

RISK ASSESSMENT FOR THE ADOPTION AND USAGE OF LIQUEFIED PETROLEUM GAS IN DIVERSIFYING ENERGY SOURCES IN MALAWI.

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ABSTRACT

This research paper assessed the risk associated with the adoption and usage of LPG by mainly focusing on how these risks affects or will affect the adoption and usage rate. Incorporating different approaches and methods like compliance safety audits, GIS mapping of distribution network, interviews and surveys, literature review and secondary data analysis, this study shows that they are mainly two hazards evidenced by the gas retailers which are and will be affecting the adoption and usage of LPG if not really taken care of and these are fire hazards and chemical release hazards (Gas leakages), And it has been found that the consumer base currently are the elite people which are mostly in the urban areas, and for this fact most of them are busy people they fail and mostly don't like to spare some time to go through LPG safe use trainings which pose a threat on safety.

Taking into account that safety comes at a cost, as the LPG market is broadening, safety is being weakened as evidenced by the increase in number of accidents over recent years. Negligence and safety ignorance have been identified as the parameters enhancing accident growth rate and on the other hand accessibility, availability and awareness are the drivers for the increasing adoption and usage rate (LPG consumption). Perception towards safety of LPG is one of the factors which is hindering the adoption and usage of LPG and that's the increase in number of accidents over the years will definitely affect the adoption and usage rate. There has to be serious care in the handling, storage, distribution and use of LPG in order to maximize safety and increase the adoption and usage rate by other and already existing consumers. Different Gas retailers experience different type of accident but overall the causative agent are just the same but magnitude of effect and the probability of occurrence depend on the safety guidelines that the company is following.

This paper suggests that in order for the safety issue to be addressed, more compliance audits should be done so that safety measures should be promoted and also LPG business or sector should be well monitored the way other petroleum products are taken serious of. And safety should be the first priority before anything else no matter what the cost it brings then will have a zero accident LPG environment or accident free industry, hence the adoption and usage rate will surely increase.

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ACRONYMS/ABBREVIATIONS

GoM	Government of Malawi
LPG	Liquefied Petroleum Gas
MERA	Malawi Energy regulatory authority
MGDS	Malawi Growth and Development Strategies
NSO	National Statistical Office
NEP	National Energy Policy
PAC	Practical Action Consulting
SSA	Sub-Saharan Africa
UN	United Nations
TEVETA	Technical Entrepreneurial and Vocational Education and Training Authority
WLPGA	World Liquefied Petroleum Gas Association
HSE	Health Safety Environment
OD	Origin - Destination
BLEVE	Boiling Liquid Expanding Vapor Explosions

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1.0 CHAPTER 1: INTRODUCTION

1.1 Background Information

Risk assessment is the systematic process of evaluating the potential risks that may be involved in a project or activity and implementing reasonable control measures to remove or reduce them. Thus main purpose of the risk assessment is to avoid the negative consequences related to risk by determining the likelihood and consequences of potential events and to implement reasonable measures to reduce or eliminate them. (Valis & Koucky, 2009)

Risk assessment provides decision-makers and responsible parties with an improved understanding of risks that could affect achievement of objectives and adequacy effectiveness of controls already in place. (Valis & Koucky, 2009). Assessment can be categorized into two categories based on the nature of results. There is qualitative assessment and quantitative assessment, in the context of Qualitative assessment, it defines consequence, probability and level of risk by significance levels, such as “high”, “medium” and “low” may combine consequence and probability and evaluates the resultant level of risk against qualitative criteria. And in Quantitative assessment there is the estimation of practical values for consequences and their probabilities, and produces values of the level of risk in specific units defined when developing the context. (Valis & Koucky, 2009)

The risk assessment is an important legal requirement which should be carried in different industries and workplaces in order to prevent any incident in future and manage emergencies better. (Anandhan, Prabaharan, Muhaidheen, & Ragavendran, 2019)

In the oil and gas industry there a lot of risks that are associated with its operations at different levels and these risks can be assessed differently, this project focuses much on the risks which are associated with LPG in Malawi, for example the issue of safety (explosion) which is among the factors or reasons contributing to the low adoption and usage of LPG. And if not taken into consideration will in one way or the other place a hindering block for the adoption and usage of LPG in Malawi.

Liquefied Petroleum Gas is colorless and odorless liquid which really evaporates into a gas. Mainly it is composed of Butane or propane and it's generally stored and distributed in a compressed form as a liquid. This gas is classified as a highly flammable and also classified as carcinogenic and Mutagenic, it is non corrosive but can dissolve some rubbers, certain plastics and lubricants. (Authority, 2023)

The danger that is there and mostly associated with LPG is gas leakage. Since the gas is colorless and odorless, intentionally an odorant has been added to it to help detect leaks. If the gas (liquid) leaks, it evaporates very quickly and forms a cloud of gas which is heavier than air, this cloud of gas will drop to the ground. This LPG vapor can run along distance and gets collected in the basements or drains. When this gas meets a source of ignition it can explode or burn. The cylinders can explode if involved in a fire accident and if the temperature of the fire exceeds the resistance temperature. (Authority, 2023). The manufacturers of the cylinders take this unto consideration and it's difficult for a non-leaking gas cylinder to explode easily. There is Liquefied Natural Gas (LNG) which is also part of the gas that is sold or distributed here in Malawi. In trying to compare and contrast between the two gases (LPG & LNG), on an overall grading, the best gas to be used is LPG for some reasons it's cheaper, portable and produces high energy. And the differences are based on these factors. (Gasask.com, 2023)

Safety, it's nearly impossible for an LPG or LNG cylinder to explode, but still accidents occurs and take lives of people due to some negligence and lack of proper knowledge. Apparently the two gases are both are safe but a deeper study and analysis shows that LNG is safer that LPG based on the specific gravity. This means if LPG safety issues are addressed, it means that LNG has also been covered. (Gasask.com, 2023). As earlier stated LPG is composed of propane or butane while LNG is composed of methane. This chemical composition differences makes the two gases to have different calorific values whereby LPG have a high calorific value which is almost three times that of LNG, this means that LPG produces three time more energy than LNG. (Gasask.com, 2023)

STATE OF THE ART INFORMATION ABOUT LPG IN MALAWI.

Through the study of the digest of Malawi energy, below is how the importation of LPG has been from the year 2015 to 2020. (GoM, 2023)

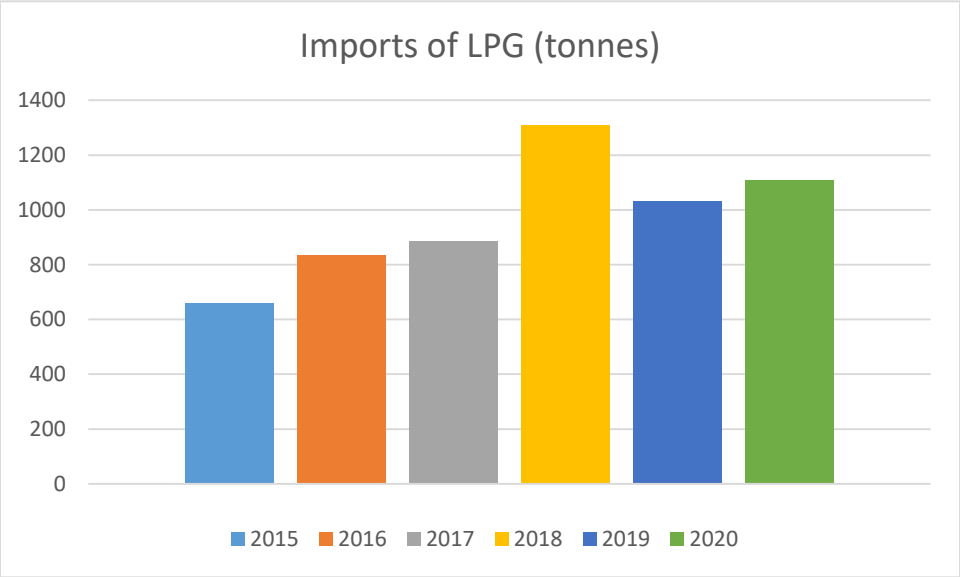


Figure 1 LPG Imports in Malawi Source: Data from (GoM, 2023)

The adoption and usage of Liquefied Petroleum Gas is being affected by so many factors in Malawi and some of these factors are stated and explained in the table below.

Table 1: Factors affecting adoption and usage Adopted in (Coley & Galloway, 2020)

Factor	Description
Weakness/ lack of infrastructure	Very weak existing market lacks economies of scale. This scarcity of LPG suppliers makes fuel replenishment inconvenient for users who must replace/refill large and heavy gas cylinders themselves. Many rural areas are almost unserviceable due to poor roads.

Unwillingness/inability to pay	High upfront costs of LPG cooking devices and large lump sum payments required for refill/replacement of cylinders relative to charcoal and electricity make them unaffordable for the majority of Malawians
Socio-cultural resistance to device adoption	Widespread perception that cooking with LPG is dangerous makes Malawians from all levels of society hesitant to adopt LPG as a cooking fuel.
Factors that shows the opportunity of LPG usage (positive)	
Geographic	Urban areas are most suited to LPG cooking as this is where there is existing demand (although currently very limited). This area will have the lowest distribution costs, highest household incomes and is perhaps most likely to be receptive to awareness campaigns around gas safety.
Behavioral	Cooking with LPG is very similar to cooking with firewood and charcoal, so requires little behavior change in terms of cooking technique. Also, it is fast (lighting and cooking), easy to control, smokeless and odorless, all highly desirable attributes.

