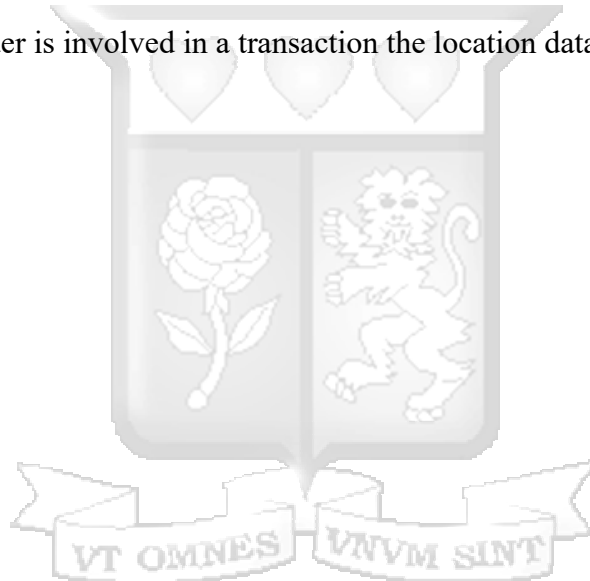
The query screen utilizes the cylinder model to retrieve information on a scanned cylinder.

When an unverified user logs into the mobile application, they are only able to access the customer cylinder query feature. The feature allows the public to check the validity of a given cylinder by scanning in. The following code outlines the logic.

```
String _calculateCondition(DateTime? lastSale) {  
  if (lastSale == null) {  
    return "Invalid Cylinder; Contact marketer";  
  }  
  
  final now = DateTime.now();  
  final difference = now.difference(lastSale).inDays;  
  
  return difference < 90 ? "Good" : "Bad";  
}
```

Figure 5.15: Code Snippet – Cylinder Query Results Weight

Every time a cylinder is involved in a transaction the location data is captured.



```

class GoogleLocation extends GetxController {
  RxDouble latitude = 0.0.obs;
  RxDouble longitude = 0.0.obs;

void onInit() {
  super.onInit();
  determinePosition();
}

Future<void> determinePosition() async {
  try {
    if (!await _checkAndRequestPermissions()) return;
    if (!await Geolocator.isLocationServiceEnabled()) {
      if (!await Geolocator.openLocationSettings()) return;
    }
    Position position = await getCurrentPosition();
    latitude.value = position.latitude;
    longitude.value = position.longitude;
  } catch (_) {}
}

Future<Map<String, double>> getLocation() async {
  try {
    if (!await _checkAndRequestPermissions()) return
{"latitude": 0.0, "longitude": 0.0};
    if (!await Geolocator.isLocationServiceEnabled()) {
      if (!await Geolocator.openLocationSettings()) return
{"latitude": 0.0, "longitude": 0.0};
    }
    Position position = await getCurrentPosition();
    latitude.value = position.latitude;
    longitude.value = position.longitude;
    return {"latitude": position.latitude, "longitude":
position.longitude};
  } catch (_) {
    return {"latitude": 0.0, "longitude": 0.0};
  }
}
}

```

Figure 5.16: Code Snippet – Location Traceability Capture

#### 5.4.6. Web Portal

The system comprises of two user interfaces; the mobile application and the dashboard. The mobile application is the core user interface. The dashboard allows easier administrative tasks to

be executed to facilitate front end features on the mobile application. Below are screen shots of the dashboard features.

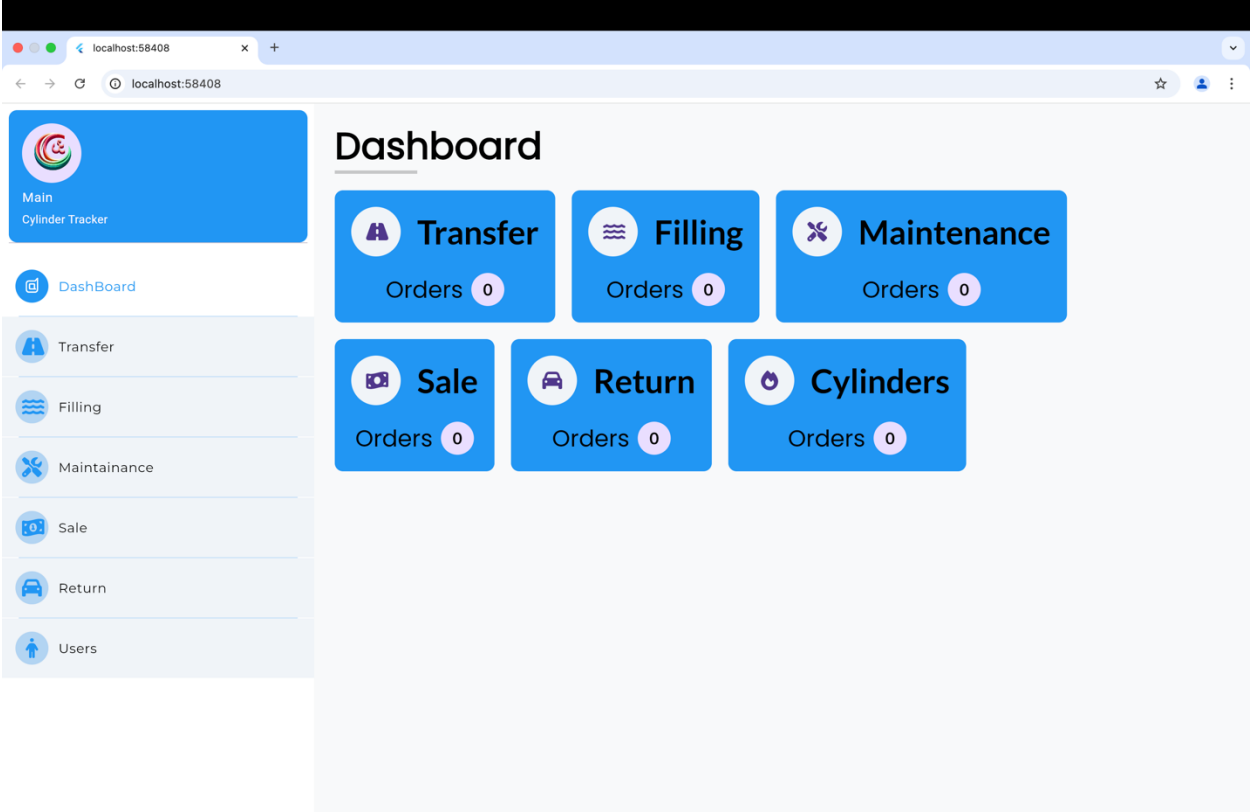


Figure 5.17: Web Home Page

## 5.5. System Testing

The developed LPG cylinder traceability system was assessed on three core areas; system functionality, compatibility, and the system usability. The core purpose for the subjecting the system to these tests was to allow the identification of any issues and defects in the code and confirm that the system satisfies the defined requirements.

