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**COLLEGE OF ENGINEERING, DESIGN, ART AND
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SCHOOL OF ENGINEERING

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FINAL YEAR PROJECT REPORT

**FEASIBILITY STUDY OF OXYGEN MANUFACTURING IN
UGANDA**

**SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENTS
FOR THE AWARD OF A DEGREE OF BACHELOR OF SCIENCE IN
MECHANICAL ENGINEERING**

By

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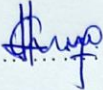
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20TH JANUARY 2022

AUTHOR DECLARATION


I **Igga Atwiine Marvin** a student of Bachelor of Science in Mechanical Engineering at Makerere University, do solemnly declare that the contents of this report are a true record of my own research and not a copy or duplicate of any work that has been submitted to any institution or university by any other person for the award of any academic qualification.

Signature: 

Date: 20th Jan., 2022


SUPERVISOR APPROVAL

I hereby declare that this project was done under my supervision and come to agreement that it is sufficient in terms of scope and quality for the award of a degree of Bachelor of science in Mechanical Engineering.

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DEDICATION

I dedicate this report to my beloved family especially my parents Mr. Justus Tusubira and Mrs. Jennifer Atukunda. They have been a strong source of support and morale in my academic journey.

ACKNOWLEDGEMENT

The journey of materialising this research has not been one that I have walked alone. I have had insurmountable support from several people and therefore I would love to extend my sincere gratitude to the following.

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TABLE OF CONTENTS

AUTHOR DECLARATION	Error! Bookmark not defined.
SUPERVISOR APPROVAL.....	Error! Bookmark not defined.
DEDICATION.....	iii
ACKNOWLEDGEMENT.....	iv
LIST OF FIGURES	viii
LIST OF TABLES	ix
ABSTRACT.....	xi
CHAPTER ONE: INTRODUCTION	1
1.1 Background	1
1.2 Problem Statement.....	2
1.3 Objectives.....	2
1.3.1 Main Objective	2
1.3.2 Specific Objectives	2
1.5 Justification	3
1.6 Scope	3
CHAPTER TWO: LITERATURE REVIEW	4
2.1 Overview of Oxygen.....	4
2.2 Medical-Use Oxygen	4
2.3 Oxygen Availability	4
2.4 Current Oxygen Supply Model in Uganda.....	5
2.5 Demand Forecasting Techniques.....	6
2.5.1 Moving Average Method	6
2.5.2 Regression Model	6
2.6 Oxygen Production Methods.....	6
2.6.1 Liquid Oxygen Plants	6
2.6.2 Pressure Swing Adsorption oxygen plants.....	7
2.6.3 Oxygen Concentrators.....	8
2.6.4 Oxygen Cylinders.....	8
2.7 Business Appraisal Computations.....	8
2.7.1 Payback period.....	8
2.7.2 Net Present Value.....	8
2.7.3 Internal Rate of Return	8
2.7.4 Profitability Index.....	9
CHAPTER THREE: METHODOLOGY.....	10

3.1 Research Design and Framework	10
3.2 Sampling	10
3.3 Data Collection	11
3.3.1 Primary Data Collection Methods	11
3.3.2 Secondary Data Collection Methods	11
3.3.3 Key parameters of data collected	11
3.4 Data Analysis	12
3.4.1 Demand Estimation and Forecasting	12
3.4.2 Average Monthly Production Capacity	13
3.4.3 Standard Manuals	13
3.4.4 Business Appraisal Computations	13
CHAPTER FOUR: DATA COLLECTION AND ANALYSIS	15
4.1 Market for Oxygen	15
4.1.1 General statement about the market for oxygen	15
4.1.2 Demand Estimation	16
4.1.3 Demand Forecasting	21
4.1.4 Plant Capacity of Oxygen Manufacturers in Uganda	22
4.1.5 Market Opportunity	22
4.2 Manufacture of Oxygen	23
4.2.1 Manufacturing Process	23
4.2.2 Plant Sizing	23
4.2.3 List of Equipment	24
4.2.4 Technical Specification of Equipment	26
4.2.5 Layout of Oxygen Plant	28
4.2.6 Organizational Structure	29
4.2.8 Maintenance of Equipment	30
4.2.9 Environmental and Social Impact Assessment	31
4.3 Costing of Proposed Oxygen Plant	32
4.3.1 Fixed Capital Costs	32
4.3.2 Operating Costs	33
4.3.3 Indirect costs	35
4.4 Financial Plan	37
4.4.1 Source of funds	37
4.4.2 Loan Repayment Schedule	37
4.5 Annual Sales	39
4.5.1 Production capacity	39

4.5.2 Sales Estimation	40
4.6 Cashflow Projections	42
4.7 Business Appraisal Computations	46
4.7.1 Net Present Value	46
4.7.2 Internal Rate of Return	47
4.7.3 Profitability Index	47
4.7.4 Pay Back Period	47
CHAPTER FIVE: RESULTS	48
5.1 Oxygen Demand	48
5.2 Capacity of Proposed Oxygen Plant	48
5.3 Cost of Investing in Proposed Oxygen Plant	48
5.4 Profitability of Proposed Investment	49
CHAPTER SIX: CONCLUSIONS AND RECOMMENDATIONS	50
6.1 Conclusions	50
6.2 Recommendations	51
REFERENCES	52
APPENDIX	54
I. Quotation for Oxygen Generation Equipment	54
II. Questionnaire	54

LIST OF FIGURES

Figure1: Supply of oxygen in public and private healthcare facilities, 2016.....	5
Figure2: Sources of oxygen concentrators at both public and private health facilities in Uganda	5
Figure3: Components of a PSA oxygen plant.....	7
Figure4: Research Framework	10
Figure5: Number of functional health care facilities by financial year and ownership	15
Figure 6:Leading causes of admissions in FY 2017/18	17
Figure 7: Leading causes of admissions in FY 2018/19	18
Figure 8: Leading causes of admissions in FY 2019/20	18
Figure9: Process layout of plant.....	28
Figure 10: Types of oxygen cylinders.....	39
Figure 11: Forecasts for oxygen demand up to 2030.....	48
Figure 12: Share of investment costs	49

LIST OF TABLES

Table 1 Number of functional healthcare facilities by region.....	16
Table 2: Hypoxemia Prevalence rate and Oxygen need per patient	16
Table 3: Oxygen utilisation for Covid-19 patients.....	19
Table 4: Estimated Oxygen demand caused by Covid-19 pandemic.....	20
Table 5: Total estimated oxygen demand for 2017/18, 2018/19 and 2019/20.....	20
Table 6: Demand forecasts for the next 10 years.....	21
Table 7: Production capacity of public manufacturing plants	22
Table 8: The proposed plant capacity	24
Table 9: Oxygen Plant equipment description	24
Table 10: Cost of oxygen generation equipment	32
Table 11: Cost of other-equipment	32
Table 12: Capacity of different oxygen cylinders.....	39
Table 13 :Number of cylinders filled per day	40
Table 14: Projected annual sales.....	41
Table 15: Present Values of Cash Flows	46
Table 16: Net Present Values.....	47

ABBREVIATIONS AND ACRONYMS

EML	Essential Medicines List
HCIV	Health Centre IV
ICU	Intensive Care Unit
IRR	Internal Rate of Return
JMS	Joint Medical Stores
LPM	Litres per Minute
MNRH	Mulago National Referral Hospital
NMS	National Medical Stores
NPV	Net Present Value
PI	Profitability Index
PSA	Pressure Swing Adsorption
RRH	Regional Referral Hospital
SDG	Sustainable Development Goal
WHO	World Health Organisation

ABSTRACT

Regardless of being an essential medicine, oxygen is still inadequate and unreliable in most healthcare facilities across Uganda. This is attributed to under-investment in oxygen manufacturing plants. Currently there are about 3000 public healthcare facilities which are being served by only 17 public oxygen plants.

As a result of being inadequate, oxygen has been limited to a few areas in the hospital like operating theatres and intensive care units. Therefore, many illnesses like pneumonia which are treatable with oxygen therapy have continued to claim the lives of patients. Moreover, accessing oxygen therapy has remained costly for most patients. This is as result of healthcare facilities incurring high costs and facing logistical challenges to access the oxygen.

Therefore, it is necessary to increase investment in oxygen manufacturing to meet current and future demand. As a way of encouraging investors, this study assessed the practicality and profitability of setting up an oxygen manufacturing plant. An estimation of past and present oxygen demand was done to enable forecasting of future demand. Available oxygen supply was determined by establishing the production capacity of oxygen manufacturers. With an understanding of supply and demand, the existing market opportunity was identified and a suitable oxygen manufacturing plant was sized. Investment requirements and costs of setting up the proposed plant were detailed. After this, projected revenue from sales was established for subsequent years. Finally, business appraisal computations like net present value, internal rate of return and profitability index were utilised ascertain whether the investment is feasible.

Analysis showed that to meet projected oxygen demand in 2030, further investment in at least two oxygen manufacturing plants is required. Each of the proposed plants has a production capacity of 60m³/hr and requires an initial capital investment of UGX 2,527,521,800. The investment generates a positive net present value at year 13, has a profitability index greater than one and an internal rate of return greater than the lending rate of 19%. This indeed shows that the proposed investment is feasible.

CHAPTER ONE: INTRODUCTION

1.1 Background

Oxygen is listed on the Essential Medicines List (EML) for use in reversing or preventing hypoxemia, a condition that results from severe shortage of oxygen in the blood. It is also referenced for; treating acute and chronic respiratory disorders like pneumonia and COVID-19, for use in emergency critical care, obstetrics, neonatal care, and as an inhalational medicine in general anaesthesia during surgery. (*World Health Organization Model List of Essential Medicines*, 2019)

According to the World Health Organization (WHO) medical oxygen and industrial oxygen are not interchangeable because they differ in purity and quality. The International Pharmacopeia has set requirements for medical oxygen not less than 99.5% v/v of oxygen. This means the volume percent concentration of oxygen in the air is at 99.5%. The gas given to patients is eventually mixed with air reaching the lungs at a concentration of up to 50%. (*Health Product and Policy Standards*, n.d.-a)

For the case of Uganda, our main oxygen supply models are cylinders, concentrators and oxygen plants. The cylinders are filled at oxygen plants with a high-pressure gas and delivered to health facilities which must exchange with empty cylinders. Oxygas, Oxygen Uganda and Mulago Hospital are the major manufacturers. Concentrators provide oxygen enriched gas by trapping air from the environment and removing nitrogen through Pressure Swing Adsorption (PSA). Oxygen plants provide oxygen through large onsite oxygen generators. (*Ministry of Health National Scale up of Medical Oxygen Implementation Plan*, 2018)

Despite being an essential medicine, oxygen supply is still scarce in low- and middle-income countries like Uganda with shortfalls largely attributed to factors like cost and logistics. The last Uganda Services Availability and Readiness Assessment from 2013 reported that only 36% of facilities that were offering a service for chronic respiratory diseases had Oxygen. (*Uganda Services Availability and Readiness Assessment 2013 Summary Report : Key Findings in Figures*, 2013) Scarcity of oxygen in low resource settings means it is only limited to operating theatres and mostly critically ill patients.

Therefore, thousands of new-borns, children and adults have continued to lose their lives to illnesses treatable with oxygen therapy. After malaria, pneumonia which is a chronic respiratory disease has been the second leading cause of death in Uganda with an average of 2000 deaths annually. (*Uganda Bureau of Statistics 2020 Statistical Abstract*, 2020). From a random verbal autopsy by WHO only 4% of children who died from pneumonia actually received oxygen.

In 2020, the advent of the novel corona virus disease (Covid-19) brought into sharper focus the burden which insufficient supply of oxygen can exert on a country's healthcare system. Shortages were even reported at the helm of health care provision which is Mulago National Referral Hospital. (*Daily Monitor*, 2020)

There is therefore an urgent need to expand on existing oxygen production capacity in Uganda. One way of achieving this is by encouraging and supporting investment in oxygen manufacturing. This study will help in one way or the other to close an existing information gap from a technical and economic perspective for prospective investors. The major focus will be on determining how much capacity is required to meet the projected demand and the due costs involved in setting up facilities.

1.2 Problem Statement

In Uganda, oxygen is inaccessible and unreliable to many severely ill patients. From a survey by Ministry of Health on the availability of equipment to offer emergency services, only 27% of the hospitals and health centre IV's had a filled oxygen cylinder. (*The Uganda Hospital and Health Centre IV Census Survey, 2014*)

Unreliable oxygen supply leaves doctors unable to offer essential treatment and has remained a profound cause of high mortality and morbidity rates in Uganda. A study done at MNRH on risk factors causing acute hypoxemic respiratory failure suggested that high pneumonia mortality maybe associated with lack of advanced oxygen therapy which leads to severity of hypoxaemia. (Kwizera, Nakibuuka, Nakiyingi, Sendagire, Tumukunde, Katabira, Ssenyonga, Kiwanuka, Kateete, Joloba, Kabatoro, Atwine, & Summers, 2020)

Even so, scarcity of oxygen in health facilities makes it an expensive commodity and inevitably leads to high health bills for oxygen therapy. For patients on extended oxygen therapy like in intensive care units (ICU) and premature babies in nursing units, the bills sky rocket by the day. Without a shadow of doubt inadequate oxygen supply has remained an important but remediable barrier to improving healthcare access for all in Uganda.

1.3 Objectives

1.3.1 Main Objective

To determine technical and economic viability of oxygen production in Uganda.

1.3.2 Specific Objectives

- i. To establish and project the oxygen demand in Uganda.
- ii. To determine the plant capacity of oxygen manufacturers in Uganda.
- iii. To determine the machinery needed and develop a facility lay out.
- iv. To determine the profitability of investing in oxygen production.

