Haaga-Helia
University of Applied Sciences

Thesis

Design and developing a digital service to deliver liquified petroleum gas (LPG) in Ghana using Internet of Things

Kingsley Obeng Asomaning

Information Systems Management, Master's Degree

Author: Kingsley Obeng Asomaning

Subject of thesis: Design and evaluating a digital service platform to deliver liquified petroleum gas (LPG) in Ghana using Internet of Things

Number of pages:	Date:	Library location

Professorship: Information system management	Code of professorship:

Supervisor: Dirin Amir

Liquefied petroleum gas (LPG) is used for domestic consumption by many households in developing countries such as Ghana for cooking and other heating purposes. It replaces the biofuels used for domestic consumption making it a better source energy for the environment. However, its adoption in these households is slow due to many factors ranging from financial barriers to lack of technological innovations in the infrastructure of the LPG business sector. Therefore, the objective of this thesis is to gather information on the business of LPG in Ghana and conceptualize an idea into a concept within the sphere of information and communication technology (ICT) that can help solve the slow adoption of the LPG in Ghana. The concept is designed and ascertained laying out its architectural infrastructure in a way that can easily be implemented to alleviate the situation in the sector in Ghana. The thesis was conducted using interview based on structured questions to get the state of the LPG sector in Ghana. The information was combined with literature to give a vivid understanding of the problems in the sector and how best it can be fixed technologically. It was inferred from the literature and present state of the sector that there is a lack of information systems in the sector. Again, it was deduced that the entire sector will be streamlined and standardized with ICT usage. Thereby making the sector more attractive and profitable to enable adoption in households. Hence a digital concept that centers on the delivery of LPG from the LPG vendor to the consumer was conceptualized based on internet of things technologies and infrastructure. Not only will this bridge the technological gap in the sector but also make it more innovative to modern standards.

Keywords: Liquefied petroleum gas, information and communication technology, innovation, technology	Publishing language: English

Author: Kingsley Obeng Asomaning

Subject of thesis: Design and evaluating a digital service platform to deliver liquified petroleum gas (LPG) in Ghana using Internet of Things

Number of pages:	Date:	Library location

Professorship:	Code of professorship:

Supervisor: Dirin Amir

Kotitaloudet käyttävät monissa kehitysmaissa, kuten Ghanassa, nestekaasua (LPG), ruoanlaittoon ja muihin lämmitystarkoituksiin. Se korvaa kotitalouskäyttöön tarkoitetut biopolttoaineet, mikä siitä ympäristölle paremman energian lähteen. Sen käyttöönotto näissä kotitalouksissa on kuitenkin hidasta johtuen monista tekijöistä, kuten taloudellisista esteistä, teknisistä innovaatioiden puutteesta nestekaasuliiketoiminnassa. Siksi opinnäytetyön tutkielman tavoitteena on kerätä tietoa nestekaasu liiketoiminnasta Ghanassa ja muuttaa tieto (ICT) konseptiksi, joka voi auttaa ratkaisemaan nestekaasun hitaan käyttöönoton Ghanassa. Konsepti on suunniteltu ja varmistettu tavalla, joka voidaan helposti toteuttaa helpottamaan alan tilannetta Ghanassa. Opinnäytetyö tehtiin käyttämällä jäsenneltyihin kysymyksiin perustuvia haastatteluja joilla selvitettiin nestekaasualan tilaa Ghanassa. Tiedot yhdistettiin kirjallisuuteen, jotta saatiin kokonaisvaltainen ymmärrys alan ongelmista ja siitä, miten ne voidaan parhaiten korjata teknisesti. Kirjallisuudesta ja alan nykytilasta voidaan todeta teknisten ICT-ratkaisujen puuttuminen alalta. Todettiin myös, että käyttämällä ICT-ratkaisuja voidaan virtaviivaistaa ja tehostaa alaa. Tällöin alasta tulee houkuttelevampi ja kannattavampi kotitalouksien adoptiolle. Tämä paitsi korjaa alan teknisen kuilun myös tekee siitä innovatiivisemman nykyaikaisten standardien mukaan.

Keywords:	Publishing language: Finnish

Table of contents

Acknowledgements

I will give thanks to God for giving me the strength and knowledge to carry me through the entire thesis work. Also, I could not have gone through this entire work without the help and guidance of my instructor Mr. Dirin Amir from the information systems master's programme of Haaga-Helia University of Applied Sciences. Also, my sincere gratitude goes to the tutor of the master's programme, Mr. Jouni Soitinaho for his guidance and patience towards all my inquiries. I also, would like to thank all the lecturers and stuff in the department whose efforts through teaching and works respectively equipped me with the necessary skills to do this thesis work. I want to show my appreciation to everyone who helped me one way or the other in my entire studies. I could not have completed the education without your endless help. Am most grateful for your effort.

My outmost gratitude goes to all my friends who in their respective ways tried to encourage me to do the work. They have helped me to stop procrastinate and do what am supposed to do to be able to graduate.

My final appreciation goes out to my family and love ones whose love, kindness and advice kept my head up to be able to finish the task. Without them I wouldn't have been able to complete the work due to the difficult personal situation at the time of the thesis.

Helsinki, June 2021

Kingsley Obeng Asomaning

List of figures

List of tables

Abbreviations

ACM Association for computing machinery

ALB Application load balancer

AMQP Advanced message queueing protocol

ATAM Architectural trade-off analysis method

ATK Aviation turbine kerosine

AWS Amazon web services

API Application programming interface

DevOps Development operations

GDICS Gas delivery integrated commerce system

IEEE Institute for electrical and electronics engineers

IS Information systems

LPG Liquified petroleum gas

LPGMC Liquefied petroleum gas marketing company

ICT Information and communication technology

IoT Internet of Things

Oauth2 Open authorization 2

OMC Oil marketing company

RFID Radio frequency identification

RFO Residual fuel oil

TOR Tema oil refinery

UI User interface

VPC Virtual private cluster

WLPGA World liquefied petroleum gas association

WSN Wireless sensor networks

1 Introduction

1.1 Background

Most African countries like Ghana have relied heavily on biomass (wood and charcoal) for their household cooking and heating. Biomass dependency destroys the forest for which the government and international bodies are fighting hard to keep. In other words, biomass usage degrades the environment. Also is heavily manpower involving and not sustainable. Therefore, the Government of Ghana had a plan to expand liquified petroleum gas (LPG) by 50 % by 2020 into most households to reduce the reliance on biomass to stop the degradation of the forest (Dalaba et a. 2018). This initiative has made the business of LPG gas lucrative. Many individuals sensing the opportunities and push by the government to stream the industry are building a business around LPG to harness the prospects. However, the gas business in Ghana lacks innovation to propel it to the level that households will be interested in ditching their wood and charcoal for. This assertion is in the fact that there is a high awareness of LPG gas among households, yet they are reluctant to use it as they perceive it to be unaffordable and inaccessible. This is also due to the entire process of delivering the product (Gas) from the vendor to the consumer is all manually done, making it time-consuming and adding to the cost of delivery. Also, there are efficiency and effectiveness issues in the delivery due to the process being laden with the heavy manual process that leads to poor performance.

The retail filling stations model where consumers own their LPG cylinders and commute to purchase LPG from retail filling stations is the mode by which LPG is consumed by the people of Ghana. This model requires that consumers commute to the nearest retail station to access LPG (Mensah et, al, 2014). Also, based on feasibility studies and literature, it is evident that the LPG business in Ghana all sell gas cylinders and offers gas delivery to homes but is devoid of any IT infrastructure that will make the LPG adoption rate as the government projects a reality. It is with this quest, that I intend to develop a platform that will inculcate smart IT infrastructure to make the LPG business more lucrative and attractive to the consumer and the LPG vendor or company. Also, in anticipation to attract government and private sector investment in the platform. In a long run, I will be elevating the use of LPG business, creating jobs and at the same time helping sustain the environment in Ghana as a whole.

IT is known to bring business deliveries closer to its customers. And it gets even better if the phenomenon of industry 4.0 like internet of things (IoT) is adopted in the LPG industry to make it seamless between the gas vendors and their consumers. This will be made possible by attaching sensors to the cylinders to collect data into a central database in the system. The database on the systems server will use the algorithms behind the system to enable accepted communication between all the parties affiliated to the system. IoT is simply the interconnected physical machines or devices with embedded systems or software that aids their interactions with the help of sensors and RFIDs on the internet. The IoT serves as a platform for all these connected devices to talk to each other seamlessly and effectively. According to Gubbi et al 2013, IoT is made up of

- ✓ Devices and sensors: These refer to the physical devices in the network of things connected. The devices are equipped with senses to be able to collect and dispatch data to the destination platform. The platform processes the data and decimates it to other devices and controllers in the network.

- ✓ Connected software: This is the embedded software that controls the devices connected in an IoT network. The software with its advanced algorithms enables real time connectivity.

- ✓ Cloud: This is the place where all the data collected in the IoT network is stored in the form that can be distributed and shared between the devices and sensors in the network.

- ✓ Data: This is the entire data collected from the connected devices and sensors. The data is collected from individual devices and sensors into the cloud for storage. It is analyzed and refined into meaningful set of data. The refined data can be sent between devices for decision making.

Therefore, service platform incorporating the IoT technology will make LPG delivery to homes in Ghana accessible and affordable. It will be a sustainable business because a good business strategy coupled with innovation will thrive easily and develop at the speed of light. A completed digital service platform for end-to-end delivery of LPG in Ghana ready to be adopted and scale in the future will deliver the following

- Create business opportunities in the LPG business as a whole in Ghana due to the platform

- Cut the cost of delivery and using of LPG in Ghanaian households that adopt the solution or do business on the platform
- Create a seamless delivery of LPG between business and consumers
- Facilitate busines to business endeavors in the LPG delivery industry
- Standardize the digital delivery of LPG in the sector

1.2 Research problem and objective

Currently over there in Ghana, gas is delivered by people carrying their gas cylinders to gas stations to refill them. Though there are vendors doing home delivery, the process is time consuming resulting in the entire transaction being expensive than it is supposed to be. Therefore, the main objective is to develop a digital service platform that would be able to facilitate the delivery of LPG and evaluate it to ascertain its modifiability in the future. The platform will help in the following ways

- ✓ Cut the journey of the consumer going to the vendor to buy it themselves
- ✓ Making it cheaper and convenient to both the vendor and the consumer
- ✓ Creating a sustainable supply chain within the LPG and its subsidiary industries

The main research question is

1. What are the concerns in LPG delivery business in Ghana?

There are specific research questions which helps make the outcome of the main research question whole and valuable. They are

2. How can technology help to alleviate the concerns of LPG business in Ghana?
3. What can be done to make the service platform suitable for the LPG business in Ghana?

1.3 Research *scope*

This is a business idea turn into an academic project. Therefore, the main idea of the thesis is to develop a digital service platform based on the phenomenon of IoT the delivery of LPG in Ghana. However due to thesis time constraints, it will not include the actual programming of the technical specification of the designed service. That means it just be proposing a concept based on the literature review, design with architecture and show on a high level how it will be evaluated.

The service design will consider all the stakeholders or partners involved in the entire length of the service. The stakeholders or partners are consumers, LPG vendors, LPG delivery agencies and the service business backend. Consumers are households that buy LPG for the home consumption. LPG vendors are companies selling LPG for purchase by household. LPG delivery agencies are those companies or subsidiaries that run the delivery of the LPG from the LPG vendors to the consumers. The service business backend is the organization running the entire service platform. The stakeholders will be able to access the service platform on their mobile apps or on their desktop browsers. Each of these partners are supposed to have a system that link or talk to each other and also with devices involved in the smart solution. However, the thesis scope will be limited to creating an instance of the service to be used from the perspective of one of the stakeholders.

1.4 Research design

Research design is defined as the research philosophy that a researcher adopts conducting a research (Sanders, 2008). Research philosophy on the other hand is the system of beliefs and assumptions about the development of knowledge. This is because the research philosophy determines the research strategy and methodology that a researcher uses in a research. The research philosophy used in this thesis in accordance with Sanders, 2008 is pragmatism in the sense that there is a problem, and the thesis will result in a service creation. The thesis approach is inductive since it involves observing an enterprise's problem and coming out with a concrete solution to the problem. Also, the thesis tends to resolve a social issue by taking an action in the form of the conceptualization, design and later implementing the design hence is an action research. Though the main part of the thesis is the design and implementation of the service, it is classified as mixed method kind because it combines literature with the design and development part to device a solution that solves the problem. It will be longitudinal and involves actual codification of intellect into artefacts in the form of an evaluated architectural design programmable.

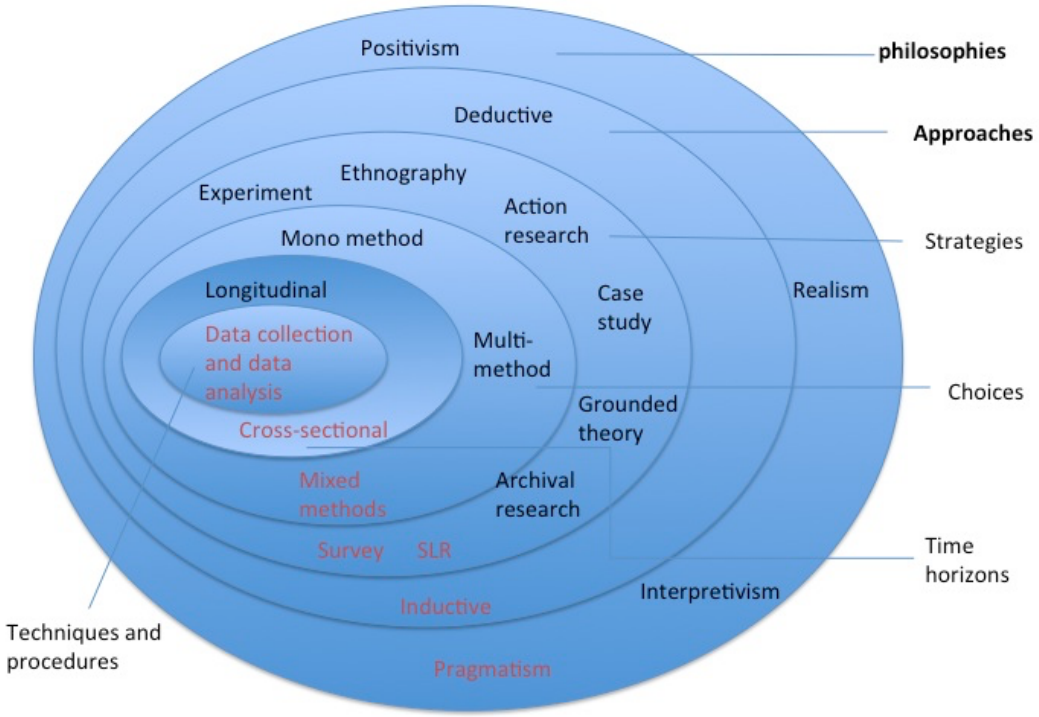


Figure 1: Research design (Sanders, 2009)

1.5 Research *structure*

The first chapter introduces the subject area of the thesis with background knowledge of the LPG business in Ghana. It also briefly defines and explains why the smart solutions based on IoT is important to make the LPG sector business more lucrative. Also, the chapter stipulates the research problem and the research questions to address the problem. The second part deals with the detailed methodology in conducting the entire thesis. It elaborates on the strategies taken in doing the literature review, the design architecture, and the evaluation of the design. Literature review will constitute the third thesis chapter. The literature part will comb through research on the subject area to justify the need for such a solution. The fourth part will be in two parts (4.1 and 4.2). The 4.1 will concentration on how the LPG concepts was come about through literature and an interview. 4.2 will concentrate on the requirements of the conceptualized system and its important use cases. The main parts will include conceptualization of the service platform, technical requirement of the platform and the design itself. Furthermore, a fifth will be the architectural design document of the conceptualized LPG system and which architectural styles and design that will be used in its implementation in the future. The sixth section of the thesis deals with the evaluation of the service platform using an evaluated tool. The evaluation will

be focused on quality attributes that are deemed good for a full functioning system. Then comes discussion of the outcomes of the thesis against the research questions and the problem prior to the commencement of the thesis. Finally, there will conclusion to put a closure on the thesis on its findings.

2 Research questions and Methods

This chapter elaborates on the methodology used in the thesis. The main thesis aim is to design and develop a service platform to deliver LPG in Ghana using IoT phenomenon. This platform will deal with data exchange between the various stakeholders in the infrastructure. However, to justify the reason why IoT phenomenon will be good in solving such a service problem in the LPG business, a literature review will precede the actual design and implementation. Section 2.1 deals with the literature review and its search strategy

Furthermore, a design science approach as elaborated by Peffers et al 2007 will be used in the design part. According to Peffers et al, 2007, design science is used to develop an IT artifact and since the thesis delivers a service platform hence the design science methodology. Section 2.2 first gives a brief background of design science and then dives into the design science approach used in building the architectural design and the reasons behind such methodology. Section 2.3 gives detail account of the evaluation tool used in evaluating the service platform developed for the LPG business. Also, a section 2.4 will elaborate on the research questions giving detail explanation on the idea behind its formulation.

2.1 Literature review

The literature review was carried out by going thoroughly through research articles and books from reputable databases adhering to steps know to produce search results relevant to a subject area. The steps used are as follows

1. Identify relevant published documents
2. Select studies or reports for inclusion
3. Assess the quality of each study or report
4. Analyze the findings from individual studies or reports based on the subject area pertaining to the thesis
5. Interpret the findings and present a balanced and impartial summary of the findings with due consideration of any flaws in the evidence

2.1.1 Databases for searching

The literature review is based on searching reputable electronic databases from 1980 to present based on the subject area and the search criteria below for publications only in English. Reputable in the sense that the database used for the literature search will be one that is accepted for academic research by educational institutions or at least in my academic institution (Haaga-Helia).

2.1.2 Searching criteria and selection

The Haaga-Helia online electronic databases powered by FINNA that holds books, research articles, magazines and thesis was searched for relevant materials on the subject using the search criteria below. Online database is home to all academic and research journals in the world and a link to all known academic search engines. Therefore, through FINNA, searches will be made that includes academic databases such as Scopus, ACM, IEEE, Springer, Ebscohost and Google scholars. Articles, related papers and articles are combed to extract information on the subject area as part of the literature review. Again, a defined search criterion is used to make sure that the review could be repeated and produce excellent amount of literature on the subject. Below is a list of search parameters used in the search of literature.

Alternative 1*: "LPG" "Ghana"*

Alternative 2*: "LPG" AND "Ghana" AND "business"*

Alternative 3*: "internet of things" "industry 4.0"*

Alternative 4*: "internet of things" AND "industry 4.0" AND "smart devices"*

Alternative 5*: "internet of things" AND "industry 4.0" AND "decision making"*

Alternative 6*: "internet of things" "developing countries"*

Alternative 7: *"internet of things" AND "industry 4.0" AND "developing countries"*

Alternative 8*: "internet of things" AND "industry 4.0" AND "strategy"*

2.2 Information system design background

Information System (IS) design is a part of computer science that works properly when a planned method is adhered to. This serves a support base for the development process and thus making the presentation deliverables deemed high quality and valuable.

Design science involves a set of carefully planned process to design artifacts with the aim of solving an observed problem and thereby to making a contribution to research by communicating the evaluated research design and artefact to its audience (Peffers et al., 2007). The artefacts delivered through the design research could include constructs such as vocabulary and symbols, models like abstractions and representations), methods such as algorithms and practices, and instantiations as implemented and prototype systems (Hevner, 2004).

The activities involved in design of an information system is important in the final product that comes out of it. Therefore, a rigorous process devoid of unnecessary activities is paramount to the success of the design. The figure below shows the systematic process used in achieving a design that best addressees a problem.

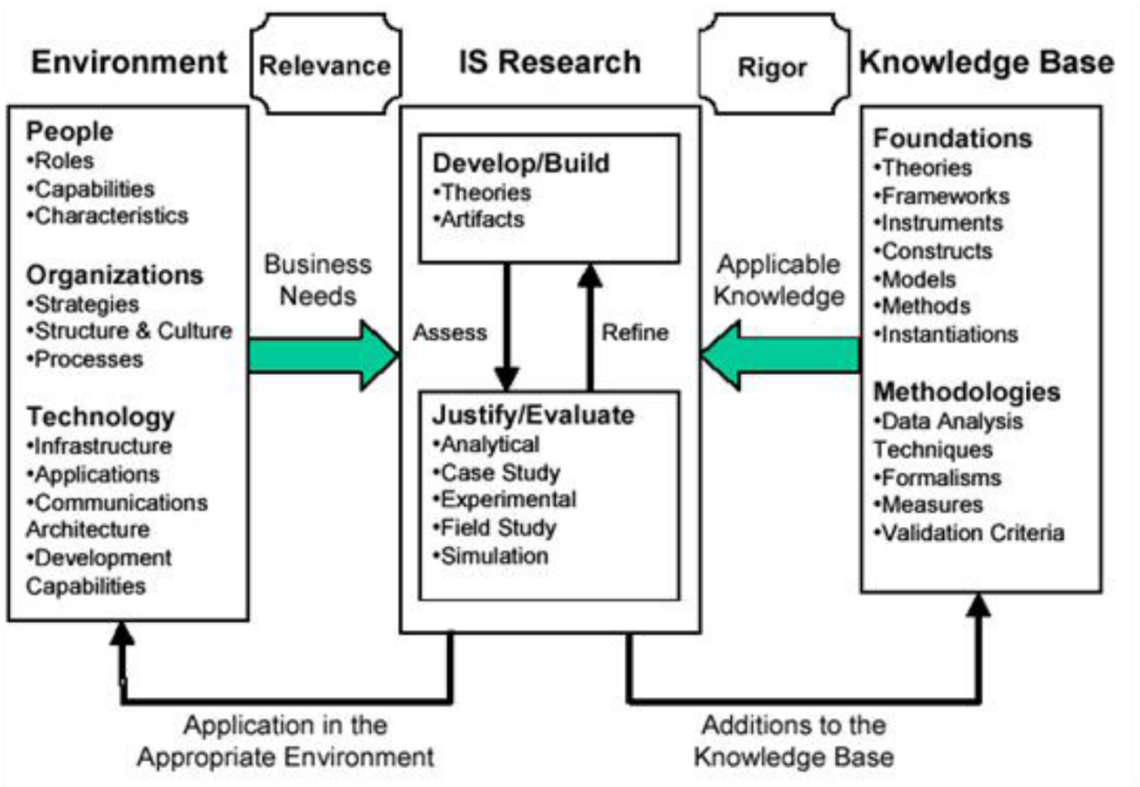


Figure 2:Information systems research framework (Hevner et al. 2004)

2.2.1 Information system design science guidelines

The design science behind the design and development of an information system (IS) uses a set of guidelines coupled with the systematic process to come at a better way of solving a problem. According to Peffers et al. 2007, the best model of designing IS, consist of six steps as follows; problem identification and motivation, objectives of a solution, design and development, demonstration, evaluation, and communication. Also, Peffers et al 2008, elaborated further on the steps by explaining how the steps could be used to achieve a perfect design through a variety of context with respect to what is to be developed.