### 5.5.1. Functional Test

Functional test involved the execution of scripts by test users to ascertain the whether the solution adequately fulfilled the defined user requirements. Core system functionalities were tested repeated by multiple users to establish the level of compliance and consistency to the defined user requirements. These tests were critical in establishing the correct level of functionality was achieved and ensuring that the key objectives of the study were met. The following is a tabular summary of the test conditions and results achieved in the functional system testing.

Table 5.2: System Test Conditions and Test Results – Installation Flow

Serial No	Test	No	Expected results	Prerequisite	Achieved Results
AT01	User is able to install the mobile application on their phone	a.	System APK (Android Package Kit) to be downloaded into the user's phone	<ul style="list-style-type: none"> <li>• Adequate disk space in the target phone</li> <li>• Internet connectivity on the target device</li> </ul>	The test user was able to download the system APK into their mobile application
		b.	The APK to be installed on the target phone	<ul style="list-style-type: none"> <li>• Adequate disk space in the target phone</li> </ul>	The application was successfully installed into the target phone. We had to disable some security features on some options due to the fact that the application source was not certified
		c.	The application installed on the target phone can load and launch the log in page		The application launched successful and correctly displayed the log in page
AT02	User is able to create a	a.	The user is able to access a self-registration form, from the application's log in screen	<ul style="list-style-type: none"> <li>• Internet connectivity on the target device</li> </ul>	The log in page has a functioning link that launched the self-registration form

Serial No	Test	No	Expected results	Prerequisite	Achieved Results
	profile the application	b.	The user is able to complete the self-registration form	<ul style="list-style-type: none"> <li>Internet connectivity on the target device</li> </ul>	The user(s) were able to complete the self-registration form and submit the filled form
		c.	The user is able to save the form and generate a new user profile	<ul style="list-style-type: none"> <li>Internet connectivity on the target device</li> </ul>	The user(s) were able to submit the filled form. An active corresponding user profile was created

Table 5.3: System Test Conditions and Test Results – Cylinder Registration

Serial No	Test	No	Expected results	Prerequisite	Achieved Results
AT03	Authorized user is able to register an LPG cylinder in the system	a.	The user is able to launch the Cylinder registration application from the home screen		The cylinder registration application was successfully launched from the home screen
		b.	The user is able to get a system generated serial number upon registering a new cylinder into the system by capturing the following data attributes of the cylinder; manufacturer, brand, month and year of manufacture, serial number, and cylinder SKU.	<ul style="list-style-type: none"> <li>Internet connectivity on the target device</li> <li>Unique cylinder details data set</li> </ul>	The user(s) were able to key in the defined parameters for cylinder registration. On successfully submitting the request the system displayed a confirmation message bearing a generated serial number
		c.	The user is able to get an error message upon trying to register the same cylinder a second time.	<ul style="list-style-type: none"> <li>Internet connectivity on the target device</li> <li>Already registered cylinder details data set</li> </ul>	Attempts to register a cylinder using data of a cylinder already registered in the system resulted in an error message indicating a duplicate cylinder exists
AT04	Store the LPG cylinder details in a database	a.	The newly registered cylinder details are stored in the system database	<ul style="list-style-type: none"> <li>Connection to a database query terminal</li> </ul>	A query on the system database confirmed that the cylinder instance was stored in the database with all relevant details

Table 5.4: System Test Conditions and Test Results – Cylinder Query

Serial No	Test	No	Expected results	Prerequisite	Achieved Results
AT05	Allow authorized	a.	An authorized user is able to launch the query		The query cylinder application was successfully

Serial No	Test	No	Expected results	Prerequisite	Achieved Results
	users to view registered cylinder details		cylinder application from the home screen		launched from the home screen
		b.	A user is able to query the cylinder details for a valid cylinder	<ul style="list-style-type: none"> <li>• Internet connectivity on the target device</li> <li>• Valid cylinder ID</li> </ul>	On querying for cylinder using valid cylinder identifier the system responded with details/attributes of the queried cylinder
		c.	A user gets an error upon trying to query an invalid cylinder	<ul style="list-style-type: none"> <li>• Internet connectivity on the target device</li> <li>• An invalid cylinder ID</li> </ul>	On querying for cylinder using an invalid cylinder identifier the system responded with an error message

Table 5.5: System Test Conditions and Test Results – Update Cylinder

Serial No	Test	No	Expected results	Prerequisite	Achieved Results
AT06	Authorized user should be able to update cylinder status	a.	An authorized user is able to access the Sales Order Processing application and perform a sale on a target cylinder. The status should reflect the cylinder as sold.	<ul style="list-style-type: none"> <li>• Internet connectivity on the target device</li> <li>• Valid sales order ID</li> <li>• Valid cylinder in a status ready for sale</li> </ul>	The user was able to retrieve and display the valid order details. Using a cylinder ready to be sold, the user was able to process the order and it was observed that the cylinder status was correctly updated
		b.	An authorized user is able to access the Transfer Order Processing application and transfer a cylinder. The system should update the cylinder status	<ul style="list-style-type: none"> <li>• Internet connectivity on the target device</li> <li>• Valid transfer order ID</li> <li>• Valid cylinder in a status ready for transfer</li> </ul>	The user was able to retrieve and display the valid order details. Using a cylinder ready to be transferred, the user was able to process the order and it was observed that the cylinder status was correctly updated
		c.	An authorized user is able to access the Maintenance Order Processing application and mark a cylinder as damaged. The system should update the cylinder status	<ul style="list-style-type: none"> <li>• Internet connectivity on the target device</li> <li>• Valid maintenance order ID – Damaged</li> <li>• Valid cylinder</li> </ul>	The user was able to retrieve and display the valid order details. Using a valid cylinder, the user was able to process the order and it was observed that the cylinder status was correctly updated as damaged
		d.	An authorized user is able to access the Maintenance Order Processing application and mark a cylinder as repaired. The system	<ul style="list-style-type: none"> <li>• Internet connectivity on the target device</li> <li>• Valid maintenance order ID – Repair</li> <li>• Valid cylinder</li> </ul>	The user was able to retrieve and display the valid order details. Using a valid cylinder, the user was able to process the order and it was observed that the