According to the study done and reported in 2022, it show that the potential for the adoption of LPG is high in Malawi and the study compared different aspects of using different energy source and come up with the conclusion that LPG is the most efficient cooking fuel tested among electricity, charcoal and firewood. Thermal efficiencies were recorded as LPG 68.1%, electricity 56.2%, Improved Firewood Stove 25.3%, and Improved Charcoal Stove 23.2%. This shows that if some of the factors mentioned above are addressed it can increase the rate of adoption and usage of LPG. (Chiumia, Thengolose, & Tembo, 2022)

1.2 Problem statement

Energy provides a platform for the development of a country, the third Malawi Growth and Development strategy (MGDS III) recognizes this central role of energy citing it as "the lifeblood of the economy". (GoM G. o., 2017) But inadequate energy supply is one of the major problems confronting Malawi, which is limiting its social, economic and industrial development. This is why there is a need to establish and promote other sources of energy. The adoption and usage of LPG is one of the ways to solve this problem, but there are some factors that are affecting the adoption and safety is one of the main contributors to the adoption and usage rate, in which if not well handled it will continue to block and affect the adoption and usage at the moment is slowly increasing. This why there is a need for a risk assessment where all the risk have to be identified and mitigated in order to increase the adoption and usage rate and bringing the surety of safety just like other sources of energy. This is summarized in the study by clean cooking alliance which among others reports or explains that.

For LPG businesses and large multinationals in particular, the risks and costs associated with LPG safety has reduced appetite for the sector, thereby reducing the uptake of LPG, particularly in sub-Saharan Africa. In order to build a dynamic and financially sustainable industry, for both LPG and other clean cooking fuels, ensuring effective safety best practices

is critical. New innovations that can make LPG more affordable while addressing safety concerns have the potential to spur private sector investment. (George, Patel, Nair, & Hyland, 2019)

1.3 Main and specific objectives

To conduct a risk assessment for the adoption and usage of liquefied petroleum gas in diversifying energy sources in Malawi.

1.4 Specific objectives

I. Identify and categorize various risks associated with the adoption and usage of LPG as an alternative energy source in Malawi (safety and environment)
II. Conduct a comprehensive analysis of the technical aspects of LPG infrastructure, including storage facilities, transportation system, and distribution network to identify vulnerabilities and potential point of failure
III. Propose strategies and protocols to address and mitigate the identified risks, encompassing safety measures, emergency response procedures.

1.5 Research questions.

I. What is the quantitative risk associated with the storage and transportation of LPG, and how does it compare to other sources considering factors such as leakage, fire and explosion probabilities
II. What are the environmental and health risks associated with the adoption of LPG and how can a comprehensive risk assessment inform strategies for minimizing these risks while maximizing the benefits of adoption.

III. How can data analysis and predictive modelling be leveraged to identify potential risk hotspots and vulnerability in LPG distribution networks, and what mitigation strategies can developed based on these insights

1.6 Significance of the study

This research project will help in the development of some control measures to mitigate the risks that are there in the LPG system for better or increased adoption and improved safety measures thereby diversifying energy source and reduce dependence on conventional fuels

It will also help LPG retailers, distributors, customers and other stakeholders to understand why safety is really an important aspect to consider in order to increase the adoption and usage of LPG.

It will also help LPG retailers, distributors and the government to take into account decisions which are cost effective and appropriate.

This project will also in one way or the other help in dealing with environmental issues that the fuel pose on the environment but incorporating much the issue of safety.

2.0 CHAPTER 2: LITERATURE REVIEW

2.1 Introduction to energy situation, historical context and adoption of LPG in Malawi

There is the energy ladder that the energy sector pass through, as generations are passing and the country is developing the energy sources being used needs to change as well. This ladder shows the transitioning process, and it's called the energy ladder theory.

The fuel stacking theory was formulated contrary to the energy ladder theory by Masera and Navia in 1997 during their study of household energy patterns in Mexico. This model argues that most households in developing countries do not follow the discrete, stepwise upward movement from traditional to modern fuels but use multiple fuels simultaneously (Doku-Marfo, 2022)

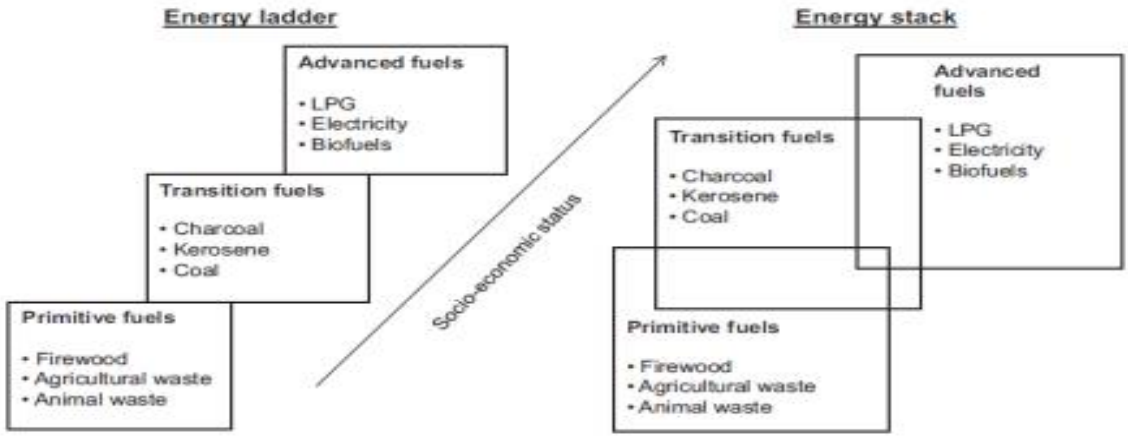


Figure 2 Energy transition process (Doku-Marfo, 2022)

The demand for energy is continuously increasing, especially in developing countries where energy access is limited. (UN, 2015) The main sources of energy that are currently in use are the type of energies that are not environmental friendly. According to the National Statistical Office (NSO) to cook the majority of households in Malawi use firewood as their main source of energy (77.4%), followed by the use of Charcoal (18%) and then electricity (2%). (NSO, 2019).

These primitive fuels and the transition fuel sources contribute to deforestation, greenhouse gas emissions, and respiratory diseases. (Lim, et al., 2013) However there are other

potential sources of energy that are cleaner and efficient to lessen the burden on these other sources, among others there is wind energy, solar energy, etc. Apart from these sources there is a potential of using Liquefied Petroleum Gas as a source of energy. Liquefied Petroleum Gas (LPG) is an efficient and cleaner-burning fuel for cooking, heating, and powering appliances in homes, industries, and institutions globally. (Abdulai, et al., 2018) This Liquefied Petroleum gas is one of the advanced energy sources of fuel, this is so because it meet a lot of requirements that people or different industries have and it is also environmental friendly compared to other sources of energy.

There are limitations on accessibility that are a function of storage and distribution, both of which limit supply because of the high storage costs and limited LPG supply from gas producers. LPG suppliers need to supply at significant volumes in order to reduce cost. For example, in Tanzania KopaGas shared their experience around accessibility: "All of our customers are within 10 km of the port due to the logistics, the more rural you move the harder and more expensive it gets." The knowledge and understanding of LPG (i.e. acceptability) in Malawi remains low. A study by Practical Action Consulting (PAC) highlighted limited knowledge of LPG efficiency and safety among potential users. Perceptions that LPG is unsafe and more expensive than other cooking fuels further hamper uptake. To demonstrate the levels of consumer discomfort with LPG, a representative of 265 Energy said: "You could literally give LPG for free and many would not take it because they think it will blow up their house." (Fay, 2019)

Table 2: Energy sources comparison from a survey (Reason for Preferred Cooking Fuel) *(Chiumia, Thengolose, & Tembo, 2022)*

	Locally available (%)	Affordable (%)	Safe (%)	Clean (%)	Fast (%)
Electricity	21.7	42.2	3.6	5.5	27.1
LPG	5.3	18.4	0.0	15.8	60.5
Charcoal	52.5	33.3	0.0	3.0	11.1
Firewood	50.0	33.3	0.0	0.0	16.7

2.2 Factors affecting the adoption of LPG

There are some factors that are affecting the adoption of LPG in Malawi, and these factors have been studied here in by some energy specialist and some of these are as follows:

i. Weakness/ lack of infrastructure

Infrastructure that involve the supply chain management of LPG is many angles, for example in the transportation sector, due to lack of adequate transport infrastructure the consumer price for LPG is affected, (Hood & UNEP, 2010) because it affects the distribution network. And this in turn affects adoption and usage. Lack of infrastructures that can support the use of LPG in homes of customers also affect the adoption rate since people fail to access or to use the gas and it also pose a safety threat (Rao, Dahal, Hadingham, & Kumar, 2020)

According to a report of September 11, 2023 says that MERA has partnered with the Technical Entrepreneurial and Vocational Education and Training Authority (TEVETA) in formulating a curriculum to guide the provision of trainings in gas systems installation in the country. And these provision are expected to commerce in the year 2024, and shall assist in improving on safety in gas selling stations.

ii. Cost or affordability (Unwillingness/inability to pay)

The price of LPG is directly affected by the distance that is there from the main depot to the customers that's accessibility or geographical location. Due to poor road network the supply chain management is affected and this affects the price of the product. (Coley & Galloway, 2020)

According to other studies done it shows that there is cost which was also discovered as a predictor of LPG adoption intention. However, it was covered that subjective norms did not affect households' intention of adopting LPG for cooking. Additionally, the cost was found to positively strengthen the relationship between perceived behavior control, personal norms and households' LPG adoption intentions. However, the relationship between subjective norms and households' intention to adopt LPG was weakened in the presence of cost. (Sandula & Awopone., 2023)

Affordability itself has numerous drivers, such as LPG regulation, proximity of Malawi from the LPG source and resulting transport costs, storage, last mile distribution, market acceptability and understanding of use. Comparing with other sources of energy it makes a lot of Malawians not to adopt LPG but go for other sources of energy for cooking.