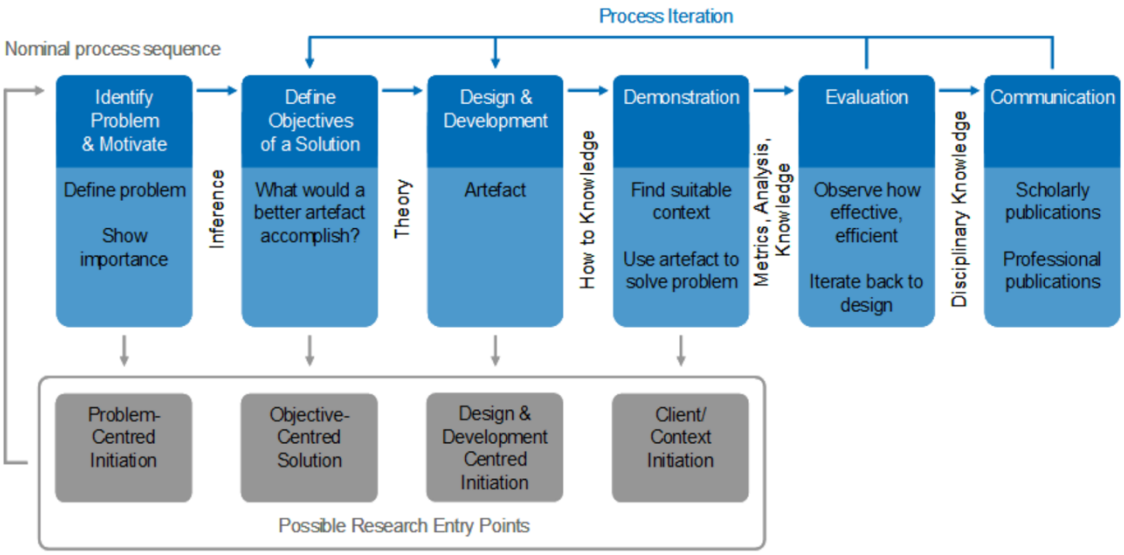


Figure 3: Design Science Research Methodology Process Model (Peffers et al. 2008)

The aim of the thesis is to conceptualize, design and evaluate an IT platform that holds data to communicate between different entities in a smart way. Therefore, given the premise of the thesis background, a problem centered solution approach will be adopted in achieving the goal.

2.3 ATAM Architecture Evaluation

Architectural tradeoff analysis method (ATAM) is used to design and evaluate the conceptualize service to solve the LPG perceived problems in Ghana. ATAM according to Kazman et al, 2000 is defined as a technique used in software architecture analysis with respect to its quality attributes and the communication between such attributes. The tradeoff is the interaction and communications that goes on between the quality attributes.

ATAM was chosen because of its reliance on design science research approach to produce an artifact in the form of a software design. The effectiveness of Software architecture can be ascertained through the use of ATAM (Barbacci et al, 1998). Also, Barbacci et al, 1998 explains that the system design, user experience and the user experience are dictated by the quality attributes of the system. Elaboratively the aim of ATAM as stated above by Kazman et al, 2000 is to evaluate how the quality attribute requirements of system affects its architectural design decisions. In a way ATAM helps determining the risk involved in the design of a system's architecture.

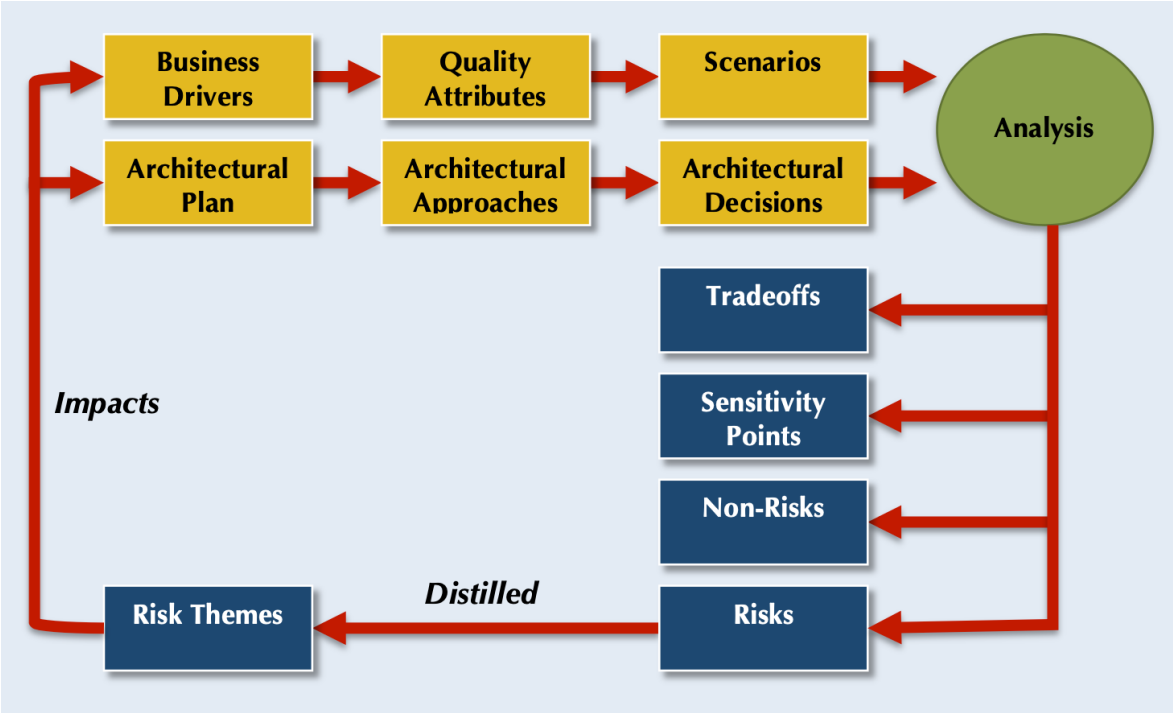


Figure 4: Conceptual Flow of the ATAM Model (Kazman et al. 2000)

Figure 4 above depicts the flow of ATAM from Kazman et al, 2000 perspective. It shows how project stakeholders enables the business drivers and the software architecture. The idea is that the information derived from the stakeholders are transferred into scenarios. Each scenario is then expanded by creating architectural decisions to justify it. Furthermore, the scenarios are analyzed to identify and eliminate all forms of risk in the architecture and its tradeoff points.

There are four phases in ATAM with activities in each phase to make it whole. The different phases are presentation, investigation and analysis, testing and reporting. They are described in detail below.

Presentation

1. **Present the ATAM**: stakeholders are briefed on the method and their expectations and concerns addressed

2. **Present business drivers:** An elaboration on how the business goals drives the development is done.

3. **Present architecture:** The architectural design specification proposed to handle the business drivers is presented.

Investigation and Analysis

4. **Identify architectural approaches:** The approaches in terms of styles and patterns of architecture are selected without analyses

5. **Generate quality attribute utility tree**: These steps bring out the quality attributes of the systems or design architecture. The attributes usually include, performance, security, modifiability. These are then refined from its high-level format to scenario level to make it more presentable.

6. **Analyze architectural approaches:** The attributes mentioned in step five are used in the architectural analysis of the approaches selected

Testing

7. **Brainstorm and prioritize scenarios:** This step broadens the scenarios identified in step five to make it bigger by systematically taking all the stakeholders through a prioritization and elicitation process

8. **Analyze architectural approaches:** step six above is elaborated more with this step by prioritizing step seven as its basis. Tradeoffs, sensitivity points and other risks are documented.

Reporting

9. **Present results:** There is final presentation of the ATAM to the stakeholders or the people concerned with the systems design. A report of the ATAM artefact is written to codify the developed architecture.

ATAM is used in the thesis as a methodology to guide the design of the conceptualize architecture of the service platform purported to enable the LPG business in Ghana based on the attributes its perceived to possess.

2.4 Research questions

2.4.1 Research question 1

What are the concerns in LPG delivery business in Ghana?

Every sector in an economy has some concerns. These concerns can be ascertained through a systematic process to find out the actual problem and its roots causes. This research question serves as a prelude to the design and developmental process undertaken by this thesis. It justifies the need for the service platform that the thesis aims to design and develop. The answer to the question can be derived through literature and or a small feasibility studies on the sector to determine how business is done. An interview with people in the LPG field will be used coupled with the literature to answer this question.

2.4.2 Research question 2

How can technology alleviate the concerns of LPG business in Ghana?

This part of the research uses literature to find the best approach to address the problem in the LPG industry in Ghana. Technology tends to improve any business performance if the information technology infrastructure and strategies are aligned carefully with the business processes (Avesano et al, 2016). Therefore, this research question will deduce from literature how technology can be used to solve the manual process of LPG delivery. This is simply using the information from literature on how the LPG sector lacks innovation and comparing it to how others have used ICT to improve their infrastructure. Through this a technological concept can be designed to solve the problem in the sector. Also, elaborate on the importance and why such technology specifically ICT is the best to solve the problem.

Academic literature will be used to solve this research question by using the right search terms to fetch the information from research databases. The information will be ascertained to see how such knowledge technology can be used to make the LPG sector more lucrative to consumers and investors.

2.4.3 Research question 3

What can be done to make the service platform suitable for the LPG business in Ghana?

Any service needs to be tested to make sure that it does what is intended to do. This research question makes sure that at least the service platform being designed and developed can be able to solve the situation on the ground. The process of finding out the answer to the question involves a bit of literature and through the evaluation process of the service platform.

3 Related research

3.1 Definition of internet of things (IoT)

This is a new paradigm thought to be the way forward for effective industrial innovation. Traditional or conventional internet usually connects people with the aim of exchanging information, but IoT rather interconnects machines and objects using the deployment of sensors to allow them to communicate on their own on the internet. In other word, IoT uses the internet to form a huge network of smart objects (Hsu et al, 2016). IoT takes on different definition and names depending on which sector of the economy that the phenomenon is applied to. IoT is simply the interconnected physical machines or devices with embedded systems or software that aids their interactions with the help of sensors and RFIDs on the internet. The IoT serves as a platform for all these connected devices to talk to each other seamlessly and effectively. Also, it can be described as the ever-expanding collection of connected devices that capture and share data (Stephens, 2016). Stephens continued to make the case that any object fitted with the correct kind of sensors can observe and interact with the environment. Again, IoT can be defined as a world of devices or sensors connected where objects are connected, monitored, and optimized through either wired, wireless, or hybrid systems (Chong et al, 2015).

From the definitions above, it can be inferred that IoT becomes operational only in situations where devices and objects are connected in a smart way using sensors that enables the connectivity and interaction between the participatory objects. Also, the sensors should be able to collect and share data between the objects. The sensor collects the data and the algorithm behind the collection and management of the entire system serves as the brain of the association between the devices connected in the network. Therefore, the degree of effectiveness and efficiency of the sensors determines the smartness of the IoT network and thereby yielding better communication outcomes.

Furthermore, IoT consist of 4 main layers, namely

1. Devices and sensors: This are the physical devices that are connected in a network of things. These devices are equipped with sensors that collects and sends data to a common platform for analyses and decimation to other devices and controllers.
2. Associated connected software: The IoT devices are controlled and connected by embedded software with advanced algorithms that make their connectivity possible on real time bases.

3. Cloud: This is the medium which provides a place for the information collected by the connected devices and sensors. It is a common place that serves as a link between the various devices. IoT creates massive data from devices, applications and users which has to be managed in an efficient way
4. Data: Large amount of data is generated by the connected devices. Each of the devices collects its own data and push it to the cloud for storage and analytical purposes. The individual data from the various devices are put together and refined into meaningful data with analytical tools and sent back and forth to purported destinations for decision making.

3.1.1 IoT technologies

Connected objects have two components in common: a sensor to collect data and a way to communicate that data (Stephens, 2016). IoT base services uses many different technologies in its infrastructure to make the service achieve the full functionality of IoT. The most prevalent of them are as follows

radio frequency identification (RFID)

This enables identification and data capture in an IoT network using radio waves coupled with a reader and a tag. The tag stores the data in the network. Three types of tags are in use in IoT networks namely passive, active and semi passive RFID tags (Lee et al, 2015). Passive RFID tags depends on the energy from radio frequency transferred between the reader and the tag to power it. This can be seen in applications involving item tracking, passports and supply chains. Active RFID uses its own battery to power itself to communicates with a reader. It deploys sensors to monitor conditions inside the network. Examples of can be found in hospital laboratories, manufacturing settings and management of IT assets. Semi-passive RFID on the other hand power its microchip during communication with a battery whiles using the reader to draw power at the same time.

wireless sensor networks (WSN)

This is made up of partially distributed sensor equipped devices that are autonomous to observe the environment that it operates in. It deploys RFID technology in its set up sometimes to make the setup more effective and efficient in the tracking of activities (Atzori et al, 2010). Different network types can be put together in a WSN infrastructure. This has encouraged devices which are efficient, low cost and low power in the building of WSN applications. Deployment of WSN includes its use in thermal packaging, maintenance and tracking systems, sensors in jet engines, turbines, and wind farms.

Middleware

Software developers uses middleware as a layer between software applications to aid communications and inputs between the applications. It is able to hide details in technologies used by developers freeing them from software services which are not important to the IoT application deployed. Middleware is used predominantly in distributed computing setting. Again, it enables the simplification of complex IoT distributed networks with new applications and services. Service-oriented architecture is used in the middleware IoT architectures (Lee et al, 2015). This makes the IoT network dynamic in terms of topology.

cloud computing

IoT generates a lot of data in the communications of the devices between them. Cloud computing is the technology used to offset the on demand of heavy infrastructure that generates massive data in the process. Cloud computing provides storage space, processing speed to enable real time decision making for the massive data created in the IoT network. According to (Gubbi et al., 2013), cloud computing makes the setting up of IoT for certain organizations possible since they can easily buy cloud computing capabilities from a third party without building the infrastructure themselves. It falls under software phenomenon known as infrastructure as a service (IaaS). Organizations will just buy such infrastructure as a service and have it aligned to their business process.

IoT application software.

IoT network consist of device and networks providing the physical connectivity in the network whereas the IoT application facilitates the device-to- device and human-to-device communication in a meaningful and reliable way. The IoT applications ensures that messages between the devices are picked up on real time bases and transmitted to the right destinations as intended. This kind of IoT application or software can be used for example in transportation business to monitor the condition of goods in transit. It can be used to check things like foods reaching expiring dates and transmits the data to centers for appropriate actions to be taken. Specific example is FedEx adopting SenseAware to monitor conditions such as temperature and location. It also uses the same technology to ascertain if packages have been tampered with or not. All these are possible because the IoT applications are built with intelligence to be able to provide vivid visualization of the data it collects to its end users for decision making.

3.1.2 IoT architecture models

IoT systems are meant to provide seamless interoperability and integration among heterogenous equipments and devices and show a high-level kind of model for the development of applications. This enhance the IoT system doing what it is intended to do to enhance the normal ICT system that it is attached to as a model. However, there are different models for IoT developers to rely on resulting to lack of standardization in the industry (Cavalcante et al, 2015). Therefore, it is important to have a reference architecture model to rely on when developing any IoT system to facilitate a business process in a any sector (Cavalcante et al, 2015). According to the literature searched through, the following architectures are known to be good in different scenarios of IoT service development.

IoT Architecture reference model (IoT-ARM)

This is a product of the European FP7 Research Project IoT-A (Bassi, 2013). It defines the processes under which an IoT system can be added to an existing system to enhance its intelligence to make a process more efficient and effective. The IoT-ARM uses the existing solution as an input in its design to modify the new system into an IoT interoperable system (Bassi, 2013, IoT-A,2013). Figure 5 below gives a high-level view of how the IoT-ARM system works with an existing system and its businesses

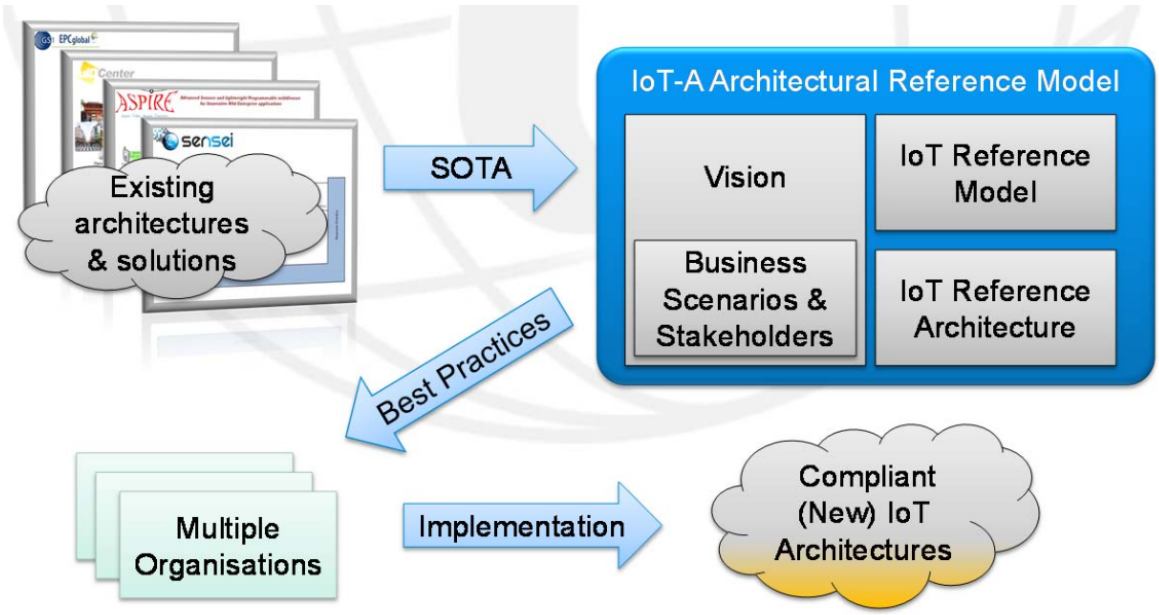


Figure 5: The building blocks of an IoT-ARM Model (IoT-A, 2013)

IoT reference model (Cisco)

This is an architecture model developed by Cisco. It is a more flexible architecture and allows a lot of freedom in terms of the distribution of the devices in the network (Cisco, 2014). These devices can be grouped in one room or distributed across the world with minimal or no effete on the topology of the architecture (Cisco, 2014). Also, trivial task processing can happen at each of the levels in the model architecture. The main aim of this model is to describe how task in an IoT system should be executed properly at each level in the system to be able to retain the simplicity, enabling scaling of the system in the future whiles the same time ensuring the system's supportability properties. In addition, it gives an elaborate description of which functions needs to be done and at what level to achieve the requirements set for the IoT system (Cisco, 2014).

The Cisco model consist of seven layers as seen in figure 6 below starting the development from bottom up.

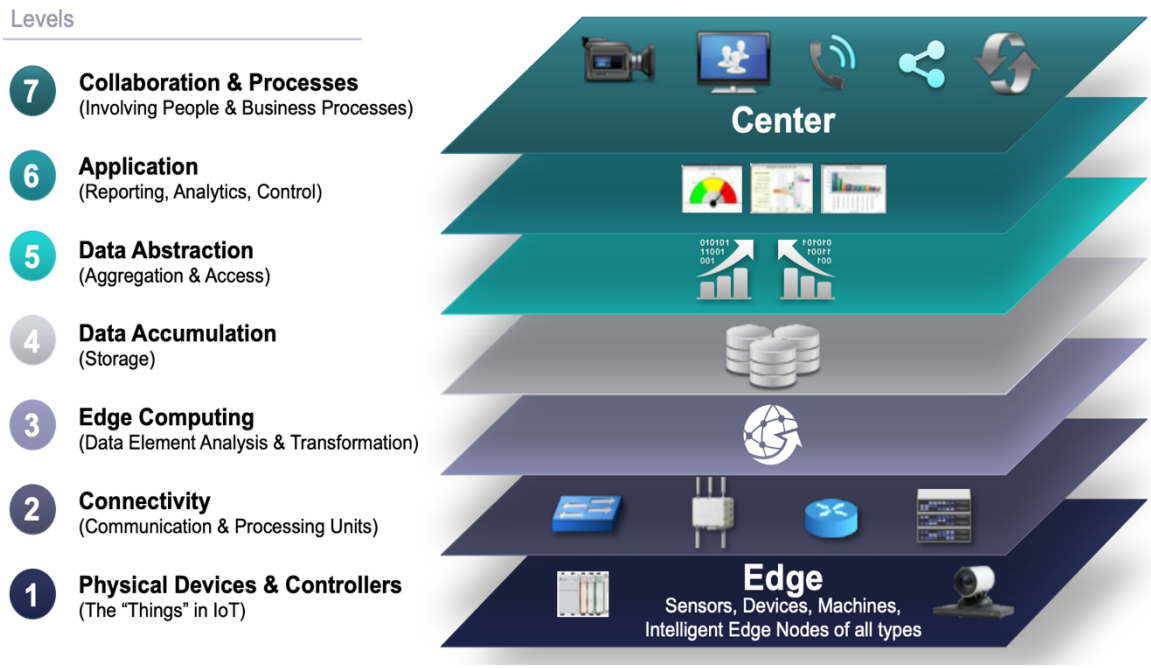


Figure 6: Cisco IoT Reference Model (Cisco 2014)

WSO2 Architecture for IoT

WSO2 is a company that specialises in developing IoT solutions for different organisations. They have a reference model that other developers could borrow or lean on in developing their own IoT systems. They employ the use of cloud architectures to enable ease communication with different devices (Fremantle, 2015). According to Fremantle, 2015, WSO2 architecture is made up of horizontal and vertical functional components with each performing a set of functionalities as seen in figure 7.

