PROCESS DESIGN AND EFFICIENCY OF ANALYTICAL LABORATORIES IN KENYA

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DECLARATION

I declare that this research project is my original work and has never been submitted to any other University for assessment or award of any degree.

Signed…………………………………… Date…………………………………….

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This research project has been submitted with my approval as the university supervisor.

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DEDICATION

I wish to dedicate this project to My mom, Sister, Brother and little niece Makayla for their advice, support and encouragement in my academic journey.

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ABSTRACT

The aim of this study was to establish if there exists a relationship between service process designs and Kenyan Analytical Laboratories operating efficiencies. The study was guided by four specific objectives; to identify the different types of process designs of analytical laboratories in Kenya, to determine the efficiency of Kenyan analytical laboratories to determine if there is a relationship between process design and analytical laboratories performances in terms of efficiency in Kenya and to determine the contribution of analytical laboratories to the Kenyan economy. The study adopted a descriptive research design. The population of the study comprised of 50 Kenyan Analytical Laboratories operating in Kenya and a census study was carried out. The sample size was 28 respondents representing a 56% response rate. The study relied on primary data collection which was done using a questionnaire. The questionnaire was administered physically through a research assistant. The findings showed Kenyan Analytical Laboratories mostly employ commodity and simplicity process designs this could possibly be attributed to Kenyan analytical laboratories having simple job tasks and responsibilities or there could be a lot of the automation of the analysis process. The average operating efficiency levels of these laboratories was 43.8% which was low compared to other international laboratories. Further findings revealed that there was no supported relationship between the type of service process designs adopted by Kenyan analytical laboratories and their operating efficiency levels, this was explained that other factors like methodology selection and application, innovation and technology, and training could be the reason. Additionally, out of the 5 key contributions of analytical laboratories to the Kenyan economy 4; Pharmacy and Drug Control, Agriculture Standards Maintenance, Environmental Pollution and Control and Research and Development were averaging between 61-80% contribution rate with the exception of food safety which the respondents rated the highest with its contribution rate being 81-100%, this was due to the fact that most of the Kenyan Analytical Laboratories samples for analysis are food, processing and manufacturing type of samples. Based on the findings, the study concluded and recommended that Kenyan Analytical Laboratories should not put a lot of emphasis on using the type of service process design they employ to drive up their efficiency levels as the study revealed that there is no supported relationship existing between service process designs and operating efficiency levels of these types of Laboratories. The study was limited to only analytical types of laboratories and not others like medical laboratories. Further research was proposed to be carried out to analyze whether this lack of relationship also exists in other types of Laboratories like Medical Laboratories.

CHAPTER ONE: INTRODUCTION

1.1 Background of the study

Analytical chemistry involves a systematic approach to how matter is qualitatively and quantitatively sampled, processed or analyzed and the information is synthesized and communicated to the relevant persons. All this takes place inside what we call analytical laboratories and the people who conduct these researches on the composition and structure of matter are Analytical Chemists. The main goal of establishing these laboratories is to provide quality assurance and maintenance of established standards. Results from the analysis of the various samples inside these laboratories are generally used to make conformance decisions, approval decisions, referral decisions or standards decisions, among others, depending on the organization involved. How these analytical laboratories are managed and run determines their levels of efficiency in delivering these objectives. There is a need to investigate and research on the different aspects of analytical laboratories operations in relation to the Kenyan perspective of how or whether their performances in relation to efficiency can be improved or maintained. One of these key operations areas of analytical laboratories is process design.

1.1.1 Process Design

Process design involves technological innovation in response to, or in anticipation of changing market requirements and trends in technology based on three principles, namely: Strategic balance, Top management approach and Teamwork (Oakland, 1993). In Analytical laboratories, Process management is very important as it's the defining factor between having a laboratory that delivers timely, reliable and actionable service information and a laboratory that cannot manage the various process variations that include: variety of services offered, structural variations, random variations and assignable variation to maximize their output deliverables.