1.5 Justification

Across Africa, the need to improve health care is considered the second most important national problem citizens want their government to address.(Brian Howard, 2020) With Uganda's commitment to the United Nations Sustainable Development Goal (SDG) No.3 of "good health and wellbeing for all", improving access to oxygen therapy should be considered a priority by all stakeholders.

Research from Papua New Guinea shows that an improved oxygen system decreased the pneumonia mortality rate by 35%. (Duke, Wandu, Jonathan, Matai, Kaupa, Saavu, Subhi, & Peel, 2008)

This study provides technical and economic knowledge to the investment options available. Therefore, it is a novel guide on the capacity, equipment and cost needed to meet oxygen demand in Uganda.

Since the study benchmarked already working market solutions and systems, access to data and information needed for analysis was easy.

1.6 Scope

This study was limited to the following;

- i. Manufacture of medical grade oxygen which is required to have a purity of $93\% \pm 3$ v/v.
- ii. Pressure Swing Adsorption technology of manufacturing oxygen.
- iii. Determining of inputs required to set up an oxygen plant to meet future demand for oxygen.
- iv. Establishing the costs involved in setting up an oxygen manufacturing plant and the profitability expected.

CHAPTER TWO: LITERATURE REVIEW

2.1 Overview of Oxygen

There is about 20.94% by volume of oxygen gas in the earth's atmosphere majorly from photosynthesis. It is considered essential to the development of all life found on earth. Oxygen is all around us in the air we breathe simply because the atmosphere maintains a balance between its emission by photosynthesis and consumption via respiration by humans, animals and plants. This oxygenated atmosphere maintains just the right amounts of oxygen able to sustain all lives without competing to breathe. (Wuebbles, 2018)

The human body is able to take in oxygen from the atmosphere through aerobic respiration and uses it within the cells to synthesise energy for maintaining biological activity functions like making the heart pump. Oxygen deficiency in the body leads to a reduction in the energy levels required to sustain biological activity. A persistent oxygen deficiency may cause death due to malfunction in biological processes. The condition resulting from severe shortage of oxygen in the blood is termed as hypoxaemia and is treated using oxygen therapy. (Hirota, 2020)

2.2 Medical-Use Oxygen

Oxygen on the market is available for industrial and medical use. Medical use oxygen is very different from industrial oxygen in purity and quality thus they are not interchangeable. Depending on the source and production method, health standards on medical oxygen (*Health Product and Policy Standards*, n.d.-b) stipulate the following specifications on purity;

For oxygen produced by the air liquefaction process, the International Pharmacopoeia defines the requirements of medical-use oxygen to contain not less than 99.5% v/v of oxygen.

For Pressure Swing Adsorption (PSA) plants, WHO interim guidance technical specifications for PSA plants specify production of medical oxygen at $93\% \pm 3$ v/v of oxygen.

For oxygen concentrators, WHO-UNICEF technical specifications for oxygen therapy devices requires concentrators to deliver oxygen of purity greater than 82% from room air.

2.3 Oxygen Availability

As shown in figure1, oxygen concentrators were the main supply of oxygen in Uganda in 2016. However only 17% of Regional Referral Hospitals (RRH), 30% of General Hospitals, and 45% of Health Centre IVs had a sufficient number of concentrators in accordance with the national medical equipment policy. (*Ministry of Health National Scale up of Medical Oxygen Implementation Plan*, 2018)

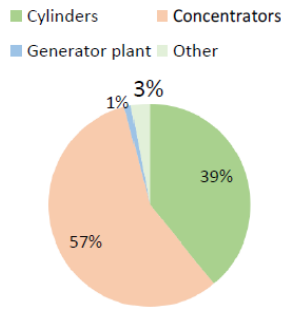


Figure1: Supply of oxygen in public and private healthcare facilities, 2016

Source: National Scale up of Medical Oxygen Implementation Plan 2018-2022(MOH)

Another important aspect to note is that a significant proportion of the oxygen concentrators are donated as shown in the figure2 below;

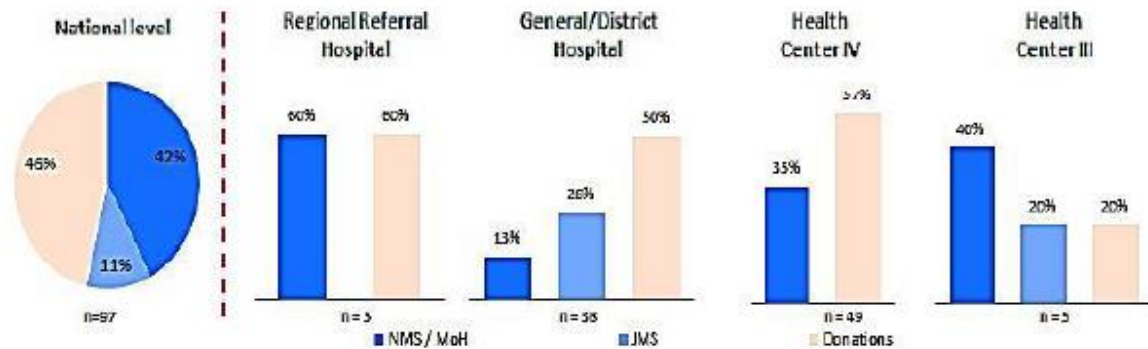


Figure2: Sources of oxygen concentrators at both public and private health facilities in Uganda

Source: National Scale up of Medical Oxygen Implementation Plan 2018-2022(MOH)

2.4 Current Oxygen Supply Model in Uganda

The public sector is currently supplied by 17 medical oxygen plants, 3 at Mulago NRH and 14 at RRHs. Supply to the peripheral health facilities is managed by National Medical Stores (NMS) while in some cases the health facilities deliver and pick oxygen cylinders from the regional plants at their own cost.

Despite the ever-growing demand, transportation of oxygen cylinders is still rather complex because oxygen must be transported separately from other commodities and distribution is limited by the number of cylinders a truck can carry. Cylinder shortage also further makes it difficult for NMS to distribute oxygen to the facilities in the respective catchment areas.

Oxygen supply in the private sector is mostly organised via the Joint Medical Stores (JMS) which leases cylinders to facilities from private oxygen generation plants like Oxygas or Uganda Oxygen. The facilities are responsible for transportation of the cylinders. In addition, some several private hospitals have invested in small oxygen generation plants. Limited data

is available on the number and capacity of such plants. (*Ministry of Health National Scale up of Medical Oxygen Implementation Plan, 2022*)

2.5 Demand Forecasting Techniques

A forecast is regarded as a prediction of what will occur in the future. Demand sometimes behaves in a random, irregular way. At other times it exhibits a predictable behaviour with trends or repetitive patterns, which the forecast may reflect. (*Operations Management for Competitive Advantage, 11e by Richard Chase, F. Robert Jacobs, Nicholas Aquilano (z-Lib.Org).Pdf, n.d.*)

The following principles are to be considered about forecasting;

- i. Forecasting is rarely perfect, so deviations are expected.
- ii. Every forecast should include an estimate of error.
- iii. Forecasting is more accurate for nearer periods.
- iv. All forecasting techniques assume that there is some degree of stability and what happened in the past will continue to happen in the future.

2.5.1 Moving Average Method

This is a time series forecast where demand in the current period is used to predict demand in the next period. This method uses several demand values during the recent past to develop a forecast. The longer the moving average period the smoother the forecast will be.

This method is easy to use, quick and relatively inexpensive. However, it does not react to variations that occur for a reason, ignores factors that cause change and is considered mechanical method.

2.5.2 Regression Model

In this method, a mathematical relationship is developed between demand and some other factor that causes demand behaviour. A linear trend line relates a dependent variable(demand) to one independent variable (time). This method is used when demand displays an obvious trend over time.

This method is simple and easy to implement however it lacks practicality and is limited because most problems in the real world are not linear.

2.6 Oxygen Production Methods

2.6.1 Liquid Oxygen Plants

Cryogenically produced liquid oxygen is always generated off-site, not at a medical facility. Medical facilities can be equipped with large bulk liquid oxygen tanks that are refilled periodically by a truck from a supplier. Liquid oxygen has the advantage of taking up less space than oxygen in its gaseous form and being safer since the oxygen tanks are under low pressure.

However, liquid oxygen plants are limited by their size, cost and constant evaporation of oxygen.

2.6.2 Pressure Swing Adsorption oxygen plants

A pressure swing adsorption (PSA) oxygen plant serves as a large, central source of oxygen that can be located on-site at medical facilities. Oxygen from a PSA plant can either be piped directly to bedside terminal units within patient areas or be used to refill cylinders for oxygen distribution. The main advantages of PSA plants are constant supply of oxygen at high pressure and being cost effective for large facilities. On the flip side, they require high capital investment and skilled technicians. (Hardavella, Karampinis, Frille, Sreter, & Rousalova, 2019)

Key Components of PSA Oxygen Plants

The stages of generating oxygen in a PSA plant include air compression, air purification, adsorption, boosting compression and then cylinder filling.



Figure3: Components of a PSA oxygen plant

Source: www.universalboschi.org

Mechanism of the adsorption process in PSA oxygen generation

In the pressure swing adsorption process, two vessels are filled with zeolite molecular sieve as the adsorber. As compressed air passes up through one of the absorbers, the molecular sieve selectively adsorbs the nitrogen allowing the remaining oxygen to pass through and exit as a product gas. When the adsorber becomes saturated with nitrogen, the inlet airflow is switched to the second adsorber. The first adsorber is regenerated by desorbing nitrogen through depressurisation. The cycle is repeated and the pressure is continually swinging between a higher level at adsorption(production) and a lower level at desorption (regeneration) (<https://www.Oxair.Com.Au/How-It-Works/How-Oxygen-Psa-Generators-Work/>, n.d.)

2.6.3 Oxygen Concentrators

An oxygen concentrator is a self-contained, electrically powered medical device designed to concentrate oxygen from ambient air. An oxygen concentrator uses PSA technology to draw in air from the environment, removing the nitrogen to produce a continuous source of concentrated oxygen. Concentrators ensure constant supply at low running cost however they require uninterrupted power supply, regular service and have a low output insufficient for emergency care.

2.6.4 Oxygen Cylinders

Oxygen gas can be compressed, stored and distributed in cylinders. These cylinders are filled at a gas manufacturing plant, either via a cryogenic distillation or a PSA plant, and then transported to health facilities which must exchange with empty cylinders. Cylinders do not depend on electricity supply however they are hugely dependant on supplier availability and transportation. (Hardavella et al., 2019)

2.7 Business Appraisal Computations

Before an investment is made, one needs to estimate the economic value it would produce. This involves evaluating performance of the business against a given set of criteria known as business appraisal computations. These include payback period, net present value, internal rate of return and profitability index.

2.7.1 Payback period

This refers to the time required to recoup funds expended in an investment or to reach a breakeven point. A short payback period appropriately indicates profitability whereas a long payback period implies that the investment is relatively poor. A short payback period is desired because it enables the investor to recover money and invest it elsewhere.

2.7.2 Net Present Value

Money now is considered to be more valuable than money later on. Therefore, Present Value (PV) is used to see what money in the future is worth now. Present value is obtained by discounting at a constant interest rate the differences of all annual cash outflows and inflows. To obtain Net Present Value, all the present values received are added and subtract the initial investment is subtracted.

A positive NPV means the investment is profitable and acceptable whereas a negative NPV will imply profitability is below the cut off rate.

2.7.3 Internal Rate of Return

This is the annual growth an investment is expected to generate. It is the discount rate at which the present value of cash inflows is equal to the present value of cash outflows and the NPV is

zero. The investment proposal will be accepted if the IRR is greater than the cut off rate which is the lowest acceptable interest rate for the invested capital.

2.7.4 Profitability Index

Profitability index is a measure of the attractiveness of an investment. PI indicates how much investment is required to generate a positive net present value (NPV). For a profitable business, the profitability index should be greater than one.

CHAPTER THREE: METHODOLOGY

3.1 Research Design and Framework

The framework illustrated below shows step by step procedures which were followed to conduct the feasibility study.

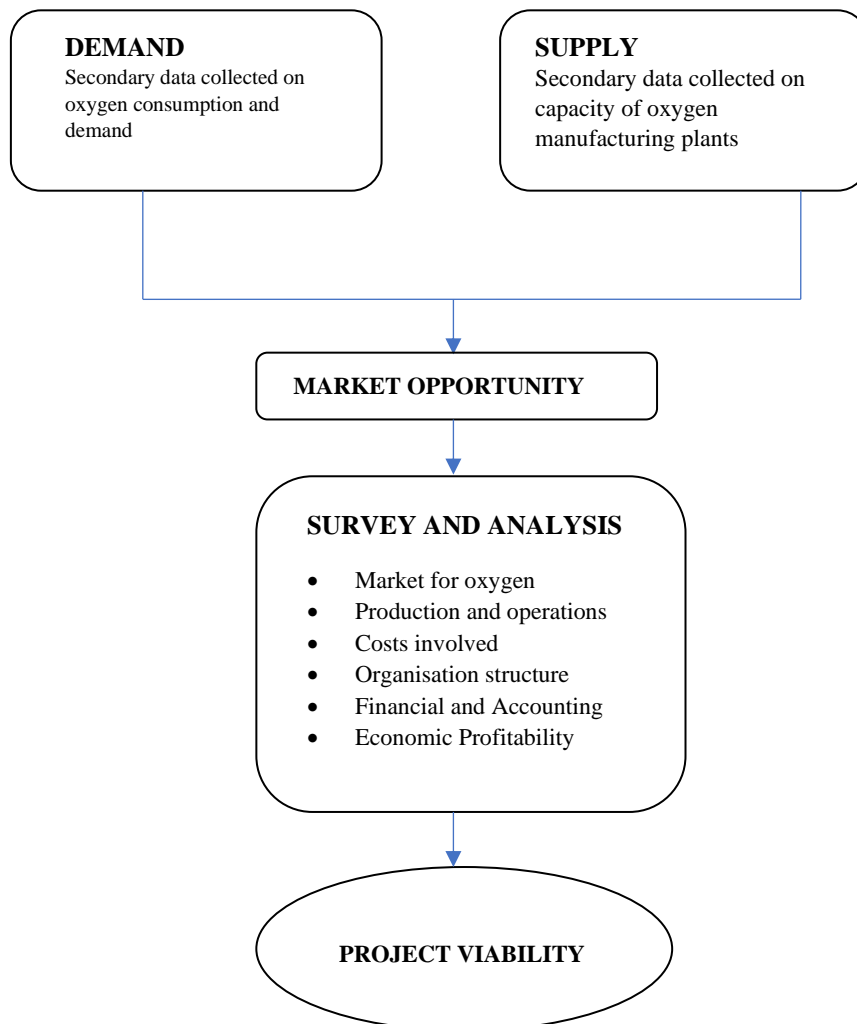


Figure4: Research Framework

3.2 Sampling

Considering resource constraints, data could not be collected from all oxygen manufacturing plants across the country. A particular area of study was selected to obtain the required primary data. The oxygen plant at Mulago National Referral Hospital was chosen because it was easily accessible, cost effective and convenient.