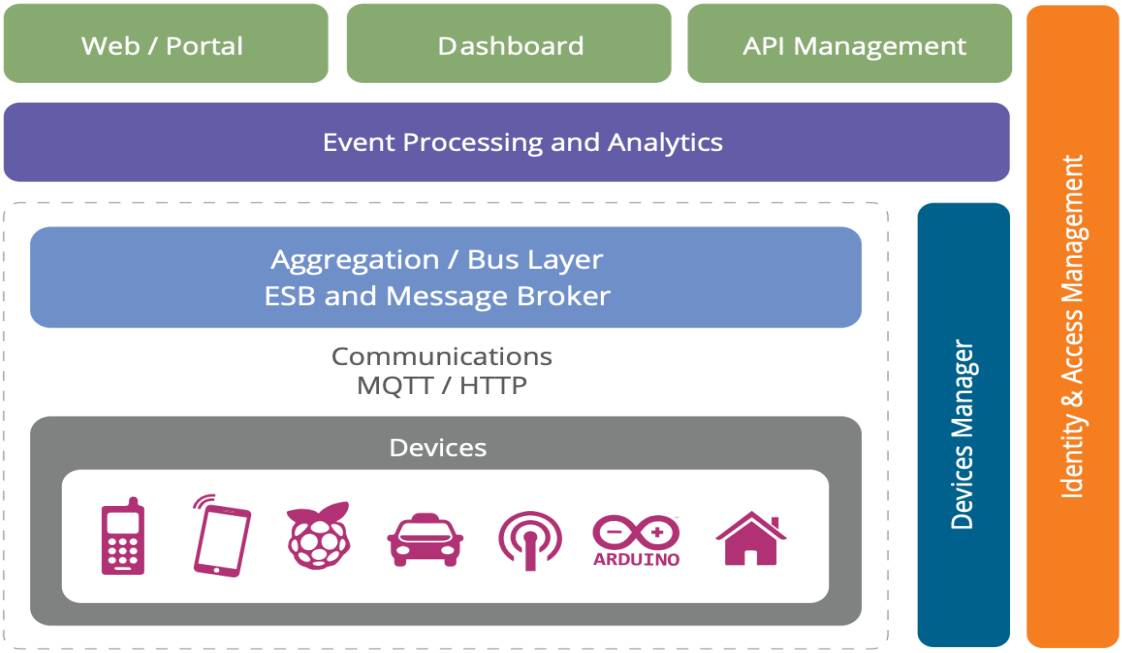


Figure 7: WS02 Architecture Model (Fermantle, 2015)

3.2 Impact of IOT on the economy of a developing country

The economy of any country depends on how industrious the country is and through new developments of technologies, the world is moving towards a more connected paradigm shift with both wired and wireless networks everywhere to help with the connectivity (Gavras et al, 2007). This form of connectivity is internet of things and defined as an open and comprehensive network of intelligent objects that have the capacity to auto-organize, share information, data and resources, reacting and acting in face of situations and changes in the environment (Madakam et al, 2015). According to Coetzee et al 2011, IoT influences societal, environmental and the economy of any country and it will be of enormous benefit to countries struggling to catch up western development like in Africa and other developing countries. Accurate information about the status, location and identity of things, which forms part of and impacts on the environment, allows for smarter decision making and appropriate action taking (Coetzee et al, 2011).

The future and prospects of IoT in developing countries like Ghana is bright and enormous (Miazi et al, 2016). Figure 5 below gives an overview of the potential of IoT in developing countries.

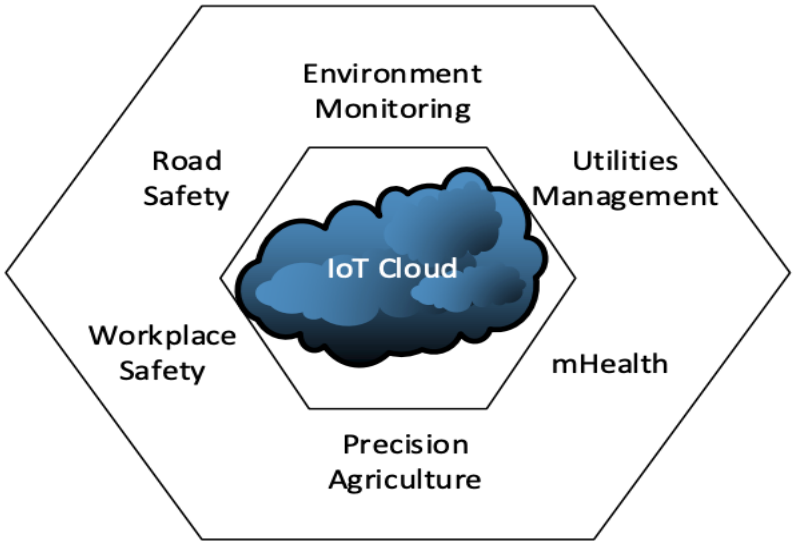


Figure 8: An overview of the potential of IoT in developing a country

The potential of IoT technologies can be helpful in the sectors shown in the figure above. The thesis area of endeavor is in the utility management sector.

Utility management

Utilities like electricity and gas are under used in developing countries due to many different factors. Some of the factors concerning gas has been elaborated in the entire thesis above. It is obvious that such utilization of utilities in developing countries are devoid of the right and adequate technology in its dissemination process to enhance the adoption and using of the utility product (Miazi et al, 2016).

The adoption of IoT in utility management systems will enhance efficiency, improve revenue and save up some business capabilities like enterprise resources (Gubbi et al, 2013). The entire premise of the thesis is on IoT adoption in Gas in Ghana and how its usage is justified. It can be seen from the literature so far that, Ghana and developing countries as a whole lack such IoT infrastructure and technologies and therefore lags behind harnessing the benefits of such good technologies. In the deployment of IoT, sensors can be used for example to increase energy like LPG adoption, and It can also help optimize water, gas, and electricity generation and distribution creating a good consumer to business relationship (Gubbi et al, 2013).

Workplace safety

Developing countries like Ghana is plagued with a lot of issues at workplaces due to cultural and ethnic differences. Sometimes, these differences amongst the work force could create a hostile environment that can affect the quality of work and thereby hampering profits of such organizations (Miazi et al, 2016). Though it is a huge issue, IoT provides systems that can be used to monitor systems and activities at the workplace mitigating the cultural differences by regulating the effect of such of processes and activities that people engage in. Sensors can be placed on machinery to alarm people when it breaks down or it needs urgent care. Such intelligent systems could nullify the negative Behavioral attributes at work and thereby making it safe to work in (Miazi et al, 2016).

Road accident mitigation and transportation safety

Ghana and Africa as a whole experience a lot of road accidents. The increase is not due to bad roads only but also to road distractions on the part of the drivers involved in the accident. According to (Stutts et al, 2011), 25% of police reported accidents are as a result of driver distractions. Also 80% of the accidents and 65% of near crashes are caused by a driver not paying attention which results in immediate accidents in a span of seconds of being distracted (Stutts et al, 2011). The road accidents can be easily mitigated by employing smart devices that gather data to show the cognitive responses of drivers. The devices could also collect data on drivers mental and physical being coupled with vehicle road worthiness. The data through the IoT algorithms could be used to intelligently stop vehicles in times of distractions and if possible, trigger alarm systems to report it to authorities or the driver of the car for appropriate action to be taken (Miazi et al, 2016).

Precision agriculture

The demand of food to feed the world's population is on the rise compared to the supply to adequately carter for the demand and this could lead to starvation in certain parts of the world if immediate solutions are not devised to handle the balance in the demand and supply (Daily et al, 1998). Though a lot have been done on farming economy practices, its impact has been minimal to offset the imbalance due to environmental conditions and economic factors related to the famers themselves and their business partners (Miazi et al, 2016). The conditions that affect agriculture are worse in developing countries as a result of lack of technology in the farming processes.

Therefore, adopting the use of technology that have the potential to monitor agricultural conditions whiles aligning it with the activities that goes on with the farming itself will

enhance crop planning, enable infield management decisions and deliver correct records on the agricultural process, Also, it will reduce the reliance on fertilizers and pesticides thereby increasing the profit margins whiles cubbing environmental pollution. Precision agriculture (PA) that uses advance technologies could be used in developing countries to ensure accurate intake of plant nutrients saving them from competition with pests and diseases that make the nutrition provided ineffective (Miazi et al, 2016). PA adoption enables governmental policy in agriculture to be streamlined making it possible to make future plans for crop production enabling effective and efficient methods for maintaining food security in a country.

Environmental monitoring

IoT is changing the way the environment is monitored and regulated by viewing it through the prism of high technological infrastructure and systems (Miazi et al, 2016). It is in fact a new paradigm in monitoring the environment. As mentioned above under precision agriculture, a lot of the factors that affect the environment like pollution, bad weather and other natural causes can be effectively and efficiently monitored by using high class IoT software and applications to collect data on real-time bases. This data can be analyzed by the IoT system and used to make decisions concerning the environment (Niyato et al, 2007).

Therefore, in the developing countries, monitoring the environment is important to forecast climate changes and to predict natural disasters. However, it is important like in adopting such IoT systems, efforts are made to make the affordable without compromising on the quality of it. IoT has enormous potential to be used in environmental monitoring to preserve and maintain nature, climate and the civilization it provides to the world (Miazi et al, 2016).

Intelligent health management

According to the world ageing population report, 2009, health is an important aspect of every human life and as such it is an area that is paid a lot of attention by most governments especially with ageing population across the globe. With such ageing and an increasing world population, it's inevitable that hospital beds might run out if an innovative solution is not created. IoT is plays a vital role in development of eHealth solutions. It is very much deployed in developed countries to a large extent. This same phenomenon can be used in developing countries to help improve their poor health systems as research towards such approaches is on the rise (Yang et al, 2014).

IoT provides a better infrastructure connecting devices that collects health data and makes its management easy. In other words, IoT makes the using of ICT in health sector easy,

effective and efficient thereby benefiting from the reason such solutions were adopted (Miazi et al, 2016).

Social security management

Social security is the backbone of anyone who aspires to retire one day, however many African countries like Ghana lacks an effective social security system that is free of security lapses. A better system could be built using IoT technologies that rely on safe cloud computing to protect, secure and manage the life savings of people.

3.3 IoT challenges in Ghana and Africa as a whole

IoT is used to solve a lot of problems in different sectors in an economy including end-to-end security, data privacy and trust, scalability, and interoperability (Al-Fuqaha et al, 2015) but the case in Africa is different since it involves a IoT challenges that require significant effort to alleviate. These challenges are unique and much more prevalent in rural and remote areas (Zennaro et al, 2015). Zennaro et al, 2015 list some of the challenges as hardware cost, deployment complexity and the lack of technological background and ecosystem.

However, IoT creates a lot of opportunities in Ghana and Africa as whole despites is adoption being plagued with challenges. Some of the opportunities include water monitoring, air and soil quality management, environmental threat warning systems, tracking systems for industries and control systems that enables deforestation (Masinde, 2014). The challenges with the adoption of IoT in developing countries like Ghana are longer range for rural access, cost of hardware and services, dependency to proprietary infrastructures, local interaction models, low-energy consumption, ease of deployment and operation, and resilience against environmental hazards (Masinde, 2014).

Longer Range for Rural Access

Communication technology are very expensive to deploy to IoT devices. Also, it is not energy efficient in to use with devices that are autonomous that rely on battery. Other technologies such as solar could be used to take care of it but can also have limited transmission range. This calls for long range transmission devices that are able to run on batteries for long. This makes it even more expensive when the idea is to reach areas that a far with less connectivity issues such as rural and remote communities.

Cost of Hardware and Services

Devices used in IoT networks are very expensive and low-income countries like Ghana struggle to adopt such technologies. On top of that, these devices are also cost a lot to repair with parts hard to find in these local economies. This issue can be resolved with low cost of IoT infrastructure built with devices that can be afforded by developing countries like Ghana. For example, open-source platforms could be used with minimal cost to build IoT platforms with long range transmission capabilities. However, this will need a lot of investments and education in the sector that uses such to reap the benefits from such open-source technologies. Again, such initiative is lacking in Ghana. Another avenue for my LPG platform and business venture to explore in the future.

Dependency on Proprietary Infrastructures.

Most organizations looking to adopt IoT in their businesses rely a lot on proprietary infrastructure to do business. The dependency and over reliance make it too expensive and also difficult for such organizations to innovate in the right way. The dependency on such proprietary infrastructure can be minimized or reduced if cloud infrastructures are used instead. Cloud infrastructure has a lot of benefits such as free account offers. Though cloud infrastructures might have limited features, it offers something that can meet the needs of most organizations business model requirements in developing countries.

The design of an IoT infrastructure will be paramount for such organizations be able to take advantage of IoT cloud solutions. The design enables customization of the data managed in the IoT network. Again, large-scale deployment scenarios coupled with integration of low-cost components can be used as the focus in building cheap IoT platforms in developing countries.

Local Interaction Model

IoT infrastructure require communications between the devices in the network. The connectivity needs a GSM connection to facilitate the storing and sharing of data between and among the devices. In the context of Ghana, connectivity can be a problem and hence makes it difficult to carry a key part of the IoT network working properly. Therefore, the best way to prevent the disruption of the IoT processes is build an infrastructure that is designed to store data generated in the network locally. This enables easier access and will not be affected by network issues in case of back outs.

Low-Energy Consumption

IoT devices uses batteries in the infrastructure, and it is efficient to run the infrastructure on low energy consuming batteries. In other words, it will be an issue if the sensors that rely on batteries are not energy efficient in their consumption. Therefore, its necessary to for the IoT network to be built using low energy consumption devices.

Ease of Deployment and Operation

Despite the advocation for IoT usage in the industrial and other businesses, there are issues with its ease of adoption. Therefore, the IoT infrastructure in adoption should be easy to use and allow easy upgrades through modifications. Also, it should be such that its maintenance capabilities are factored in the design of the platform. The platform should be user friendly to attract people to use it and to preach its benefits to others. This goes a long way to enable the increase in adoption of IoT networks in businesses.

Resilience against Natural Environmental Hazards

IoT networks are deployed in environments that are hash such manufacturing, wildlife and other societal settings. Therefore, the infrastructure of the IoT network should be designed to withstand any environmental and natural disasters. This is an important challenge in the network because if is not taken care of properly will lead to malfunctioning of the entire network thereby slowing business process or shutting it entirely.

3.4 The gas business in Ghana

The liquified petroleum gas marketing companies (LPGMC)s and oil marketing companies (OMC)s is responsible for the distribution of the petroleum products in Ghana. 27 companies are licensed to by the government to sell petroleum products on a wholesale basis. However, there are only 7 of those companies that deal in LPG solely. The rest deal other forms of petroleum products. There are both foreign and local LPGMC and OMC business organizations.

3.5 Key challenges in the LPG industry

According to the report by (Edjekumhene et al, 2007), the LPG industry is plagued by issues affecting the progress and development of the industry. The challenges include

1. Lack of an efficient and reliable supply chain for LPG

2. Absence of effective policy measures and regulatory regime
3. High recurrent cost of refilling large cylinders
4. Lack of sufficient knowledge in health and environmental benefits associated with the use of LPG
5. Lack of cost-effective LPG equipment for users

3.6 Innovating the gas business in Ghana

Innovation typically follows a technological narrative, but it follows a different pattern in the in the energy including the LPG sector (change (Grubler et al, 2014; Jacobsson et al, 2004). Also, Grubler et al, 2014 and Jacobsson et al, 2004 categorize innovations in the gas sector to follow two distinct ways. One is the innovations brought about by technological change and the other is innovation due to political and economic factors. Therefore, the innovations can be set to be driven under just the influence of the state towards its goal or as a derivative of technology advancement (Jacobsson and Johnson, 2000). Whereas the political and economic innovations stem from existing markets fluctuations and pollical institutions policies, technological innovations emanate just from developments driven by business ecosystems (Popp, 2016). This means the innovations will be affected by the negative and positive fluctuations in the in a country's pollical system (Popp, 2016). It is in my opinion that the lack of innovations in the Ghanaian context might be as a result of a pollical system that cannot be trusted for its stable economic and pollical capital. It does drives innovations within and from outside.

Furthermore, the challenges of the LPG can be addressed and alleviated partly if substantial amount of effort is put into revamping the sector of technology as it lacks significantly. As noted by Norberg-Bohm, 2002, Fundamental changes in energy sector are necessary to alleviate the problems and challenges they face worldwide. Some of the challenges including those above are security of energy supplies; social and economic development; security from the spread and use of nuclear materials; and management of the environmental problems associated with energy use, including local and regional air pollution and greenhouse-gas induced climate change (Norberg-Bohm, 2002). Again, Innovation drives every sector and the search for innovative ways of doing business is on the ascendancy in Ghana and Africa as a whole (Kammen, 2011). Kammen, 2011, reiterates that revolutionizing the gas sector help to reduce poverty, stop climate change and enhance global health and empower women. Therefore, there is the need to innovate in the LPG sector and energy sector to stop the over reliance on fossil fuels which tend to

fluctuate irresponsibly affecting the political economy of the country (Agbemabiesea et al,2012)

LPG is a known proven technology for handling domestic energy needs as affirmed by the World LPG association. Therefore, its lack of innovation baffles researchers since it has a user base of over 2 billion people using it for cooking, heating, and other uses (Kammen, 2011). This makes the need for innovation across board in the energy sector especially in LPG is of crucial importance to enable the move from traditional over reliance on biofuels to a more sustainable energy efficient and environmentally friendly energy sources. Therefore, from the literature above it can be inferred that some of the innovative ways that can be adopted or improve to make the LPG business better are centered on

1. Governmental policy: Regulation from government can streamline the LPG industry by instilling trust in the business making it more lucrative to investors. Also, governments leading by example will drive innovations into the sector. In Ghana, the government switched all government kitchen stoves to LPG in an effort to normalize the use in households (WLPGA, 2015). Also, the government of Ghana started a National LPG Promotion Programme in 1989/1990 which include subsidizing the use of LPG as a way to get more people to start using it and provide incentives for LPG sales at distances more than 200 km from the refinery (WLPGA, 2015). Though the impact of the programme has been limited, it has paved a way for the popularity of LPG usage in Ghana to be on the ascendancy. The issues include difficulty in targeting rural settings due to fragmentation, entry barrier for obtaining an LPG stove being very high, disparity in economic levels of the citizens of Ghana, lack of safety culture and poor regulation and enforcement, Cylinder sizes not being enough, competition from cheaper sources of energy like kerosine and finally the policy itself was not enough. To better the effort from government, in 2010 it made a commitment to increase the consumption of LPG from 10% to 50% by 2020 and has partnered with neighboring countries to provide a steady distribution of LPG (WLPGA, 2015). Again, Ghana has a plan together with LPG global partners to use LPG to reduce the reliance on biofuels.
2. Cooking stove: In a developing country like Ghana, simple ways of doing things could go a long way to change the mode of operation doing any business. The LPG sector is no exception. Stoves are the basic necessity when it comes to LPG usage. Therefore, innovating the stove to suit the basic use in the Ghanaian context will enhance the adoption of LPG itself (Carrion et al, 2018). According to carrion et al, 2018, the adoption of LPG is dependent on the stove technology. The emphases on the stove's use with respect to the LPG adoption is based on the household setting characteristics such as things that determine the way the people live with their neighbors and how they are as

people (Rehfuess et a, 2014). Also, it is dependent on the infrastructure of the household that uses the stoves and the knowledge and perception of the intended user base of people (Rehfuess et a, 2014). From the above literature it can be inferred that one cannot just pick any stove for a certain people in a locality. Therefore, innovation in stoves to suit the Ghanaian society as small as it might be, will be a good redesign or design of the stove.

3. Cylinder recirculation: The circulation is more of innovating the ways of doing business rather than it being technology inclined innovation. However, innovation of business models is good enhancing business in any organization irrespective of the kind of business they do so is the LPG sector. As mentioned above, in the policy innovative ways, it will be best if government initiate the process of cylinder recirculation to make it a standard. This is because majority of the LPG vendors or suppliers have no clue about the cylinder recirculation as a means to help with the adoption of the LPG and those who have heard of it have fears of bad cylinders being used (Dalaba et al, 2018). Therefore, a policy to increase awareness will help in the recirculation gaining popularity and trust as the way forward for an economic impoverish society like many Ghanaian rural areas. It will cut the cost of adoption of LPG making it easier for poorer communities to be able to change over reliance on biomass and use LPG.
4. Digitalization: introduction of information systems into the energy sector will help streamline its processes with the intended business itself. But as mentioned above the LPG business in Ghana lacks such digitalization to elevate it to the next level. This shows that doing a thesis on such a sector is important. It will illicit the issues of the LPG industry in Ghana and justify why the concept out of the thesis will alleviate or minimize the problems that plaque the industry making it more lucrative and accessible to all Ghanaian who needs it. This is because digitalization enhances safety whiles improving productivity of any business. It also increases accessibility and makes systems that controls energy sector like LPG more sustainable.

3.7 The impact of IoT on LPG business in Ghana

The takeover of machines and their infrastructure in business whiles remotely controlling them can have enormous benefit to society. That is emerging economies stand to gain a lot from IoT) and its associated applications through the delivery of important services. Also, the impact of IoT on the dissemination of LPG is enormous. However, the expenditure on IoT in the energy sector are minimal to nothing (Cisco, 2016). Therefore, IoT adoption will create a lot of opportunities in the LPG business. According WLPGA report 2019, the impact

on the LPG business can be felt through the well head and refinery, the supply and distribution chain of the LPG to retailers and the dissemination to end users.

The impacts are due to advancements in technology in the IoT which creates environments in the LPG business sector making it the workplace smart, safer, effective and efficient in attaining their business goals. This in a way helps adoption of LPG by households where low income is a barrier for adoption in developing countries like Ghana. The application of IoT in the LPG industry can be termed as industrial internet of things (IIoT). IIoT is the application of IoT in manufacturing. In other words, IIoT is a network of intelligent computers, devices, and objects that collect and share huge amounts of data in a manufacturing plant to improve the entire operation and processes of the plant and business.

Generally, IIoT can affect the LPG business in many diverse ways. Each way complimenting each other to make the impact more appropriate and indispensable. Many things drive the businesses in the LPG business to adopt IoT and figure 9 gives the summary of why IoT is adopted and the weight on each purported reason.

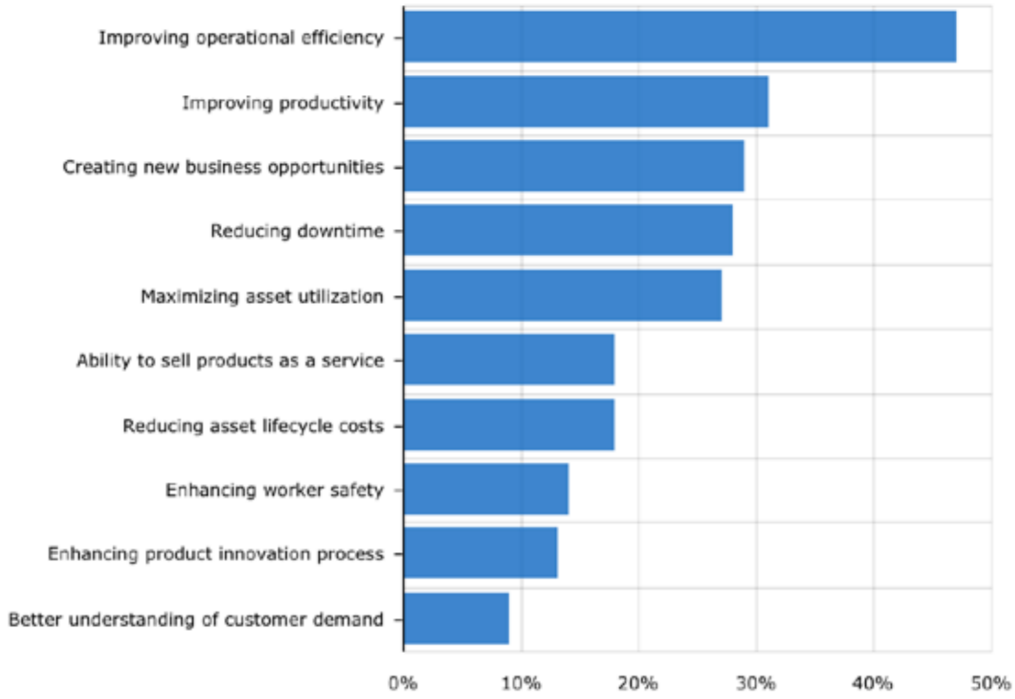


Figure 9: Weighted reasons for IoT adoption in LPG sector (WLPGA, 2019)

However, the specific impact of IoT in the LPG sector can be elaborated as follows

- Real time positioning and arrival information of vessels shipping LPG products can be collected using IoT technologies like RFID to enhance the supply chain thereby

making it more effective and efficient. Also, the sensors could give actual information on products being moved in tankers, pipes and on the road. This will improve calculating availability of the LPG in the sector correctly.