Serial No	Test	No	Expected results	Prerequisite	Achieved Results
			should update the cylinder status		cylinder status was correctly updated as repaired
		e.	A user will get an error message when an incorrect order number/reference entered in the system	<ul style="list-style-type: none"> <li>• Internet connectivity on the target device</li> <li>• Invalid order number</li> </ul>	Upon querying for an invalid order the system returned an error message

Table 5.6: System Test Conditions and Test Results – Transaction Logging

Serial No	Test	No	Expected results	Prerequisite	Achieved Results
AT07	Store cylinder status transaction update in a database	a.	Application stores change to the cylinder details in the database.	<ul style="list-style-type: none"> <li>• Connection to a database query terminal</li> </ul>	A query on the system database confirmed that the cylinder details were update in the relevant table.
AT08	Allow authorized users to view cylinder status history	a.	Authorized users are able to query cylinder status history	<ul style="list-style-type: none"> <li>• Internet connectivity on the target device</li> <li>• Valid cylinder ID</li> </ul>	An authorized user was able to query cylinder status history
AT09	Allow users to validate cylinder status	a.	A user can query a cylinder and see the validity status of the cylinder. The system should have the requisite rules to define a particular cylinder as valid or invalid.	<ul style="list-style-type: none"> <li>• Internet connectivity on the target device</li> <li>• Valid cylinder ID</li> </ul>	User(s) were able to query a valid cylinder; the system response included the validity status of the queried cylinder; cylinders were marked as valid or invalid and additional details of the cylinder given
AT10	Provide report of individual cylinder life cycle	a.	The system should be able to provide a report of an individual cylinder life cycle	<ul style="list-style-type: none"> <li>• Internet connectivity on the target device</li> <li>• Valid cylinder ID</li> </ul>	A backend user is able to generate a report of an individual cylinder's movement through the life cycle

### **5.5.2. Compatibility Test**

System compatibility testing assesses the system's functionality across different environments and devices. System compatibility tests were carried out on the LPG cylinder traceability system to ascertain that the system was capable of seamless operation and functionality across different Android based mobile devices, different browsers, and operating systems. The main objective of this is to ensure that the built system will function as expected on consumer's choice of device. The mobile application compatibility was evaluated largely through simulation using Android Studio. Some of the tests were also done on available android based mobile devices including Samsung A03, Samsung A73, Huawei P30 and Techno Pop 7. Conducting the test on physical devices also provided an opportunity to calibrate the Android Studio.

### **5.5.3. Usability Test**

In the usability test segment, potential system users were allowed to interact with the system and assess the system in terms of usability. The survey was administered through a short questionnaire. The questionnaire was structured to assess the response using a Net Promoter Score (NPS) approach. Net Promoter Score (NPS) is a measure to gauge customer sentiments that's calculated on a scale from zero (0) to ten (10). The computation of response was by subtracting the percentage of user who selected a rating of 6 and below from the percentage of user who picked a rating of 9 or 10. The idea behind use of the Net Promoter Score measure in the usability test is to allow for a wholesome assessment of the user sentiments taking into account the overall outcome both positive and negative.

#### **5.5.3.1. Mobile Application's Ease of Use**

Using the provided NPS index where, zero (0) is very difficult to use and ten (10) is very easy to use, the sample users were asked to rate the application. Majority select nine (9) accounting for 39% of the test users. The following diagram illustrates the frequency distribution of the responses.

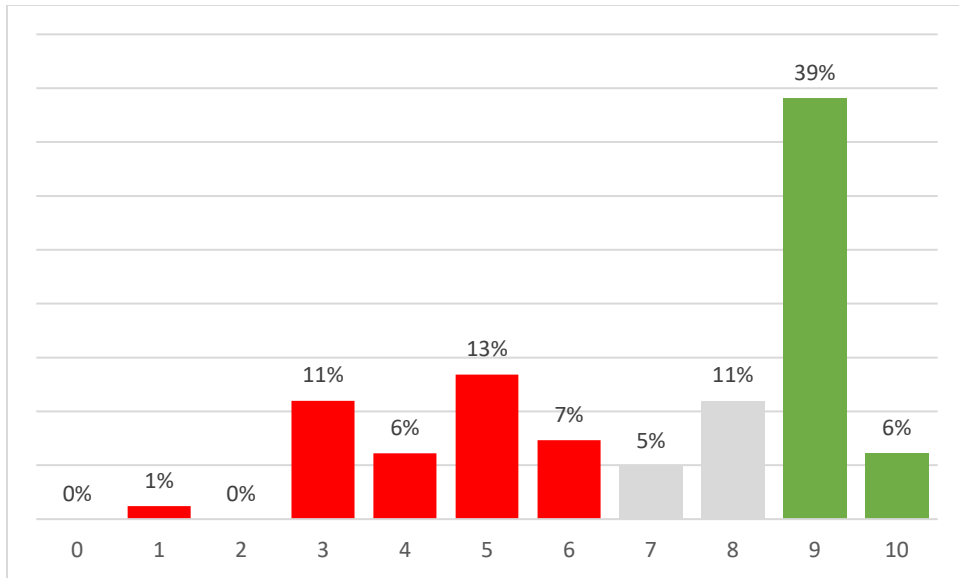


Figure 5.18: NPS Frequency Chart - Ease of Use

Based on the polled scores, 45% of the test user were promoters and 39% were detractors. Only 16% polled in the passive category. This implies that the application has a Net Promoter Score of 6%, indicating that the mobile application is fairly easy to use. The following diagram represents the response distribution by category.