3.3 Data Collection

Data was obtained from both primary and secondary sources. Primary sources included surveys, interviews and observations. The secondary sources included information obtained from publications, annual reports, research journals and the internet.

3.3.1 Primary Data Collection Methods

Surveys

A direct field visit to the oxygen plant at Mulago NRH was done to obtain information on the operation of an oxygen plant. A questionnaire with a pre-set choice of questions, tick boxes and scales was used.

Interviews

Face to face interactions with key personnel at the oxygen manufacturing plant were done, a choice of pre-set questions was asked to obtain the required information.

Observations

Visual observations of operations, equipment and processes at the plant during the field visit, helped in acquiring important information.

3.3.2 Secondary Data Collection Methods

The relevant secondary data was collected by analysing the following documents;

- i. Annual reports and records from Ministry of Health
- ii. Statistical abstracts from Uganda Bureau of Statistics
- iii. Journal articles and publications about oxygen
- iv. Legislation and local policies on oxygen
- v. Standard specification manuals for oxygen manufacturing plants

3.3.3 Key parameters of data collected

Throughout the study, emphasis was put on obtaining the following key parameters from the data collection stage.

Consumption level parameters

Oxygen consumption levels were computed by obtaining the following information from secondary data sources;

- i. Hypoxemia prevalence by ward
- ii. Total number of admissions per ward
- iii. Oxygen need per patient per ward

Production capacity parameters

To determine the production capacity of oxygen manufacturers the following key parameters were obtained from secondary sources of data.

- i. Oxygen plant capacity in m³/hour
- ii. Oxygen plant operating hours per day
- iii. Operating days per month

Oxygen manufacturing plant inputs

The following data was collected while studying the inputs to production for an oxygen plant.

- i. List of the machinery in a typical oxygen plant
- ii. Size or capacity of the machinery
- iii. Raw materials for production
- iv. Cost of utilities consumed
- v. Sources of machinery and raw materials

Costs of equipment and market price of oxygen

A market survey was done to obtain;

- i. Average price for machinery utilities
- ii. Market price for oxygen

3.4 Data Analysis

3.4.1 Demand Estimation and Forecasting

Consumption Level Method

Based on oxygen consumption per case and number of hypoxemic cases per ward, demand for oxygen was estimated by summing up demand from all the wards utilising oxygen.

*Number of hypoxemic patients per ward = Prevalence rate * Total number of admissions*

*Oxygen consumed per ward = Number of hypoxemic patients * Oxygen need per patient*

Total oxygen consumed per year = \sum oxygen consumed in all of the wards

Regression Model

Forecasting of future oxygen demand was done using the regression model technique. Equation for the regression model is;

$$y = a + bx$$

Where; y= forecast a=intercept b=slope of line x=time n= number of periods

$$b = \frac{\sum xy - n \bar{x}\bar{y}}{\sum x^2 - n \bar{x}^2} ; a = \bar{y} - b\bar{x} ; \bar{x} = \frac{\sum x}{n} ; \bar{y} = \frac{\sum y}{n}$$

3.4.2 Average Monthly Production Capacity

The production capacity from different oxygen plants was determined using the equation below;

Average Monthly production

$$= \text{Operating Plant capacity per hour} * \text{No. of filling hours per day} \\ * \text{Plant operating days per month}$$

3.4.3 Standard Manuals

Specification manuals provided by WHO were used to determine the technical aspects of machinery required in an oxygen plant. An optimal plant layout was then drawn up using a process lay out drawing to display the most effective physical arrangement of machines.

3.4.4 Business Appraisal Computations

Profitability of investing in an oxygen manufacturing plant was determined using the following computations;

Payback period

$$\text{Payback period} = \text{Initial Investment} / \text{Annual cash flow}$$

Net Present Value (NPV)

$$NPV = \sum_{n=0}^{n=j} \frac{NCF}{(1+r)^n} - I$$

Where; NCF is the annual cash net cash flow in the years n=1, 2....j

$$\text{Discount factor } a_n = (1 + r)^{-n}$$

r = interest rate

I = Initial Investment

Internal Rate of Return (IRR)

The IRR was calculated by using the following interpolation formula;

$$i_r = i_1 + \frac{PV(i_2 - i_1)}{PV + NV}$$

Where i_r is the IRR, PV is the positive NPV (at a lower discount rate i_1), and NV is the negative NPV (at a higher discount rate i_2).

Profitability Index (PI)

Profitability index was computed using the formula below;

$$PI = \frac{NPV}{PVI}$$

Where NPV is the net present value and PVI is the present value of the investment.

CHAPTER FOUR: DATA COLLECTION AND ANALYSIS

4.1 Market for Oxygen

4.1.1 General statement about the market for oxygen

The number of functional health care facilities in Uganda has been growing irrespective of their status of ownership. Figures from the UBOS Statistical Abstract 2020 indicate a 39% increase in 2017/2018 from 4981 facilities in 2011/2012 making up an additional 1956 health facilities.

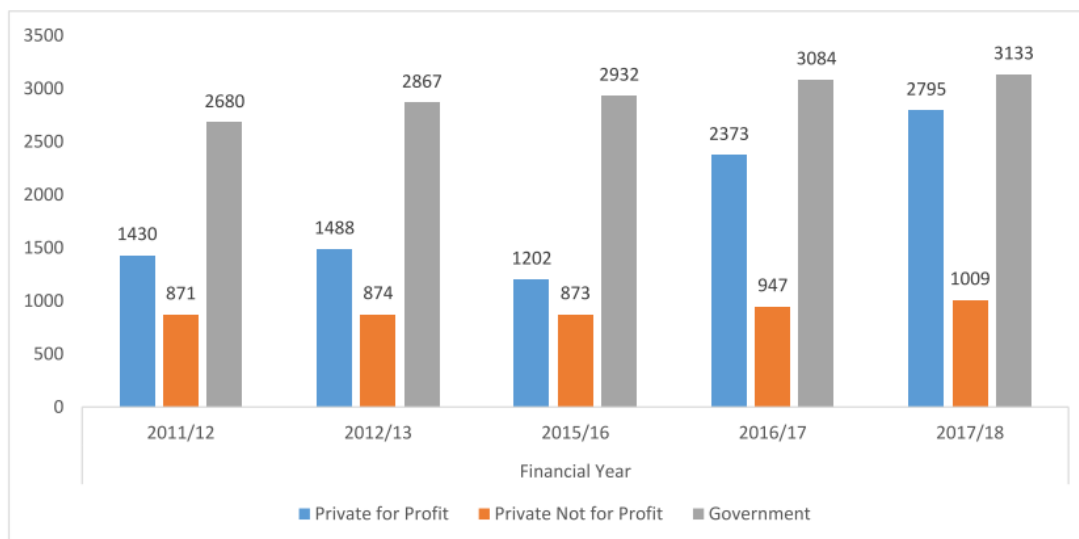


Figure5: Number of functional health care facilities by financial year and ownership
Source: UBOS Statistical Abstract 2020

Distribution of health care facilities is not even across the country with 45% of the health care facilities are located in the central region whereas Karamoja and the North Eastern region have the least number of healthcare facilities. Table1 indicates the number of functional healthcare facilities for each region in Uganda.

Table 1 Number of functional healthcare facilities by region

Region	Health Facility level									Total
	Clinic	Health center II	Health center III	Health center IV	General Hospitals	National Referral	Regional Referral	Special clinics	Blood collection*	
North Buganda	294	422	310	33	28		1	5		1,093
South Buganda	91	316	139	22	12		1			582
Kampala	781	585	48	13	22	2	3	4		1,458
East Central	60	349	112	18	12		1	3		555
Mid-Eastern	86	218	190	20	17		1	3		535
North Eastern	15	127	78	14	8		1	1		244
Karamoja	2	89	44	4	4		1			144
Mid Northern	78	307	147	18	13		2	2		567
West Nile	38	158	129	11	12		1	1		350
Mid-Western	42	286	189	26	14		2			559
South Western	91	507	183	43	21		2	4		851
Total 2017/18	1,578	3,364	1,569	222	163	2	13	23		6,937
Total 2016/17	260	4,208	1,510	215	153	2	13	26	14	6,404

Source: UBOS Statistical Abstract 2020

4.1.2 Demand Estimation

Prevalence Rate of Hypoxemia and Oxygen need per patient

An understanding of the prevalence rate of hypoxemia (an abnormal low concentration rate of oxygen in the blood) is required to estimate demand for oxygen at different wards within a health care facility. However, data on hypoxemia recognition and prevalence is not properly documented by healthcare facilities. This makes it difficult to predict the number of hypoxemic cases per ward.

Regardless of these limitations faced, the study done analysed data on oxygen utilisation provided by a report from Ministry of Health (*Ministry of Health National Scale up of Medical Oxygen Implementation Plan, 2022*). The data analysed provided information on prevalence rate of hypoxemia by ward and oxygen needs per patient for the neonatal, paediatric, adult, surgery, and emergency care/ ICU wards.

Table 2: Hypoxemia Prevalence rate and Oxygen need per patient

Hospital ward	Hypoxemia prevalence by ward	Oxygen need per patient per ward (L)
Neonatal	20%	2,160
Paediatric	6%	6,480
Adult	4%	12,960
Surgery	100%	2,880
Emergency care/ ICU	100%	7,200

Number of hypoxemic cases per ward per year

Based on prevalence rate of hypoxemia, the total number of hypoxemic patients per ward was computed as;

*Number of hypoxemic patients per ward per year = Hypoxemia prevalence rate * Total number of admissions per ward per year*

Total number of annual hospital admissions per ward were determined by analysing data on the leading causes of admissions as provided by annual sectorial performance reports published by Ministry of Health for the financial years 2017/2018, 2018/19 and 2019/2020. Analysis was limited to these years because performance reports from previous years did not give account of the number of admissions. Extracts from the performance reports are shown in figures 6, 7 and 8 below.

No.	Diagnosis	Total Cases Under 5	Total Cases 5 and above	Total Cases	%
1.	Malaria	247,940	250,899	498,839	32.3%
2.	Pneumonia	94,732	36,052	130,784	8.5%
3.	Respiratory Infections	46,138	37,948	84,086	5.4%
4.	Diarrhoea – Acute	54,837	18,073	72,910	4.7%
5.	Injuries: (Trauma due to other causes)	6,727	47,470	54,197	3.5%
6.	Anaemia	26,221	27,065	53,286	3.4%
7.	Septicemia	31,570	19,613	51,183	3.3%
8.	Urinary Tract Infections	3,861	47,056	50,917	3.3%
9.	Gastro-intestinal disorders (non-infective)	11,271	38,143	49,414	3.2%
10.	Injuries: Road Traffic Accidents	2,242	29,652	31,894	2.1%
11.	Hypertension (Old cases)	-	20,463	20,463	1.3%
12.	Other Neonatal Conditions	19,195	-	19,262	1.2%
13.	Injuries: Motor Cycle (Accidents)	1,246	15,000	16,246	1.1%
14.	Asthma	2,091	11,937	14,028	0.9%
15.	Hernias	2,175	11,760	13,935	0.9%
16.	Sickle cell Anaemia	6,114	7,373	13,487	0.9%
17.	Neonatal Sepsis 0-7 days	13,279	-	13,279	0.9%
18.	Diseases of the skin	4,635	7,094	11,729	0.8%
19.	Premature baby	11,022	-	11,026	0.7%
20.	Diabetes mellitus (re-attendances)	-	10,939	10,939	0.7%
21.	Other diagnoses	90,445	230,888	321,262	20.8%
	Total	675,741	867,425	1,543,166	100%