- Sensors on LPG plants could also communicate to customer portals and based on cylinder and LPG availability, the system can be altered to supply to the customer in need.

- Cylinder tracking can be made easily with IoT. It could be tracked in transit to show the actual time it can be delivered to distributors, retailers, and consumers. Also, the RFID or barcodes on the cylinder could give information on the manufacturing of the cylinder and the state of the cylinder. This information could be used for accurate maintenance of the cylinder ensuring that the entire LPG supply chain is sage from the retailers to the end user's home.

- The LPG operation is effective if the end users (consumers) are connected to LPG distributors through IoT. This ensures that the distribution of the LPG is made on exact need bases saving waste and over hooding in certain areas in the sector.

- Asset monitoring is possible and efficient with IoT in play. It allows the LPG organizations to be able to monitor all their assets in their entire operations. It ensures real time visibility of assets in operation thereby making its allocation to appropriate departments of needs possible

- Cost optimization is ensured when IoT is adopted, and the above benefits achieved. It saves on LPG supply, assets supply and maintenance. Also, the effective and efficient supply chain cuts down on waste thereby saving money for the organization.

- New business opportunities are created in the LPG sector. There are a lot of areas in the LPG sector that is underdeveloped or with no development at all when it comes to IoT. This creates avenues for investors to dive in to invest. Through such investments, the investors will reap their money worth whiles improving the entire system.

3.8 Architectural definition and methodology

The attribute of any software determines the quality of that software. Also, the durability and stability are as a result of the architectural make-up of the software. Hence, emphasis should be put on the architecture of a software when designing any software system. Therefore, the architecture of the LPG system will follow a similar pattern involving requirement identification, design, implementation, and final testing of the final software.

Paul et al, 2010 defined software architecture of a system as the set of structures used as the basis to justify a system consisting of software elements and the relation that exist amongst them together with their respective properties. The architecture represents a high-level representation of the system structure including the key attributes of the system. Also, the structural components of the software with their relation to each other are identified using the interfaces between them. The interaction between components in a software system structure are defined by the interfaces that exist in the software showing the external visibility and behavior.

However, despite the importance of the structure and behavior of a software architecture, it does not stand on its own but affected by the software's functionality, performance, flexibility, reuse, understandability, restrictions, economic and technological commitments, and their aesthetics with relation to decisions involving the design of the software (Jacobson et al. 2000). The views represented in the LPG system architecture will show the responsibilities of each of the components in the system, the interfaces and how they related to each other in the central database of the LPG system. The views depicted in the architectural design will show the specific requirement of the LPG registry with respect to the different stakeholders. This serves as the basis for correctness and architecture quality assurance.

In this thesis, the 4+1 view model of software architecture shown in figure 10, will be used to address the importance of the stakeholders and the components that will be important to serve their needs in the system. The model is best to justify and enable an elaborated design and implementation of LPG software registry system. The 4+1 view model consists of multiple views and perspectives that handles the specific need of a stakeholder in the LPG software.

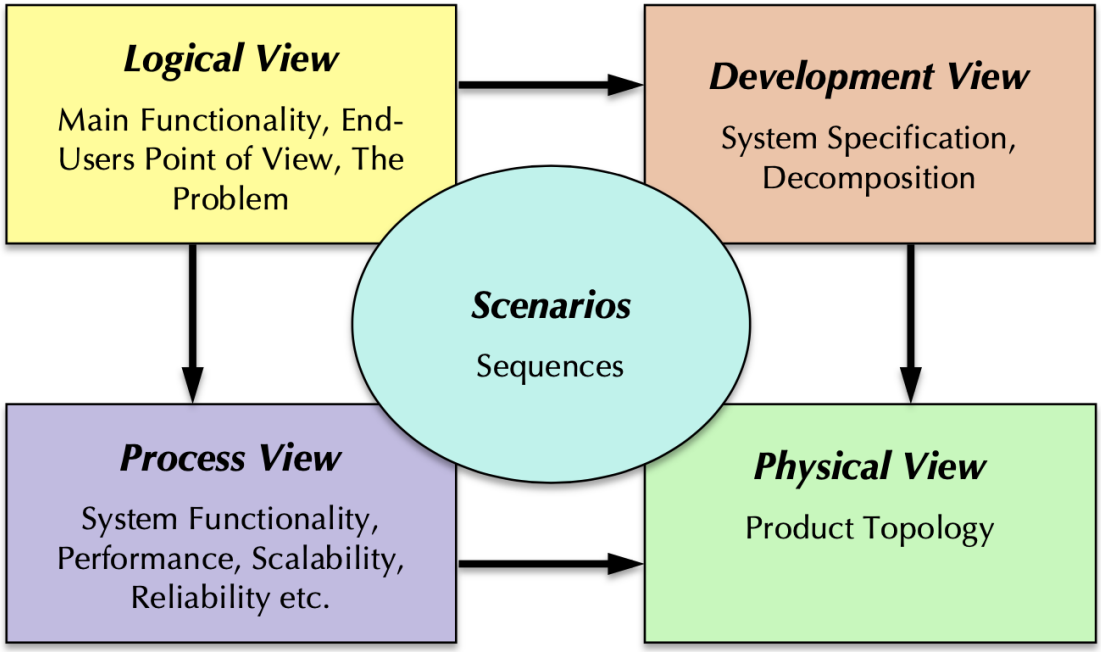


Figure 10: Model of a software architecture view

Kruchten, 1995, describes the 4+1 view model as follows,

1. Logical view: This part represents what the system is designed to perform through its functionality showing key system abstraction with their dependencies together with the data that they hold.
2. Development view: Function decomposition takes place under this view. The decomposition involves the relationships between objects, functions and their procedures.
3. Process view: This view describes the non-functional requirements of the software system like performance and the availability. The view elaborates and gives detail account of the integrity of the system coupled with the distribution and concurrency of any issues related to the system.
4. Physical view: The various views above are integrated through the physical view considering also the non-functional requirements of the system including scalability, availability, performance and reliability.
5. Scenarios: This view gives a vivid understanding of the entire system by combining the logical, development,, process and physical view using use cases. It depicts the interaction objects amongst themselves in the system

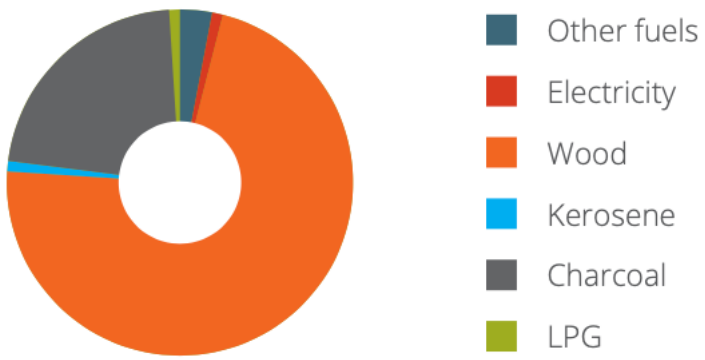
4 Design

4.1 Conceptualisation through feasibility studies

This idea was conceived through a feasibility studies done by talking to people in the field. The information retrieved from the interviews was combined with literature on the subject to ascertain the importance of such a solution for the LPG market in Ghana.

The LPG business in Ghana is becoming lucrative as the government has shifted its focus on the adoption of LPG consumption in households. Despite a slight dip in the growth in 2013, the adoption of LPG has been steady over the past decade. The steep growth in LPG forces Ghana to import LPG since it falls short of meeting the demands of the consumers. The consumers are mostly for residential and industrial purposes. According to WLPGA, 2018, LPG demand per capita has risen to over 6 kg per year driven by a government driven programme to transition the population away from traditional fuels to LPG. Though Figure 10 show more than 85% of households in Ghana still rely on traditional sources of fuels including wood and charcoal to take care of their household needs, it is evident that there is a rise in the LPG compared to the biomass fuels (wood, charcoal) (WLPGA, 2018).

It can be seen that the reliance on LPG is very small Ghana (figure 11). It is about 10% in comparison to other forms of energy consumption. This low consumption is due to many factors for which one is the reason why am undertaking this endeavor.



.

Figure 11: The consumption of fuels in Ghana (WLPGA, 2018)

Despite the low consumption of LPG in Ghana, majority of the consumption goes to household usage as seen in the figure 12 below. This makes it a lucrative sector to do

business. Also, the focus on LPG in recent years by the government has shifted attention on the use of LPG in Ghana. Currently the use of LPG compared to the rest is on the ascendancy. This is bringing a lot of business around LPG. From the government initiative to promote the use of LPG in Ghana to enhance overreliance on biomass to improve the environment, it was documented that the adoption of LPG is due to three factors. These are technological gap, delivery mechanisms, inadequate margins, and illicit use.

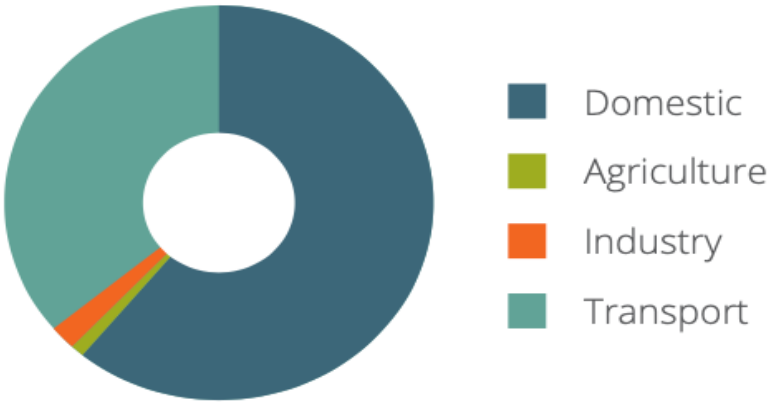


Figure 12: The consumption of LPG by sector in Ghana (WLPGA, 2018)

Therefore, the idea behind the research is to find out the need for a digital service platform as a business if needed at all. But from the feasibility studies it can be deduced that not only will such a platform enhance the adoption of LPG in Ghana but also create an entrepreneurial opportunity within the LPG business sector

4.1.1 Present state of the LPG business in Ghana

This part reiterates some of the players mentioned through the people I spoke with as to which people are involved in the LPG business from the refinery to its consumption.

The stakeholders in the LPG business

A Consumer is the final consumer of the LPG for home consumption. The consumer is a person from a household that purchases the LPG for its use in the house. The consumer buys the LPG in secured cylinders. The cylinders are filled when empty at a vendor station and returned to the consumer.

LPG manufacturer is the sole manufacturer or importer of the LPG in Ghana. The LPG manufacturer produces the LPG and distribute it to LPG wholesalers in the country to redistribute to retailers.

LPG wholesaler is a business that buys LPG directly from the manufacturer or importer. Wholesalers sell the LPG to retailers where consumers can directly fill the LPG cylinders. However, some wholesalers own a retail station of their own to sell to consumers.

The LPG Vendor is the final retailer where a consumer can buy LPG. Usually, the consumer fill or refill their cylinders at the vendor station nearby or anywhere they can get the LPG.

The LPG Courier is the person who fills an LPG cylinder and delivers it to the home of the consumer. Some LPG vendors have that service of filling a cylinder of a consumer upon request and taking it back to the consumer.

The LPG manufacturing process

In Ghana, LPG is either refined or imported to make up for the demand in the increasing quest for the fuel. The lack of adequate amount to meet the needs is due to the fact that LPG is manufactured by only company in Ghana namely, Tema Oil refinery (TOR). Oil is refined in Ghana, and it provides the Ghanaian population with a host of refined oil end products including LPG (Mensah et al, 2013). TOR on the other hand is regulated by the national petroleum authority to make sure that the production of the LPG and other products are according to the standard set by the head governmental body the energy commission. The only task of TOR is to refine and distribute it to the LPG Marketing Companies (LPGMCs) and Oil Marketing Companies (OMCs).

The refinery

TOR takes into its manufacturing and refineries crude oil and refine it into various petroleum products. These products are LPG, Gasoline, Kerosene, Aviation Turbine Kerosene (ATK), Diesel/Gasoil, Premix Fuel, and Residual Fuel Oil (RFO). These refined products are then sold in its form to various petroleum companies in accordance with the guidelines set by the Ghana petroleum authority.

Transportation of LPG

TOR transports its finished refines oil products to wholesale oil companies. These wholesale oil companies are termed OMC or LPGOMC. The marketing companies purchase the refined LPG and other oil products and transport it with their own trucks to their storage the facilities across the country. The predominant vehicle used for the delivery of LPG to retail vendors are bulk road vehicles.

The LPG Wholesale business process

The people I spoke with just as the literature states that the wholesale LPG business is a vital part of the LPG business in Ghana. They are the link between the refinery and the final retailers. The good of the business they do, enhance the availability of the LPG across the country since the transportation burden is on them. The wholesalers also known in technical terms as LPGOMC uses storage facilities to unload their trucks in vantage points close to their retail partners. There are many LPGOMC in Ghana. Some are bigger and have their own retail stations to sell directly to consumers. There are a few individual or private business citizens involved in the wholesaling. Currently there are about 19 wholesale companies in Ghana. Some have their own retail stations as mentioned above or are franchising. Some of the companies according to (Mathew et al, 2011) and also reitereated through the interview include Anasset Company Limited, Annandale (Ghana) Limited, Cent-Eastern Gas Limited, Go-Gas Ventures Limited, GOIL (Ghana Oil Company Limited), Joekona Company Limited, Kaysens Limited, Lambark Gas Company Limited, Lone Star Gas Company Limited, Louis Gas Company Limited, Manbah Gas Company Limited, Nextbons Gas Limited, Ocean Oil Company Limited, Rootsenaf Gas Company Limited, Shakainah Ventures Limited, Shelleyco Petroleum Limited, Trade Cross Limited, Trinity Oil Company Limited, Virgin Petroleum Limited and Xpress Gas Limited.

The LPG retail business process

The business through the literature and as told by people in the business is that the business of LPG retail is as simple. The Wholesalers unload their trucks into storage facilities of retail stations, and they intend sell directly to consumers. Some of the wholesalers (LPGOMC) have their own retail stations or they are using franchising to expand their reach in the country. There are a lot of private or individuals involved in the LPG retail business especially in the rural areas and areas that are out of the reach of prominent companies.

Consumers come to the retail station with their LPG cylinders to refill it. There are few of the retail companies offering the refilling and delivering the cylinders to the consumers. This means they will pick up the cylinder from the household when a consumer calls for refill and then return it back. This is the only sophisticated service that one can get in the LPG business in Ghana. There are about 60 retail LPG vendor companies in Ghana. The most popular doing business can be seen in table 1.

Table 1: LPG retailers in Ghana

Retail vendor	**Market share**
Goil	11.10
Trinity	8.94
Mamba Gas	6.98
Louise Gas	6.39
Lone Star	5.73
Virgin	5.43
Joekona Co	5.14
Anasset	4.35
Kaysens Ltd	3.31
Trade Cross	2.96
Star Oil	2.36
Modex Pet	2.33
Cent Eastern	2.14
GOGAS	2.10
Quantum Pet Ltd	1.96
Superior	1.95
Glory Oil	1.80
Frimps Oil	1.75
Galaxy	1.30
Lambark	1.11

The filling, distribution, and management of LPG cylinders

The LPG distribution system or structure in Ghana employs the use of filling plants across the country usually supplied with bulk LPG. The consumers own, retain, and maintain their own LPG cylinders. Cylinders are used by consumers for their household usage. There are different sizes of cylinders used in Ghana since there isn't any standard for the cylinders yet. Though 14.5 kg size is the predominant size being used. The have to own the cylinders and make sure that it is in good condition. There are regulations in the sector but there seem to be no one actually enforcing it to make sure that people are obeying it. There are policies and ideas going around of cylinder rotating to make it easy for many Ghanaians to be able to afford the use of LPG since the initial cost of adoption is high.

Consumers take the cylinders to a nearby LPG station, and it is filled with the gas. They then take it back home. As mentioned above there is a service of filling and refilling of LPG gas by some retailers, but this is not prevalent and comes at a hefty price. The cost of new 14.5 kg cylinder in 2018 was about was 67 Ghana Cedis (US$44) (Mathew et al, 2011). This makes it very expensive for an average Ghanaian. This is because there are only 2 dealers (Ghana Manufacturing Cylinder and Sigma Gas) in cylinder manufacturing. They do not manufacture them from scratch with steel but import semi-finished cylinders and refine it. The system of consumers owning the cylinders with no procedure of check and exchange tends to compromise safety.

The management of cylinders falls solely on the consumer. Though there are regulations and principles for a cylinder to be deemed safe before use, there isn't anyone checking to make sure that consumers do abide by the regulations. Cylinders needs to be recertified and no one is checking that either. Some retail vendors do offer cylinder checking but they do only basic maintenance including leaks, valve, and repair for a leaked head.

4.1.2 ICT state of LPG home consumption business

Everyone will assume that in the 21st century a business as lucrative as LPG home consumption will be laden with an IT infrastructure but not in the Ghanaian context. The business of LPG being refined till it gets to the consumer at home is purely manpower base. Everything is done manually with minimal or no IT at all. This will slow the progress of the business and hamper the rapid adoption of LPG by many households in Ghana. Though the business is profitable in perspective of the business owners, it will be more expensive to the consumer since the cost are passed on to them.

4.1.3 Problems and development needs

The LPG industry is profitable, but it is with a lot of challenges that if rectified benefits the business and consumer as well. The market tends to be more concentrated more in cities whiles leaving the rural areas deprived of LPG. Figure13, shows the some of the reasons why households in Ghana do not use LPG. The list is not exhaustive, and the rest of the reasons are listed below and described.

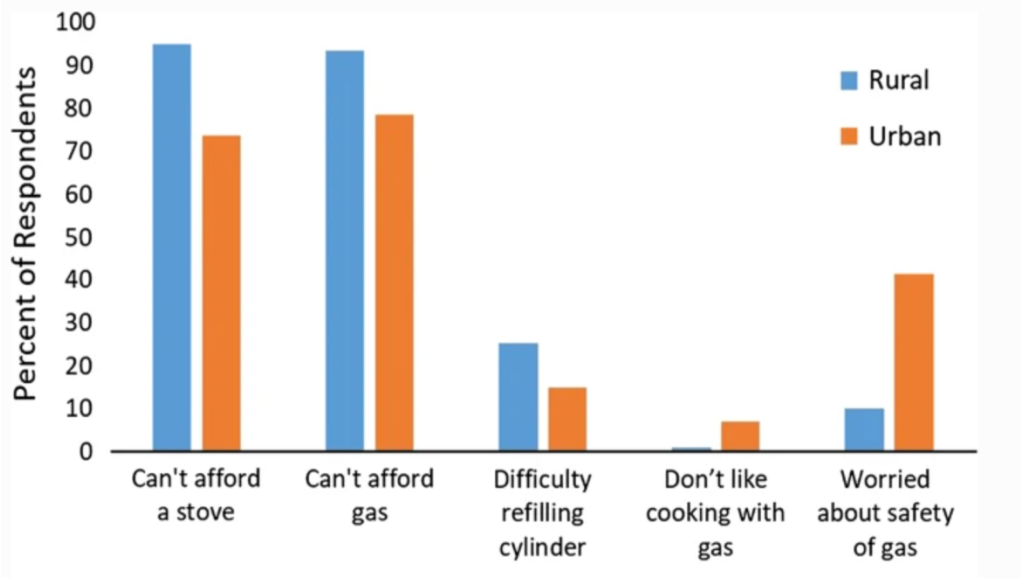


Figure 13: Reasons for not adopting LPG

Technological gap

Technology is the backbone of every business lately and LPG business is not an exception. However, the technology level of the entire is minimal creating a situation whereby people rely on manual processes and operations. This leads to downtime in the operations resulting in erratic LPG shortages in the country. Also, there is an effect on the retailing of LPG. Furthermore, there is gap in the actual equipment used in the households for the consumption of the LPG. Is either the stoves are old fashioned or the cylinders are not of the best quality and technological standard.

All these needs to be addressed for the LPG business to reach the height that the government and businesses envisage.

Delivery issues

Though LPG is a lucrative business, private enterprises are unwilling to venture into the sector fully or to help a part of the supply chain between the production to consumers

(WLPGA, 2018). This is because private enterprises find it difficult to attain loans or investments for such the LPG business. This creates a gap in the delivery of the LPG to consumers since bigger companies cannot do it all. Therefore, delivery of the LPG itself remains one of the areas that is less explored and laden with business opportunities. Solving the delivery issues will go a long way to not only in helping in the adoption of the LPG by Ghanaians but will in itself create a lot of business opportunists for Ghanaians.

Inadequate margins

Ghana is a dispersed country with a lot of people living in rural areas which are difficult to access. This makes it difficult of LPG companies to reach those areas as equal as they do in the urban areas due to cost involved in getting to the rural areas. Also, the rural communities lack the financial ability to adopt the LPG usage due to entrance barriers like the cost of LPG stove, hose, regulator, and cylinder. Alleviating all these issues will help with enhancing the business of LPG.

Lack of an efficient and reliable supply chain for LPG

TOR produces enough LPG to meet the demand and supply of LPG. However, there are frequent shortages of LPG in the country due to excessive downtimes at the refineries. Also lack of enough of operational storage facilities makes it unable to accommodate over production during times that the capability can cope with. As mentioned above, technology plays a role in the erratic unreliable supply of LPG in Ghana. Therefore, it would be effective to combine the technological gab solution with this to make the solution very efficient.

Absence of effective policy measures and regulatory regime

There is a lack of standard and regulation in the LPG sector hampering its development. Most of the LPGOMC and OMC are using their own standards which creates an uneven business environment in the sector. The bigger companies take environmental and safety issues seriously and spend a lot on it whereas the smaller companies do not. It makes the competition different in terms of profitability. This has led to some big Oil companies like Shell and Total exiting the LPG business. Again, the low investment in the LPG business is as a result of lack of policies and regulations that creates a hostile environment (Edjekumhene et al, 2007).

High recurrent cost of refilling cylinders

The nature of the LPG usage is such that its incumbent on the user to always take their cylinders to nearby stations to refill them. This process is repeated every time the cylinder

is empty of gas. This is an unnecessary process that puts a lot of strain on the adoption of LPG. It repeats a process that can easily be eliminated if the entire gas system is structured in a way to avoid repetition of some process. In other words, it will be better if the system is automated a bit to avoid redundant processes.