Table 3: Fuel costs *(Chiumia, Thengolose, & Tembo, 2022)*

Fuel	MWK/KG	MWK/kWh
Firewood	69.77	13.64
Local Charcoal	135.87	16.41
Kawandama Hills Plantation Charcoal	227.27	27.73
LPG	2583.33	208.05
Electricity	-	78.50

Studies show that LPG at current pricing is cost competitive versus traditional charcoal used in a baseline 'jiko stove', but not cost competitive versus any type of charcoal used in an intermediate or ultra-efficient cook stove. However, it is important to note that charcoal prices have been on an upward trajectory, which is anticipated to continue due to large and increasing demand for charcoal and limited supply of biomass to produce charcoal. This pose an opportunity for LPG adoption, but LPG in Malawi is extremely expensive relative to the global average and has potential to decrease with greater volume of sales. (Fay, 2019)

iii. Safety (Socio-cultural resistance to device adoption)

The role of perception in LPG safety

To discuss the issue of LPG safety multiple angles are to be taken into consideration, knowing the fact that LPG is a safe cooking fuel, the perception that it is more dangerous than other cooking solution is/and has proven to be the great barrier to the adoption or switching. Some dramatic and devastating nature of LPG accidents have led to sensational reporting and public fears. (George, Patel, Nair, & Hyland, 2019)

There are not such serious accidents in most countries involving LPG and mostly are relatively infrequent, the most common accidents are non-fatal ones like burns caused by direct flames from the burner. If serious accidents occurs they are from the leakage of the

gas from the pipe or cylinders and the subsequent ignition of the released gas. There are also some serious accidents yet extremely rare, these accidents involve the exploding of the gas inside the storage tank or the cylinder, and this occurs in an incident known as Boiling Liquid Expanding Vapor Explosions (BLEVE). This occurs due to the failure of the safety valve to release gas from the cylinder during a fire accident or when the cylinder has been heated up, which increases the pressure inside. (George, Patel, Nair, & Hyland, 2019)

The main reason that people have for not using LPG is safety (afraid of explosion), as shown below.

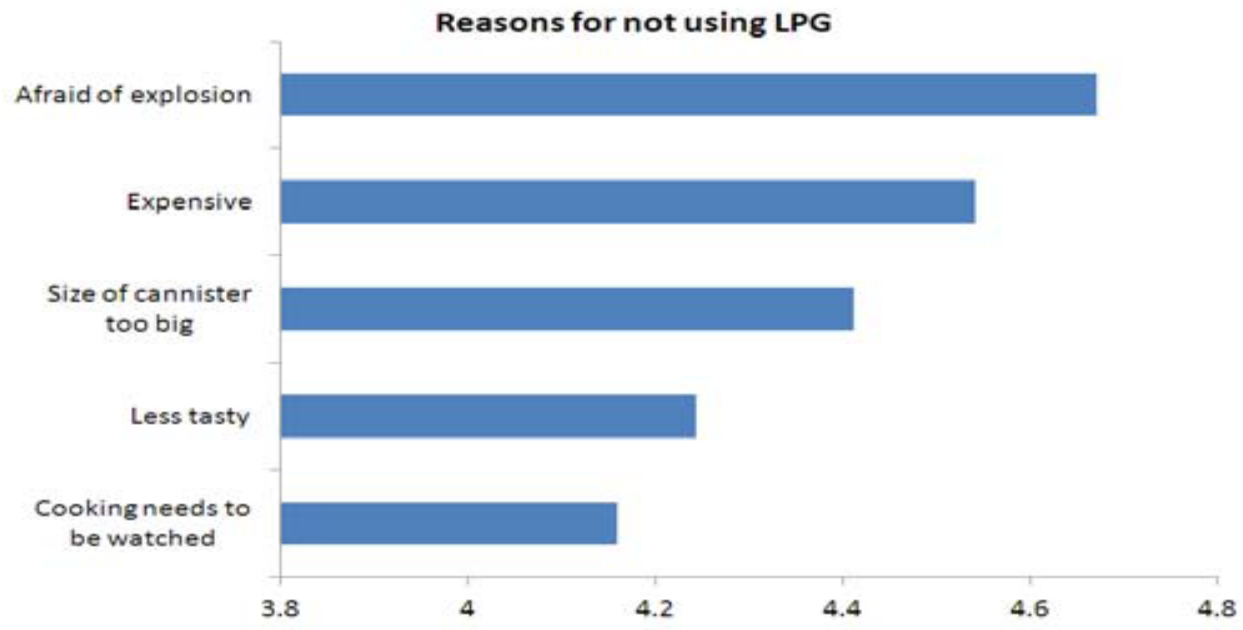


Figure 3 Reasons for not using LPG (George, Patel, Nair, & Hyland, 2019)

Generally studies show that LPG-related accidents occur more frequently in developing countries, this is because the safety standards are less respected and enforcement is not of great. (George, Patel, Nair, & Hyland, 2019)

To the potential users of gas, ultimately, affordability, accessibility and safety of LPG are key variables that determine adoption. All three of these variables must be clear to the potential customer otherwise adoption will remain limited. On the other hand, MERA

recommends the retail price of LPG per kg, as of April 2019 the cost was MK2, 044.22 ($2.69 USD), significantly higher than the global average price of $0.63 USD per kg. (Fay, 2019)

2.3 Review of LPG safety and health Risks

Like all forms of energy, LPG is potentially hazardous that is if it is mishandled or misused. The World LPG Association (WLPGA) has one of its aims to promote this issue of safety, and this is included in its vision. WLPGA is the authoritative global voice for LPG which promotes the use of LPG worldwide that's to foster safe, cleaner, healthier and prosperous world. (WLPGA & UNEP, 2018)

Although safety is an important issue, it should also be emphasized that LPG is an excellent, versatile and often preferred fuel for hundreds of applications. Care in the storage, handling, distribution and use of LPG will mitigate any incidents, accidents and their consequences. A hazard that is commonly associated with LPG is an uncontrolled release of product, followed by fire. The distributor/ retailer has a task to move LPG product in a safe and efficient manner to the end user, but as LPG moves further down the distribution chain that is from the depot the customer, the control over safety by the supplier or marketer becomes weaker, thorough analysis show that this is the point in the distribution chain where the customer interface occur and it is of great importance that safety receives increased and focused attention. (WLPGA & UNEP, 2018)

Safety guidelines that Malawi follow in LPG safety

LPG safety regulation in Africa follows a European standard which is generally higher than that of South America and Asia. While this is good for maintaining safe use of LPG, it makes LPG even more expensive and accessibility more difficult than it is in Europe. Regional gas storage facilities are important for ensuring safe storage of large amounts of LPG for easy onward transmission to the consumer. Shorter distances from the storage facility to consumer's home may also go a long way to forming a denser network of distributors and consequently, users. With more players in the LPG value chain, regulation can be better defined and contextualized over time. (Fay, 2019)

Handling, the cylinders should always be kept in an upright position, securely and in a well-ventilated area under a shade to keep the temperature of the gas low. These cylinders must be stored outside the kitchen or away from ignition sources. The higher the temperature, the higher the pressure buildup within the cylinder. They must not be kept in enclosed units and or basements to avoid the accumulation of leaked gas if gas may be leaking, to reach the ignition limit. The cylinders should not be subjected to any mechanical shock that could cause damage to their valves or pressure relief devices. They should not be dropped, dragged, slid, or used as rollers for moving material or other equipment. The cylinders should have caps to protect the valve on the top of the cylinder from damage if it is knocked over and if gas is accidentally released through the valve, the cap will vent the gas out of both sides, minimizing the likelihood that the cylinder will topple. Cylinder caps should not be removed until the cylinder is secured in place and ready for use. (Amorin & Dabo., 2022)

2.4 Data and methodologies

DATA

I. Primary data

Geospatial data

GIS data for mapping infrastructure, such as LPG distribution centers and also on the hand to produce a map showing the distribution network of LPG from distributor to customer

Interviews on safety issues

II. Secondary data

Number of players in the LPG industry in Malawi (2016 to 2022)

Data on usage, availability and distribution (2016 to 2022)

Data on accident and safety incidents records related to LPG usage (2016 to 2022)

METHODOLOGIES

a) Qualitative risk assessment or analysis

The main purpose of qualitative risk analysis is to identify the risk, the expounding more details about this risk (analysis) and the necessary controls and actions based on the risk's effects. Two methods are applied in this method.