Figure 6: Leading causes of admissions in FY 2017/18

Source: Annual Health Sector Performance Report MOH 2017/18

No.	Diagnosis	Admissions Under 5 years			Admissions 5 years and above			Total	%
		Male	Female	Total	Male	Female	Total		
1.	Malaria	141,382	130,866	272,248	101,278	154,236	255,514	527,762	32.9
2.	Pneumonia	49,468	45,945	95,413	16,822	20,784	37,606	133,019	8.3
3.	Injuries (All)	5,822	4,584	10,406	64,786	32,357	97,143	107,549	6.7
4.	Respiratory Infections (Other)	22,283	21,677	43,960	14,476	20,178	34,654	78,614	4.9
5.	Diarrhoea – Acute	28,835	24,388	53,223	7,305	9,649	16,954	70,177	4.4
6.	Septicemia	19,978	17,429	37,407	10,444	13,942	24,386	61,793	3.8
7.	Anaemia	16,822	13,904	30,726	13,697	15,676	29,373	60,099	3.7
8.	Gastro-intestinal disorders (non-infective)	5,885	5,306	11,191	16,362	32,089	48,451	59,642	3.7
9.	Urinary Tract Infections	1,698	1,802	3,500	12,294	38,760	51,054	54,554	3.4
10.	Mental Illnesses	651	595	1,246	18,059	18,272	36,331	37,577	2.3
11.	Hypertension	57	85	-	12,416	22,180	34,596	34,596	2.2
12.	Other Neonatal Conditions	12,549	10,442	22,991	8	5	-	22,991	1.4
13.	Diabetes Mellitus	132	102	234	8,894	10,699	19,593	19,827	1.2
14.	Typhoid Fever	650	699	1,349	6,636	11,294	17,930	19,279	1.2
15.	TB	940	762	1,702	8,558	5,298	13,856	15,558	1.0
16.	Sickle cell Anaemia	3,777	2,810	6,587	4,366	4,420	8,786	15,373	1.0
17.	Neonatal Sepsis 0-7days	8,082	7,066	15,148	na	na	-	15,148	0.9
18.	Diseases of the appendix	112	67	179	12,587	1,661	14,248	14,427	0.9
19.	Measles	7,158	6,597	13,755	2,870	3,536	-	13,755	0.9
20.	Dental Caries	247	250	497	5,105	7,781	12,886	13,383	0.8
21.	Others	41,395	36,118	77,655	81,417	72,319	160,155	230,752	14.4
	TOTAL	367,923	331,494	699,417	418,380	495,136	913,516	1,605,875	100

Figure 7: Leading causes of admissions in FY 2018/19
Source: Annual Health Sector Performance Report MOH 2018/19

Diagnosis	Admissions under 5 years			Admissions above 5 years			Total	%
	Male	Female	Total under 5	Male	Female	Total above 5		
Malaria	193,332	173,457	366,789	143,219	212,671	355,890	722,679	34.9%
Pneumonia	50,030	42,189	92,219	15,998	20,313	36,311	128,530	6.2%
Anaemia	25,348	21,671	47,019	18,136	20,953	39,089	86,108	4.2%
Septicemia	18,689	16,300	34,989	11,640	15,716	27,356	62,345	3.0%
Diarrhoea - Acute	23,762	20,781	44,543	6,884	9,241	16,125	60,668	2.9%
UTI	2,472	1,870	4,342	12,963	42,102	55,065	59,407	2.9%
Injuries (Trauma due to other causes)	3,686	3,127	6,813	29,082	17,934	47,016	53,829	2.6%
Respiratory Infections (Other)	13,210	12,373	25,583	7,907	11,542	19,449	45,032	2.2%
No Pneumonia - Cough and cold	8,877	8,516	17,393	6,638	8,873	15,511	32,904	1.6%
Gastro-intestinal disorders (non-infective)	2,816	2,450	5,266	9,182	18,345	27,527	32,793	1.6%
Other Neonatal Conditions	13,251	11,330	24,581	-	-	-	24,581	1.2%
Hypertension	-	-	-	8,305	15,247	23,552	23,552	1.1%
Peptic Ulcer Disease	-	-	-	6,063	12,557	18,620	18,620	0.9%
Injuries Road Traffic Accidents	551	417	968	10,208	4,166	14,374	15,342	0.7%
Neonatal Sepsis 0-7days	7,887	7,078	14,965	-	-	-	14,965	0.7%
Diseases of the skin	3,027	3,060	6,087	4,016	4,477	8,493	14,580	0.7%
Premature baby	7,250	7,177	14,427	-	-	-	14,427	0.7%
Hernias	1,384	478	1,862	8,328	4,208	12,536	14,398	0.7%
Asthma	967	756	1,723	3,889	7,873	11,762	13,485	0.7%
Diabetes mellitus	-	-	-	6,022	7,248	13,270	13,270	0.6%
All others	79,172	73,139	152,311	210,500	254,984	465,484	617,795	29.9%
Total	455,711	406,169	861,880	518,980	688,450	1,207,430	2,069,310	100%

Figure 8: Leading causes of admissions in FY 2019/20
Source: Annual Health Sector Performance Report MOH 2019/20

Oxygen consumption per ward per year

Using the computed number of hypoxemic cases and the established oxygen need per patient, the oxygen consumed per ward was calculated as;

$$\text{Oxygen consumed per ward year} = \text{Number of hypoxemic patients per year} * \text{Oxygen need per patient}$$

Therefore; *Total oxygen consumed per year = Sum of oxygen consumed in all of the wards.*

Oxygen consumption caused by Covid-19 pandemic

In 2020, the Covid-19 pandemic led to a sharp and unprecedented rise in oxygen demand at different healthcare levels. This is certainly because severe and critically ill Covid-19 patients consume significantly larger quantities of oxygen. Therefore, it is important to consider contribution made by the Covid-19 pandemic on oxygen demand and consumption in 2020 and beyond.

Ministry of Health guidelines on Covid-19 management(*National Guidelines for Management of COVID-19, 2020*) showed that of all confirmed cases, 15% progress to severe disease and end up on oxygen therapy, 5% become critically ill and require ICU with oxygen whereas 80% have mild disease. Data on hypoxemia prevalence rate, oxygen flow rate and treatment duration for severe and critically ill patients was obtained from an oxygen planning tool by UNICEF.(*UNICEF Oxygen System Planning Tool Quick Reference Guide and FAQ Purpose and Use of the UNICEF Oxygen System Planning Tool, n.d.*)

Table 3: Oxygen utilisation for Covid-19 patients

Condition	% Of Total Cases	Hypoxemia Prevalence Rate	Flow rate (LPM)	Treatment Duration (Days)	Treatment Duration (minutes)	Oxygen need(L)
Severe	15%	100%	10	7	10,080	100,800
Critical	5%	100%	30	14	20,160	604,800

Using total number of covid cases obtained from WHO Covid-19 dashboard (“WHO Coronavirus Disease (COVID-19) Dashboard With Vaccination Data | WHO Coronavirus (COVID-19) Dashboard With Vaccination Data,” 2021), oxygen demand during the pandemic period was estimated as shown in table 4. Analysis time was set to a shorter period of 4 months to reflect a real scenario of the pandemic.

Table 4: Estimated Oxygen demand caused by Covid-19 pandemic

Year	Months	Total No. of cases	No. of Severe cases	No. of Critical cases	Oxygen consumed by Severe cases(L)	Oxygen consumed by Critical cases(L)	Total Oxygen consumed (L)
2020	Jan - April	85	13	4	128,520	85,680	214,200
	May – Aug	3,454	518	173	5,222,448	3,481,632	8,704,080
	Sept - Dec	32,173	4,826	1,609	48,645,576	32,430,384	81,075,960
2021	Jan - April	6,195	929	310	9,366,840	6,244,560	15,611,400
	May – Aug	57,794	8,669	2,890	87,384,528	58,256,352	145,640,880
	Sept - Dec	-	-	-	-	-	-

Total Oxygen consumed by Covid-19 wards (2020); = (214,200 + 8,704,080 + 81,075,960) L

= 89,994,240 L

Table 5: Total estimated oxygen demand for 2017/18, 2018/19 and 2019/20

Year	Hospital Ward	No. of patients admitted/ ward	No. of hypoxemic patients/ward	Oxygen consumed (in litres) /ward	Total Oxygen consumed (L)
2017/ 18	Neonatal	11,026	2,205	4,763,232	
	Paediatric	867,425	52,046	337,254,840	
	Adult	675,741	27,030	350,304,134	
	Surgery	36,670	36,670	105,609,600	
	Emergency/ ICU	86,091	86,091	619,855,200	
					1,417,787,006
2018/ 19	Neonatal	15,148	3,030	6,543,936	
	Paediatric	699,417	41,965	271,933,330	
	Adult	913,516	36,541	473,566,694	
	Surgery	36,670	36,670	105,609,600	
	Emergency/ ICU	107,549	107,549	774,352,800	
					1,632,006,360
2019/20	Neonatal	14,427	2,885	6,232,464	
	Paediatric	861,880	51,713	335,098,944	
	Adult	1,207,430	48,297	625,931,712	
	Surgery	36,670	36,670	105,609,600	
	Emergency/ ICU	69,171	69,171	498,031,200	
	Covid-19			89,994,240	
					1,660,898,160

4.1.3 Demand Forecasting

The linear trend line method was appropriately chosen for use in forecasting demand because data collected on oxygen consumption was limited to three years. Moving average method requires a large number of periods for analysis therefore using it in forecasting would give inaccurate results.

Determination of the constants in the regression model equation

	Period(x)	Demand(y)	x*y	x ²
	1	1,417,787,006	1,417,787,006	1
	2	1,632,006,360	3,264,012,720	4
	3	1,660,898,160	4,982,694,480	9
Total	6	4,710,691,526	9,664,494,206	14

Number of periods, n=3

$$\bar{x} = \frac{6}{3} = 2$$

$$\bar{y} = \frac{4,710,691,526}{3} = 1,570,230,509$$

$$b = \frac{\sum xy - n \bar{x} \bar{y}}{\sum x^2 - n \bar{x}^2} = \frac{9,664,494,206 - 3(2)(1,570,230,509)}{14 - 3(2^2)} = 121,555,577$$

$$a = \bar{y} - b\bar{x} = 1,570,230,509 - 121,555,577(2) = 1,327,119,355$$

Linear Trend line Equation

Substituting the constants 'a' and 'b' into the generic equation gives the linear trend line equation;

$$y = a + bx$$

$$y = 1,327,119,355 + 121,555,577 x$$

Forecasts of Oxygen Demand for Next 10 Years

Table 6: Demand forecasts for the next 10 years

Period(x)	Year	Oxygen Demand (L)	Forecast (L)	% Error
1	2017/18	1,417,787,006	1,448,674,932	2.2
2	2018/19	1,632,006,360	1,570,230,509	3.8
3	2019/20	1,660,898,160	1,691,786,086	1.9
4	2020/21	-	1,813,341,663	-
5	2021/22	-	1,934,897,240	-
6	2022/23	-	2,056,452,817	-
7	2023/24	-	2,178,008,394	-
8	2024/25	-	2,299,563,971	-

9	2025/26	-	2,421,119,548	-
10	2026/27	-	2,542,675,125	-
11	2027/28	-	2,664,230,702	-
12	2028/29	-	2,785,786,279	-
13	2029/30	-	2,907,341,856	-

The overall forecast error is < 5% indicating that the forecasting technique used is fairly accurate.

4.1.4 Plant Capacity of Oxygen Manufacturers in Uganda

The capacity of oxygen manufacturer's was determined from secondary data obtained in a Ministry of Health report (*Ministry of Health National Scale up of Medical Oxygen Implementation Plan*, 2018), This report indicated that the public sector is currently served by 17 medical oxygen plants, 3 at Mulago NRH and 14 at RRHs. All the 14 RRHs have functional 15m³/ hr oxygen plants with exception of Mbarara which is 10m³/hr. The field visit done revealed that the plant at Mulago NRH has an improved total capacity 195m³/hr.

Limited data is available on the capacity of private oxygen manufacturing plants in Uganda. As a result, estimating their contribution to the current oxygen supply capacity was rather difficult. Therefore, this study used available data on public production plants to estimate current capacity.

Table 7: Production capacity of public manufacturing plants

	Production Capacity (m³/hr)	No. of operating hours/ day	No. of operating days/ month	Average Monthly Production (m³/month)
Mulago Plant	195	24	30	140,400
RRH plants (13)	15	16	20	62,400
Mbarara	10	24	30	72,000
Total				210,000

Therefore, Annual production capacity = 12 * 210,000

$$= 2,520,000 \text{ m}^3 = \mathbf{2,520,000,000 \text{ L}}$$

4.1.5 Market Opportunity

By comparing the current demand and supply, the existing need for oxygen is supposed to be fulfilled. However, based on demand-supply analysis, the following market opportunities exist;

- i. Oxygen demand is increasing every year therefore more oxygen plants will be required to make the supply match up with demand.
- ii. There is uneven distribution of production plants which necessitates setting of plants at unserved locations.
- iii. Oxygen consumption resulting from the Covid-19 pandemic is high and has random behaviour. This necessitates setting up new oxygen plants to cushion the available supply from being overstretched.

4.2 Manufacture of Oxygen

4.2.1 Manufacturing Process

Pressure Swing Adsorption (PSA) was considered as the technology to be used in the manufacture of oxygen because of the following reasons;

- i. Requires less capital to set up compared to liquid oxygen plants
- ii. It is the most commonly used technology
- iii. It is readily available

In this process ambient air passes through a filtration system which has a large enough total surface area to separate nitrogen from the air concentrating the remaining oxygen to a known purity.

After generation, oxygen can either be distributed directly to the wards through a hospital pipeline or further compressed to fill cylinders. Piped oxygen is possible for onsite generation plants however requires developing a piping network or infrastructure to supply each of the end users.

The easiest distribution method for an offsite generation plant serving multiple consumers is filling of cylinders. Therefore, this study focused on producing oxygen to fill cylinders which are then supplied to the consumers.

4.2.2 Plant Sizing

By 2030 the demand for oxygen will be **2,907,341,856 L** which is equivalent to a 75% increase from the current demand of **1,660,898,160 L**.

Therefore, the estimated available capacity of **2,520,000,000 L** needs to be increased by at least **387,341,856L** within the next 10years to meet the required oxygen demand for 2030.