Lack of knowledge in health and environmental benefits associated with the use of LPG

LPG using by people directly saves the natural vegetation of depletion since people will not be relying on biomass fuels. Also, it indirectly helps with pollution of the environment from its clean emissions compared to other forms fuels for household activities. However, there is lack of education on the importance of LPG and the good that it does to society as a whole. Therefore, people tend to depend on biomass without knowing the consequences of their actions will do to society in the years to come.

4.1.4 Summary of feasibility

From the studies combing through the LPG market coupled with interview and questions, it cand be deduced that there is a lot of things happening in the LPG busines sector in Ghana. Most of the things taking place are for the better of the sector. However, there is a lot of room of improvement. A lot of things to add to the sector to make it more lucrative and to attract new businesses and consumers. The summary of the deductions is as follows

- Ghana has only one LPG refinery or importer of LPG by law in the entire country namely Ghana petroleum company
- The refined or imported LPG is dispatched to wholesale companies collectively called LPGOMC or OMC.
- The LPGOMC and OMC redistribute the LPG to retailer stations for which someone of them own themselves.
- Consumers buy LPG with their own cylinders directly from retailers
- The LPG business process is manual base with no automation or IT infrastructure
- Consumers have to go back and forth to the retail station to refill their empty LPG cylinders for use.
- There are a few home deliveries but that is also done manually with no IT or automated system.
- Lot of waste in terms of time and money in the system due to the manual nature of the process

- Plagued with a lot of challenges that borders on technology, regulation and cost related issues.

4.1.5 Deductions from feasibility

I deduce from the studies above that for the LPG business to be more lucrative devoid of the issues above, there should be the following

1. Investments in ICT and it should be aligned properly with the business process
2. The ICT adoption should create a platform that links all stakeholders together
3. The platform should be smart to weed away all the waste in the system
4. The system should be consumer centric to create value for the consumer

Therefore, I propose an LPG service delivery platform that will consist of

- A mobile application for all the stakeholders (Wholesalers, retail vendors, consumers, Delivery merchant). This will have links to each other so each business partner can seamlessly be on real time contact with the other.
- Incorporated LPG delivery process
- Smart cylinders
- A regulation process

The mobile application

The mobile application will be built based on the business requirements of the entire LPG process from how the LPG retail vendor is stocked until the LPG gets to the house of the consumer. It will be able to take care of all the processes involved. The application will make it possible for all stakeholders to monitor the business they do with their partners including the consumer. That means there will be a consumer management system as part of the application. There will a as many tailored applications as there are stakeholders. Furthermore, there will be a backend application that manages all the applications.

LPG delivery process

There will be delivery partner in the business that works to deliver LPG gas to consumers. However, to make this easy the application will have a delivery management system as part of it. This will work in conjunction with the smart cylinder to monitor when to fill and refill. Therefore, anytime the is a need for a cylinder to be refilled, the delivery management agents will pick the information from the system and do the delivery accordingly.

The smart cylinders

Smart cylinders will be used in this business process. Sensors will be attached to cylinders. The sensors will pick and transfer LPG usage information to the application for processing. The processed information will be decimated to the required section in the entire business supply chain to act on. This is a difficult part of the solution to the Ghanaian LPG issues, but it is a wise and viable way to make the system effective and efficient.

Business management system

This is the part of the web application that will manage all the various instance of the applications used by the stakeholders. It will be the backend of the entire business. In other words, it is the administration portal of the business I will be building. The security of the system will be given absolute importance to avoid any disruption in doing business.

The regulation processes

The smart cylinders will pick up leakages and other faults with cylinders together with the usage of the LPG. This information will help in making sure that the cylinders are in good condition and conform to a standard accepted condition of a cylinder in the business. The gathering of cylinder condition will help regulate the entire LPG business as whole. It will make it safer and environmentally friendly to use thereby increasing the trust people will have in adopting it. If this is done properly, it will serve as the basis of regulating the cylinders used. This means the business needs to work with the authorities to set out the criteria for the cylinders used.

4.2 Technical specification

This chapter presents and describes the requirements for the central database service of the LPG system. Section 1 presents a general overview of requirements engineering and the methodology that will be used to achieve it. The LPG system components and their functionality are broken down on a high level under this chapter section. Also, the business use cases, and the business drivers are presented in section 4.3 and 4.4 respectively. Section 4.5 describes the quality attributes. Section 4.6 presents the scenarios based on identified qualities attributes. Lastly, a utility tree for the intended system is presented in section 4.6.4.

4.2.1 Definition

There are many definitions for a requirement for a system. It is defined by the IEEE 1998, as

5. The capability or assumption required by a user of a system to alleviate a problem or reach a goal
6. The capability or height to be reached by a system to abide by a set contract, specifications or any other agreed upon document

The sole purpose of requirement engineering in any software development is to capture the needed capabilities from the business side of things and provide a framework as a guideline to achieving the what the system is set out to do. It is a formal and systematic way of making sure that all the necessary parts of a system to solve a problem or reach a goal is met and not missed

The LPG system requirements is elicited from the interview conducted coupled with the known facts in literature. The ATAM framework would be used to ascertain the perceived system based on the attributes of the intended system to see if it is of good help to solve the the LPG sector problems. Therefore, the requirements of the LPG sector elicited through the interviews and the literature will be evaluated from the angle of quality attributes and how well it can help the LPG sector in Ghana. This will be done considering expansion of the LPG system in the future. Though the elicitation of the business requirements was done using the interview and literature during the conceptualization process, the business drivers (what actually drives the business) are used to come up with the best non-functional requirements (quality attributes) of the LPG system. The quality attributes in a way is needed to ascertain the system's operation in the future. Furthermore, the quality attributes derived from the process are compressed into a utility table based on the ATAM framework to show priority placed on each attribute during actual implementation.

4.2.2 Requirement analysis

The complete specification of the LPG system is outlined by using the ATAM process to analyze the system's architecture. The specifications are further divided into functional and non-functional specifications or requirements to give better clarity of the purpose of each in the system.

The boundaries of a system are ascertained properly by checking it against standard peer reviewed similar work or using a set requirement attributes and comparing the system's characteristics with. By so doing, the system can be checked against criteria like

- ✓ Necessary: A characteristic or a requirement that if missing the system loses its capability to perform as perceived
- ✓ Appropriate: This is the criteria that tends to avoid anything in the development of the system that is not necessary. In a way, are the requirements within what is necessary or appropriate to achieve the set requirements.
- ✓ Unambiguous: This check if everything in the system is clearly stated in the requirement or that is not beyond the scope of laid down requirement.
- ✓ Complete: Also, this describes the ability of the development captures all the requirements that is necessary to give the system its intended capabilities within the constraints and quality set out in the requirements
- ✓ Singular: in determining the proper boundaries of the system, it's good to set the capabilities, constraints and quality factors explicitly
- ✓ Feasibility: This check if the development of the systems capabilities can happen within all the constraints such as schedule, cost, legal issues within an allowed risk level
- ✓ Verifiable: It brings out the idea of making sure that the requirements set out to develop can be verified in a way that it can be accepted by the customer
- ✓ Correctness: this is to ascertain that the system is the right representation of what the customer needed and asked to be built for.

When the above criteria are adhered to during the requirements elicitation to set the boundaries of the system then all the components of the system are considered properly using a structured framework. The boundaries of a system can derive from the user's perspective on what their needs are, but it is the architect or the designer's responsibility to determine the actual boundaries of the system prior to building the system.

4.2.3 Requirement's elicitation assumptions

Several assumptions are made in any software development process to enable the smooth design of the system. This makes it easier and effective to get the intended purpose of the system and keeping it within scope. The assumptions made in the design and development of the LPG system includes the following,

- ✓ Unlimited gas is available between the times a merchant opens up and closes. Gas vendors should be able to indicate the availability of their product in the service portal.
- ✓ Gas vendors don't have their own online ordering system/infrastructure, they will solely rely on us for all orders.
- ✓ Customers will be shown Gas vendors within a particular radius, say 10 miles.
- ✓ Customers are allowed to order gas from only one vendor at a time in an online order. Menu items from multiple gas vendors can't be combined in an order.

4.2.4 System components

The parts of the system are listed and explained this section. Based on the feasibility studies, literature review and the user requirement of the stakeholders involved in the LPG system, The system will consist of the following,

User Interface Client

The users of the system will access the system through the user interface via mobile or web interfaces. This makes it easy for its use on many gadgets available in the markets today. The UI will be built to make it more user friendly

Search Ecosystem

Search functionality is important in any system to provide an easy shortcut in locating vital things in the system. It's even more necessary in the LPG system considering the way LPG vendors are scattered around in the localities. Therefore, one of the most important and coveted functionalities that must be provided by the system is the capability of searching on gas products, gas vendors, among other things.

Ordering Service

The ordering system handles the buying of LPG in the system. It is designed to be able to make it easy for consumers to use considering the ICT knowledge in the society that it will be deployed in. in other words, the service will manage the time reservation and product selection, shopping cart management, and placement of gas delivery orders and payments.

Order Fulfillment Service

This is the service through which an LPG is ordered by consumers and the order fulfilled by the system. The requirements and the step by step process that the fulfillment of the order is accomplished is given below,

- ✓ Gas vendors accepts the order (using the client app)
- ✓ Customers can check the status of their orders.
- ✓ Courier partners can check the readiness of a placed order to pick up. The detail of the order is also shown.
- ✓ Notifies the couriers partner when an order is ready to be picked up

User Profile Management

This is the part of the system that deals with user profile creation and its management. It will be like an administration too for the individual stakeholders who uses the system to be able to create a profile and manage it. In other words, actors (stakeholders) in the system, namely, consumers, gas vendors staff, courier partners, and system administration will needs a way to create a personalized profile with all their details including address and contact. They will then be assigned a role based on their profile.

Courier Partner Service

The LPG is delivered by courier services. The courier service is linked to the entire LPG system and this part of the system will be used to manage the transactions between couriers and the rest of the actors in the system. In a technical level, this service will be used to accomplish use-cases relating to a courier partner. In this service, a courier partner will be able to the following in the system,

- Vieworders to pick-up from a list, and have the ability to accept.
- Accept an orders.
- View past orders that they have accepted already.
- Able to view the customer information from an order when there is a need to communicate with the consumer or inform the restaurant about any problem that stops them from picking up or delivering

Gas Vendor Profile Service

This service will be used to manage the data related to gas vendors, gas products, offerings, etc. Through this service the profiles and data pertaining the vendors, the products, and the offerings available to consumers can be managed without losing trace of it in the system. The things that can be done by a vendor concerning the products and their offerings include,

- ✓ Onboard
- ✓ Update/Delete their profile.
- ✓ Create/Update/See/Delete menus, dishes etc.

- ✓ Upload images of their LPG products into a storage service
- ✓ View their financial details on past orders etc.
- ✓ Setup a payment method for money transfers.

Notification Service

This part of the service will be responsible for sending notices to actors in the system whenever necessary. Notices sent will be dependent on the transactions of that actor and the settings placed on such transactions to receive notices.

4.2.5 IoT Module

A mobile application will be built with all the functionality mentioned above. Then upon the mobile application becoming fully functioning with all the capabilities, then that an IoT module will be added to the functioning mobile application.

Therefore, the LPG system will become fully functioning IoT service system after adding it to the existing mobile application as a separate module. In other words, the system will be built starting with a functioning mobile application tested to see its viability in the environment within which it is deployed. The IoT module is then added to the mobile application to make it a complete comprehensive system capable of doing all the things set out under the business requirements.

4.2.6 User stories for functional requirements

User stories for the functional requirements are important to bring out the paramount transactions of the main actors in the system and what the designed perceived system is supposed to fulfil upon completion. The following three user stories are also considered to give clear examples about user requirements of each user group.

User story 1: Customers/ Consumers

In the designed LPG system, Customers will be able to perform the following actions to the end of,

- ✓ Search for gas vendors based on service type and location.
- ✓ Make service reservation for gas pickup or home delivery
- ✓ Create a cart, add items to the cart and order.
- ✓ Notifications on orders placed are received promptly
- ✓ Track the order status in the app.
- ✓ Cancel the order.

- ✓ Pay for the order.
- ✓ Create/Update their account and contact information.

User story 2: Gas Vendors

Also, in the LPG system, Gas vendor will be able to the following,

- ✓ Create personalized profile (onboarding) and create/refresh/add new product items, pictures
- ✓ Receive notifications about orders placed, assigned courier partner, and update the status of order.
- ✓ Offboarding: If the gas vendor goes out of business, or decides to discontinue taking online orders.

User story 3: Courier Partner

The LPG system will facilitate and allow Courier partner to perform the following transactions,

- ✓ Receive notifications on orders in within their area or reach and choose from
- ✓ Know when the order is available for pickup.
- ✓ Inform the customer/gas vendor of any problems they encounter while executing the order pickup/delivery.
- ✓ De-register in case they don't want to continue with the job anymore.

4.2.7 Non-functional requirements

This part of the requirement details the ability of the system to provide services to many users simultaneously and still making sure that the access is granted at all time without any interruptions or denial. The service should be able to do the following

- ✓ Provision of accurate and reliable information to the users of the system at all times
- ✓ Guaranteed privacy concerning the data exchange during clients transactions of all user information with authentication that goes with the highest degree of certainty.
- ✓ The designed LPG system should have an inherent trust built into it by ensuring that there is no perceived or known mistrust between client/user interface and the central server. This helps prevent intrusion of entities that are anonymous to the system.
- ✓ The uptime of the system should be about 99% and it should be built in a way that any failure on the part architecture accommodated by the system without any adverse effect on the business transaction.

- ✓ High loads during peak times of transactions shoud be manageable with out any problems or downtimes.
- ✓ Ability to extend the features of the system when the need arises should be possible without necessarily altering the architecture of the entire system.

Stakeholders

The stakeholders in the LPG system being designed as mentioned above will be consumers, Gas vendors and Courier partners. Gas delivery integrated commerce system (GDICS) will be the commercial name of the LPG system being designed when ready to deploy as a commercial entity in the LPG sector in Ghana.

4.3 Business use cases

In accordance with the system being designed as described above in previous chapters, the intended system will be leveraged by various stakeholders, by allowing Consumers, Gas Vendors and Courier partners to use such an integrated commerce system. The primary goal is to provide accessibility and reliability, to allow identified components to connect and interact with the integrated commerce system from any platform, anywhere and anytime.

In order to understand the scope and therefore the initial constraints of the system, it is important to analyze the quality of the service that shall be provided to the client applications talking to the central system. There will be a deployment based on business operational for a proper quality of service.

4.4 Business drivers

The system to be developed from the concept conceived, would be implemented to be independent of any other technology or systems out of its inner network. However, it would be built to extensible friendly to third parties that will want to join simply by addition of extra modules to take care of the externability of the proprietary software or systems.

Furthermore, analyses of the system's purported service based on the requirement from the use cases above will be done properly taking into consideration the core business of the LPG system as a whole

4.5 Quality attributes

Quality attribute elaboration during a system design help to inculcate into the system the desired attributes to help the system survive the test of time and to scale properly. The GDICS attributes will be described in detail as required by the evaluation tool used in the thesis (ATAM). ATAM requires that the attributes are finely and properly characterised to be able to use it as a basis of judging how well the system will withstand test going forward. The attributes that will be considered in the LPG system include the following

4.5.1 Performance

Performance is an important quality attribute of any system. However, in the context of the LPG system (GDICS), it will be considered in the perspective of how it can be accessed on a real-time basis when queries and updates are made from clients in the system. It is a critical service feature architecturally since it goes to the core of how the system serves the clients or users of the system. The user experience of the system will reflect on the prevalence of congestion in the system when requests are made. If the congestion becomes a drawback and making real-time service delivery a problem.That will have an impact on the reliability and availability of the system to its users. Therefore, performance as an attribute is important thing to look at during the design. Technically the performance quality attribute can be look at properly under the following factors,

- ✓ Data Latency
- ✓ Transaction Response Time
- ✓ Transaction Throughput

4.5.2 Reliability

Reliability is an important quality component of a system, and it shows the degree to which a system can be operational under all conditions with respect to time. It's a measure of a system's ability to do what is intended to do without failing its users. The reliability of the LPG system can be properly ascertained technically looking at

- ✓ **Backup Plans:** There should be a systematic and prudent plan that will automatically create an exact copy of the data of the LPG system for use in case of any failure. The system will fall on whenever it loses its operating data. Thereby making the system reliable in the eyes of all stakeholders.

- ✓ **Replication of site:** This is a phenomenon in which a site in used is cloned for other purposes. It is like having something to fall on in case of the original site going down to be able to be up and running straight away.
- ✓ **Service Availability:** This is giving assurance that the service provided by a system availability will extend beyond its normal availability irrespective of system, hardware, or software failure. Hence making it highly reliable.
- ✓ Data Availability: This is similar to service availability only that the emphasis is on highly availability of data within a service through calamities and normal situations.

4.5.3 Security

Security is the ability of any system to prevent external actors from gaining access to it deliberately or accidentally. Hence the importance of security in the LPG system and it should be designed to inculcate all the features to guarantee a high security. The quality attribute can be obtained technically effectively by dividing the security into aspects such as

- ✓ **Authentication:** The process of designing a system to only allow authorized users of the LPG system in by comparing their user credentials to that stored in the database of the system
- ✓ **Authorization:** This is the access levels that will be allowed in the system through authentication above for users to be able to access certain parts or functions of the system.
- ✓ **Encryption:** It's the process of ensuring that the users of the LPG system are the only ones that can decrypt any data in the service. This will keep the integrity of the information stored in the service preventing unauthorized persons from accessing them.
- ✓ **Integrity:** This is achieved when the above security attributes are achieved. Then it guarantees that the service's data are correct, accurate and devoid of threats from bad actors in the system

4.5.4 Modifiability

Modifiability is one of the business drivers needed for the proper functioning of the LPG system and therefore, it is essential to build the system with such capabilities. Modifiability according to IEEE 1998 consist of two parts

1. Maintainability which is the ease for any software or software component to be modified to change faults, enhance performance to reflect to environmental change

2. Flexibility which is the ease for a software to be altered when necessary to be used in a different application or environment than what it was initially designed for.

Modifiability as a quality attribute can be divided into the following sub factors to make it easier to look at concerning the LPG system

- Addition of a new module or functionality
- Module or functionality removal
- Flexibility

4.5.5 Usability

Another business driver that is necessary for the LPG system is the degree of how the system is used by its intended users. This relates to its simplicity, user-friendliness and how its interface is well designed to fit the capabilities of its users. The quality attribute beneath this is therefore the user experience of the application itself. The more the application is designed to be clear and intuitive to capture the imagination of how its users will use it, the better its usability. The usability has the following sub-factors

- ✓ Learnability (Ease of learning)
- ✓ Adaptability
- ✓ Effectiveness
- ✓ Efficiency
- ✓ Error tolerance
- ✓ Engagement

4.6 Use Case Scenarios

There are many approaches to analyze a system's intended purpose and ATAM is one of them (Kazman et al, 1996). ATAM employs the use of scenarios to specify a system's requirements in the best possible way. The scenarios in this context are used to examine the effects of the architecture of the intended LPG system in the future. Scenarios are categorically divided into Use-case scenarios, growth scenarios and exploratory scenarios. Use cases is a way of elaborating how a system's users will interact with it when is fully functional. Growth scenario on the other hand the future description of how any change to the system's usage will be. Also, exploratory scenario happens under extreme conditions when a drastic change needs to happen to the system.

4.6.1 Quality Use case scenario

Use case Scenario 1

This is a derivative from performance as quality attribute and it specifically relates to the intended transaction response time of the LPG system when implemented. In other words, how well and long request made in the LPG system will take

Table 2: Use case 1 (Performance)

UCS 1	
Quality attribute	Performance
Stimulus	A user adds an item into shopping cart while the system is under peak load
Response	Users' shopping cart is updated
Latency	Update data in 200ms
Priority	High
Level of difficulty	Medium

Use case Scenario 2

This is also based on the performance and again on the response time of the LPG system when implemented and operational

Table 3: Use case 2 (Performance)

UCS 2	
Quality attribute	Performance
Stimulus	A user adds an item into the shopping cart while the system is under twice the current peak load
Response	User's shopping is updated
Latency	Update data under 1 second
Priority	High
Level of difficulty	Medium

Use case Scenario 3

Again, this is on performance as a quality attribute but centered on the data latency of the system when in operation.

Table 4: Use case 3 (Performance)

UCS 3	
Quality attribute	Performance
Stimulus	Retrieve active orders for a LPG vendor
Response	Reduced storage latency on GDIS database
Latency	200ms
Priority	Medium
Level of difficulty	Low

Use case Scenario 4

This concerns the throughput as a sub factor under performance of the intended LPG system in full operation

Table 5: Use case 4 (Performance)

UCS 4	
Quality attribute	Performance
Stimulus	At peak load, the LPG system is able to complete 300 normalized transactions
Response	Transaction processed
Latency	Transaction processed under 3 s
Priority	Medium
Level of difficulty	Medium

Use case Scenario 5

This deals with the security of the LPG system and it dwells on the authentication and authorization sub-factors of security. This shows how the trust between the system user and application are mutually built. This is a high in terms of priority since is one of the system's concerns when it comes to confidentiality.

Table 6: Use case 5 (Security)

UCS 5	
Quality attribute	Security
Stimulus	Trust establishing request in the system: 1. Application and user/client 2. Authentication credentials 3. Authorization credentials
Response	A relationship based on trust is established between the system and user/client who initiated the request
Latency	5 seconds
Priority	High
Level of difficulty	Medium

Use case Scenario 6

Reliability and back up capability quality attribute of the system is shown with this use case scenario. It shows all the things involved with a database going down and the accepted activities and time deemed proper to have it fully functional. This includes reboot, upgrade, and any fault existence. In the LPG system, any severe failure, should switch the system on a backup standby system.

Table 7: Use case 6 (Reliability)

UCS 6	
Quality attribute	Reliability
Stimulus	MongoDB fails due to Amazon Web Services (AWS) maintenance or fault.
Response	System switched automatically over to failover/backup system's database
Latency	Less than 3 seconds
Priority	High
Level of difficulty	Medium

Use case Scenario 7

This is also on the reliability show how well the LPG system will react to system failure when in use. It elaborates on how request will be routed to get the response on the replicated backup site. It's similar to the availability of the system.

Table 8: Use case 7 (Reliability)

UCS 7	
Quality attribute	Reliability
Stimulus	The system server went down for therapeutic reboot or occurrence of fault
Response	Request is routed to a backup/failover system
Latency	Less than 3 seconds
Priority	High
Level of difficulty	Low

Use case Scenario 8

This is on the usability part of the LPG system, and it borders on the learnability factor of the system. That means this section shows how well a user can adapt and learn how to use the LPG system.

Table 9: Use case 8 (Usability)

UCS 8	
Quality attribute	Usability
Stimulus	Any new vendor with minimal computer skills should be able to use the system
Response	The new vendor attains the knowledge the necessary basic systems functionality
Latency	A person a day
Priority	Medium
Level of difficulty	Medium

4.6.2 Growth scenarios (GS)

Any change in the architecture with respect to future scaling of the system are handled under the growth scenario. Its specifically deals with modifiability of the system to expand the system to include any new features or functionality. Therefore, this enables the addition of new module or functionality attributes to the system with time.