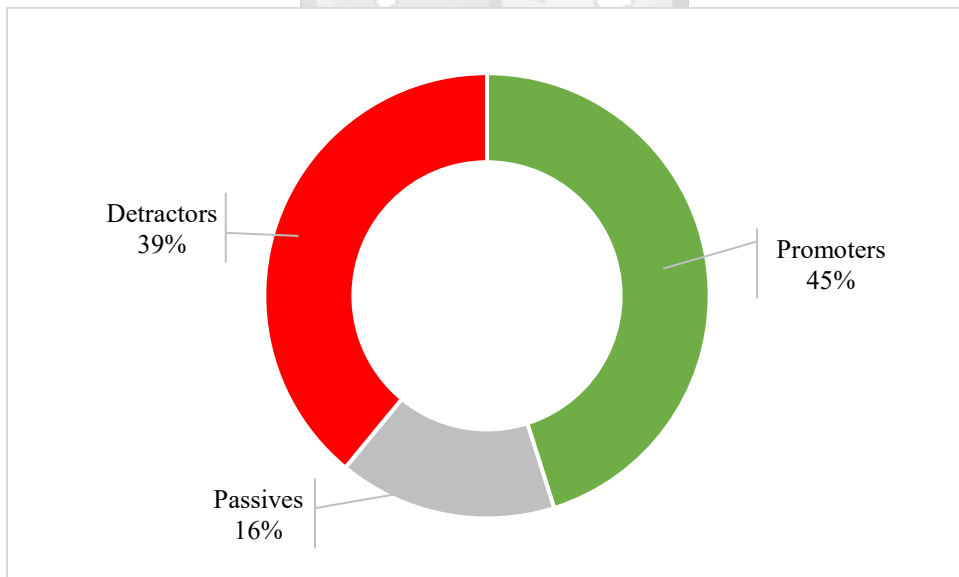


Figure 5.19: Net Promoter Score - Ease of Use

### 5.5.3.2. Solution's Fitness for Purpose

The test user were also asked to assess and score the mobile application on the basis of is its fitness for purpose. Similarly the NPS approach was used, with zero (0) representing that the application is Completely not fit for purpose, and ten (10) representing strongly fit for purpose. Majority select nine (9) accounting for 45% of the test users. The following diagram illustrates the frequency distribution of the responses.

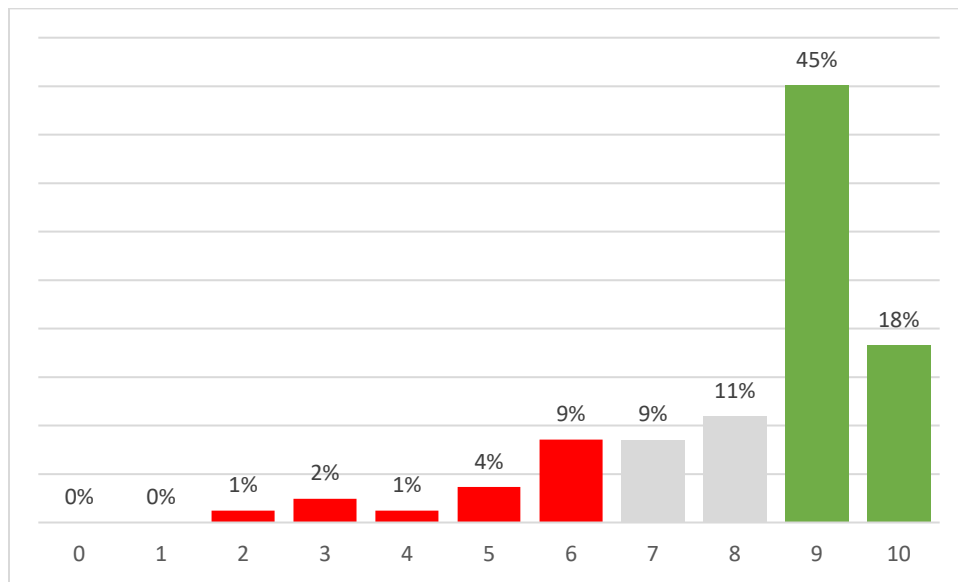


Figure 5.20: NPS Frequency Chart - Fitness for Purpose

Based on the polled scores, 63% of the test user were promoters and 16% were detractors. 21% of the users seemed in different having polled in the passive category. This implies that the application has a Net Promoter Score of 48%, indicating that the mobile application has a good fit for purpose from the users perspective. The following diagram represents the response distribution by category.

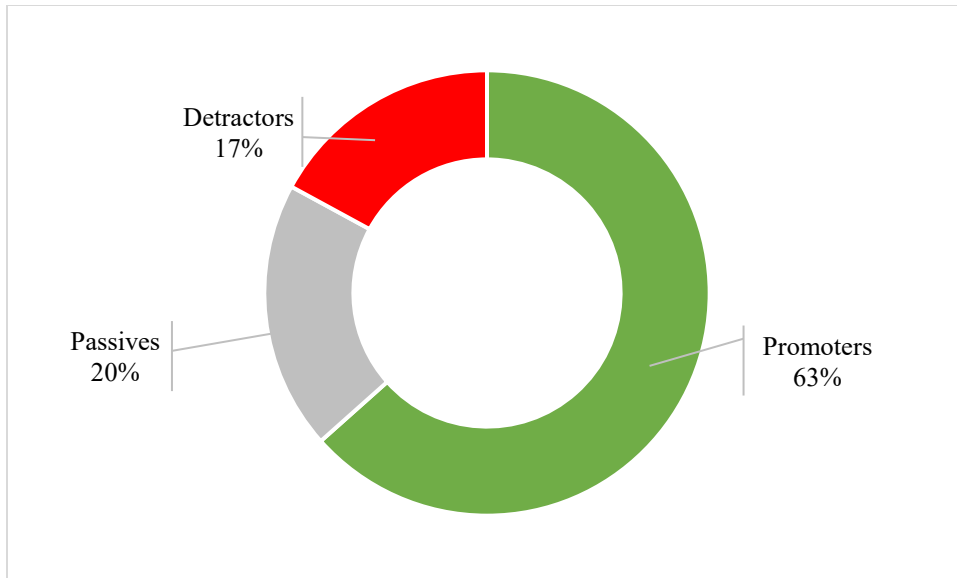
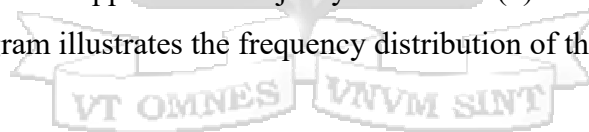


Figure 5.21: Net Promoter Score - Fitness for Purpose

### 5.5.3.3. Willingness to Recommend the Application to Others

As strong measure of a user's adoption of a mobile application is in the users agreeableness to refer the application to others. The NPS scores was used in the assessment of this parameter with zero (0) signifying not likely to recommend the application to others and ten (10) denoting highly likely to recommend the application. Majority select nine (9) accounting for 45% of the test users. The following diagram illustrates the frequency distribution of the responses.