Technical information gathered during the field study revealed that an oxygen plant requires at least 2 production lines to be installed. This ensures continued operation of the plant in case of a breakdown on one of the lines. Therefore, the proposed oxygen plant will have 2 units each having a capacity of 30m³/hr. Operations will be done in two 8-hour shifts for 20 days a month.

Table 8: The proposed plant capacity

No. of Units	Production capacity for each unit (m ³ /hr)	Total capacity of plant (m ³ /hr)	No. of operating hours/ day	No. of operating days/ month	Average monthly production (m ³ /month)
2	30	60	16	20	19,200

Annual production capacity of proposed plant = 19200*12 = 230,400 m³ = 230, 400,000 L


This implies, a minimum of two new oxygen plants nneed to be setup within the next 10 years to meet the projected increase in oxygen demand in 2030. These would have a total capacity of 460,800,000L which meets and exceeds the required increment of 387,341,856L.

4.2.3 List of Equipment

The machinery required in a PSA oxygen plant include; air compressor, air dryer, filters, air tank, PSA oxygen generator, oxygen tank, control unit, booster compressor, cylinder filling ramp, cylinders.

Table 9: Oxygen Plant equipment description

Images Courtesy of: Oxygen plant at Mulago National Referral Hospital

Equipment	Use
Air compressor 	Supply compressed air to the oxygen generator
Air dryer	Removes moisture and impurities such as oil to ensure quality of air meets the standards



Lowers the temperature of air for better efficiency

PSA oxygen generator






Has two chambers with molecular sieve beds that adsorb nitrogen from air and separate the oxygen using PSA technology

Oxygen tank



Collects necessary volume of oxygen from generator

<p>LCD control panel</p> 	<p>Monitors signals from pressure sensors, provides alarm system.</p> <p>Displays key information such as oxygen purity, pressure, dew point and flow rate.</p>
<p>Booster compressor</p> 	<p>Compress oxygen to required pressure</p>
<p>Oxygen filling ramp</p> 	<p>Device for filling gas cylinders</p>
<p>Oxygen cylinders</p>	<p>Store compressed oxygen gas</p>

4.2.4 Technical Specification of Equipment

Equipment	Capacity	Specification
Air Compressor	37KW, 8bar, 380V/3Ph/50Hz	<ul style="list-style-type: none"> -Feed air compressor -Oil free/ filtered-oil injected / lubricated rotary screw type -Minimum 750kPa/ 7.5bars / 108OPsi
Air Dryer	Sized to compressor	-Continuous and fully automatic with no air loss

Filters	Filter assembly to include; -Prefilter > 5 micron -Coalescing filter (0.1 micron)	-Highly efficient coalescing filters.
Oxygen generator unit	30m ³ /hr, oxygen purity 93%±3%, outlet pressure 4 bar, ambient temp 10- 40 °C	-Have dual separation chambers -Product purity of USP 93%
Reservoir tanks	1000L, 10bar	With a bacterial outlet filter
Control Panel		-Oxygen concentration monitor with ± 1 accuracy -Audible and visual alarms for high temperature, low/high pressure, power failure
Cylinder	47L and 10L	-ISO regulated -Have a neck ring, standard cap and valve
Power supply		-Locally compatible (frequency, voltage and plug type need to be specified)

Other considerations to be made by procurement in purchasing of the equipment include;

- i. Standards for the manufacturer (should be ISO certified)
- ii. Warranty for at least 48 months with an option to extend
- iii. Training offered to engineers for transfer of knowledge
- iv. Necessary documentation should be provided
- v. Spare parts included (3years) as per the recommended preventive maintenance programme

4.2.5 Layout of Oxygen Plant

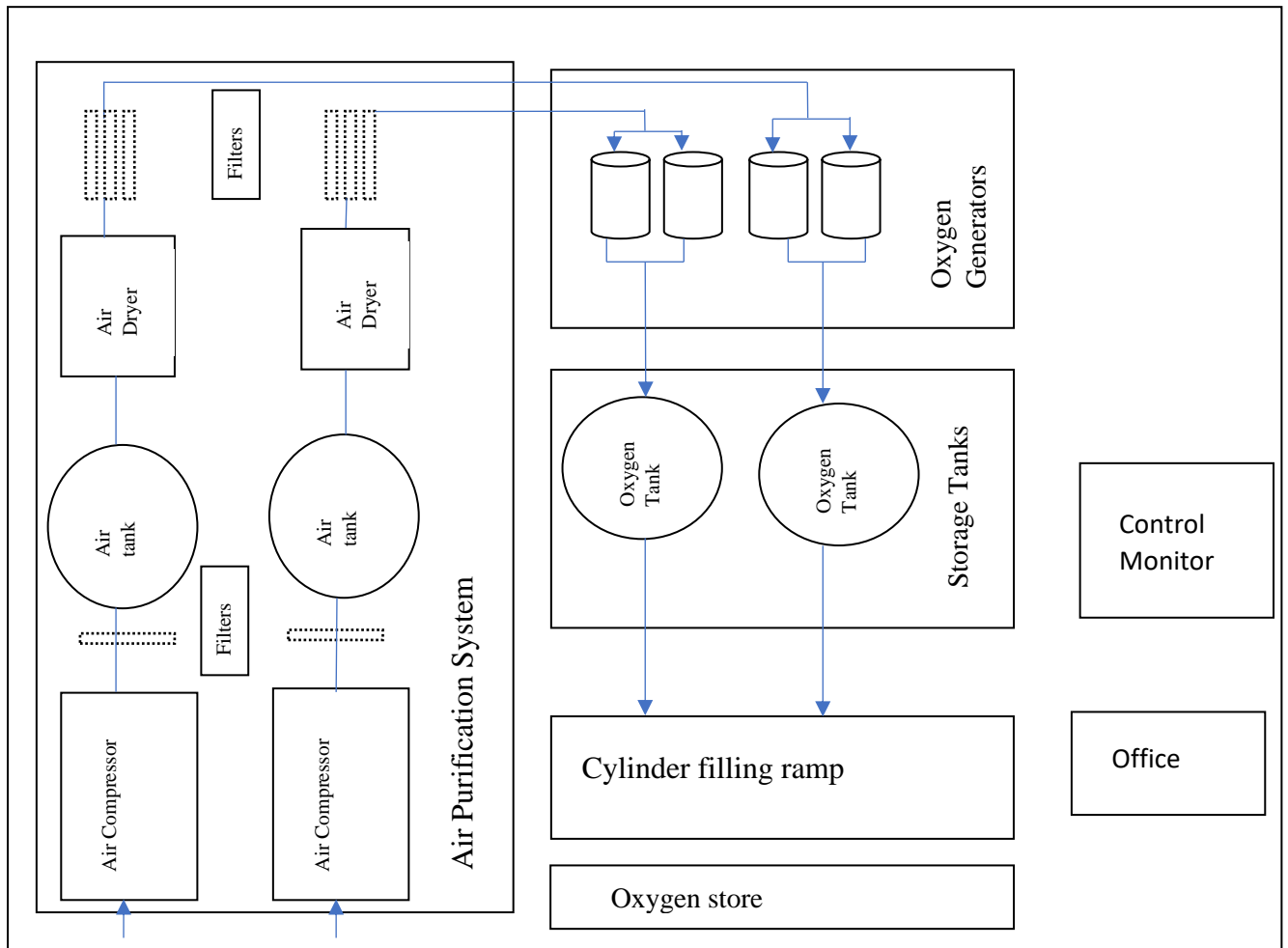
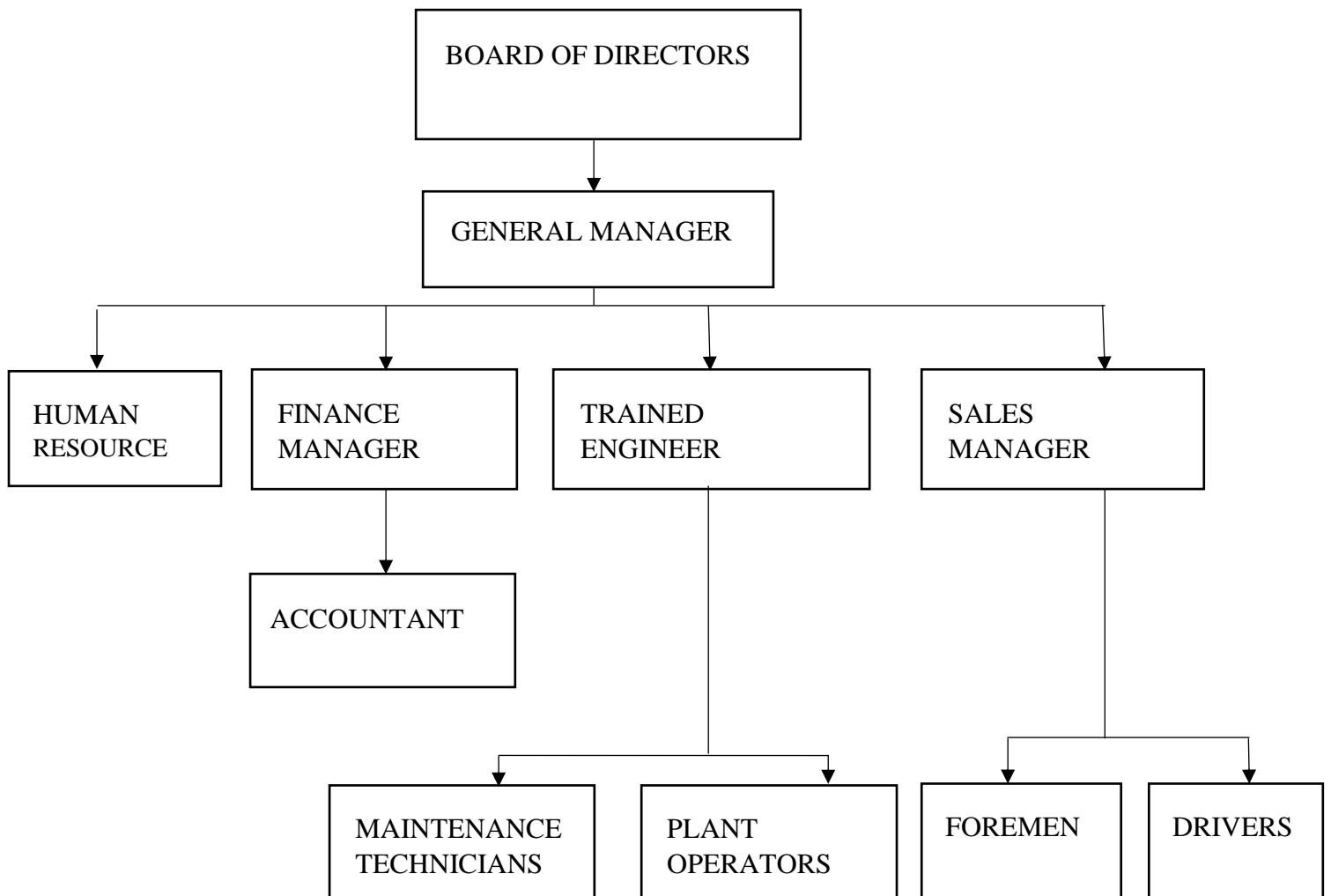


Figure9: Process layout of plant

4.2.6 Organizational Structure



The roles and responsibilities of each individual in the organisation are described below;

Board of Directors

Responsible for forming policies and providing general oversight and direction to the organization.

General Manager

In charge of implementing policies as made by the Board of Directors. All the other managers are answerable to him and he reports to the Board of Directors. He or She should possess good technical and administrative skills.

Human Resource Manager

Responsible for the welfare of all workers and also does recruitment of skilled workers on behalf of the organization.

Finance Manager

Generally responsible for the overall financial functions of the plant. He or She supervises the accountant and as a team they prepare a budget, manage expenditures and prepare financial reports.

Trained Engineer

In charge of all the technical aspects of the plant that is production and maintenance. He should be well trained in oxygen manufacturing technologies and have good technical ability. He supervises plant operators and technicians.

Sales and Marketing Manager

Responsible for sale of the product. They look for market for the company and ensure that the product produced meets the required standards. Sales managers require both technical and marketing knowledge. They supervise the foremen and drivers.

4.2.7 Personnel Requirement and Work Program

The plant will have a total work force of 19 people in the different sections as shown below;

Personnel	Day/week	Shifts/day	Workers/shift	Total workers
Manager	6	1	3	3
Sales and marketing	6	2	1	2
Trained Engineer	6	1	1	1
Plant operators	6	2	3	6
Mechanical technicians	6	2	1	2
Electrical technicians	6	2	1	2
Foreman	6	1	1	1
Drivers	6	2	1	2

4.2.8 Maintenance of Equipment

The plant requires fixed preventive maintenance to be done. This includes daily maintenance and time-based maintenance.

Daily Maintenance

This is to be carried out at least once every day and lasts for about 30 minutes. It involves the following activities;

- i. Blowing of dust from the air compressor
- ii. Checking for leakages in the whole system
- iii. Checking the power system
- iv. Checking the operating temperature

- v. Checking the machine monitor

Time-Based Maintenance

This is preventive maintenance done after every 3000 hours of operation and takes approximately 1 hour to complete. It involves the following routines;

- i. Changing of oil
- ii. Changing of oil filter
- iii. Changing of air filter

Sources of spare parts

The spare parts are pre-ordered with the Original Equipment Manufacturer since sourcing them on the local market is difficult.

4.2.9 Environmental and Social Impact Assessment

This involves identifying, predicting, evaluating and suggesting mitigation measures for the likely impacts to be caused by developing the proposed project. The assessment also incorporates social, culture and health effects.