Table 10: Growth scenario 1 (Modifiability)

GS 1	
Quality attribute	Modifiability
Stimulus	A new feature is added to the LPG system
Response	The new feather added to the system is completed successfully
Latency	1-to-2-person work depending on the scope of the feature to be added
Priority	Medium

Level of difficulty	Medium

Growth scenario 2

This conerns the modifiability with respect to flexibility built into the system and how well the LPG system can be modified to be used in applications that the LPG system was not designed to be used for.

Table 11: Growth scenario 2 (Modifiability)

GS 2	
Quality attribute	Modifiability
Stimulus	Changing systems/platforms
Response	Successful migration of the system to a new system platform
Latency	A day
Priority	High
Level of difficulty	High

Growth scenario 3

This is also about modifiability and specifically on the flexibility sub-factor part of the LPG system

Table 12: Growth scenario 3 (Modifiability)

GS 3	
Quality attribute	Modifiability
Stimulus	Database software change
Response	Successful change of the systems database
Latency	A week
Priority	Medium
Level of difficulty	Medium

4.6.3 Exploratory scenarios (ES)

An exploratory scenario refers to instances where a difficult module or task needs to be added to the system. In the concept proposed, A functioning system needs to be in place first. And then an IoT module added to it later. Therefore, the IoT module addition will under this scenario. This will require a lot of effort to change the architecture. It could be just a separate system connecting with an API or built from scratch to connect. This can be a low priority scenario since it is not an immediate need of the stakeholders involved in the LPG system.

Table 13: Exploratory scenario

ES 1	
Quality attribute	Modifiability
Stimulus	Adding an IOT module into an existing application.
Response	The addition of the IOT module is completed successfully.
Latency	N/A
Priority	Low
Level of difficulty	High

4.6.4 Utility Tree

The three comprises of the quality attributes that can be tested immediately on the system. Though there are other quality attributes, those selected are what is deemed to be of paramopuint important to the immediate functioning of the system to meet its current design.

Table 14: Utility tree of the LPG system

Quality Attribute	**Quality Attribute Refinement**	**Quality Attribute Scenario**	**Importance**	**Difficulty**
Performance	Transaction Response Time	UCS 1: A user adds an item to shopping cart while the system is under peak load and the transaction completes in at most 200ms	**H**	**M**

		UCS 2: A user adds item to shopping cart while the system is under twice the current peak load and the transaction completes in less than 1 seconds	**L**	**M**
	Data Latency	UCS 3: Reduce storage latency on LPG databases to less than 200ms	**H**	**L**
	Transaction Throughput	UCS 4: At peak load, the system is able to complete 300 normalized transactions per second	**M**	**M**
Security	Provide authentication and authorization on all resources	UCS 5: Establish trust between system, services and user in 5 seconds	**H**	**M**
Reliability	Backup Plans	UCS 6: System switched automatically over to failover/backup database and system switched automatically over to failover/backup database in less than 3 seconds	**H**	**M**
	Data and Service Availability	UCS 7: A clinical reboot or a problem occurs, causing a service container to go down and request routing to a failover container service in less than 3 seconds of downtime	**H**	**L**
Usability	Learnability	UCS 8: A new merchant with basic computer skills should be able to use the system within a day of introduc-tion	**M**	**M**
Modifiability	Adding new module / functionality	GS 1: Adding new feature system and completed successfully by 1-to-2-person week depending of the scope of the feature	**H**	**M**
	Changing platform	GS 2: Changed platform and system migrated to new platform system successfully within 1 day.	**H**	**M**
	Changing database software	GS 3: Changed database software and system data migrated within 1 week	**M**	**M**
	Adding IOT module into existing system	ES 1: Adding IOT module into existing system.	**M**	**M**

H = High, M=Medium, L=Low

The utility tree in table 5 comprise the utility of the system defined as the high-level node, refined down to the level of scenarios, annotated with stimuli and responses, and prioritized. This shows the “goodness” of the system by providing relation between quality attributes and scenarios.

5 Implementation

5.1 Architectural Design

This section describes and elaborates on the design of the LPG system. It will also present the definition and methodology used in the architecture design. Also, the underlying criteria used for the architectural decisions will be described showing the entire architecture of the system with emphasis on the various views involved with LPG central registry.

5.2 The Architectural methodology

The definitions and methodology used in the thesis are detailed under the literature under section 3.8. The view model mentioned gives the design a structured way of analyzing the architecture of the system in an acceptable way

5.3 Architectural requirement analysis

The LPG system's architectural requirements will be described in this section. The selection of the architectural styles will depend on the requirements identified preceding the styles. The mapping of properties of architectural styles between them will give the chosen architecture. Again, the architectural style and their requirement sheds light on the requirement of the entire system architecture.

The boundaries and framework within which the LPG system will operate will be determined by the architecture requirement. Also, it will define the technological requirements that the system needs to support important business drivers. The LPG system can only achieve its business, technological and objectives through proper architecture requirement analysis

Table 15 tabulates the quality attributes and functions that is generated from the analysis of the User requirements.

Table 15: Nonfunctional requirements

ID	Description	importance of use	Impact to architecture	Design decision for this requirement
N1	Simple, user-friendly and well defined admin interface	High	Medium	Use React, a JavaScript library for building web user interfaces and React Native to create native apps for Android and iOS.

N2	Real-time	Medium	High	Real-time implementation of the system that supports publisher-subscriber pattern
N3	99% uptime for system	High	High	Load balance Clustering for system APIs
N4	Performance	Essential	Hight	Nodejs
N5	Secured system	High	Medium	JSON Web Tokens and data encryption would be used for client access
N6	Expandable, reusable	High	High	microservices-based and NodeJs for services

5.4 Architectural styles

Architectural style is defined as a family of systems witt respect to the pattern in a structural organization determining components vocabulary and the connectors used in instances of the the style adopted considering all the set of constraints involved in combination of styles (Garlan et al, 19994). The definition is reiterated by Klein et al 1999, stating that the types of components, topology, pattern of data description and the interaction that exist among the various components make up an architecture style. Also, the architecture style shows the benefits and drawbacks related to a particular style.

Furthermore, according to Monroe et al, 1996, Architectural style consist of four distinct parts, namely,

1. **A Vocabulary**: This defines the design elements and components. It also explains the connector types including databases, clients, parsers, filters, servers and pipes.

2. **Design rules / constraints:** The rules set out the allowable and permitted mixture of the elements involved in the design.
3. **Semantic interpretation**: This is where emphasis is made that the constraints put on the composition of the design elements by the design rules maintains their meanings.
4. **Analyses:** This is the final step to ascertain the system that it is indeed built with the style intended.

Architectural style is a significant designing artifact in classifying different classes of designs while enabling the use of experience based knowledge to show how various classes in a design are used with their associated properties.The use of architectural styles has become

popular with systems design requirement and it includes styles such as client-server, pipes and filters, data abstraction and object-oriented organization, repositories and web services. However, most systems combine design styles so they can complement each other to give the best system.

5.5 Architectural quality attributes

The quality attributes of the system based on the sector needs of the LPG sector are listed and justified in table 16 below.

Table 16: Quality attributes of the LPG system

Stakeholder	Scenario	Quality Attribute
Customer	No unauthorized access to the system is allowed.	**Security**
	All system operations should be processed in fastest possible time	**Performance**
	Any system failure should be followed by immediate system recovery	**Availability**
	Simple, user-friendly, and well-defined admin interface	**Usability**
System Architect	Components need to interact in a coordinated way	**Functionality**
	Overall consistency of the behavior of architecture is required	**Conceptual Integrity**
	Addition of new modules, like the exploratory IOT system shouldn't impact the architecture of existing system	**Modifiability**

	The system and all other system built on top of the API can scale up more properly	**Scalability**
	Major parts of the components should be re-usable for future architectures	**Modularity**
	Different parts of the system will be maintained without affecting the rest of components, as long as the API specification is respected through the changes.	**Maintainability**
System Developer	System framework should be clear, complete and perform exactly as intended	**Functionality**
	All system errors should be handled appropriately	**Reliability**

5.6 Architectural representation

The architectural requirements chapter above dealt with the system's needs of the LPG application to solve the delivery issues of the LPG business in Ghana. This chapter deals with making sure that the needs gathered from the stakeholders, LPG business and the consumers are represented properly in the overall system by building a robust architectural structure. A 4+1 system by Kruchten, 1995 would be used to represent the LPG system architecture in a systematic way. A detailed representation of the LPG architecture based on the architectural requirement are as follows.

5.6.1 Logical representation

The functions of the LPG system will be represented in this view of the design model. It will give the detail of the key architectural functionality of the LPG system. It will elaborate on how the system is built to support its functional requirements. The phenomenon behind the logical representation is to use layering strategy to summarise the various functional

requirements of the LPG system. Each of the layers in the architecture shows a representation between the layers and their responsibility in an object-oriented style. Figure 14 below represents the LPG proposed system in a level architecture.

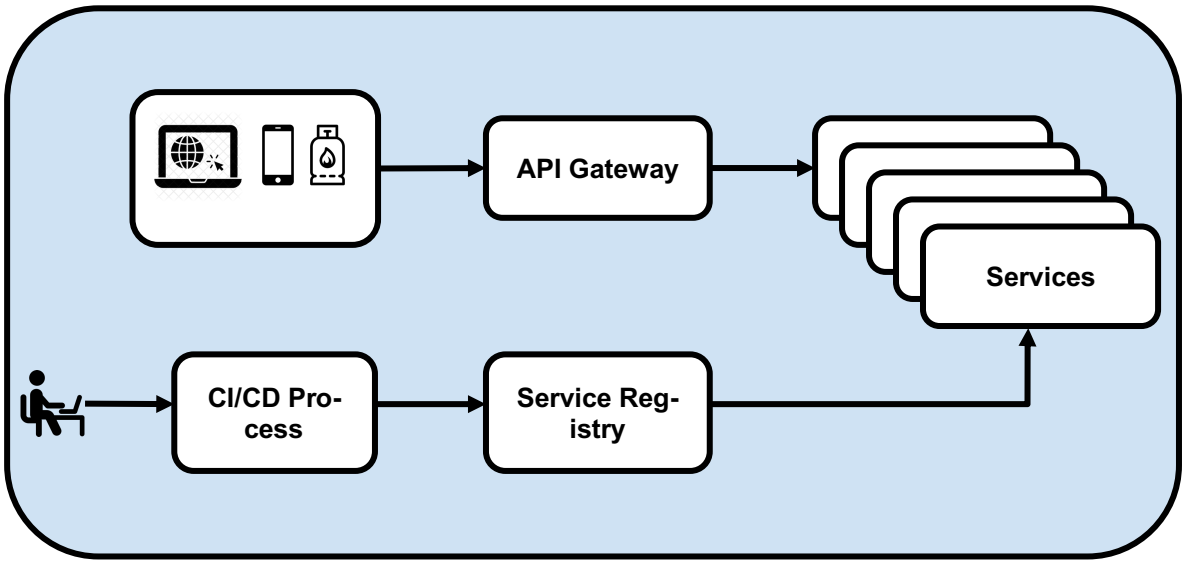


Figure 14: LPG Cloud Native Architecture

5.6.2 Cloud Native Architecture

Cloud native is an phenomenon used to build and run applications based on the advantages of the delivery model of cloud computing. It is intended that the LPG system will be deployed in the cloud infrastructure, and microservices are a critical part. In a cloud model development, applications in its complexity are designed and bundled as services and data, fully decoupled away from the application itself. This will be microservices. Microservices are architectural that builds and design an application as a bundle of services. Howver, the services bundled can be implemented with different programming languages independent of each other. This means they can be deployed and bindled into services independent of each other based on their capabiliities.

IoT is comprised of a huge deployment ecosystem with multiple applications, protocols, servers, and sensors, making it more complex to integrate applications, data, and devices. As Microservices are based on loosely coupled architecture, this can be achieved seamlessly. In the case of LPG system, each microservice can focus on a single business capability outlined as system components in the previous chapter.

Each microservice are used as a way of targeting a particular business capabillity (e.g., Search Service, Ordering Service, Order Fulfillment Service, User Profile Management Service, Courier Partner Service, Gas Vendor Profile Service, IOT Service and Payment Gateway Service). The services above can each implemented with a different language and infrastructure whiles managing it with different teams. Again, the services will have their own databeses to enable loose coupling with communication between the services and other protocols. That is evident of the flexibility expressed above.

cloud native phenomenon helps developers to be able to run applications in public, private and also in hybrid clouds. Also, it makes it easier to get products into the software market faster. Furthermore developers life is made simple as it aids them in their proesses and the technologies they employ to build and deploy. On top of that it helps with the management of apps in the cloud they develop.

The above benefits from such design styles justify why they are the best styles of design for the designing of the LPG application.

5.6.3 Process architecture

This view describes the non-functional requirements of the LPG application. It also shows how the LPG application deals with concurrency and synchronization issues in the system. The system will be built to handle multiple clients/consumer requests simultaneously so as to cater for the disconnected pattern of HTTP request or response and the ability of the database system used (relational database system). Sessions maintenance for user request will be handled using a server module (browser request). However, since the service will be stateless, the web service module will not have a session management. There will be authentication of all the systems that connects to the main LPG service/application. A successful authentication gives way to access control to the system to check the privilege accorded to the user before an action can be taken.

The J2EE model will be the basis of the LPG platform and it will handle the instances of the process (Thread). Therefore, the architecture will involve concurrency issues including synchronous and asynchronous mechanisms.

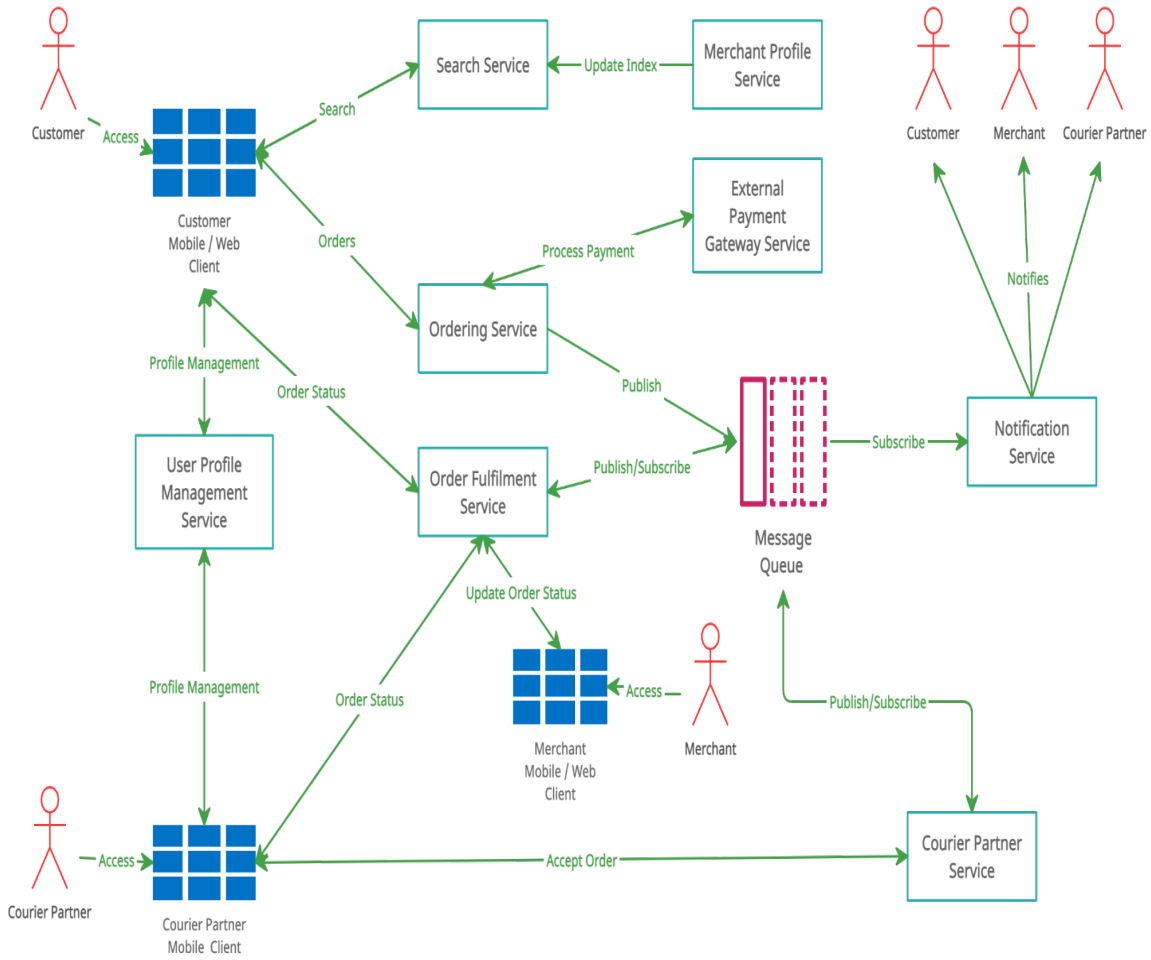


Figure 15: LPG system Process View Diagram

5.6.4 Development architecture

This part of the architecture design stipulates the system's physical composition and how its subsystems and other components are implemented. It outlines how the directories and files, data,executable files and source codes are structured in the system. Such structuring includes the nature in which software components are reused and also the issues related to programming and management of software codes. The LPG system will be built such that its layers are based and defied in the logical layer. A high level and limited implementation documentation will be done in the thesis due to time constraints. Again, the functionality implementation of the LPG system is described in this section and is shown in figure 16 below. The functionality implementation documentation will include the explicit link between use-cases, constraints and other functional attributes and their importance to the architecture.

High level implementation view

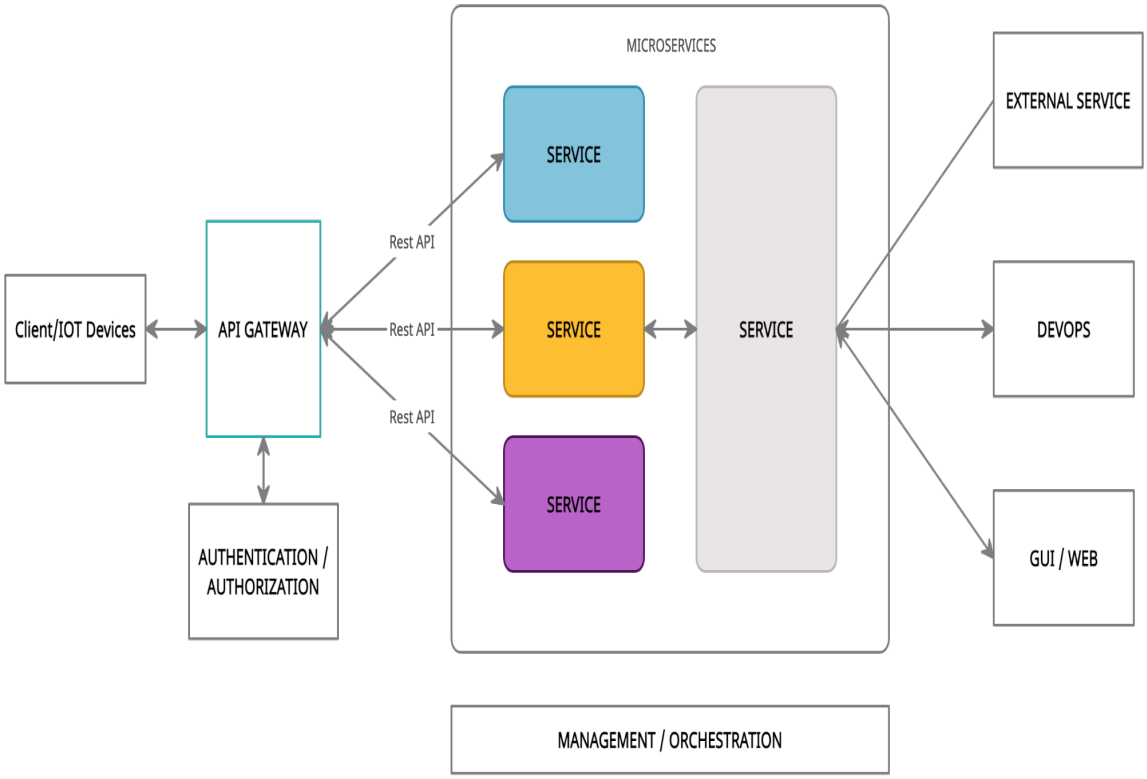


Figure 16: Implementation view diagram

The central database of the LPG system will consist of components each with a specific responsibility. A description of the components is as follows,

1. **Management/Orchestration**, which manages the start-up of services, identifies potential failures, and rebalances the workload (Kubernetes, Dockers).
2. **Client/ IOT Devices** that are part of the physical entity can be sensors, mobile devices, or computer systems.
3. **API Gateway** is an entry point for client calls, which are redirected to appropriate back-end services**.** The API gateway is used to forward client calls, decoupling clients from services.
4. **The authentication and authorization technology** is used to ensure that microservices are secure**.** As an example, OAuth2, a well-known authorization protocol, can be used.
5. **Messaging protocols** are used to communicate between different services. Depending on the requirements of the application, different protocols like synchronous (HTTP) or asynchronous (AMQP) can be used.

6. **Cloud Infrastructure** provides services like storage, analytics, and visualization, among others. A cloud computing advantage is that resources can be scaled horizontally whenever needed.
7. **DevOps** provides continuous integration and continuous delivery for the independent service due to changes in requirement or functionality.

5.6.5 Physical architecture

The physical architecture shows the degree of flexibility in the system by illustration of the non-functional requirements of the system and then showing how the software itself is mapped to the hardware that runs as the engine of the system. The LPG application physical architecture is shown in figure 17 below.