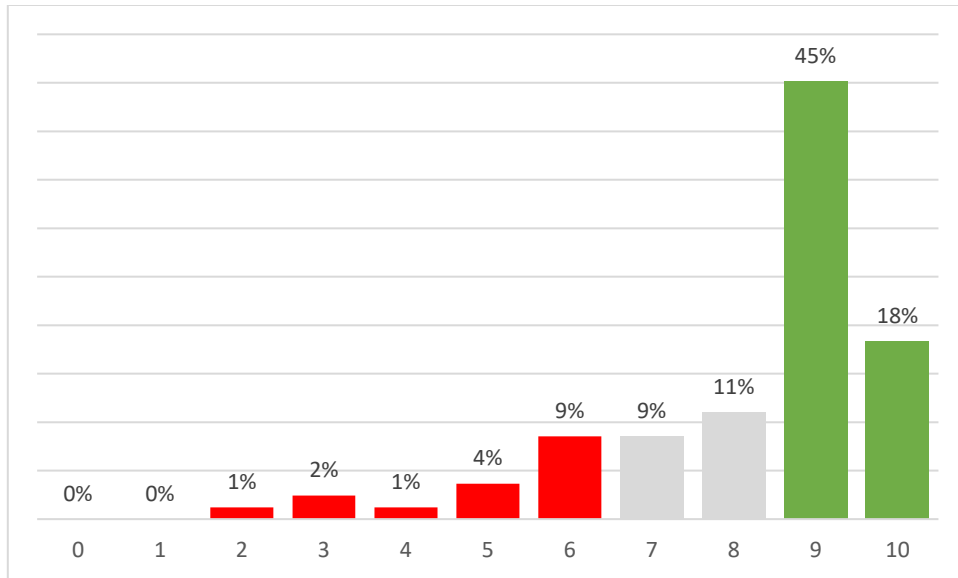


Figure 5.22: NPS Frequency Chart - Willingness to Recommend

Based on the polled scores, 63% of the test user were promoters and 17% were detractors. 20% of the users polled in the passive category. This implies that the application has a Net Promoter Score of 46%, indicating that the mobile application has a good fit for purpose from the users perspective. The following diagram represents the response distribution by category.

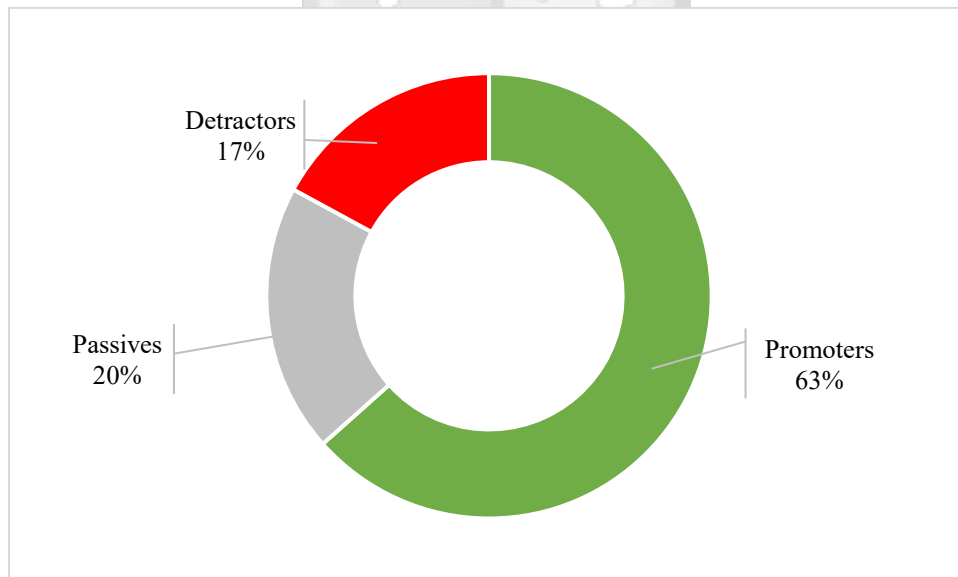


Figure 5.23: Net Promoter Score - Willingness to Recommend

## Chapter 6 : Discussion

### 6.1. Introduction

The study primarily had five (5) objectives. Drawing from the survey, analysis and interpretation of results; to the system design and implementation, and ultimately the system testing the study sought to achieve LPG cylinder traceability in the Kenya market through the use of a mobile application. The following is a discourse on the study's achievement of its stated objectives.

### 6.2. Review of Research Objectives: Findings and Achievements

The identification of information requirements for tracking of LPG cylinders in Kenya was the first primary objective of the study. This was achieved through literature review and a research survey. The literature review identified the legally required attributes of a cylinder in Kenya; attributes include; month and year of manufacture, and the cylinder serial number. The research survey pointed out to the need to track cylinders by manufacturers. This was informed by the fact that majority of the LPG marketers in the country use purchased cylinder. In follow-up sessions it was confirmed that LPG marketers acquire the cylinder from different manufacturers and that depending on the manufacturer the cylinder serialization may repeat itself. The survey also provided useful insights as to the supply chain players. The results confirmed that all LPG marketers do not sell to consumers and employ the use of depots. It was noted that the depots are predominantly third-party owned. This statistic was equally confirmed by the fact that the survey finding indicated that majority of the consumers acquired their LPG cylinders solutions through retailers. This informed the need to have retailers and other third-party players in the supply chain as key actors in the cylinder life cycle. An interpretation on the issues that would drive consumer reasons for marking a cylinder as suspect, provided insights as to the parameters that should be provided to a consumer querying for a cylinder.