Below are the likely impacts of setting up an oxygen manufacturing plant and the proposed mitigation measures.

Leakage of oxygen gas which can lead to fire hazards

Oxygen greatly supports combustion and can accelerate fire hazards or fireballs. Leakages can be within the system or from cylinders. Presence of any flames in the vicinity will likely cause a fire to start.

Mitigation measures include;

- i. Doing regular checks for leaks
- ii. Avoiding naked flames within the vicinity of the plant
- iii. Installing water hydrants at the plant site
- iv. Installing fire extinguishers
- v. Use of safety caps to seal all cylinders

Noise pollution from the compression and pressure swing adsorption units

If one spends long hours at the plant, the noise generated can have a detrimental effect on their health. Neighbours to the plant are also affected by the noise.

Mitigation measures include;

- i. Locating the plant away from community or living spaces
- ii. Giving employees ear buds to offer personal protection

Injury to operators of the machinery

Mistakes made when operating the machines can lead to injury on the workers which affects their quality of life.

Mitigation measures;

- i. Proper training of operators and personnel
- ii. Providing and encouraging use of relevant personal protective equipment

4.3 Costing of Proposed Oxygen Plant

4.3.1 Fixed Capital Costs

Equipment costs

The price of machinery required to generate oxygen were estimated based on a quotation obtained from Amcaremed Medical Gas Solution China. (See appendix)

Table 10: Cost of oxygen generation equipment

Item	Quantity	Unit Price (UGX)	Total Cost (UGX)
Air compressor	2	221,700,000	443,400,000
Air dryer	2	12,250,000	24,500,000
Air tank	2	2,800,000	5,600,000
Oxygen generator	2	82,250,000	164,500,000
Filters	16(2sets)	420,000	6,720,000
Oxygen tank	2	2,800,000	5,600,000
Booster compressor	2	84,000,000	168,000,000
Filling ramp	2	4,200,000	8,400,000
TOTAL			826,720,000

Table 11: Cost of other-equipment

Item	Quantity	Unit cost	Total cost (UGX)
Oxygen cylinders	Type D (200)	1,000,000	200,000,000
	Type B (100)	400,000	40,000,000
Tool box	2	150,000	300,000
Gas cylinder trolleys	10	70,000	700,000
Vehicles	2	40,000,000	80,000,000
Total			321,000,000

Total cost of equipment = (826,720,000+321,000,000)
= UGX 1,147,720,000

Land and Building Cost

In selecting the best location for the investment, the following factors were put into consideration;

- i. Distance from the market which should be fairly close to minimise transportation costs
- ii. Reliable road infrastructure for ease of access
- iii. Availability of electricity as a paramount resource input
- iv. Government policies
- v. Presence of towns in the vicinity

The plant was estimated to occupy (100metre x 50 metre) = 5000square metres (approx. 1.5 acres) Adding room for expansion, the total land required will be approximately 2 acres.

According to market prices for land in Uganda, the average price for 2 acres in selected locations is;

Area	Cost (UGX)
Kampala	1,000,000,000 -1,400,000,000
Jinja	200,000,000 – 250,000,000
Mbarara	300,000,000 – 400,000,000
Mukono	65,000,000 – 150,000,000

Therefore, Mukono is the best location for the plant, 2 acres of land in Mukono will cost $2 \times 100,000,000 = \text{UGX } 200,000,000$

According to Estate Cloud, the leading platform for real estate news, research, content and data, constructing ware houses and basic factory units' costs about UGX 1,200,000 per square metre.

If buildings occupy an area of 700 square metres, then;

Building costs = $1,200,000 \times 700 = \text{UGX } 840,000,000$

4.3.2 Operating Costs

These include costs to start the business and keep it operational. They are expected to increase until the business reaches a normal level of operation. After this point operation costs stay constant throughout the project lifetime. They include salary cost, raw materials cost, utilities.

Raw materials

The main raw material in the generation of oxygen is air which is readily available at no cost

Cost of Electricity

Electricity is the main utility consumed at the plant. The electricity costs were estimated based on these assumptions;

- i. Efficiency of plant is 65% since it's impossible to operate at 100% efficiency
- ii. The plant works for 16hrs per day for 20days per month
- iii. Electricity used in other units of the plant is 1% of total requirements

Electrical power specifications of equipment

PSA generator unit	2 x 0.6kW (220V /50Hz / 1 phase)
Feed air compressor	2 x 37 kW (380V /50Hz / 3 phase)
Feed air dryer	Included with air compressor
Booster compressor	2 x 7.5 kW (380V /50Hz / 3 phase)

Power tariffs for supply to large industrial areas as provided by Umeme at quarter 4, 2021

Energy Tariff	UGX / kwh
Peak	474.8
Shoulder	355.8
Off Peak	226.1
Average	355.0

Cost of electricity used by machinery

Machinery	Power (kW)	Energy Tariff	UGX/ kWh	kWh/day at 100%	kWh/day at 65%	kWh/month at 65%	kWh/year at 65%	UGX/year
PSA generator unit	1.2	Average	355	19.2	12.48	249.6	2,995.2	1,063,296
Feed air compressor	74	Average	355	1,184	769.6	15,392	184,704	65,569,920
Booster compressor	15	Average	355	240	156	3,120	37,440	13,291,200
							TOTAL	79,924,416

Assume;

Hours/day = 16 and Days/month =20

Cost of electricity used in other areas (at 1%) = 7,992,441.6

Total cost of electricity/year = UGX 87,916,857.6 = approx. **UGX 90,000,000**

Maintenance Costs

Initially the maintenance costs are assumed to account for 1% of the total equipment and vehicle costs.

Initial maintenance costs = 1% (cost of vehicle and equipment)

$$= (0.01 \times 1,147,720,000)$$

$$= \text{UGX } 11,477,200$$

The maintenance costs increase by 5% in subsequent years

Salary of the Staff

Position	No.	Salary /Month (UGX)	Total Annual Salary (UGX)
General Manager	1	2,500,000	30,000,000
Trained Engineer	1	1,500,000	18,000,000
Managers	3	1,000,000	36,000,000
Accountant	1	400,000	4,800,000
Technicians and Plant Operators	10	400,000	48,000,000
Foreman	1	200,000	2,400,000
Drivers	2	200,000	4,800,000
	19		144,000,000

Total Estimated Salary paid/year = **UGX 144,000,000**

Employee salary is increased by 5% every year to maintain motivation and account for inflation.

4.3.3 Indirect costs

Indirect costs incurred in setting up and operating the proposed oxygen plant include; promotion, insurance, depreciation and tax.

Promotional activities

The approximated monthly expenditure on doing advertisement is UGX 200,000.

Annual promotion budget = UGX 2,400,000

Insurance

Insurance companies like Jubilee and UAP charge a premium rate of about 1.5% of the total value of assets insured against fire and burglary per year

Insurance cost per year = 0.5 % of total cost of equipment and buildings

$$= (0.005 \times 1,907,720,000)$$

$$= \text{UGX } 9,538,600$$

Depreciation

Item	Depreciation rate	Depreciation costs (UGX)
Equipment	5%	53,386,000
Building	2.5%	21,000,000
Vehicles	10%	8,000,000
Total		82,386,000

Taxes

Cooperate income tax is stipulated at 30% by the 1997 Income Tax Act of Uganda.

4.3.4 Summary of Investment Requirements

Cost	Item	Amount (UGX)
Fixed	Equipment	1,067,720,000
	Land	200,000,000
	Buildings	840,000,000
	Vehicles	80,000,000
Sub-total		2,187,720,000
Operating	Electricity	90,000,000
	Salaries	144,000,000
	Maintenance	11,477,200
Sub-total		245,477,200
Indirect	Promotion	2,400,000
	Depreciation	82,386,000
	Insurance	9,538,600
Sub-total		94,324,600
Total		2,527,521,800

4.4 Financial Plan

4.4.1 Source of funds

It is proposed that the business promoters will provide 50% of investment requirement and the balance will be acquired from a bank loan.

	Amount (UGX)
Promoters' contribution	1,263,760,900
Loan	1,263,760,900
TOTAL	2,527,521,800

4.4.2 Loan Repayment Schedule

Statistics from the Bank of Uganda (BOU), show that the average industry lending rate for commercial banks is about 19%.

The following loan terms were used in computing the loan repayment schedule;

Annual interest rate: 19%

Tenure of loan: 5years

Loan Repayment type: Reducing balance

Repayment: Monthly

Grace period: 1 Year

Year	Period	Principal Balance	Principal Paid	Interest Paid	Total Paid	Principal Balance
1	1	1,263,760,900	-	20,009,548	20,009,548	1,263,760,900
	2	1,263,760,900	-	20,009,548	20,009,548	1,263,760,900
	3	1,263,760,900	-	20,009,548	20,009,548	1,263,760,900
	4	1,263,760,900	-	20,009,548	20,009,548	1,263,760,900
	5	1,263,760,900	-	20,009,548	20,009,548	1,263,760,900
	6	1,263,760,900	-	20,009,548	20,009,548	1,263,760,900
	7	1,263,760,900	-	20,009,548	20,009,548	1,263,760,900
	8	1,263,760,900	-	20,009,548	20,009,548	1,263,760,900
	9	1,263,760,900	-	20,009,548	20,009,548	1,263,760,900
	10	1,263,760,900	-	20,009,548	20,009,548	1,263,760,900
	11	1,263,760,900	-	20,009,548	20,009,548	1,263,760,900
	12	1,263,760,900	-	20,009,548	20,009,548	1,263,760,900
3	13	1,263,760,900	17,777,053	20,009,548	37,786,600	1,245,983,847
	14	1,245,983,847	18,058,523	19,728,078	37,786,600	1,227,925,325
	15	1,227,925,325	18,344,449	19,442,151	37,786,600	1,209,580,875
	16	1,209,580,875	18,634,903	19,151,697	37,786,600	1,190,945,972
	17	1,190,945,972	18,929,956	18,856,645	37,786,600	1,172,016,016
	18	1,172,016,016	19,229,680	18,556,920	37,786,600	1,152,786,336
	19	1,152,786,336	19,534,150	18,252,450	37,786,600	1,133,252,186
	20	1,133,252,186	19,843,441	17,943,160	37,786,600	1,113,408,746
	21	1,113,408,746	20,157,628	17,628,972	37,786,600	1,093,251,117
	22	1,093,251,117	20,476,791	17,309,809	37,786,600	1,072,774,326

	23	1,072,774,326	20,801,007	16,985,593	37,786,600	1,051,973,319
	24	1,051,973,319	21,130,356	16,656,244	37,786,600	1,030,842,963
3	25	1,030,842,963	21,464,920	16,321,680	37,786,600	1,009,378,043
	26	1,009,378,043	21,804,781	15,981,819	37,786,600	987,573,262
	27	987,573,262	22,150,024	15,636,577	37,786,600	965,423,238
	28	965,423,238	22,500,732	15,285,868	37,786,600	942,922,506
	29	942,922,506	22,856,994	14,929,606	37,786,600	920,065,512
	30	920,065,512	23,218,896	14,567,704	37,786,600	896,846,616
	31	896,846,616	23,586,529	14,200,071	37,786,600	873,260,087
	32	873,260,087	23,959,982	13,826,618	37,786,600	849,300,104
	33	849,300,104	24,339,349	13,447,252	37,786,600	824,960,756
	34	824,960,756	24,724,722	13,061,879	37,786,600	800,236,034
	35	800,236,034	25,116,196	12,670,404	37,786,600	775,119,838
	36	775,119,838	25,513,870	12,272,731	37,786,600	749,605,968
	4	37	749,605,968	25,917,839	11,868,761	37,786,600
38		723,688,129	26,328,205	11,458,395	37,786,600	697,359,924
39		697,359,924	26,745,068	11,041,532	37,786,600	670,614,856
40		670,614,856	27,168,532	10,618,069	37,786,600	643,446,324
41		643,446,324	27,598,700	10,187,900	37,786,600	615,847,624
42		615,847,624	28,035,680	9,750,921	37,786,600	587,811,944
43		587,811,944	28,479,578	9,307,022	37,786,600	559,332,367
44		559,332,367	28,930,505	8,856,096	37,786,600	530,401,862
45		530,401,862	29,388,571	8,398,029	37,786,600	501,013,291
46		501,013,291	29,853,890	7,932,710	37,786,600	471,159,401
47		471,159,401	30,326,576	7,460,024	37,786,600	440,832,825
48		440,832,825	30,806,747	6,979,853	37,786,600	410,026,078
5	49	410,026,078	31,294,521	6,492,080	37,786,600	378,731,557
	50	378,731,557	31,790,017	5,996,583	37,786,600	346,941,540
	51	346,941,540	32,293,359	5,493,241	37,786,600	314,648,180
	52	314,648,180	32,804,671	4,981,930	37,786,600	281,843,510
	53	281,843,510	33,324,078	4,462,522	37,786,600	248,519,432
	54	248,519,432	33,851,709	3,934,891	37,786,600	214,667,722
	55	214,667,722	34,387,695	3,398,906	37,786,600	180,280,028
	56	180,280,028	34,932,167	2,854,434	37,786,600	145,347,861
	57	145,347,861	35,485,259	2,301,341	37,786,600	109,862,602
	58	109,862,602	36,047,109	1,739,491	37,786,600	73,815,493
	59	73,815,493	36,617,855	1,168,745	37,786,600	37,197,638
	60	37,197,638	37,197,638	588,963	37,786,600	-

The total interest paid is UGX **790,110,48** and the computed monthly repayment is UGX **37,786,600**

4.5 Annual Sales

4.5.1 Production capacity

Oxygen cylinders differ in size as shown in figure 10 below and are categorized based on water capacity rather than the volume of oxygen they can carry. Therefore, the volume of oxygen required to fill each cylinder is more than its given size in water capacity since the gas it carries is pressurised.