1. Keep It Super Simple (KISS)

This method is mainly used on narrow-framed or small projects, where unnecessary complexity should be avoided and the assessment can be made easy. This is a one dimensional technique involves rating risk on a basic scale. (Volkan, 2021)

2. Probability or Impact

This method is used on large or more complex issues with multilateral teams having much experience in the risk assessment. This is a two dimensional technique which is used to rate **Probability** (the likelihood of that a risk will occur) and **Impact** (consequences or effects of the risk). (Volkan, 2021)

		Consequence				
		Negligible 1	Minor 2	Moderate 3	Major 4	Catastrophic 5
Likelihood	5 Almost certain	Moderate 5	High 10	Extreme 15	Extreme 20	Extreme 25
	4 Likely	Moderate 4	High 8	High 12	Extreme 16	Extreme 20
	3 Possible	Low 3	Moderate 6	High 9	High 12	Extreme 15
	2 Unlikely	Low 2	Moderate 4	Moderate 6	High 8	High 10
	1 Rare	Low 1	Low 2	Low 3	Moderate 4	Moderate 5

Figure 4 impact or probability rating matrix

b) Quantitative assessment or analysis

There are several tools and techniques that can be used in quantitative risk analysis. Those tools and techniques include:

1. Heuristic methods—Experience-based or expert based techniques to estimate contingency
2. Three-point estimate—A technique that uses the optimistic, most likely and pessimistic values to determine the best estimate
3. Decision tree analysis—A diagram that shows the implications of choosing various alternatives
4. Expected monetary value (EMV)—A method used to establish the contingency reserves for a project or business process budget and schedule
5. Monte Carlo analysis—A technique that uses optimistic, most likely and pessimistic estimates to determine the business cost and project completion dates
6. Sensitivity analysis—A technique used to determine the risk that has the greatest impact on a project or business process
7. Fault tree analysis (FTA) and failure modes and effects analysis (FMEA)—the analysis of a structured diagram that identifies elements that can cause system failure. (Volkan, 2021)

The most common problem in quantitative assessment is that there is not enough data to be analyzed. There also can be challenges in revealing the subject of the evaluation with numerical values or the number of relevant variables is too high. This makes risk analysis technically difficult. (Volkan, 2021)

PROCEDURES USED IN RISK ASSESSMENT

The risk assessment procedures is best illustrated by the diagram below, where there is:

Identifying risk, Assessing risk, Controlling risk and Review and control measures.



Figure 5 Risk assessment procedures (western Sydney University)

c) Interviews

Interview is a very important data gathering technique that involves verbal communication between the researcher and the participant. These interviews are commonly used in survey designs and in exploratory and descriptive studies. The quality ton data obtained from the interview depend on both the interview design and the skill of the interviewer. (Fox, 2009)

Interviews are categorized into two

i. Structured or standardized

This type enable the interviewer to ask the same question (closed questions) to different respondents. This is often used in order to do quantitative method of data analysis.

By minimizing open-ended responses, the amount of time coding and content analysis is greatly reduced. (Fox, 2009)

ii. Unstructured or In-depth

This is sometimes referred to qualitative interview, because they have very little structure. In this type the researcher tries to find great details of the topic that is being studied. So open-ended questions are used. This type takes a lot of time. (Fox, 2009)

Interview methods

The following are the methods that are used in interview and the method name simply indicate what is done in the process.

i. Individual

Individual interviews are valuable to provide detailed information about the meaning of an event, situation or social context to each participant in a setting

ii. Group

Group interviews (sometimes known as "focus groups") are only really appropriate for qualitative approaches, and can be used where there is some benefit in getting a "group story" about a setting or incident

iii. Face-to-face

This is the best way of collecting high quality data, in cases of collecting high sensitive data or the questions are complex. Compared to other methods of data collection, face-to-face interviewing offers a greater degree of flexibility.

iv. Telephone and Video links

This can be used in cases where a face-to-face interview is not possible, and may be appropriate where the topic is not sensitive and non-verbal behavior is less important

v. Web interviews

The Internet provides opportunities through chat rooms for interviewing, and is a growing method of conducting in-depth interviews.

d) Safety Audit

It is the process that evaluates the health and safety of a work setting. Systematically it collects information on a company's efficiency, productivity, reliability and safety. An auditor will evaluate the procedures, work environment, equipment and other factor to assess these attributes. Safety audit forms part or it's an integral part of the safety

management system, and they are of great importance or relevant in examining and identifying the various gaps and issues in the safety procedures. (TSM, 2023) The safety audit process touch multiple angles and some of these include

i. Routine inspections to ensure compliance to norms
ii. Identifying, Drafting, and communicating safety violations
iii. Dealing with the management and safety adherence by staff
iv. Periodic examination of the machinery
v. Ensuring compliance to the OSHA safety Audits and other regulations
vi. Recommendations for improving company safety

Through these the audit process helps to improve the current working conditions and helps also to develop a better recommendation that directly engage in the effective implementation of safety procedure in different organizations. (TSM, 2023)

Types of Safety audit

Safety audits are classified into three types and each type has its unique emphasis and goal. The types are as follows:

i. Compliance Audit

Compliance audit in mainly focused on verifying an organization's compliance with the applicable laws, regulation, standards and policies. These audits are typically or mainly conducted to ensure that the organization is meeting its legal obligation and it's following established safety requirements. It does this in order to ensure that effective safety measures are followed in order to protect employees, customers and other stakeholders from safety risks. (TSM, 2023)

ii. Program Audit

This type of audit involves evaluating various safety practices after heavy dissection of all the input by the employees and every individual component to determine positive safety outcomes of the program. Safety program audit are the only feasible way of putting Health Safety and Environment (HSE) to the test in rigorously evaluating the program

design and efficacy of the plan by diving deep into the rules and foundations of practice. (TSM, 2023)

iii. Management system Audit

Management System audit is a combination of both a compliance audit and program audit, and this type of audit aims at evaluating the existing performance of the entire safety procedure and determine its alignment with the company policy and regulatory norms. It helps to integrate the standard auditing procedure and worker interviews, compliance reviews, and workplace observation. This is an intertwined system in which its collaboration helps to project an overall image of the organization's safety program. (TSM, 2023)

e) Geospatial mapping of distribution network

The mapping distribution network, this is how LPG is distributed from the retailer or LPG distributor to the consumer.

The use thematic map (Flow line maps), Flow line maps are a type of thematic map used in Cartography to show the movement of objects between different areas.

Flow maps illustrate movements of tangible and intangible phenomena between locations. While there are many types of flow maps, origin–destination (OD) flow maps illustrate directed flows between origin and destination locations while ignoring the actual routes between locations. (Caglar Koylu, Tian, & Windsor, 2023)

2.5 Policy and regulatory frameworks

Absence of LPG specific policy and strategy in relation to cooking

The revised 2018 National Energy Policy of Malawi has one of its goals "to increase access to affordable, reliable, sustainable, efficient and modern energy for every person in the country". LPG is mentioned as the fuel to be prioritized, as indicated in one of the objectives to achieve the policy goal "is to ensure availability of LPG, biogas and natural gas in sufficient quantities at affordable prices for industrial and domestic use. However, there is