The research sought to identify the challenges experiences or perceived in the traceability of LPG along the supply chain. From the research survey a major challenge was observed to be the information asymmetry along the supply chain. There is a Chinese wall between various players. This was interpreted from the fact that most LPG marketers deal with retails and not their end consumers. Equally the retailers polled in the survey confirmed trading in multiple brands and similarly a number of consumers polled showed no brand loyalty. This implied that there exists a

Chinese wall between the LPG marketers and the retailers. The lack of visibility of the consumer to the LPG marketer was confirmed by the research study which showed that a majority of the sampled population had at one point or another questioned the authenticity of the LPG cylinder supplied to them on grounds that bordered on lack the LPG marketers guarantee of quality due to visibility limitations. An important challenge observed during the literature review was the need for a cylinder tagging system, this was critical in ensuring ease of traceability and a common reference for the cylinder across the supply chain. It was observed that the cylinder tagging system alone was not enough. A few of the players had implemented cylinder tagging but had no infrastructure to effectively optimize the return on investment done in tagging the cylinders. The lack of incentive to track the cylinder was also noted a major challenge. Many of the LPG markets, who are the legal owners of the LPG cylinders, were noted to adhere to the basic legal requirement of cylinder traceability – recording of cylinders filled at your filling plant. For some players despite the investment made into modernized solutions such as tagging cylinders with 2D barcode tags, there was no farther incentives to extensive use and deploy more. This demanded that the proposed solution must address this by offering value to multiple players across the supply chain to elicit support for adoption of a LPG cylinder traceability system.

An important object for the research was to analyse the existing traceability frameworks and models. This allowed an in-depth view of possible frameworks and models to employ. A critical consideration was the adoption of blockchain technology; since blockchain is a preferred traceability solution in many industries and verticals. This was however dispelled by the fact that blockchain technology is primarily suited for environments where the record or transaction is owned by multiple independent players hence each participating player becomes an authoritative node in the eco-system. In the case of the Kenyan LPG industry it was observed that the LPG marketer is the legal owner of the cylinder and many other players had not loyalty to the brand and hence any traceability effort must be routed in the LPG vendor. Since the retailers have no brand loyalty it is almost impossible to allow data sharing by the different LPG marketers to allow for the establishment of multiple authoritative nodes. In such an environment the adoption of block chain becomes an expensive solution as opposed to traditional simpler yet effective approaches.

Operation and event data model that traces objects based on existence of a causal link between operation and event. For example, the loading of cylinder associated to a sales order processing event. This is a model that has formed the understanding of the adopted framework for

the developed LPG cylinder traceability system. From the study it has also been asserted that the operation can be tied to a location. Hence the localization data model has been used to mark locations through which traceable objects pass through. This data model is fundamental model, owing to the fact that LPG cylinders, due to the explosive nature of the product are guided by the ATEX standard which make it almost impossible to have an active device on the cylinder to trace its location. The location data model has enabled the prescribing of cylinder location in the LPG cylinder traceability system.

The fourth objective of the study was to develop an application to enhance visibility and traceability of LPG retail products within the supply chain. The process involved the administration of a survey to a sample audience cut from different stakeholders in the LPG cylinder products supply chain. The purpose of the survey was to verify the hypothesis, identified truths and consideration derived from the review of literature undertaken, and get insight into areas of concern for the traceability system. The analysis and interpretation of the survey results was critical in the development of the system design and architecture. The study employed various design tools to model the system to ensure a near perfect match with real-life scenarios. The tools provided invaluable insights and modelling of the major processes and interactions of the system entities. The application was developed using Agile methodology. The system consists of three layers, the presentation layer, the business layer and the data layer. The presentation layer was the core focus where a mobile application was developed to satisfy the defined functional requirement.

The final objective of the study was to test the proposed system. The developed application was subjected to various test to ascertain its fit for purpose and alignment to user requirements. The application was evaluated against the pre-defined functional and non-functional requirements. The testing of the system and experimentation done was in fulfilment of the objective.

### **6.3. Critical Appraisal**

As per the objectives of the research a LPG cylinder traceability mobile application was developed and tested. The application is able to capture the information requirements for tracking of LPG cylinder. This is based on the understanding of the challenges in the traceability of LPG cylinders derived from the study findings. The application allows users to query for a cylinder and responds with attributes that define the cylinder's current position in the supply chain.

### 6.3.1. Benefits of the Developed Mobile Solution

Compared to other system the developed LPG cylinder traceability solution has the following benefits.

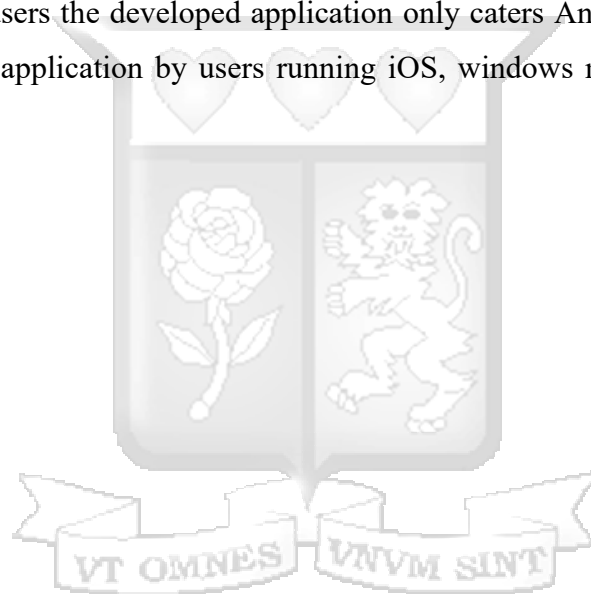
- i. The system allows for easy compliance with legal requirements. The Government of Kenya requires all LPG marketers to record details of cylinders filled at their filling plant. Majority of the marketers have complied with this using manual systems; logbooks maintained at the filling plants. This approach is cumbersome and slows down productivity. The developed cylinder traceability solutions have made compliance in this regard seamless. Not only is the record capture automated, but also the retrieval is easier on a digital platform.
- ii. The system provides the LPG marketer with statistics of the cylinder utilization. The cylinder is an asset acquired by the LPG marketer to facilitate their business. It can be classified as a returnable packaging. This implies that the cylinder must be turned around as many times as possible. With the developed LPG cylinder traceability solution, the LPG marketer can assess the level of utilization of the cylinder. This can be employed as one of the metrics of assess good retail partners and sales regions/areas.
- iii. For the consumer the system provides the much-needed link to the LPG marketer. Using the system, a consumer can access vital information that determine the cylinder validity. Validity here is used to defined validation of the source of the cylinder and the route to market the cylinder was last captured on.
- iv. Compliance both regulatory and legal requires that enforcement staff are equipped with necessary tools to investigate cases in the market. The LPG cylinder traceability offers such a tool to enforcement officers. It allows them to conduct spot checks and ascertain the authenticity of a product or its source. This is a major advantage not only to the LPG companies but also consumers and the general public, as illegally filled cylinders and
- v. The system creates brand equity for the LPG marketer. The study revealed that a majority of the users have experienced questionable cylinder supply. This lowers the brand equity especially in cases where the quality of the product is genuinely compromised. The LPG cylinder traceability solution offers customer greater assurance of the product hence a boast to the LPG marketer's brand as it promotes brand loyalty.