Figure 10: Types of oxygen cylinders

Source: <https://www.tec2med.com/oxygen-cylinder>

Hence, by assuming a maximum working pressure of 150bar for the cylinder and atmospheric pressure of 1 bar, Boyles law of pressure ($p_1 v_1 = p_2 v_2$) can be used to compute volume of oxygen required to fill each cylinder.

For Boyles law; p_1 = working pressure in cylinder; v_1 = volume of cylinder in water capacity

p_2 = atmospheric pressure; v_2 = volume of oxygen in cylinder to be measured

Table 12: Capacity of different oxygen cylinders

Cylinder Type	Water capacity	Volume of oxygen in cylinder (L)
A	5L	750
B	10L	1500
C	40L	6000
D	47L	7050

For computation purposes, the study done assumed that;

- i. type A and B cylinders have closely similar capacity
- ii. type C and D cylinders equally have closely similar capacity

Therefore, only type B and D cylinder capacities were used in the analysis. The table below shows analysis done to estimate the number of cylinders which can be filled in a day.

Table 13 :Number of cylinders filled per day

	D	B	Total
Time to fill cylinder	12min	4min	
Number of cylinders filled/hour at 100% production per filling station	3	2	5
Number of cylinders filled/day at 100% production (16hrs) for 2 filling stations	96	64	160
Oxygen consumed/day filling cylinders	676,800L	96,000L	772,800L

Analysis above indicated that;

- i. Oxygen consumed/ hour in filling cylinders is = $772,800/12 = 48,300\text{L/hr} = 48.3\text{m}^3/\text{hr}$. This fits within the proposed total plant capacity of $60\text{m}^3/\text{hr}$ with 80% utilisation of available capacity.
- ii. The plant operating at 100% capacity will be able to fill **160** cylinders per day from 2 shifts per day and 2 filling stations.

4.5.2 Sales Estimation

Sales will be generated from purchase of a new cylinder or refilling of an empty cylinder. A first-time customer without a cylinder will have to make a new purchase whereas customers who already possess cylinders will be exchanging an empty cylinder for a filled cylinder of equal size.

To enable estimation of revenue generated from sale of new cylinders, the following assumptions were made;

- i. Of the 300 cylinders purchased, 100 cylinders will be held in inventory to fulfil new purchases whereas the remaining 200 will be used for exchange during refilling.
- ii. Inventory consists of 30% type B cylinders whereas type D form 70%.
- iii. Best sales achieved from new cylinder purchases per year will be at 10% of number of cylinders held in inventory.
- iv. Average prices will be set based on benchmarked market prices since oxygen is an essential commodity.

Annual sales from first-time cylinder purchases

Cylinder Type	No. of cylinders in inventory	No. of new cylinders sold/year (10%)	Average price of new cylinder (UGX)	Sales /year (at 100%) in (UGX)
D	70	7	1,500,000	10,500,000
B	30	3	500,000	1,500,000
Total				12,000,000

Annual sales from refilling of cylinders

Cylinder type	No. of cylinder refills/day (100% production)	No. of cylinder refills /month	No. of cylinder refills/ year	Average price for refilling of cylinder (UGX)	Sales /year (UGX) at 100%
D	96	1,920	23,040	35,000	806,400,000
B	64	1,280	15,360	20,000	307,200,000
Total					1,113,600,000

Total Annual Sales at 100% capacity = (1,113,600,000 + 12,000,000) = **UGX 1,125,600,000**

Initially in Year 0, no income is generated because project is still under development and operations have not begun. In year 1 it is assumed capacity reaches 75% and increases by 5% in subsequent years up to 100% when operations are at optimum level. Therefore, the projected annual sales are shown in the table below

Table 14: Projected annual sales

Year	Income (UGX)
1 (75%)	801,990,000
2 (80%)	855,456,000
3 (85%)	908,922,000
4 (90%)	962,388,000
5(95%)	1,069,320,000
6 (100%)	1,125,600,000

4.6 Cashflow Projections

	Year 0	Year 1	Year 2	Year 3	Year 4	Year 5
	0% Cap	75% Cap	80% Cap	85% Cap	90% Cap	95% Cap
INFLOW						
Balance B/F	-	5,362,629	9,878,138	45,023,492	101,609,738	173,204,608
1. Income	-	801,990,000	855,456,000	908,922,000	962,388,000	1,069,320,000
2. Equity	1,263,760,900					
3. Loan	1,263,760,900					
Total Inflow	2,527,521,800	807,352,629	865,334,138	953,945,492	1,063,997,738	1,242,524,608
OUTFLOW						
1. Fixed assets						
Equipment	1,067,720,000					
Land	200,000,000					
Buildings	840,000,000					
Vehicles	80,000,000					
2. Operating costs						
Electricity	-	90,000,000	90,000,000	90,000,000	90,000,000	90,000,000
Salaries	-	144,000,000	151,200,000	158,400,000	165,600,000	172,800,000
Maintenance	-	11,477,200	12,051,060	12,624,920	13,198,780	13,772,640
3. Indirect costs						
Depreciation	82,386,000	82,386,000	82,386,000	82,386,000	82,386,000	82,386,000
Insurance	9,538,600	9,538,600	9,538,600	9,538,600	9,538,600	9,538,600
Promotion	2,400,000	2,400,000	2,400,000	2,400,000	2,400,000	2,400,000
4. Interest	240,114,571	220,521,267	172,202,209	113,859,313	43,413,126	-
5. Principal	-	232,917,937	281,236,995	339,579,890	410,026,078	-
Total Outflow	2,522,159,171	793,241,004	801,014,864	808,788,724	816,562,584	370,897,240
Balance before tax	5,362,629	14,111,625	64,319,274	145,156,768	247,435,154	871,627,368
Tax (30%)	-	4,233,488	19,295,782	43,547,030	74,230,546	261,488,210
Balance after tax	5,362,629	9,878,138	45,023,492	101,609,738	173,204,608	610,139,158

	Year 0	Year 1	Year 2	Year 3	Year 4
	0% Cap	75% Cap	80% Cap	85% Cap	90% Cap
INFLOW					
Balance B/F		5,362,629	9,878,138	45,023,492	101,609,738
1. Income	0	801,990,000	855,456,000	908,922,000	962,388,000
2. Equity	1,263,760,900				
3. Loan	1,263,760,900				
Total Inflow	2,527,521,800	807,352,629	865,334,138	953,945,492	1,063,997,738
OUTFLOW					

1. Fixed assets					
Equipment	1,067,720,000				
Land	200,000,000				
Buildings	840,000,000				
Vehicles	80,000,000				
2. Operating costs					
Electricity	0	90,000,000	90,000,000	90,000,000	90,000,000
Salaries	0	144,000,000	151,200,000	158,400,000	165,600,000
Maintenance	0	11,477,200	12,051,060	12,624,920	13,198,780
3. Indirect costs					
Depreciation	82,386,000	82,386,000	82,386,000	82,386,000	82,386,000
Insurance	9,538,600	9,538,600	9,538,600	9,538,600	9,538,600
Promotion	2,400,000	2,400,000	2,400,000	2,400,000	2,400,000
4. Interest	240,114,571	220,521,267	172,202,209	113,859,313	43,413,126
5. Principal	0	232,917,937	281,236,995	339,579,890	410,026,078
Total Outflow	2,522,159,171	793,241,004	801,014,864	808,788,724	816,562,584
Balance before tax	5,362,629	14,111,625	64,319,274	145,156,768	247,435,154

	Year 6	Year 7	Year 8	Year 9	Year 10
	100% Cap	100% Cap	100% Cap	100% Cap	100% Cap
INFLOW					
Balance B/F	610,139,158	954,987,640	1,195,979,876	1,364,272,739	1,481,676,042
1. Income	1,125,600,000	1,125,600,000	1,125,600,000	1,125,600,000	1,125,600,000
2. Equity					
3. Loan					
Total Inflow	1,735,739,158	2,080,587,640	2,321,579,876	2,489,872,739	2,607,276,042
OUTFLOW					
1. Fixed assets					
Equipment					
Land					
Buildings					
Vehicles					
2. Operating costs					
Electricity	90,000,000	90,000,000	90,000,000	90,000,000	90,000,000
Salaries	172,800,000	172,800,000	172,800,000	172,800,000	172,800,000
Maintenance	14,346,500	14,920,360	15,494,220	16,068,080	16,641,940
3. Indirect costs					
Depreciation	82,386,000	82,386,000	82,386,000	82,386,000	82,386,000
Insurance	9,538,600	9,538,600	9,538,600	9,538,600	9,538,600
Promotion	2,400,000	2,400,000	2,400,000	2,400,000	2,400,000
4. Interest	-	-	-	-	-
5. Principal	-	-	-	-	-
Total Outflow	371,471,100	372,044,960	372,618,820	373,192,680	373,766,540
Balance before tax	1,364,268,058	1,708,542,680	1,948,961,056	2,116,680,059	2,233,509,502
Tax (30%)	409,280,417	512,562,804	584,688,317	635,004,018	670,052,850
Balance after tax	954,987,640	1,195,979,876	1,364,272,739	1,481,676,042	1,563,456,651

	Year 11	Year 12	Year 13	Year 14	Year 15
	100% Cap	100% Cap	100% Cap	100% Cap	100% Cap
INFLOW					
Balance B/F	1,563,456,651	1,677,971,576	1,700,060,121	1,715,120,401	1,725,260,895
1. Income	1,125,600,000	1,125,600,000	1,125,600,000	1,125,600,000	1,125,600,000
2. Equity					
3. Loan					
Total Inflow	2,689,056,651	2,803,571,576	2,825,660,121	2,840,720,401	2,850,860,895
OUTFLOW					
1. Fixed assets					
Equipment					
Land					
Buildings					
Vehicles					
2. Operating costs					
Electricity	90,000,000	90,000,000	90,000,000	90,000,000	90,000,000
Salaries	172,800,000	172,800,000	172,800,000	172,800,000	172,800,000
Maintenance	17,215,800	17,789,660	18,363,520	18,937,380	19,511,240
3. Indirect costs					
Depreciation		82,386,000	82,386,000	82,386,000	82,386,000
Insurance	9,538,600	9,538,600	9,538,600	9,538,600	9,538,600
Promotion	2,400,000	2,400,000	2,400,000	2,400,000	2,400,000
4. Interest	-	-	-	-	-
5. Principal	-	-	-	-	-
Total Outflow	291,954,400	374,914,260	375,488,120	376,061,980	376,635,840
Balance before tax	2,397,102,251	2,428,657,316	2,450,172,001	2,464,658,421	2,474,225,055
Tax (30%)	719,130,675	728,597,195	735,051,600	739,397,526	742,267,516
Balance after tax	1,677,971,576	1,700,060,121	1,715,120,401	1,725,260,895	1,731,957,538

4.7 Business Appraisal Computations

4.7.1 Net Present Value

To determine NPV, present values for future values of cash flows are required. These were computed at two different discounting rates of 19 % and 25% as shown in table 15 below.

Table 15: Present Values of Cash Flows

Year	Net Cash flow	19%		25%	
		Discounting Factor	Present Value	Discounting Factor	Present Value
0	5,362,629	1.000	5,362,629	1.000	5,362,629
1	9,878,138	0.840	8,297,636	0.800	7,902,510
2	45,023,492	0.706	31,786,585	0.640	28,815,035
3	101,609,738	0.593	60,254,574	0.512	52,024,186
4	173,204,608	0.499	86,429,099	0.410	71,013,889
5	610,139,158	0.419	255,648,307	0.328	200,125,644
6	954,987,640	0.352	336,155,649	0.262	250,206,762
7	1,195,979,876	0.296	354,010,043	0.210	251,155,774
8	1,364,272,739	0.249	339,703,912	0.168	229,197,820
9	1,481,676,042	0.209	309,670,293	0.134	198,544,590
10	1,563,456,651	0.176	275,168,371	0.107	167,289,862
11	1,677,971,576	0.148	248,339,793	0.086	144,305,556
12	1,700,060,121	0.124	210,807,455	0.069	117,304,148
13	1,715,120,401	0.104	178,372,522	0.055	94,331,622
14	1,725,260,895	0.088	151,822,959	0.044	75,911,479
15	1,731,957,538	0.074	128,164,858	0.035	60,618,514
Total	16,055,961,240				

Table 16: Net Present Values

Year	19%		25%	
	Cumulative PV	NPV	Cumulative PV	NPV
0	5,362,629	-2,522,159,171	5,362,629	-2,522,159,171
1	13,660,265	-2,513,861,535	13,265,139	-2,514,256,661
2	45,446,850	-2,482,074,950	42,080,174	-2,485,441,626
3	105,701,424	-2,421,820,376	94,104,360	-2,433,417,440
4	192,130,524	-2,335,391,276	165,118,249	-2,362,403,551
5	447,778,831	-2,079,742,969	365,243,893	-2,162,277,907
6	783,934,480	-1,743,587,320	615,450,654	-1,912,071,146
7	1,137,944,523	-1,389,577,277	866,606,428	-1,660,915,372
8	1,477,648,436	-1,049,873,364	1,095,804,249	-1,431,717,551
9	1,787,318,728	-740,203,072	1,294,348,838	-1,233,172,962
10	2,062,487,099	-465,034,701	1,461,638,700	-1,065,883,100
11	2,205,125,468	-322,396,332	1,605,944,255	-921,577,545
12	2,521,634,347	-5,887,453	1,723,248,404	-804,273,396
13	2,700,006,869	172,485,069	1,817,580,026	-709,941,774
14	2,851,829,827	324,308,027	1,893,491,505	-634,030,295
15	2,979,994,685	452,472,885	1,954,110,019	-573,411,781

NPV (Year 15) = (Cumulative PV – Initial Investment) = (2,979,994,685 - 2,527,521,800)
=452,472,885

4.7.2 Internal Rate of Return

NPV (19%) = 452,472,885 NPV (25%) = -573,411,781

IRR = (19%) + [452,472,885 / (452,472,885 + 573,411,781) * (25-19)] = 21.65%

4.7.3 Profitability Index

Profitability Index = 2,976,089,000 / 2,527,521,800 = 1.18

4.7.4 Pay Back Period

Payback period = 16,055,961,240 / 2,527,521,800 = 6.35

CHAPTER FIVE: RESULTS

5.1 Oxygen Demand

Oxygen demand in 2019/2020 was estimated at **1,660,898,160 Litres**. The demand for subsequent years was projected to increase progressively as shown in figure 11. By 2029/2030, oxygen demand was forecast to be **2,907,341,856 Litres**.