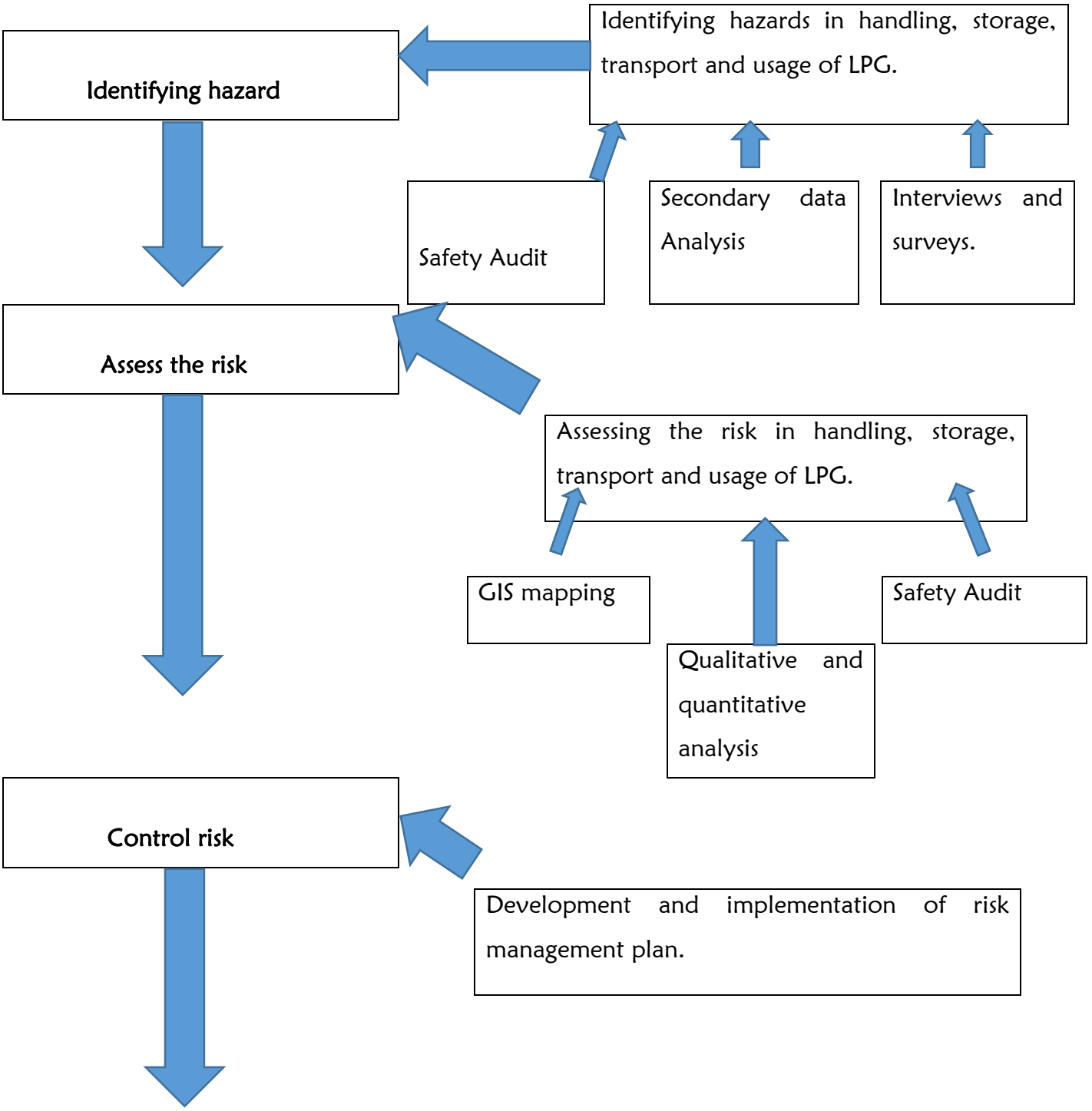
no strategy (or master plan) to achieve this policy objective on LPG. Also, there is no standalone policy that could cross-cut other sectors that have a bearing on successful implementation of LPG consuming program. These sectors include forestry, finance, transport, science and technology, industry, infrastructure development, and gender mainstreaming. Absence of LPG specific policy results in technology not receiving the required support (for example in forms of subsidy) from government and its development partners the way how other clean energy technologies (e.g. solar) receive the support. Also, the key players in the LPG cooking technology chain are not coordinated. Also, the data on LPG consumption is scanty and not systematically collected by relevant authorities in Malawi. (Government of Malawi, 2021) Therefore, LPG activities are not informed as well as not coordinated in the country. Further, Malawi's energy policy (both first and the revised one) pays more attention to petroleum (petrol and diesel), and electricity than any to other sources of energy. This is because these two are seen by decision makers as the only energy sources that will drive Malawi into industrialization. Furthermore, policy elements on prioritizing and facilitating use in households including promotional activities involving education is missing. There are a number of organizations (both government and non-government based) involved in LPG promotion in Malawi, for example Energy Affairs Department, Department of Forestry, Environmental Affairs Department, Malawi energy regulatory Authorities, Consumers Association of Malawi. However, these organizations work in isolation, contributing to limited focus in designing and implementing policy issues. (Government of Malawi, 2021)

Limitations in LPG standards, regulation and its enforcement

Malawi Energy Regulatory Authority (MERA) is mandated to be an energy sector-wide regulator. However, the stakeholders felt that MERA is seen to be more active on petroleum and electricity regulation. In terms of standards, standards on LPG fuel are available. Also, safety standards are on design, construction and installation of tanks and cylinders are available. The safety standards on transport and distribution as well as on the end use of the LPG systems are not yet developed and enforcement of the standards is challenge. (Government of Malawi, 2021)

3.0 CHAPTER 3: METHODOLOGIES

3.1 Research design



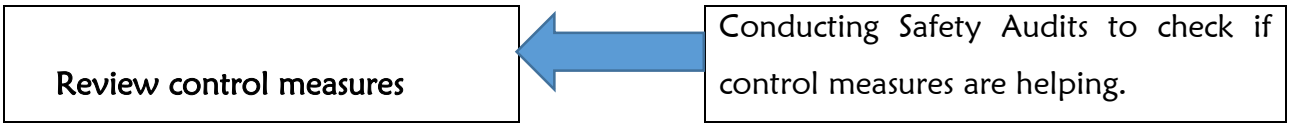


Figure 6 Research Design

3.2 Materials and methods

This research project used so many materials and methods to achieve the objectives and some of these are

3.2.1 Sampling Technique

This project used a sampling technique which is random sampling, where LPG retailers or distributors in the city of Blantyre were sampled based on how accessible they are for the project progress. The list of Gas retailers or distributors for the southern region was obtained from MERA highlights report.

3.2.2 Data collection

Consumer base data for this research project was collected or obtained from different LPG retailers and distributors and these are Gasman located in LImbe, 265 Energy in the trade fair compound in Blantyre, Meru Gas located in Limbe near Illovo offices and Afrox Malawi limited located at Ginnery corner. The data included percentage distribution of the customers a retailer has and the location of the customers (consumer or customer base data)

This data was used to create thematic maps (Flow Line map) for the distribution network of the Liquefied Petroleum Gas for different retailers in the city of Blantyre. These maps were used to show the areas that can be much affected if at any cost safety is compromised or areas that are at a high risk of experiencing accident if chances allow and also the area to target with different safety promotion programs.

Data on accidents was also obtained from the LPG retailers and distributors which included number of accidents encountered in the course of handling, storing, distribution and usage

(from customers). This data was used to predict the trend of accidents taking into account also some other factors like availability

LPG imports and sales data was obtained from Malawi Energy Regulatory Authority (MERA) and general accidents associated with LPG data was also obtained from MERA Madam Nomalha Wittika the director at MERA Blantyre offices provided these datasets. This data was used to compare with the data that was obtained the LPG retailers or distributors. It was also used to analyze the impact of increase in usage and increase in players or retailers on accidents and forecast the trend for the future.

Safety data was obtained from LPG retailers or distributors through safety audit process, this was the basic compliance safety audit. A basic compliance safety audit manual was made and was used to check the compliance of different LPG distributors. This data helped to show how the companies are complying with standards at different levels in the supply chain management taking the issue of safety into consideration and how serious they are with the customer safety and also on handling, storage and distribution of the Gas.

3.2.3 Methods

There are different methods which were used to achieve the objectives like Interviews or surveys, were some questions were asked basing on the safety audit compliance manual. And other methods include safety audit and GIS mapping as well as data analysis.

3.2.4 Software

In this research, GIS software such as ArcGIS and QGIS was used. These software are used for creating, editing, manipulating, and processing data that has spatial coordinates. And in this project they were used to create maps that indicated or showed the distribution network of Liquefied Petroleum Gas in Blantyre city and also the study are a map.

Excel software was also used to analyze data and come up with different graph that helped in the interpretation of the data. It was also used in the trend forecasting of the accidents based on the past data.

3.3 Analysis

After all the data was obtained it was analyzed through graphical analysis where different datasets like Consumer base, number of accidents and number of retailers or distributors against the year they ventured into the business was inserted into the excel software and graphs were produced.

Qualitatively data was analyzed using probability or impact risk rating matrix, where there is the determination of the likelihood of the occurrence of the risk and the determination the consequences they produce.

3.4 Limitations of the project and its solutions

In conducting a research there are a lot of ups and downs that affect the progress of the research.

Data collection is one of the problem or limitations that affected this project, most of the data which was necessary for this project is not documented in different companies. And since this project involved the retailers or distributors, more of them have no well-established database for their business and in requesting data from their companies it was like a wakeup call for them to organize the data, and this in turn affected the time to receive the data. Some could just provide oral data.

Despite having all these challenges the research project was still carried out and had shown results that could be used in different aspects like decision making and so many more.

3.5 Study area

This research was carried out in Blantyre City located in the Shire highlands in the southern region of Malawi surrounded by four mountains with varying topography. This area was chosen because is commercial city of Malawi.