Physical view diagram

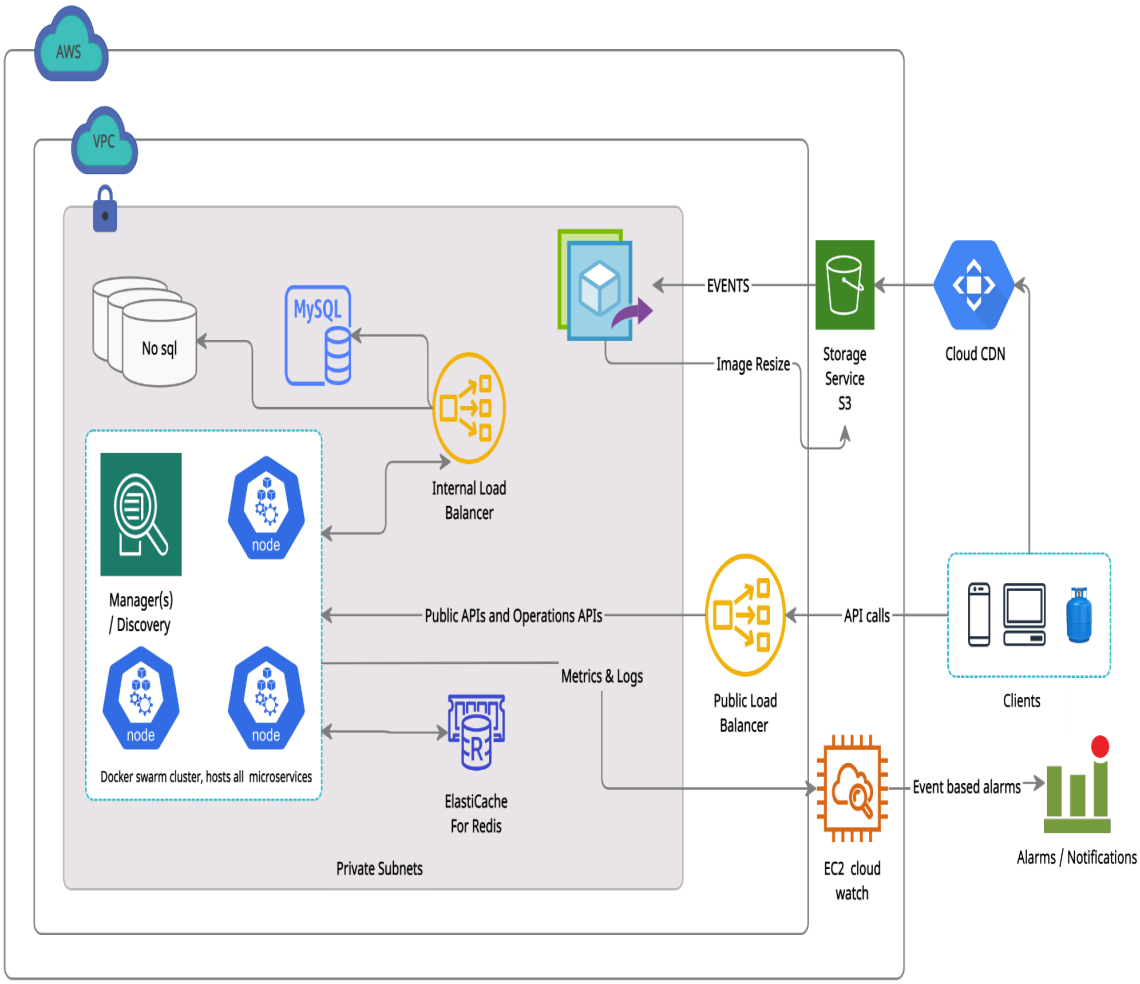


Figure 17: LPG Architecture physical view

The diagram above illustrates the proposed AWS infrastructure for LPG system in detail. The clustering concerning the detail deployment includes the following components:

1. **Virtual Private cluster (VPC):** In the cloud, this is a private network, which is logically isolated (hidden) from other virtual networks. A VPC can contain one or more subnets (logical divisions of the VPC). Subnets can be divided into two types: public subnets, in which resources are exposed to the internet, and private subnets, which are completely isolated from the internet.
2. **AWS Application load Balancer (ALB):** Used as a primary point of contact, an application load balancer distributes workload among its clients. Load balancers evaluate requests based on a set of predefined rules and direct them toward the appropriate target group. Further, the load balancer balances load among targets registered with a target group. A load balancer can be externally facing or internally located.
3. **AWS CloudWatch:** AWS's tool for monitoring all its services and resources. The system collects and displays various metrics of resources deployed on AWS (e.g., CPU utilization, memory consumption, disk reads and writes, throughput, etc.). A CloudWatch alarm can be programmed to trigger notifications (e.g., an email alert), or to complete actions automatically (e.g., auto scaling).
4. **AWS S3:** A service that allows you to store and retrieve objects.
5. **AWS CloudFront:** A Content Delivery Network (CDN) service that delivers content (data, video, images, etc.) to users upon request. An Amazon S3 bucket, or any other server that hosts data, can be connected to CloudFront, which caches the objects on these servers and serves them to users based on their requests.

As shown above, multiple resources are deployed in the proposed infrastructure. Except for S3, Cloudfront, and Cloudwatch, all resources are created and deployed within the VPC. Furthermore, all resources are located inside private subnets, as shown in the diagram. A resource spawned in a private subnet only owns a private IP address, and can therefore not be accessed directly from outside the VPC. In this way, the security is maximized.

5.6.6 Scenarios

The scenario view takes precedence over all other views and controls them. It controls all the other views discussed above. This view details the behavioral pattern of the system from the stakeholder perspective. It might seem like a redundant view since the other views

describe aspects of the system already but it is an important view considering the fact that it gives account of how the various stakeholders needs are represented in terms of architectural requirements. Figure 18 shows how the intended system will behave when the services interact with each other. Also, a detail flow of the sequence is below the digure 18.

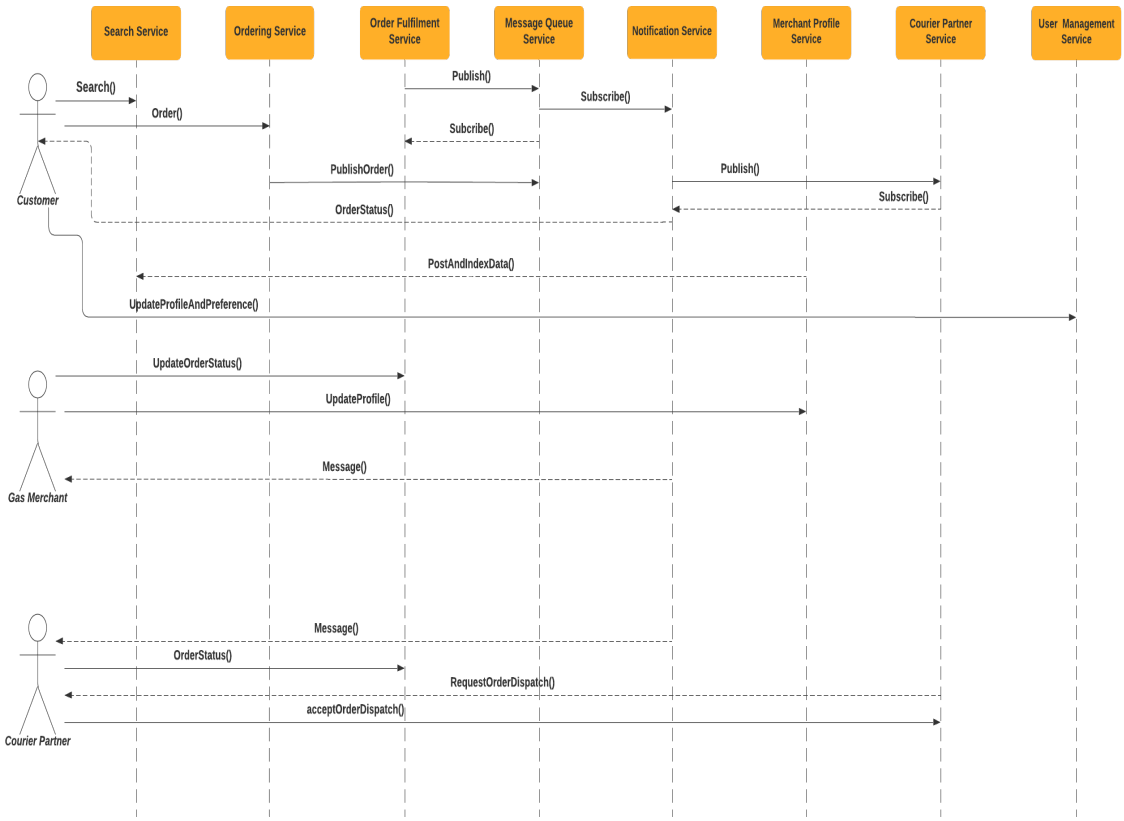


Figure 18: Browser sequence diagram of designed LPG System

When an order is placed in the LPG system, it will go through a series of sequence to fulfil the customer/consumer's request. The sequence when a customer places an order using the mobile/web client through the usage of the ordering service (OS) is as follows,

1. The Order Services picks a request and then publishes a message to the queue about an order so that the downstream services can start processing.
2. Then request put through is read by Notification Service (NS) and in turn sends a notice to the customer about the placed order being accepted.

3. The LPG vendor accepts the order using the order fulfilment service (OFS) and immediately sends a message to into the queue in the system about the order being accepted (Does changing order status)
4. The courier partner service is used to read the message sent by the LPG vendor and redirect the system by sending a message to a specific area where the order was made, or the customer is. The courier partner services have the ability to assign a courier partner to do a delivery if available. It does that by sending another message into the system's queue.
5. A message after this step is sent through the notification service to the customer of the order being accepted by an LPG vendor.
6. Also, notification sends another message at the same time to courier partners in the specific area of an availability of an order that has been accepted.
7. The courier partner service of the system is used by the courier partner to accept the order using the Courier partner service and send a message back into the system to update it of a courier having an assignment or of an acceptance.
8. The customer is then informed by the notification service when it reads the message from the courier partner service
9. The process goes on and a cylinder is filled and made ready to be picked up a courier. The LPG vendor then uses the order fulfilling service to inform the system that the cylinder is ready to be picked up by posting a message.
10. Both the courier and the customer are made aware of the cylinder being ready through a message also by the notification service.
11. The courier partner then picks up the LPG cylinder from the LPG vendor. The LPG vendor staffs then updates the system of the cylinder being picked up through the order fulfilment service.
12. The customer again is made aware of the order being picked up through the notification service
13. The courier service delivers the LPG cylinder to the customer and then sends a message to the system through the order fulfilment service that the order process is complete.
14. The status of the order in the system is then updated as being completed with a message into the system through the order fulfilment service
15. Notification service finally sends notices to both the customer and the LPG vendor of the LPG cylinder being delivered to its destination.

5.7 Summary

The architecture of the conceptualized LPG system is explained on a high-level overview under this chapter using the 4+1 view model. The chapter gave a summary of what can be detailed in an implementation requirement when actual deployment starts. It includes the architectural requirements, styles/approaches and representations depicted in view forms. The views depicted in the representations, each takes care of a stakeholder concern and needs. It also shows the implicit decisions concerning architectural approach decisions that were taken during the architecture design. This part will serve as the base for the architectural analysis in the next chapter.

6 Architectural analysis and Evaluation

Design science research involves evaluation of the product developed or designed (artifact). In other words any artifact developed needs to be taken through a thorough and rigorous process to make sure that it is built with integrity and quality. Therefore, in this sedition, ATAM will be used to evaluate the artifact designed to be developed touching on quality and risk attributes of the LPG system designed.

6.1 Definition and methodology

ATAM method is the evaluation tool adopted for the purpose of the architectural and design and analysis of the LPG system. The idea is to ascertain the system-to-be to be sure that it meets the required standard set for such a system based on the needs of the business it serves. Therefore, the ATAM will be based on the scenarios that capture the business needs at the architectural requirements level and compare it to the quality attributes of the architectures above.

The main aim of ATAM is access how architectural decisions during designing of a system affects its quality attributes and provides a cautionary way to avoid those consequences of a bad decision being made before the actual implementation of the system (Kazman et al, 2000). Again, it enables risk detection during the designing phase at the architectural level. Scenarios that depict the business transactional requirements of a system are used for the architectural evaluation analysis.

Architectural decisions are hard to make and it usually is hard to be devoid of risk and therefore it is paramount that the developer stipulates sensitivity points in the architecture with respect to the components and their relationship as a prerequisite for achieving a desired quality of the system. Evaluation and the analysis involves risk and non risk assessments also taking into account the sensitivity and trade- offs within the system. Also, Kazman et al, 2000 defines non-risk factors in an architecture design as valid and or excellent decisions that are based on the ideas implicit in the architecture design. On the other hand, sensitivity points are the touch points of components and their relationships. Tradeoffs are properties of an architecture that has the ability to affect multiple attributes in the system. This section will deal with all of such parameters.

6.2 Scenario analysis

A scenario describes a transaction of a particular stakeholder in the system and how the system addresses the need of the stakeholder. Scenarios help to ascertain how functional

requirements of a system are met with the architecture designed to carry out the functions out. Therefore, the stories in the scenario description help a developer to translate business requirements of a system into functional requirements that can be inculcated in the architectural design. Through the scenarios, quality attributes (such as performance, modifiability, availability etc.) can be assessed to see how well they meet the functions of the intended system

As the representation of the quality attributes and its importance are elaborated in the previous chapters above, this chapter involves analysing the risks and sensitivity points with the architectural design approach with respect to the use cases identified in chapter 4. Table 17 gives a bried picture of the priority of scenarios deduced from the utility tree in chapter 4.

Table 17: Priority scenario representation from the utility tree

High priority scenarios extracted	**Quality Attribute Refinement**	**Scenario**	**Outcome**
(H, M)	Transaction Response Time	UCS 1: A user adds an item to shopping cart while the system is under peak load and the transaction completes in at most 200ms	System Performance is importance to the system
(H, L)	Data Latency	UCS 3: Reduce storage latency on LPG services database to less than 200ms	System Performance is importance to the system
(H, M)	Authenticating and authorizing all resources	UCS 5: Establish trust between system, services, and user under 5 seconds	Security is importance to the system
(H, M)	Backup Plans	UCS 6: MongoDB fails due to Amazon Web Services (AWS) maintenance or fault.	System reliability is importance
(H, L)	Data and Service Availability	UCS 7: A clinical reboot or a problem occurs, causing a service container to go down and request routing to a failover	System reliability is importance

		container service in less than 3 seconds	
(H, M)	Adding new module / functionality	GS 1: Adding new feature system and completed successfully by 1-to-2-person week depending of the scope	System modifiability is importance

The tables below give a high level evaluation of the quality attributes identified for the LPG system and how they are prioritised based on the scenarios described in chapter 4. The quality attributes in each of the scenarios are judged and or evaluated with respect to the scenario itself, the stimuli and the perceived responses and their latency.

6.2.1 Performance

Scenario	UCS 1: A user adds an item to shopping cart while the system is under peak load and the transaction completes in at most 200ms
Attribute	Performance (Transaction Response Time)
Environment	Normal operations
Stimulus	Users add gas product to shopping cart
Response	User's shopping cart updated
Architectural approach	1. Containerized applications 2. Clustering and load balancing
Evaluation	The Transaction Response Time is the amount of time it takes for a service to complete a transaction or process. Processing time depends on the database server and the network latency between the database and the services. Also considered is the time it takes for the client to receive the data.

	Based on this assumption, throttling can be kept to a reasonable level if system parameters are optimized. For example, by allocating more resources to CPU or memory consumption in each cluster of the physical view, you can provide high availability and performance, but may incur maintenance costs. It is important to make a trade-off between performance and cost of maintenance.

Scenario	UCS 3: Reduce storage latency on LPG services database to less than 200ms
Attribute	Performance (Data Latency)
Environment	Normal operations
Stimulus	Retrieve active orders for a merchant
Response	Reduced storage latency on LPG services database
Architectural approach	1. Containerized applications 2. Clustering and load balancing
Evaluation	Data Latency refers to the time interval with which a response to an event should be executed. The process is affected by factors including Request Handling System (R), the time taken to retrieve information from the Database Server (D), Network congestion (N), complexity of security algorithms (S) and the time taken to load client screen (U). **Latency = f (R, D, S, N, U)** From the given analysis, data latency can be kept within an acceptable level if system parameters are optimized. There should be a tradeoff between the latency of data and the complexity of security algorithms used.

6.2.2 Security

Scenario	UCS 6: Establish trust between system, application, and user in 5 seconds
Attribute	Security (Provide authentication and authorization on all resources)
Environment	Runtime
Stimulus	Trust establishment request: 1. Application and user/client 2. Authentication credentials 3. Authorization credentials
Response	A trust relationship between the system and the initiator is established. Unauthorized access denied
Architectural approach	1. JSON Web Token 2. Logging
Evaluation	It is important to use an authentication method that does not allow for spoofing of user identity, as well as encrypting and decrypting of data to prevent unauthorized access.

6.2.3 Reliability

Scenario	UCS 6: MongoDB fails due to Amazon Web Services (AWS) maintenance or fault.
Attribute	Reliability (Backup Plan)
Environment	Runtime
Stimulus	Database goes down for backup, therapeutic reboot, upgrade or fault occurs.

Response	System switched automatically over to a failo-ver/backup database. No data is lost.
Architectural approach	1. Back-up system 2. Failover routing
Evaluation	In cases of a database server failing, the backup system should automatically take over. There are many factors that affect the maintenance of the backup system, such as the size of the databases (S), the time period of the backup activity (P), the time needed to switch from the failed system to the backup system (T) and the location of the backup system (L). **Backup= f (S, P, T, L)** Based on the analysis outlined above, a proper backup system can be implemented. Backup systems have an impact on performance depending on the number of components involved in processing the work. There should be a trade-off between reliability and performance.

Scenario	UCS 7: A clinical reboot or a problem occurs, causing a service container to go down and request routing to a failover container service in less than 3 seconds
Attribute	Attribute Reliability (Data and Service Availability)
Environment	Runtime
Stimulus	Service container goes down for therapeutic reboot or fault occurs.
Response	Request routed to failover service container
Architectural approach	1. Clustering and Load balancing 2. Heartbeat 3. Failover routing
Evaluation	This is needed in case of service instance failure, where requests are re-routed to other instances of the service

	running on a different node. A trade off should be done between reliability and performance

6.2.4 Modifiability

Scenario	GS 1: Adding new feature system and completed successfully by 1-to-2-person week depending of the scope of the feature
Attribute	Modifiability (Adding new module / functionality
Environment	Design time
Stimulus	A new feature is added to the system.
Response	The addition of the new feature is completed successfully.
Architectural approach	1. Containerized applications 2. Clustering and load balancing
Evaluation	Among the factors that determine the modifiability are: the decomposition of the system components (D), the relationship between these components (C), design and implementation of the architecture (A) and the system's relation to its environment E). **Modifiability = f (D, C, A, E)** Additions and deletions should be handled with care so as not to affect the existing functionalities and end result of other components.

7 Discussion

The idea behind the thesis was to find a solution (in the form of a software service) to the slow adoption of LPG by households in Ghana. This was done with the anticipation of creating a lucrative LPG sector that can attract investment for all corners of the earth. I always thought that an IT solution will always help propel any business to a good level if the need of the business is used as a basis for adopting a particular IT solution. Therefore by aligning the business needs with a specific IT solution will always help to create a successful business that withstand competition with time.

Furthermore, I started by asking basic questions to understand the business and what it lacks. That knowledge coupled with the literature made it clear that an IT solution of modern nature such as an IoT base platform will enable the delivery of LPG and directly affect its adoption through easy access, affordability and better customer care. However, in bringing the best out of the thesis quest, I structured the thesis under different research questions with a combined effect of bringing out a concept to solve the LPG adoption situation in Ghana, and laying out the design of the concept to implement later. the respective research questions will be discussed to understand how it lead to the concept in general

What are the concerns in the LPG delivery business in Ghana?

This is the main research question and it resulted in the IoT concept designed to solve the LPG situation in Ghana. The concept is as a result of knowing the problems that plague the LPG sector in Ghana and finding out what is the best possible way to solve through a digital service platform. The concerns of the LPG industry in Ghana, was carefully studied through interviews and literature. The concerns were analysed and out of it came what could be done to solve it with requirement elicitation in the design phase under section 4.1. Section 4.2 continued to break the requirements into proper business requirements to use as a requirement document in the actual implementation after the architecture design.

Therefore, section 4.1 of the design phase section gathered the knowledge from the interview coupled that with the literature review to determine the issues that plague the LPG business. It came out that the issues that most dominated the sector was lack of technology, delivery issues, cylinder problems and lack of standardised process as listed in section 4.1. of the design phase. It was from this that a concept that will be mobile application base was conceptualized to tackle the all the problems. On top of the mobile application will be an IoT module later to make the entire system IoT compliant in the end. The functions as listed under systems components (Section 4.2.4), shows that if implemented and the right quality

attributes followed will solve the LPG issues to a large extend. The concept was also further detailed to show its architecture in section 5 and specifically under section 5.6.1 showing the logical flow of the perceived system. The architecture as designed in section 5, is such that a mobile application will be developed and implemented. Test to see its full functionality and then an IoT module added to it as a modification or an upgrade of the system. This way the issues will be dealt with in increment of time without the entire sector having to wait for it for a long time

Furthermore, it is evident in the literature as shown in figure 13 and the feasibility studies as is listed under section 4.1, that the LPG sector in Ghana lacks a lot of things to make it a sustainable and lucrative business both to the consumers and the organisations. Some of the concerns or challenges identified includes technology gaps or deficits in the system, lack of efficient and reliable LPG supply chain (Delivery issues), lack of effective policy measures and regulatory regime, high recurrent cost of refilling large cylinders, insufficient knowledge about health and environmental benefits associated with the use of LPG and lack of cost-effective LPG equipment for users. But as reiterated by Norberg-Bohm, 2002, the challenges that face the LPG sector can be made better if efforts are put into revamping its technological aspects. Also, it is a known fact that innovation in the sector in technology will drive its prospects up (Kammen, 2011). Yet with all this knowledge in place the sector lacks basic technology to even talk about innovation. The lack of innovation in the LPG sector in developing countries like Ghana baffles researchers since it boost of a user base of over 2 billion people using it for cooking, heating, and other uses (Kammen, 2011). This means with a vast majority using the LPG for different purposes, any change in the infrastructure will be profitable and a win-win situation for both the consumer and the business. Also the country will benefit since it will prevent over reliance on fossil fuels and enhance clean energy use like LPG (Agbemabiesea et al,2012).

Looking at the challenges mentioned above and also in section 4.1.3 of the feasibility part, I decided to coin a concept that could address all the issues above if implemented properly. in other worlds, the challenges that affects the LPG sector as i have experienced it personally when back home in ghana, drove my interest in designing a concept that not only will bring technology to the entire LPG sector in Ghana operations of delivering LPG to consumers but to be one that will be looked upon by our neighbors as a pioneer. Therefore looking at the concept under section 4.2 onwards it will solve the problems and concerns in the LPG sector in Ghana the ways that are about to be discussed.

Firstly, the IoT technology-based service platform to be implemented later will enrich the entire sector, if the LPG vendors and businesses use the service in their business process

to serve their customers. That in itself will bring IT at the highest level to the LPG business operations in Ghana as a whole. This will bridge the technological gap and lack of innovation in the system making it more sustainable and lucrative to investors. Secondly, the service platform will incorporate a delivery process into the entire chain of the system to enable smooth buying of LPG by consumers till its delivered to them securely. The system ensures that lack of LPG gas on the consumer part can be detected by vendors and also consumers able to see the availability of LPG in the area that they reside. This part of the system I anticipate to solve insufficient supply and delivery issues in the system. Thirdly, the idea of the concept is to use LPG cylinders with sensors attached to them to collect data to be shared across the service platform. There is a plan to partner with a cylinder manufacturer to produce such cylinders and circulate it in the market. Either vendors will use that as a way to lock their user base or customers could own it outright. This will cut the money involved in the first place to adopt an LPG usage in a household because consumers could easily buy into a vendor that gives free cylinders so far as one is a customer. Finally, the service platform, if used by many or enforced in a way to be used as the main LPG service delivery platform in Ghana, will streamline and standardise the LPG business in Ghana. That eases the pressure on government to lay out policies to regulate the entire LPG sector enabling trust between businesses and their consumers.