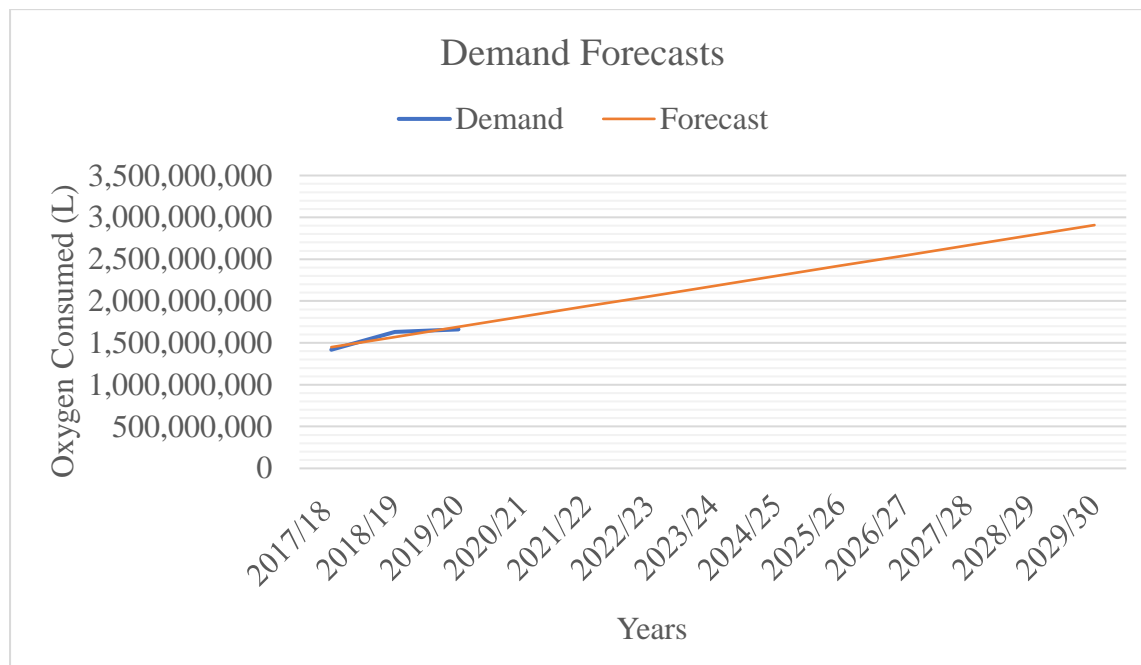


Figure 11: Forecasts for oxygen demand up to 2030

5.2 Capacity of Proposed Oxygen Plant

The proposed oxygen plant had a total capacity of 60m³/h. This comprises of two oxygen generation units each with a capacity of 30m³/h.

5.3 Cost of Investing in Proposed Oxygen Plant

Investing in the proposed plant was estimated to cost a total of **UGX 2,527,521,800**.

Item	Amount (UGX)
Fixed Capital Costs	2,187,720,000
Operating Costs	245,477,200
Indirect Costs	94,324,600
Total	2,527,521,800

The cost of the initial investment is divided amongst fixed capital costs, operating costs and indirect costs. As shown in figure 12, fixed capital costs were estimated to take up 86% of initial investment, operating costs 10% and indirect costs 4%.

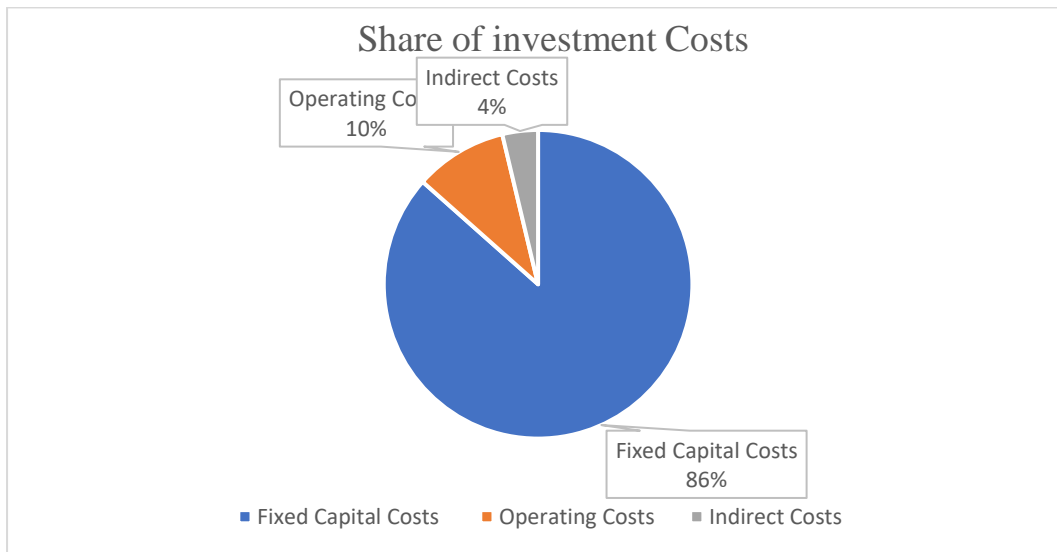


Figure 12: Share of investment costs

5.4 Profitability of Proposed Investment

5.4.1 Net Present Value

Net Present Value of UGX 172,485,069 was obtained in year 13. This is greater than zero indicating that the investment becomes financially viable or acceptable at year 13. In year 15, the prospects were even better with a greater NPV of UGX 452,472,885.

5.4.2 Internal Rate of Return

Internal Rate of Return was 21.65% which is greater than the lending rate of 19%. This makes the investment acceptable.

5.4.3 Profitability Index

Profitability index obtained was 1.18 and since it is greater than 1, the investment is acceptable.

5.4.4 Payback period

An early payback period of 6years and 5months was obtained. This indicates that the money invested can be recovered in a short time.

CHAPTER SIX: CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

The study done was aimed at determining technical and economic viability of investing in an oxygen manufacturing plant. Objectives were to establish and forecast oxygen demand, determine capacity of available oxygen supply, describe machinery required to set up an oxygen plant and ascertain profitability of the planned investment.

From the results, oxygen demand was projected to increase by about 75% in the next 10 years. Furthermore, the Covid-19 pandemic was found to significantly increase oxygen consumption because severe and critically ill Covid-19 patients require high flow rates of about 10 LPM and 30 LPM respectively. This growing demand offers a strong market opportunity which investors can tap into to set up more oxygen manufacturing plants.

Estimating production capacity of oxygen manufacturers was limited to public production plants because information on the capacity of private oxygen manufacturers was not easily accessible.

The study revealed that there is uneven distribution of production capacity for public oxygen plants. The plant at Mulago had an estimated combined capacity of about 195 m³/hr whereas each of the regional plants had an average capacity of about 15 m³/hr.

A well-designed oxygen plant was found to require more than one oxygen generation unit. This ensures the plant can stay in operation in case of a breakdown or maintenance on one of the production units.

For a feasible investment, a medium sized plant of about 60 m³/hr has to be set up and the investment should be spread over more than one oxygen plant. Investing in one big plant to meet the demand is costly and does not yield profitability.

Operating the plant after commissioning will be less costly compared to the initial investment made. This is because operating costs computed were about 10% of initial investment whereas fixed assets comprised 86%.

The investment is profitable and therefore acceptable since a positive NPV was obtained in year 13, the IRR was greater than the borrowing rate, and a profitability index greater than one was obtained.

The short payback period of 6 years and 5 months which was obtained indicates that investors will be able to recover their funds early and invest them in other areas.

6.2 Recommendations

Since data on oxygen consumption and utilisation was not well documented in the literature, the study done was limited to analysing demand for only three years. Therefore, the author recommends proper documentation of data on oxygen utilisation. This will facilitate future studies and enhance proper planning for resources.

Given that the Covid-19 pandemic has caused increased oxygen consumption, there is need to increase capacity of oxygen manufacturing in the country. The stakeholders should plan and accelerate investment in more oxygen plants.

Estimating the contribution made by private manufacturing plants to oxygen supply was difficult. Therefore, the author recommends proper recording and publishing of the capacity of all public and private oxygen manufacturers to enable comprehensive estimation of the available supply of oxygen.

The author recommends increasing capacity of regional oxygen plants in the public sector. This will boost the ability of regional oxygen plants to serve healthcare facilities in their catchment areas.

The capital investment required may seem unachievable for a sole proprietor however the author recommends formation of partnerships by investors to pool financial resources and make the investment achievable.

The author recommends a future feasibility study focusing on liquid oxygen plants to be carried out. The study done was particularly limited to Pressure Swing Adsorption oxygen plants because liquid oxygen plants were not easily accessible. However liquid oxygen plants could be an achievable investment in the future.

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APPENDIX

I. Quotation for Oxygen Generation Equipment



+(86) 550 3028928
 info@amcaremed.com
 www.amcaremed.com

ATTENTION:

Atten: Marvin Atwiine
 Address: Uganda
 Tel: +256 781 567982
 ORIGIN: CHINA

QUOTATION

INVOICE NO: PI-AM211122J-3
 DATE : Nov 22 .TH 2021

Items	Model	Products Description	QTY	Unit	Unit Price(USD\$)	Amount
PSA OXYGEN GENERATOR OY-300						
1	UD37-8C	Medical Air compressor system screw type Moto rating 37 KW 8bar G 380V / 3Ph / 50Hz	1	SET	US\$6,200.00	US\$6,200.00
2	DSA-LT	Medical Air dryer plant refrigerant	1	SET	US\$3,500.00	US\$3,500.00
3	CG-1.0/0.8	1000 L Air receiver 10 bar, GB/T, with manual opening	1	SET	US\$800.00	US\$800.00
4	OY-300	Oxygen Generator Capacity: 30 Nm ³ /h Oxygen purity 93% ± 3% Air consumption - 4.25 m ³ / min FAD Outlet pressure - 4 bar (g) Color - White Class / regulation - GB/T Ambient temperature - 10 to 40 ° C Hose connection - [DN] Inlet / Outlet 25/20 Height above sea level - Less than 200 meters Oxygen Purity Analyzer Instrument* 1	1	SET	US\$23,500.00	US\$23,500.00
5	OY-BF-1	Medical Filter Water separator filter General purpose oil filter High efficiency oil filter Oil vapor filter Dust removal filter Off-odor removal filter Bacterial removal filter	8	PCS	US\$120.00	US\$960.00
6	CG-1.0/0.8	1000 L Oxygen receiver 10 bar, GB/T, with manual opening	1	SET	US\$800.00	US\$800.00
7	OY-BC	Oxygen booster compressor , high pressure booster compressors for the recompression of Medical Oxygen Max Pressure 150 bar Capacity 30 Nm ³ / hour	1	SET	US\$24,000.00	US\$24,000.00
8	OY-BC	Oxygen booster compressor Chiller	1	SET	US\$3,000.00	US\$3,000.00
9	OY-BC	Filling Ramp Filling platform manifold 5+5 type with 2 main valve	1	SET	US\$1,200.00	US\$1,200.00

EXW US\$63,960.00
 SUM US\$63,960.00

Terms & Conditions:

II. Questionnaire

Information relating to production of oxygen is required so that a feasibility study of investing in more oxygen plants is prepared. Completing this questionnaire will greatly assist the researcher in the study. Thank you very much for your participation.

A. Production Method

What is the main method used for oxygen production?

Method	Tick option
Pressure Swing Adsorption Generator	
Liquid Oxygen plant	
Oxygen concentrator	

B. Production Capacity

What is the production capacity of the plant? Circle the units used.

Capacity (LPM / m ³ /hr)

Does the plant operate at full or half capacity?

Full Half

C. Operating Time

No. of operating Hour/ Day	No. of operating Days/Month

D. Quantity Produced

Sizes of Cylinders	Number of cylinders filled in a day	Time taken to fill a cylinder

E. Machinery in a typical Oxygen plant

No.	Name	Size	Brand
1			
2			
3			
4			
5			

F. Maintenance of Machinery

How many times do you carry out maintenance in a month?

How long does the maintenance period last?

G. List of Sections/ Departments in the plant

--

H. Raw Materials Used

What are the raw materials used in production?

Raw Material	Quantity	Cost

I. Utilities Consumed

Utility	Quantity
Electricity	
Water	

J. Personnel Required to operate the plant

Title	No. of people

K. Work schedule

No. of Shifts/ Day	No. of Workers/ Shift

L. Pricing of Oxygen

Do you sell oxygen to other hospitals, if yes what is the average price?

Cylinder Size	Amount	
	Purchase	Refilling

Interview Questions

Q. What are the major challenges faced in the production of oxygen?

.....

.....

.....

.....

.....

Q. Is the maintenance?

- i. Outsourced overseas
- ii. Provided by the workers
- iii. Provided by consultants