- vi. Cost saving a major benefit for the LPG marketer as compared to the current manual system that are labour intensive currently deployed by some of the polled LPG marketers, the LPG cylinder traceability system is efficient and has a lower labour demand.

### 6.3.2. Limitations of the Application

The LPG cylinder traceability solution design and development is informed by research. In the course of the study and development some limitations as listed below where observed.

- i. Despite the high level of smartphone penetration observed in the survey, there is still a sizeable number of users that still use and prefer feature phones. The developed application does not cater for this segment of users.
- ii. For smartphone users the developed application only caters Android based devices. This limits use of the application by users running iOS, windows mobile or other operating systems.



## Chapter 7 : Conclusion and Recommendations

### 7.1. Conclusion

This research set to investigate, identify and attempt to address challenges that exist in the LPG cylinder industry in Kenya. The main goal of the research was develop a LPG cylinder traceability mobile application based on the identified challenges faced in LPG cylinder traceability at different levels of the supply chain. As part of the study empirical and theoretical literature analysis was conducted. The research included a survey. The literature review sought to identify of the recent developments made in product traceability, frameworks and models that would be applicable to LPG cylinder traceability in Kenya. The review also included a review of the regulatory framework in the Kenyan LPG industry. To compliment the findings of the literature review exercise a survey was conducted. The survey sought to understand viability and use case for a mobile application for LPG cylinder traceability. The survey was administered to three identified levels of stakeholders; LPG marketers, LPG cylinder resellers, and consumers.

Findings from the literature review assert that in Kenya the LPG cylinder is the property of the LPG marketer and there is a legal requirement for the marketer to maintain information of the cylinders filling. The regulatory framework requires each and every cylinder in the market to have the following identifier parameters engraved on the cylinder; month and year of manufacture, the cylinder serial number and the quality standardizations the cylinder is certificate on. The review revealed that the industry regulator, the Energy Regulatory Authority of Kenya and other industry leaders pinioned that much of the shortage seen in the market is artificial due to the lack or cylinder. The regulator recommended the need for an LPG cylinder tracking solution as requirement to streamline the industry and guard investments by LPG marketers. The survey also indicated that a number of the LPG marketers have not capability to trace their cylinders. The review of results confirmed that a number of consumers sampled had received suspicious cylinders, the interpretation was that there was great demand for a traceability solution to give comfort to the consumers on the source and hence quality of the LPG cylinder delivered to them.

In summary, it is this study's conclusion that the adoption and use of a LPG cylinder tracking solution provide the following benefits.

- i. Restoring consumer confidence in the market and hence promoting the adoption of LPG in the country as expressed in Kenya's Vision 2030 blueprint.
- ii. Safeguarding investment by LPG marketers by ensuring that cylinder assets are monitored and are yielding the projected return on investment.
- iii. Providing enforcement officers with a tool to help in enforcement efforts and investigation in real-time in a more efficient way hence increasing quality and coverage of enforcement activities.

## **7.2. Recommendations**

As observed from the study the use of an LPG cylinder traceability solution provided massive benefits to all the stakeholders; from marketers to consumers to government agencies. As a conclusion to the study below are recommendations for improving the study.

- i. LPG marketers to adopt the solution asserted by this study to help them monitor their assets and ensure return on investment.
- ii. Regulatory framework should be introduced to make cylinder traceability a mandatory requirement as a means of promoting public safety.
- iii. There is need to sensitize the consumers of industry best practise and legal and/or regulatory requirements around the trading and use of LPG cylinders. This would promote understanding of the industry and adoption of such a solution.

## **7.3. Suggestions for Future Research**

This study has presented a prototype LPG cylinder traceability solution. However, the study has also brought to the fore areas for possible further research and improvement. The following are eth recommendations given regarding future research in the study area.

- i. Research should consider undertaking future research to identify a framework that can be used by various stakeholders to share data; and possible implementation of blockchain to anchor this.
- ii. Researchers should consider studying the human/non-technical factors that would hamper the adoption of such a solution.

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# Appendix A: Similarity Report



**Brian Wamwenje Onjeri**

**Mobile Application for Traceability of Liquid Petroleum Gas  
Cylinders in Kenya.docx**

Strathmore University (Main Account)

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## Appendix B: Ethical Clearance Release Letter



2<sup>nd</sup> October 2023

**Brian Wamwenje**

094875

brian.wamwenje@strathmore.edu

Dear Brian,

**RE: Mobile Application for Traceability of Liquid Petroleum Gas Cylinders in Kenya**

This is to inform you that the Strathmore University Institutional Scientific & Ethical Review Committee (SU-ISERC) and the Research Services Office received your above Thesis for Ethical Clearance. However, as communicated to you by SU-ISERC via email and further referred to the Office of Graduate Studies, your study cannot be reviewed since you have already collected data. The ethics approval process is ONLY done before any collection of primary or secondary data. Additionally, ethical clearance is mandatory for all studies including desktop research.