In a nutshell the LPG service platform conceptualised will help solve the issues raised above and also help with the following

- ✓ Enable government policy and regulation in the sector
- ✓ Bring about industry standardisation in the sector
- ✓ Increase adoption LPG adoption in Ghana

How can technology alleviate the concerns of LPG business in Ghana?

From the literature and the feasibility studies, it's clear that any form of IT solution will enable the delivery of LPG in Ghana and aids it adoption in more households in Ghana since use of ICT in the LPG delivery in Ghana is minimal to none. Thereby creating a service platform with enabled businesses will enhance opportunistic business ecosystem. In the business of LPG just like any other businesses, ICT solutions are used to enhance business process. These solutions form the backbone of the processes from human resource management, operations and to the actual delivery of the product to the customers. However, from the feasibility studies and the literature done on the LPG sector in Ghana, the best way for any

technology to help the sector can be done in 3 distinct ways. The same approach I have used to conceptualize the system in this thesis. These distinct ways are

1. Identify the right kind of IT (Technology) solution to be used
2. Either customize or design the IT solution to suit the nature of the business in the sector
3. Align the IT solution carefully with the business of the LPG sector

From the Ghanaian perspective inferred from the literature and the interview, a simple mobile application that link all the stakeholders in the LPG business will be okay to help streamline the delivery of LPG from the vendor to the consumer. However, as discussed above under the business requirements, the concept will adopt the use of sensors in an IoT framework to make the entire supply chain better. Smart solutions are used in the LPG sector in the world in general in the operations to make the entire operations efficient (Salemeh et al, 2020). The most popular of smart solution employed in the LPG sector are sensors in an IoT system framework to pick up important data in the transactions for different purposes (Salemeh et al, 2020). Therefore, besides the normal managerial ICT systems used in other departments of a business, connected networks are the best in the aiding the business of LPG delivery (Almalaq et al, 2019).

Also, from the literature, it can be inferred that IoT is the most modernized and best technology to enhance such energy sector as its being used in developed countries in different capabilities and capacities. Hence the idea behind the concept in this thesis and not just a simple mobile application though that will also help in the Ghanaian context. Furthermore, the mobile application proposed above will be built taking into consideration the exact sector needs of the Ghanaian market with the ability to scale as stipulated in the use cases and the quality attributes. However, a full functioning mobile application that incorporates all the stakeholders will be implemented first and later adding the IoT component as a separate module as shown in the architecture diagrams. In other words, the entire LPG system will be built in an agile way in iterations to make sure that the system is solid devoid of system failure in the future.

The LPG system as seen from the quality attribute assessment and development will be built with the on the exact business ideas of the sector that is going to be used for. That means it will inherently be aligning the end ICT product in the form of the service with the LPG business. Thereby enabling the business to reap the benefit of what an ICT solution of service is supposed to do for a business.

What can be done to make the service platform suitable for the LPG business in Ghana?

A service platform is supposed to serve a particular purpose that it was developed for. However, it could miss its intended purpose if care is not taken to make sure that it does what is designed for. As it can be seen through the process of conceptualization to the architecture design, a particular style of software development was followed. It is imperative to do the development of any software by taking into the account the political, social and economic situation of the people and place that the intended software is going to be used. By simply following the steps below one should be able to build a system that will suit the LPG system anywhere. These steps from the the experience of doing this thesis and understanding of the subject matter from the literature and people in the business point of views.

- ✓ Understand the business of LPG
- ✓ Check for their needs
- ✓ Look for a solution a solution that will address their needs
- ✓ Make sure that the busines needs of the LPG business and the functionality of the IT solution aligns
- ✓ Finally check to see how the conceptualized concept can be evaluated to to do what it purports to do.

7.1 Main findings

Table: Summary of research findings

Research questions	Findings
1. What are the concerns in the LPG delivery business in Ghana?	There are many issues that plague the LPG sector and it includes lack of Technology in the sector, delivery issues, insufficient supply chain, lack of governmental policy, No standardisation, high cost in adopting LPG due to cost of equipment. Solving it brings about ✓ Enable government policy and regulation in the sector ✓ Bring about industry standardisation in the sector ✓ Increase adoption LPG adoption in Ghana

2.How can technology to alleviate the concerns of LPG business in Ghana?	In Ghana, a simple mobile application will help. However an IoT service as proposed will be the best to make it more suited for future and stifle competition. But the three steps below should always be followed ✓ Identify the right kind of IT (Technology) solution to be used ✓ Either customize or design the IT solution to suit the nature of the business in the sector ✓ Align the IT solution carefully with the business of the LPG sector
3.What can be done to make the service platform suitable for the LPG business in Ghana?	To ascertain that an IT service platform fits or is able to suit an LPG business it needs to follow a systematic process to bring it functionality in accordance with the need of the LPG business. The process should include, ✓ Understand the business of LPG ✓ Ascertain the needs of the LPG business ✓ Look for a solution a solution that will address their needs ✓ Make sure that the busines needs of the LPG business and the functionality of the IT solution aligns ✓ Finally check to see how the conceptualized concept can be evaluated to do what it purports to do.

8 Conclusion

The deductions from the research will be a requirement document for the implementation of a software service platform that will incorporate all the stakeholders in the delivery of LPG in Ghana. The feasibility and the literature justified the development of such a solution as the best to solve the delivery problems that plague the LPG sector in Ghana. It will also enable the adoption of LPG in households in Ghana.

8.1 Limitations of the research

The goal of this research is to conceptualize and design a software platform to enable better delivery of LPG in Ghana through conceptualisation. The input was from literature review, a few interviews to bring out the needs and the tools. Therefore the thesis research comes with the liabilities that are associated with such methods of research. But specifically the limitations will include

- ✓ The research was done based on literature review and a small interview of people in the field in Ghana and as such the results do not represent all LPG organizations in the world. However, it gives an idea on how the LPG business is in a developing country setting.
- ✓ The research aim was to conceptualise the concept and the literature part was not systematic enough to give a representative generalisation on the subject area. Therefore, care should be taken when making reference to the literature part.
- ✓ The discovery of the problems with the LPG sector was an overview in nature based on the small interview and therefore, it should be taken as such and not taken as a holistic representation of the situation in Ghana.

8.2 Validity and reliability

The methods used in the thesis research process were all carefully selected in line with known and approved methodology in such research areas making it accurate and thorough. The literature review was done using techniques used in systematic literature review to get as much literature as possible though the synthesis was not done systematically. The search was based on research problems and research questions. This was to help keep the scope and the focus on what is needed in the research concerning LPG Ghana. That enabled the amount of literature retrieved from the search engines being precise and informative on the subject area.

The conceptualisation on the other hand was done using literature combined with a small interview to get the problems on the ground and in literature too. The literature as mentioned earlier was done in accordance with what the aim of the thesis was. The interview also bothered on the same line asking people questions that pertains to the LPG sector and its problems including what they thought was the way forward for a better LPG business in Ghana.

The setting methodology of the thesis research was done in a way that a repeat by anyone should yield the same result. This is in the fact that the literature was done with a consistent set of phrases while making sure they capture all the research questions stipulated. This makes the reliability of the thesis information highly reliable and dependent upon. The design and evaluation method used are also known methods in the conceptualisation and designing of a software solution. The ATAM methodology helps streamline a design to ascertain its functionality in real life in case the system is fully implemented.

Furthermore, before any assumptions are made the following considerations should be taken to assure that is in line with the limitations of the thesis scope,

- ✓ The research was conducted in the confinement of the LPG sector in Ghana and the results and solutions to their problems should be interpreted and represented as such with reference to Ghana.
- ✓ Also, the literature and interview was not systematic and therefore it can not be representative of a holistic research approach that justify using it as a basis for proven academic literature.
- ✓ Though the methodology of the thesis was good, there were still time and manpower constraints that made the actual implementation of a solution impossible. Therefore the evaluation of the perceived solution was done on a high level.
- ✓ Also due to not implementing the actual solution, the architecture of the IoT system for the LPG delivery was also done on a high level.

8.3 Academic contribution

This thesis research was done in accordance with a master's degree in information systems management fulfillment. Hence it is bound within the scope of such academic endeavors. However, it does add value to academic literature just like any other academic research paper. The contributions of this research is enormous and will not be exhaustive to the following contributions,

- ✓ Addition of knowledge to the academic literature and also gives a path for further scientific research into the area
- ✓ Adding to the number of publication my academic institutions (Haaga-Helia) has within its research area
- ✓ The LPG sector in developing countries is booming, and this will serve as a basis for students interested in the sector to be able to further their academic studies in the field. In a way it is a motivator for students wishing to go into the field of LPG research.
- ✓ Also, the methods used in this thesis research could aid students interested in undertaking similar research making it easier for them to rely on such academic research similar as this.
- ✓ Finally, the reference base of this research can serve as a basis for some other students to dive into areas similar to this thesis without any difficulty.

8.4 Practical implications

The thesis result can be deemed accurate due to methods used. Literature review was done using reputable search engines with a vase base of research articles and books. And through the literature and the interview the concept came up. This makes the deliverable of the thesis one that can be relied upon and used for further academic research or business endeavour.

The only implications of the research deliverable, is to note that its a representative of only the LPG situation in Ghana and as such should not be construed to be a representative of the entire LPG sector in Africa or the world. But despite the limitations, the thesis should be given the necessary academic stature in accordance with a master's thesis. .

8.5 Reflections

I gained a lot of knowledge and experienc3 in undertaking the thesis work. The enormous knowledge coupled with the experience will help me in my career path.. I encountered some challenges in the process of doing the work but there were parts that made the challenge worth going through.

The challenges came with trying to do the heavy work within the constraints of a thesis. That was difficult to overcome since the entire work involved was heavier than I initially anticipated. But there were easier and fun parts like searching for the research materials. The database engines made it easier to look for what I was interested in once I had the right

search criteria in place. The search process also solidifies my knowledge in doing research in a professional manner and still doing it accurately. My supervisor was of good help. His advice and direction made it easier to focus and do the right things with the right tools and methods. Again, like I said earlier, the thesis had issues and challenges. The main being the time within which I was supposed to get the thesis done considering how much time I had to graduate. That was very stressful and i had to rush and burn the midnight candle to get it ready properly at the right time

In a nutshell, the thesis taught me a lot and I am ready to roll the thesis into a proper business once the time is right.

8.6 Recommendation for further study

The thesis topic on LPG, is an area that is developing in Ghana and has an enormous growth potential. My initial goal was to find a niche sector to dive in as an IT entrepreneur and I certainly got one. However, due to the limitations and constraints with thesis like time and manpower resources, it was limited without any actual implementation. Therefore, i believe the following recommendation will help the research in this sector in the future,

- ✓ A systematic literature review could be done on the same subject area to make it more representative of the knowledge concerning the LPG business in Ghana
- ✓ It is apparent that most LPG organisations and vendors do not use any proper IT solutions in the business but it will be interesting to have a research to understand why they are not harnessing the benefits of IT solutions in their business. This will gives a understanding of the sector from an IT perspective.
- ✓ Am curious in knowing how the implementation of the designed concept will lead to the adoption of the LPG by more consumers. Therefore as a further study, I will recommend a study in determining how the adoption of IT solutions like what the thesis has conceptualised will lead to LPG adoption in Ghana.

Bibliography

1. Atzori L., Iera A., and Morabito G., (2010), “The Internet of Things: A survey. Computer Networks”, 54(1), 52787—52805.
2. Al-Fuqaha A., Guizani M., Mohammadi. M., Aledhari M., and Ayyash M., 2015 ”Internet of things: a survey on enabling tech- nologies, protocols, and applications”, 2015, IEEE Communications Surveys & Tutorials, vol. 17, no. 4, pp. 2347–2376.
3. Agbemabiesea L., Nkomob J., and Sokonab Y., 2012, ”Enabling innovations in energy access: An African perspective” Elsevier, vol. 47(S1), pages 38-47.
4. Almalaq A., Hao A., Zhang J. J., and Wang F., 2019, “Parallel building: A complex system approach for smart building energy management,” IEEE vol. 6, no. 6, pp. 1452–1461.
5. Aversano L., Grasso C., and Tortorella M., 2016, “Managing the alignment between business processes and software systems”, information and software technology journal vol 72, pp 171-188.
6. Bassi.A, 2013, “Enabling Things to Talk”, Designing IoT solutions with the IoT architecture reference model, Springer, pp 17-37.
7. Chong A.Y.L., and Ngai E. W. T., 2015, “Supply chain management in the era of the internet of things”, International Journal Production Economics 159, PP 1–3
8. Carrión D., Dwommoh R., Tawiah T., Agyei O, Agbokey F., Twumasi M., Mujtaba M., Jack D., and Asante K.P., 2014,“Enhancing LPG adoption in Ghana (ELAG): a factorial cluster-randomized controlled trial to Enhance LPG Adoption & Sustained use”, BMC Public health, pp 2-11.
9. Cavalcante E., Alves M., Batista T., Delicato F., Pires P., 2015, “An Analysis of Reference Architectures for the Internet of Things”, CobRA ’15 Proceedings of the 1st International Workshop on Exploring Component-based Techniques for Constructing Reference Architectures pp. 13-16, 2015.
10. Coetzee L., and Eksteen J., 2011, “The Internet of Things - promise for the future? An introduction”, IEEE conference publication pp 1-5
11. Cisco, 2014, “The Internet of Things Reference Model (Online). Available:https://www.cisco.com/c/dam/global/en_ph/assets/ciscoconnect/pdf/bigdata/jim_green_cisco_connect.pdf (Accessed: April, 12, 2021)
12. Dalaba M., Alirigia R., Mesenbring E., Coffey E., Brown Z., Hannigan M., Wiedinmyer C, and Oduro A., 2018, ”Dickinson, Liquified Petroleum Gas (LPG) Supply and Demand for Cooking in Northern Ghana”, KI Published in: Ecohealth, Vol.15(4), pp.716-728

13. Daily G., Dasgupta P., Bolin B., Crosson P., du Guerny. J, Ehrlich P., Folke C. A., Jansson M. Jansson B. O., Kautsky N., Kinzig A., Levin S., Mler K. G., Pinstrup-Andersen P., Siniscalco D., and Walker B., 1998, "Food production, population growth, and the environment Science", vol. 281, no. 5381, pp. 1291–1292,
14. Edjekumhene I, Atta-Owusu O. F., and Ampong C. A., 2007, "Ghana oil and gas sector study, World bank oil and gas policy division", Kite, vol II, pp 14-16.
15. Fremantle. P, 2015, "A Reference Architecture for the Internet of Things", Version 0.9.0. Whitepaper, WSO2, pp 6-20.
16. Grubler A., Nemet, G., 2014, "Sources and consequences of knowledge depreciation. In: Energy Technology Innovation-Learning from Historical Succeses and Failures", Cambridge University Press, Cambridge, UK, Ch. Case study 5: Knowledge Depreciation, pp. 309–331.
17. Gubbi, J., Buyya, R., Marusic, S., and Palaniswami, M., 2013, "Internet of Things (IoT): A vision, architectural elements, and future directions", Future Generation Computer Systems, 29 vol 7, 1645—1660.
18. Gavras A., Karila A., Fdida S., May M., and Potts M., 2007, "Future internet research and experimentation," ACM SIGCOMM Computer Communication Review, vol. 37, 19, pages291–311 (2013)
19. Hsu C., and Lin J. C., 2016 "An empirical examination of consumer adoption of Internet of Things services: Network externalities and concern for information privacy perspectives", computers in human behavior, Vol 62, pp 516-527.
20. [IEEE-830] Institute of Electrical and Electronics Engineers, IEEE Recommended Practice for Software Requirements Specifications, IEEE Std 830-1998, Institute of Electrical and Electronics Engineers.
21. ITU and Cisco, 2016, 'Harnessing the Internet of Things for Global Development', pp 1-12, http://www.itu.int/en/action/broadband/Documents/Harnessing-IoT-Global-Development.pdf
22. IoT-A (European project partners, 2013) "Introduction to the Architectural Reference Model for the Internet of Things", 2016. Page 7 (Online). https://docplayer.net/4211897-Introduction-to-the-architectural-reference-model-for-the-internet-of-things.html (Accessed: April 10, 2021].
23. Jacobsson, S., Bergek, A., 2004. "Transforming the energy sector: the evolution of technological systems in renewable energy technology", Ind. Corp. Change 13 (5), 815–849.
24. Jacobsson, S., Johnson, A., 2000, "The diffusion of renewable energy technology: an analytical framework and key issues for research", Energy Policy 28 (9), 625–640.

25. Kammen, D., 2011, ”Development in a Changing Climate: Making Our Future Sustainable,(Online)Blogs.worldbank.org:/http://blogs.worldbank.org/climatechange/more-and-targeted-financingneeded-expand-energy-access, (Accessed October, 2020)
26. Lee I., and Lee. K, 2015, ”The Internet of Things (IoT): Applications, investments, and challenges for enterprises”, Business horizons journal, vol 58, pp 431-440.
27. Madakam S., Ramaswamy. R, and Tripathi S., 2015, “Internet of Things (IoT): A Literature Review”, Journal of Computer and Communications, Vol.03(5): 164-73.
28. Mensah S. G, Kemausuor F., and Brew-Hammond A., 2013, ”Energy access indicators and trends in Ghana”, Renewable and Sustainable Energy Reviews, Elsevier, pp 317-323
29. Mathew G. W., and Zeissig R. Hilmar, 2011, ”Residential Market for LPG: A Review of Experience of 20 Developing Countries”, Houston international business corporation, Energy and Environmental Policy Consultants, pp 46-58
30. Miazi N. S., Erasmus Zenville E., Abdur R., Zennaro M., and Antoine B.,2016, ”Enabling the Internet of Things in developing countries: Opportunities and challenges”, IEEE conference publications, pp 565–567.
31. Masinde.M, 2014, “IoT applications that work for the African continent: Innovation or adoption?” in Proceedings of the 12th IEEE International Conference on Industrial Informatics, pp. 633–638,
32. Norberg-Bohm V., 2002, ”the role of government in energy technology innovation: insights for government policy in the energy sector”,
33. Niyato. D, Hossain E., Rashid M., and V. Bhargava,2007, “Wireless sensor networks with energy harvesting technologies: a game-theoretic approach to optimal energy management” Wireless Communications, IEEE, vol. 14, no. 4, pp. 90–96.
34. Popp D., 2016, ”Economic analysis of scientific publications and implications for energy research and development”, Nat. Energy 1, pp 1–8.
35. Peffers, K., T. Tuunanen, M. A. Rothenberger and S. Chatterjee, 2008, “A Design Science Research Methodology for Information Systems Research,” Journal of Management Information Systems, Vol. 24, No. 3, 2008, pp. 45-77.
36. Rick Kazman, Len Bass, Mark Klein, Tony Lattanze and Linda Northrop, 2005, Kazman A Basis for Analyzing Software Architecture Analysis Methods, Software Quality Journal volume 13, pages329–355
37. Rehfuess E. A, Puzzolo E, Stanistreet D, Pope D, Bruce N.G, 2014, “Enablers and barriers to large-scale uptake of improved solid fuel stoves: a systematic review”, Health Perspect, pp 120–30.

38. Saunders M. N.K., 2009 ” Understanding research philosophies and approaches”, PP 122-161
39. Salameh H. A. B., Dhainat M. F., and Benkhelifa E., 2020, “An End-to-End Early Warning System Based on Wireless Sensor Network for Gas Leakage Detection in Industrial Facilities”, IEEE Systems Journal, pp 1-9
40. Stephens O., 2016, “The Internet of Things, and the explosion of interconnectivity”, core concepts, Vol 113, no. 40, pp 11059–11060
41. Stutts. J.C, Reinfurt D.W., Staplin L., and Rodgman E. A, “The role of driver distraction in traffic crashes.” 2011, .University of North Carolina Highway Safety Research Center, Chapel Hill, NC, pp 13-23
42. World population ageing 2009,”, Department of Economic and Social Affairs of the United Nations. United Nations.
43. WLPGA, 2015, Accelerating the LPG transition, global lessons from innovative business and distribution models, pp 44
44. WLPGA, Accelerating the LPG transition (2018), global lessons from innovative business and distribution models, pp 33-36
45. Yang. G, Xie L., Mantysalo M., Zhou X., Pang Z., Xu L. D, KaoWalter S., Chen Q., and L.-R. Zheng L. R., 2014“, A health-iot platform based on the integration of intelligent packaging, unobtrusive bio-sensor, and intelligent medicine box,” Industrial Informatics, IEEE Transactions on, vol. 10, no. 4, pp. 2180–2191.
46. Zennaro, M and Bagula A., 2015, “IoT for development (IoT4D),” (Online) https://iot.ieee.org/newsletter/july-2015/iot-for-development-iot4d.html (Accessed November 2020)

Appendices

Appendice A

Interview questionnaire

Background information (Respondent)

1. What is your current position in this company?
   - ✓ Follow up on what he does exactly in the company if it didn't come out
   - ✓ Get how knowledgeable he is about company's business
2. How many people works for the entire company?
   - ✓ Follow up on the number in his branch
3. Do you know how much revenue you company made?
   - ✓ What was the annual revenue?
   - ✓ Follow up if the company makes profit
4. How will you classify you company's business? (Keeping in mind if is Wholesale, retailing)

The LPG Sector

1. What is the chain of production of LPG before it gets to you?
2. How many companies are involved in the business of LPG production?
   - ✓ Can you name some of them if you know?
   - ✓ What about where they operate from
3. What about the distribution of LPG?
   - ✓ Can you name them?
4. Do you know the business of LPG retailing (Selling for home consumption)
   - ✓ Can you name some companies besides yours that do retailing?
5. How is the retailing done (Tell me about the process of LPG retailing)?
6. Please explain in detail the process by which the consumers (Home users) get the LPG from you to their house

The Infrastructure of LPG business

1. How will you describe the equipments you use in your business?
   - ✓ Do you think they ae sufficient? If not, why?
   - ✓ What about those of competitors
2. Do you use any IT systems in your daily business running?
   - ✓ What are they if any and what do you use it for?

- ✓ In case of lack of it, ask why they are not using it

3. Do you know if a competitor is using any IT system?
   - ✓ How sure are you of this?
   - ✓ Do you have an idea why your competitor is using it or not?

Problems and concerns

1. Tell me some of the general problems or concerns you have in this business
   - ✓ Is management aware of such problems
   - ✓ Why are they not solving it
2. What are the causes of the problems you are face if any?
3. What do you think can help solve the problems?
   - ✓ Will management support it? Why and why not?
4. Do you have any means to get customer feedback on you selling LPG to them to use at home?
   - ✓ Can you tell me how the feedback is?
   - ✓ And if is documented can I have it?
5. Do you have any complaints your customers (consumers) of the way the business is?
   - ✓ What are they problems?
   - ✓ How do you intend to solve them?
   - ✓ What have they expressed about how they want it solved?

End remarks

1. Anything else to add to the interview that I have not asked?
   - ✓ Follow up on any issue from that and if there is not time ask for such information to be sent by email
2. Thank the interviewee and leave the possibility of any further information be sent to you by other media