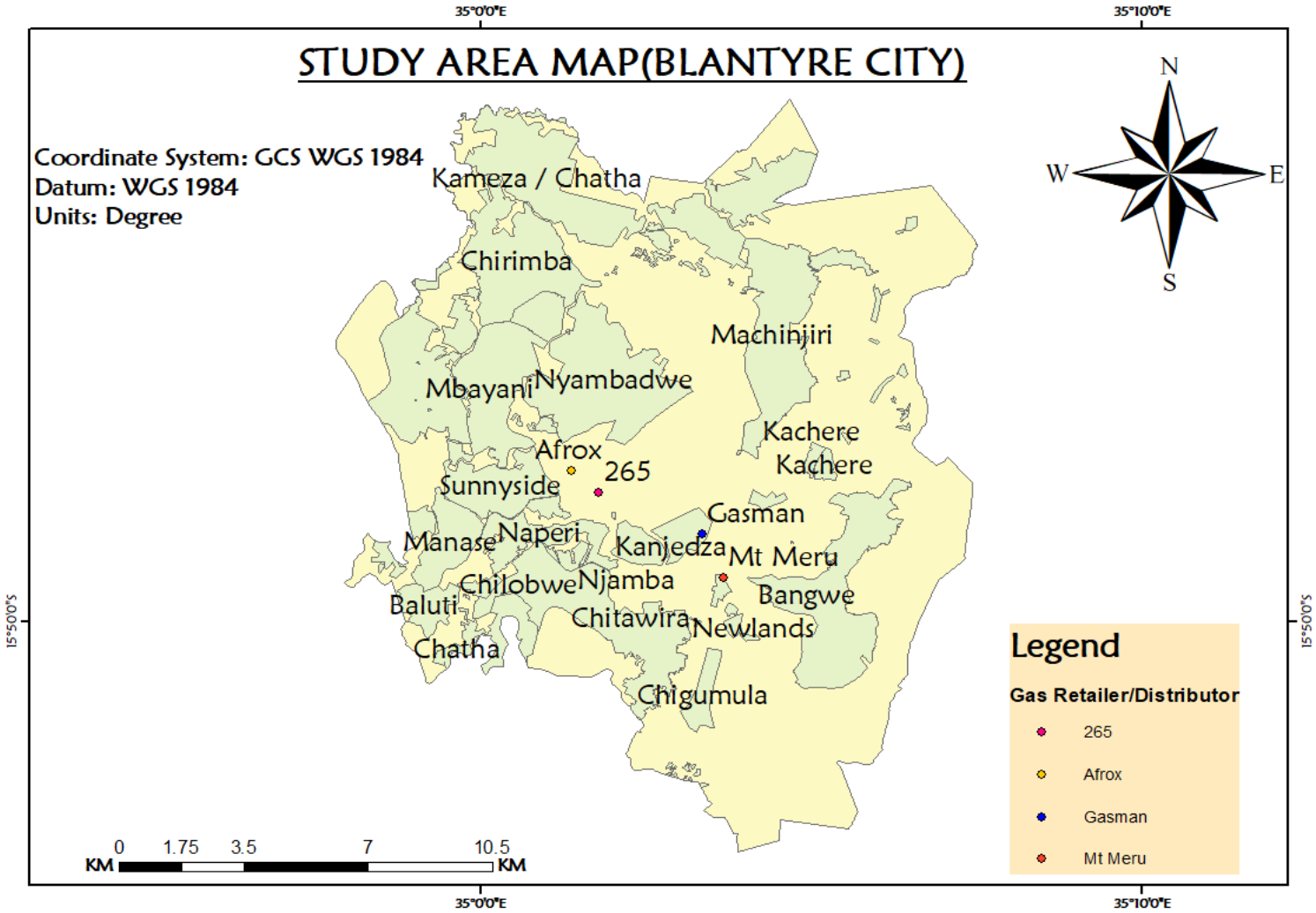


Figure 7 study area map

4.0 CHAPTER 4: RESULTS AND DISCUSSIONS

Analysis of different retailers or distributors on hazards or risks associated with their operations using the probability/ impact risk rating matrix.

Fire hazard, Explosion hazard and Chemical release (leakages) hazard are the hazards that have been identified, which are associated with the adoption and usage of LPG in the area of study. With explosion hazard never experienced before but cannot be sidelined because it can happen and take the life of innocent people. But more focus will be on the ones that has been experienced before which are fire and leakage.

Retailer or Distributor 1

	Occurrence (Likelihood)	Consequence (damage)	Risk rating matrix result
Fire hazard	2 (unlikely)	2 (minor)	4 (moderate)
Chemical release	4 (likely)	3 (moderate)	12 (high)

Retailer or Distributor 2

	Occurrence (Likelihood)	Consequence (damage)	Risk rating matrix result
Fire hazard	3 (possible)	2 (minor)	6 (moderate)
Chemical release	2 (unlikely)	3 (moderate)	6 (moderate)

Retailer or Distributor 3

	Occurrence (Likelihood)	Consequence (damage)	Risk rating matrix result
Fire hazard	3 (possible)	1 (negligible)	3 (low)
Chemical release	4 (likely)	2 (minor)	8 (high)

Retailer or Distributor 4

	Occurrence (Likelihood)	Consequence (damage)	Risk rating matrix result
Fire hazard	3 (possible)	3 (moderate)	9 (high)
Chemical release	4 (likely)	3 (moderate)	12 (high)

The hazards that pose the high risks are these and differs with different retailers in terms of rating based on the safety measures that they do follow and how they make sure they are implemented for the safety success.

DISTRIBUTION NETWORK FOR LPG IN BLANTYRE CITY

The flow line (thematic) map shows the distribution network of LPG in Blantyre city for the four Gas retailers or distributors. It shows also the consumption percentages of the areas and people from these areas are the ones at risk for any inconvenience or accident that can happen at different distribution chain levels.

These are the areas to be targeted with the safety awareness campaigns and other awareness initiatives in order to enhance safety among the ones that have adopted and are using and attract more to adopt and start using the cleaner energy (LPG).

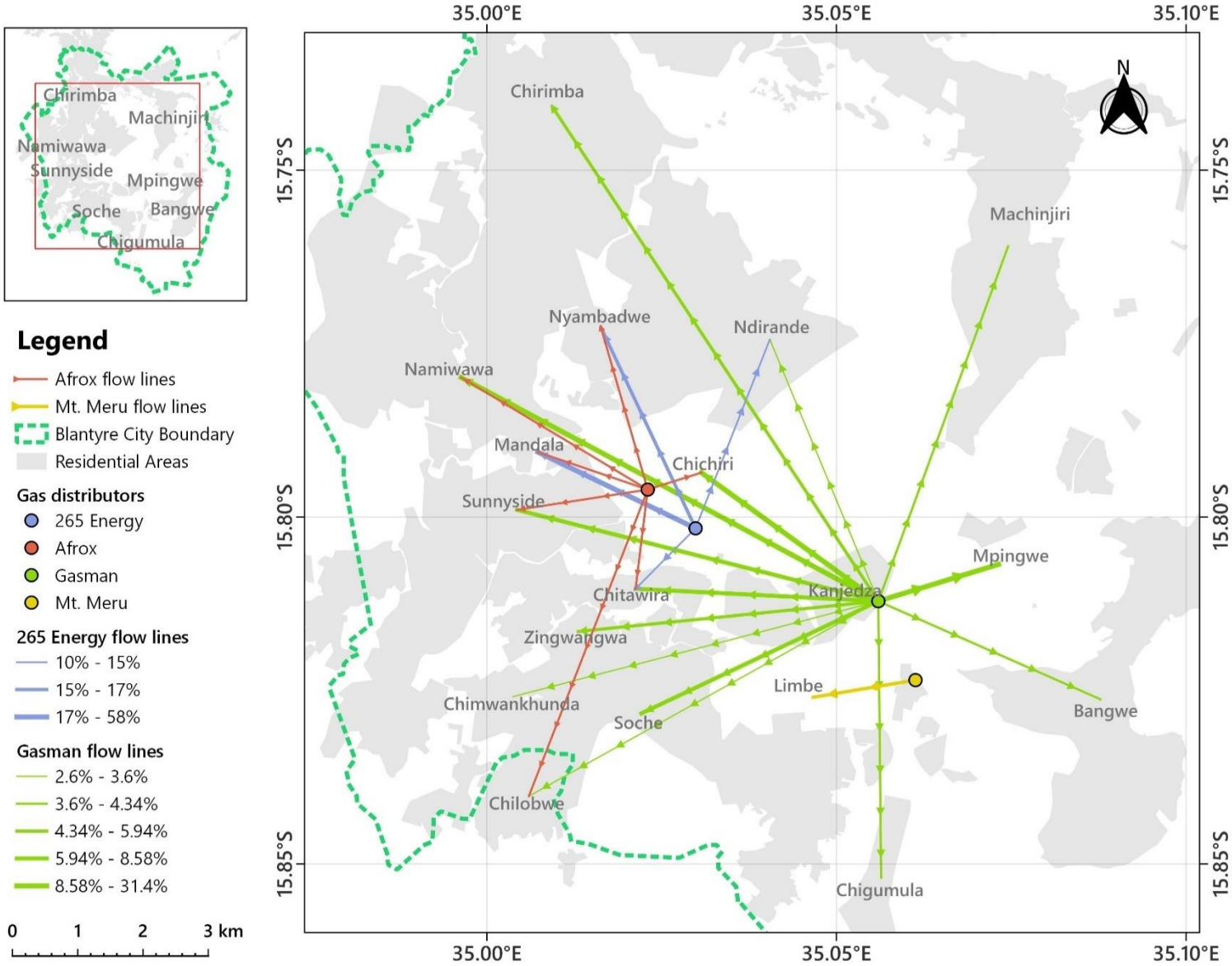


Figure 8 Distribution network map

NUMBER OF ACCIDENTS AND THE ACCIDENT TREND

Different Gas retailers have experienced different kinds of accidents in different years and here is the data on accidents that have occurred for different retailers.