The office notes that: On the grounds of not having completed the ethical clearance process, with reason of having only sampled the annual reports of NSE listed companies and henceforth having already proceeded to data collection before ethical clearance. This is a letter for you to proceed with the next steps of your academic requirements.

Please be advised, that in future, all research proposals should be submitted to the SU-IERC through the RHInno Ethics platform: <https://strathmoreuniversity.rhinno.net/login>

*Disclaimer: 1) This is not in any way an ethical approval letter. 2) Should there be any legal implications/actions emanating from the research in terms of any ethical violations, you will be personally liable.*

Yours sincerely, \*

Dr. Bernard Shibwabo

**Director of Graduate Studies**

Ole Sangale Rd, Madaraka Estate. PO Box 59857-00200, Nairobi, Kenya. Tel +254 (0)703 034000  
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## Appendix B: Questionnaire for Collecting Data

### Questionnaire for collecting data for Development of a Mobile Application for Traceability of Liquid Petroleum Gas Cylinders in Kenya

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Dear respondent,

I am a student undertaking a course in Masters of Science in Information Technology at Strathmore University, Nairobi, Kenya. I am conducting a study seeking to develop a Mobile application for traceability of Liquid Petroleum Gas (LPG) cylinders in Kenya. I will appreciate your participation in this study as a respondent. You have been selected to participate in this study because you are considered a stakeholder in the LPG supply chain.

The information you will provide will be treated with uttermost confidentiality and will be used only for the purpose intended for.

I will be glad to offer any clarification and you can reach me through [Brian.Wamwenje@strathmore.edu](mailto:Brian.Wamwenje@strathmore.edu).

Thanking you in advance.

Your sincerely,

Brian Wamwenje



**SECTION ONE**

---

1. Kindly provide the name of your company/business:

2. Nature of Stakeholder

- a. LPG Marketer
- b. Distributor
- c. Retailer
- d. Consumer

3. Please indicate the years of experience in the LPG supply chain cycle.

---

**SECTION TWO**

**LPG Marketers Section**

---

This section should only be responded to by LPG Marketers and/or their agents.

4. As an LPG marketer do you trade in LPG cylinder products?

Tick on only one applicable answer:

- Yes
- No

5. If your answer to question 4 is 'Yes'; kindly indicate the source(s) of your cylinders. Tick on applicable options.

- Purchase
- Manufacture
- Lease

6. If your answer to question 4 is 'Yes'; please indicate the LPG cylinder sizes you trade in.-

- 6 Kgs LPG cylinder
- 13 Kgs LPG cylinder
- 50 Kgs LPG cylinder
- Other

If you indicated other please specify: \_\_\_\_\_

7. Do you utilize the following approaches in your route to market:-  
(Depots refers to stocking locations controlled by the company or its agents)

- No depots
- Company owned depots
- 3rd party owned depots
- Hybrid of company and 3rd party owned depots

8. Do you sell LPG cylinder products to end-users?

(End-user refers to user who purchase the gas for they own use and not for resale)

- Yes
- No

9. Do you tag your LPG cylinders, as a form of unique identifier?

- Yes
- No

10. Application of cylinder tracing system.

a. Have you implemented any cylinder tracing system?

- Yes
- No

b. If yes, do you have the capability of tracing the cylinder at the following points along the supply chain?

- Own stores
- Distributor/Retails
- Consumer

11. Outsourcing of LPG cylinder refilling services.

a. Do you outsource LPG filling services to other entities?

- Yes
- No

b. If yes, does the entity dispatch the filled LPG cylinders directly into the market?

- Yes  
 No

### SECTION 3

#### Distributors / Retailers Section

---

This section should only be responded to by distributors/retailers and/or their agents. Distributors/Retailers refer to trades that purchase the LPG cylinder products for resale purposes.

12. How do you source for your LPG cylinder products?

- Marketer  
 Distributor  
 Parent company

13. Kindly indicate which of the following LPG cylinder sizes you trade in, by ticking against the appropriate unit.

- 6 Kgs LPG cylinder  
 13 Kgs LPG cylinder  
 50 Kgs LPG cylinder  
 Other

If other please specify \_\_\_\_\_

14. Kindly indicate if you sell LPG cylinders to the following categories of people.

- Other retailers  
 End users

15. Do you have internet connectivity at your business premises?

- Yes  
 No

16. Would be willing to have your stock movement data captured automatically on a shared platform?

- Yes  
 No

17. How many brands of LPG cylinder products to you trade in? \_\_\_\_\_

## SECTION 4

### Consumer Section

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This section should only be responded to by LPG cylinder product consumers. 'Consumers' refer to individuals/entities that purchase LPG cylinder products for their internal consumption; not for resale.

18. Do you consume LPG cylinder products from two or more brands?

- Yes  
 No

19. Kindly indicate which LPG cylinder sizes you use?

- 6 Kgs LPG cylinder  
 13 Kgs LPG cylinder  
 50 Kgs LPG cylinder  
 Other

If other please specify \_\_\_\_\_

20. How do you source for the LPG cylinder products that you use?

- Delivered by the marketer  
 Delivered by the retailer  
 Delivered by an identified person  
 Picked at the retail outlet including petrol station.

21. Suspect Cylinder Case

Suspected cylinder is any cylinder that is deemed to be fault or possible not handled in the proposer manner.

a. Have you ever received a suspicious cylinder?

- Yes  
 No

b. If yes, which of the following factors made you suspicious of the LPG cylinder?

Select a maximum of three answers.

- Cleanliness of the cylinder  
 Empirical weight of the cylinder  
 Source of the cylinder

- Quality of the gas i.e. flame quality, value for money
- Cylinder defect i.e. leaking valve
- Other

If other please specify \_\_\_\_\_

22. Would wish to have a platform to validate the quality and/or source of the LPG cylinder products you purchased?

- Yes
- No

23. Do you use a smartphone?

- Yes
- No

24. Kindly indicate which of the following mobile application services do you use.

- Mobile money - MPESA, Airtel money etc
- Mobile banking application
- Mobile banking USSD
- Logistics i.e. Uber

25. How frequently do you purchase LPG Cylinder products?

- Less than a month
- Monthly
- within 1 to 3 months
- within 3 to 6 months
- Above 6 months

Thank you for taking time to respond to this questionnaire.