Table 4: Number of accident for specified retailers

Year	2019	2020	2021	2022	2023
Retailer 1	0	0	0	0	1
Retailer 2	0	0	0	1	0
Retailer 3	0	0	1	0	0
Retailer 4	0	0	0	0	2

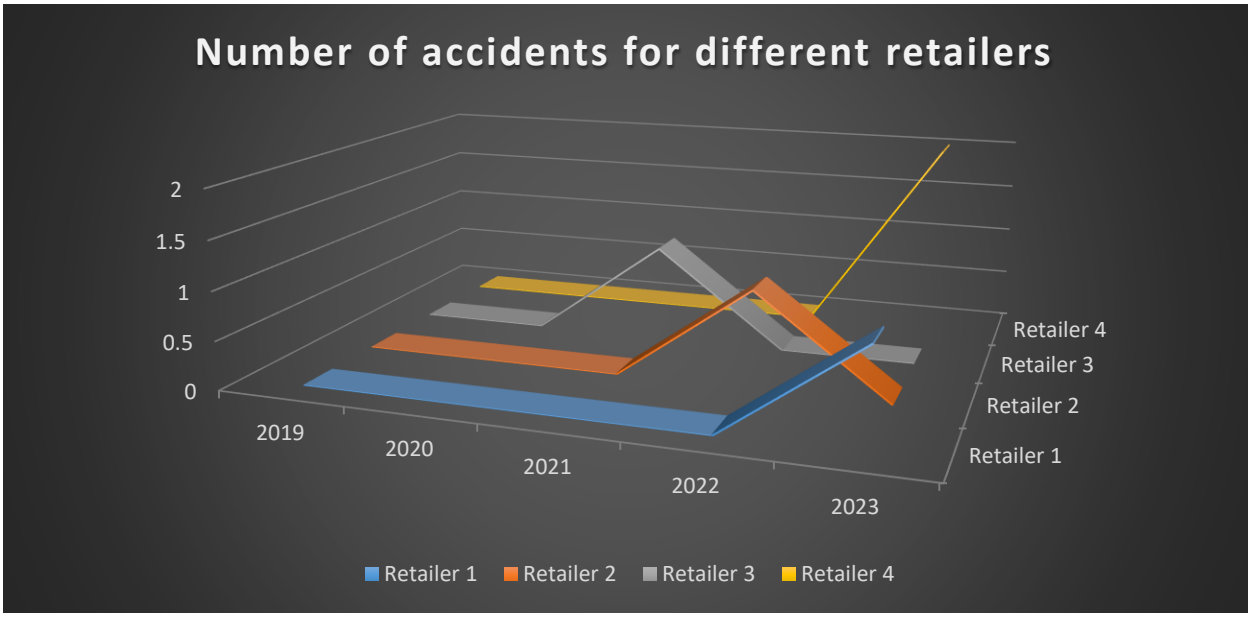


Figure 9 Graph of number of accidents

The Factors or Parameters that affects the number of accidents which are occurring at different levels in the supply chain or distribution chain based on this research are negligence in terms of safety and also ignorance in issues to do with safety of LPG.

This is represented by the following variation equation;

Number of accidents varies directly with negligence and directly with safety ignorance

$N \propto n + i$ (where N is number of accidents, n is negligence and i is safety ignorance)

This simply means that there is a direct relationship between the parameters, in that when negligence increase or safety ignorance (by the user) increases, it directly increases the number of accidents that will be experienced

An overall accident trend for Liquefied Petroleum Gas at different levels in the distribution chain for 5 years.

Table 5: Overall number of accidents

Year	Number of accidents
2019	0
2020	0
2021	1
2022	1
2023	3

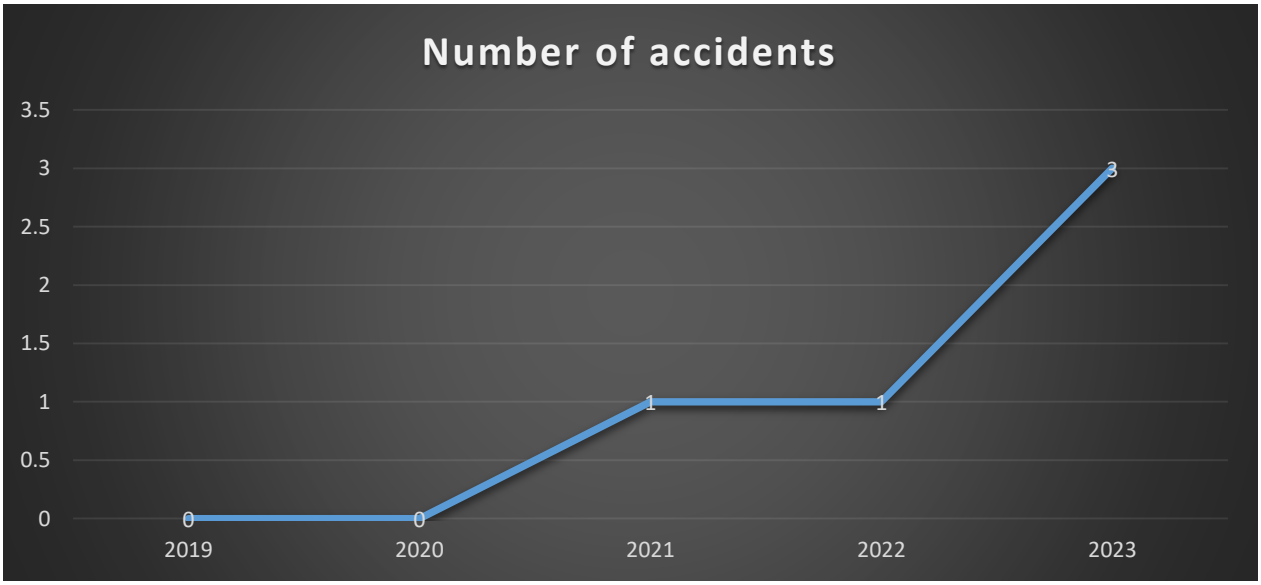


Figure 10 Overall number of accidents graph

This trend shows that as the years are going the number of accidents is increasing, this means that as the years are increasing safety negligence or user ignorance is also increasing hence increasing the accident rate.

LPG CONSUMPTION AND THE RELATIONSHIP WITH NUMBER OF ACCIDENTS

Table 6: LPG Consumption

Year	LPG consumption millions (KG)
2019	1.2
2020	1.3
2021	1.55
2022	2.2
2023	2.6

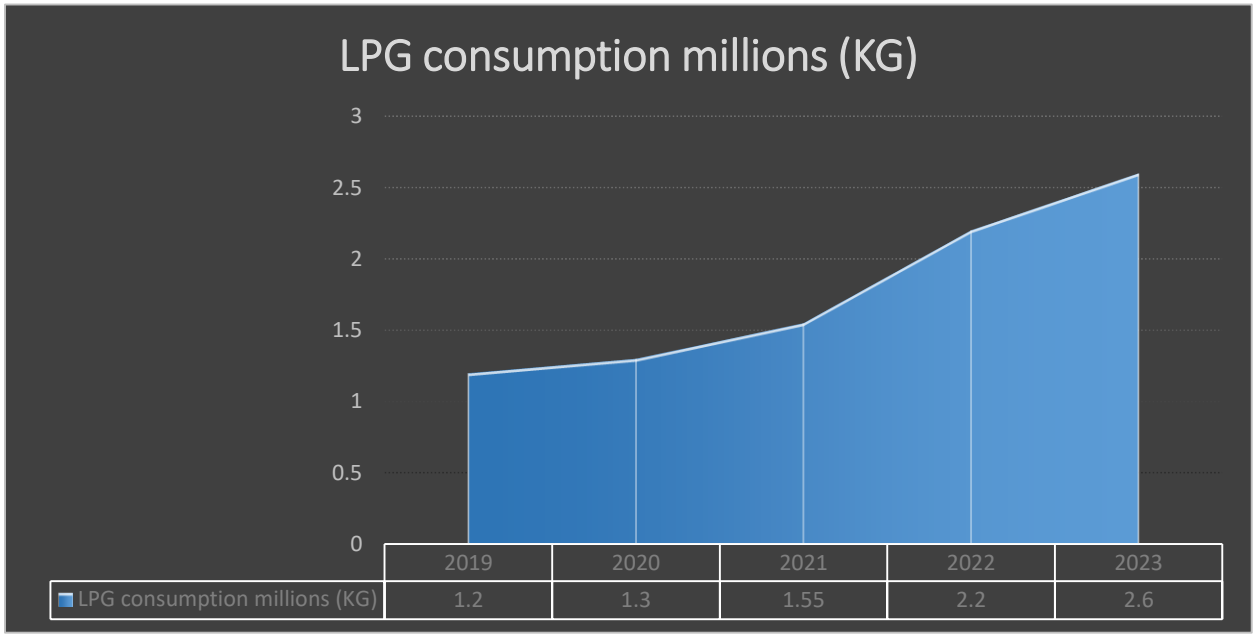


Figure 11 LPG consumption graph

This LPG consumption trend shows that as the number of years are increasing the consumption rate is also increasing. According to this research this has been brought about by some factors or parameters, and these are availability, accessibility and awareness (awareness campaigns based on safety and general knowledge of LPG)

In this case consumption varies directly with availability, accessibility and awareness and all this is summarized in the following variation equation.

$C \propto XYZ$ (where C is the consumption, X is availability, Y is accessibility and Z is awareness)

This simply means that increase in those parameter will surely increase the consumption rate in this equation.

CONSUMPTION VERSUS NUMBER OF ACCIDENTS.

A comparison of Consumption trend and accident trend, this is showing how these two are changing over 5 years period of time. As it is in the figure below both variables are increasing with increase in number of years.

Table 7: Consumption vs. Number of accidents

Year	LPG Consumption millions (KG)	Number of accidents
2019	1.2	0
2020	1.3	0
2021	1.55	1
2022	2.2	1
2023	2.6	3

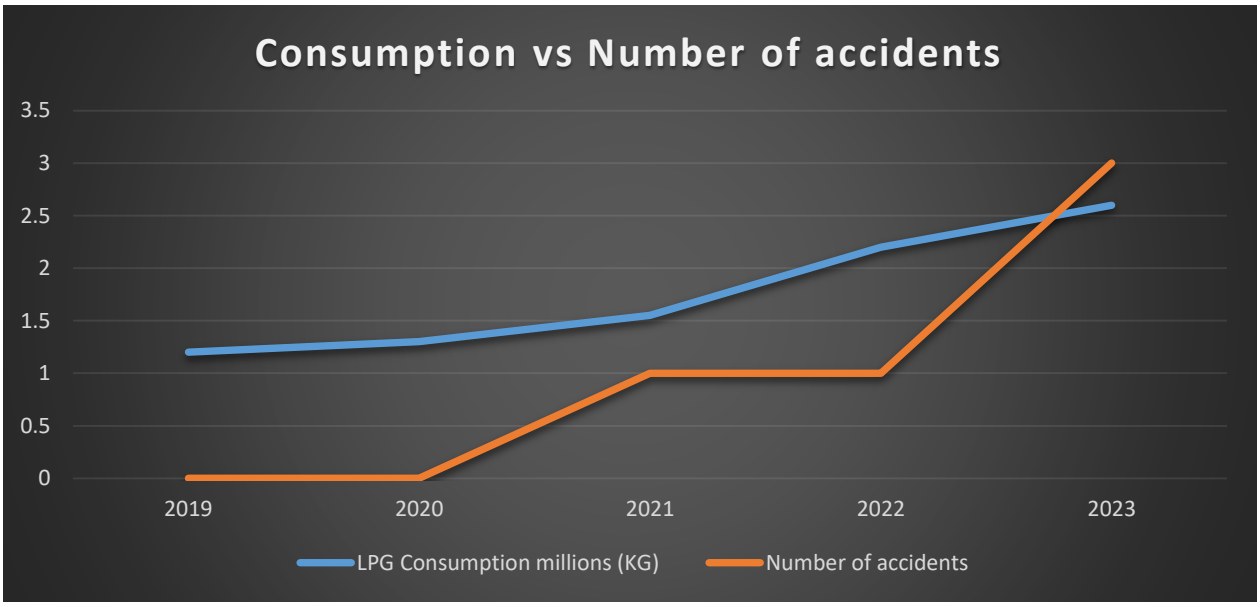


Figure 12 Accidents vs. Consumption graph

This trend shows that the parameters which are involved in both the consumption and number of accidents are increasing making both of these to increase too since there is a direct relationship between them.

Now since safety has been a factor that really has and is affecting the adoption and usage of LPG as highlighted in this research project, therefore this increase in LPG related accidents will negatively affect the consumption at a certain point and this will turn the relationship between these into an inverse relationship.

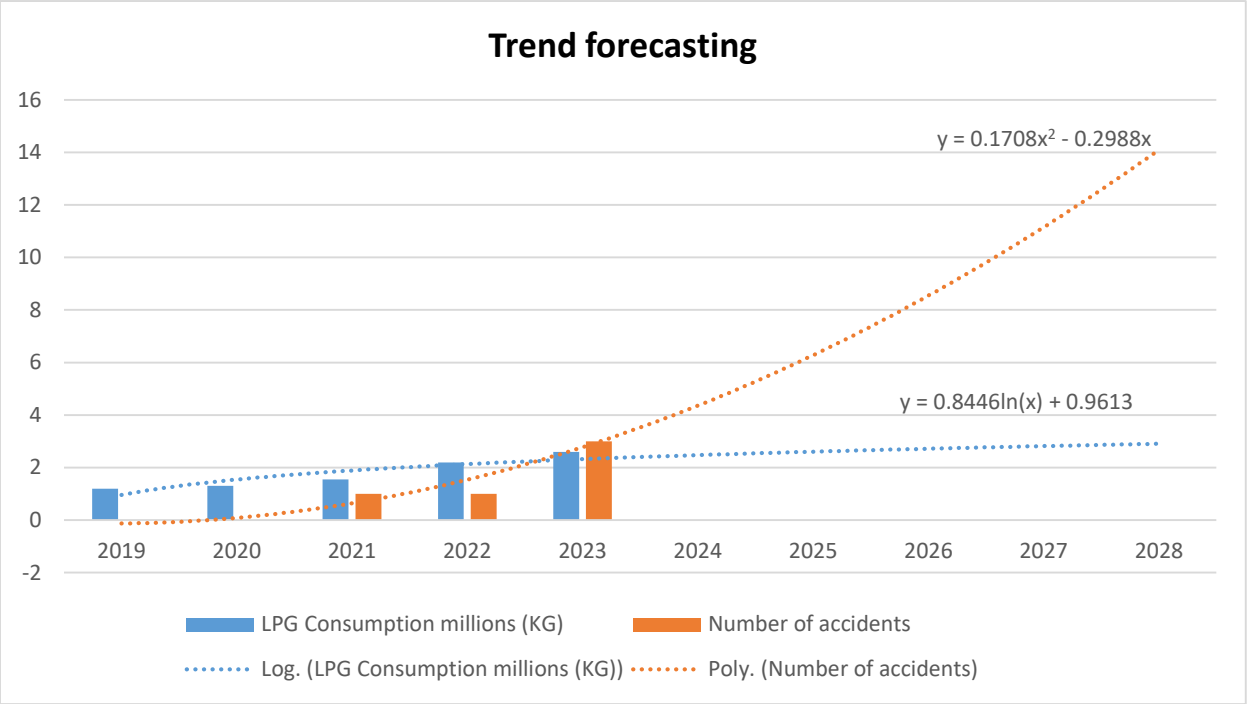


Figure 13 Trend forecasting graph

Using the polynomial trend forecasting method and the logarithmic trend forecasting for number of accidents and LPG consumption respectively in excel software. Formula for the slope of number of accidents is $y = 0.1708x^2 - 0.2988x$ and also formula for the LPG consumption slope is $y = 0.8446\ln(x) + 0.9613$, so this trend shows that as the number of accidents increases it affect the consumption by directly affecting the adoption rate.

5.0 CHAPTER 5: CONCLUSION AND RECOMMENDATION

5.1 Conclusion

The results show that there is an increase in the consumption rate on the other hand number of accidents is also increasing. For the accidents improper transport and handling means which is brought about by negligence or ignorance are contributing to the increase in accident. While 50% of the retailers are recovering from the accident zone, the other half is experiencing their first accidents. The goal is to have zero LPG related accidents.

Safety comes at a cost, and since LPG is in the business circles as the adoption and usage rate is increasing more players will venture into this business and safety will be compromised in one way or the other and will increase the number of accidents related to LPG, because as LPG moves down the distribution chain to the consumer safety measures tend to weakens.

Now if the trend of accidents continues like that, the adoption and usage rate will be negatively affected since people will be afraid of using the gas enhanced by the perception that they already have

Care in the storage, handling, distribution and use of Liquefied Petroleum Gas will mitigate incidents, accidents and their consequences.

5.2 Recommendation

They are so many points to take into consideration in order to mitigate the risks associated with LPG at different levels and some recommendations are:

Safety should always come first before conducting any operation, this will help to protect the individual conducting the operation preventing accidents and on the other hand promoting LPG adoption and usage.

Safety or general compliance audits should be done more and more in order to enhance adherence to standards

Regulations and policies specific for LPG usage should be developed and LPG should be given much consideration or concentration as other petroleum products do for example diesel and petrol.

LPG safety information dissemination, via the use of different internet platforms or through different awareness campaigns safety and usage information should be delivered to people in order to reduce the rate of ignorance and reduce the accident rate.

At the distribution centers, there has to be regular checks of the valves for leakages like the way MERU Gas does, by using the method of safe test.

On handling and transportation the safety guidelines has to be followed in order to prevent the increase in leakage rate by making sure that the cylinders are positioned in an upright position all the times.

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APPENDICES

Appendix 1 Safety audit manual

BASIC COMPLIANCE SAFETY AUDIT MANUAL

Key: Yes ☑ No ☒

Parameters to focus on

I. HANDLING

Personal Protective Equipment's (PPE)

Basic PPE for workers

Safety boots ☐ Hard huts ☐ Work suit ☐ Gloves ☐

Expertise (Personnel)

Safety experts ☐

Emergency response ☐

Ignition sources (electrical)

Any ignition source around ☐

Specify……

……

……

……

II. STORAGE

Storage of cylinders (empty and filled ones)

Position upright ☐ not upright ☐

Area stored safe ☐ not safe ☐

Prevention of corrosion

Followed ☐ not followed ☐

If followed specify the procedure:

……

……..

Routine cylinder inspection

Valve `☐

Firefighting Equipment

Present ☐

Specify……

……

Updated ☐ expired ☐

III. TRANSPORT

How cylinders are transported

Retailers: vehicle ☐ bicycle ☐ motorcycle ☐

Customers: vehicle ☐ bicycle ☐ motorcycle ☐ manual (i.e. head) ☐

IV. USAGE

Knowledge of safety by consumers