Therefore, there was a need to investigate how Kenyan Analytical Laboratories process designs affect their levels of efficiency to meet their objectives or their mandates.

Analytical Laboratories are generally comprised of batch processes that involve medium variety and volume of services offered. Process designs for analytical laboratories are generally comprised of Pre-analytical, analytical and post-analytical processes that follow a systems approach.

According to Frank Brown (2009), the analytic process work-flow must have pre-defined objectives and follows the following steps; Issuance of a laboratory request that is obtained, Data capture arising from the sample analysis using the analytical instruments, Raw data reduction of information from the instruments used to test the sample into meaningful and digestible results, Data indexing, this is done normally for future referencing, Reporting, where data is logically grouped for presentation to the relevant parties that use the information to support service-related decisions and lastly Sharing, this is where the laboratory report is distributed in a consistent, predictable, and timely manner to the intended parties for the purpose of scientific and business decision-making.

To effectively research on process designs of analytical laboratories, process mapping needed to be carried out, where the following information needs to be collected; the processes names, process outputs, who is involved in delivering the process, who is responsible or in-charge of the process, the level of process mapping to be carried out, the activities that define the process, the metrics linked with the overall process including the key steps, variations in the process and lastly the start and ending points of the process (Barr and Silver, 1994).

Recent studies that were carried out on challenges that chemists, specifically chemical analysts that work in laboratories face in developing countries and one of the major challenges discovered was lack of infrastructure in terms of proper locations, layouts and equipments used in most analytical laboratories is sub-standard or outdated (Brown, 2011). Kimengech, Waithaka, Onyuka and Kigondu in 2017 researched on what types of errors compromise the quality of laboratory services in clinical-chemistry laboratories in Kenya and through their research we can see some of the errors are because of how the laboratory is design and the processes used in the various laboratories. Additionally, some workshops were organized in relation to analytical laboratories, like how to develop scientific equipment policies in Africa for analytical laboratory equipments in 2014 chaired by Dr. Wandega. There was still a lot of research to be carried out concerning analytical laboratories and how they impact industry trends and the role they play in Kenya. This study looks at process designs which are often neglected by analysts, managers and the organizations involved, its these process designs that are the key fundamentals in the laboratory work carried out in analytical laboratories.

1.1.2 Analytical Laboratories in Kenya

Analytical Chemistry is a science of inventing and applying the concepts, principles and strategies that measure the characteristics of chemical systems and species or generally known as matter (Harvey, 2000). Analytical laboratories are generally mandated to offer laboratory services like, materials testing which might be organic or inorganic in nature for industries, markets or clients that use this information for quality assurance, research or trouble-shooting purposes. Analytical Laboratories usually use analytical techniques, equipments and methods to interpret the raw data obtained from the analysis of the various samples, so that the information can be disseminated to the relevant parties concerned and in turn they use it to make critical decisions that concerns them meeting their objectives (Intertek, 2016). Such information is used to make decisions that may include research directions to take, conformance decisions or quality assurance standards decisions.

In Kenya, there are 50 registered Analytical Laboratories that are spread majorly over Pharmaceutical, Agricultural and Food processing industries that are the driving force in quality superiority of their products. Kenya's expected GDP growth rate from 5.6% in 2015 to 7.1% in 2017 is largely based on these industries activities (World Bank group and Indee Kenya, 2016). Therefore, analytical laboratories in Kenya play a very crucial role in terms of Kenya's economic growth. Basic research that is conducted by some analytical laboratories in Kenya is growing and Kenya is ranked amongst the top-ranking countries in Africa when it comes to basic research (Kenya Laborum, 2016).

The Government of Kenya is making efforts to strengthen test laboratories in terms of their performance through the ministry of planning and natural development, in their economic recovery strategy for wealth and employment creation of 2013. In Kenya, the number of Government owned analytical laboratories and privately-owned laboratories are steadily increasing but not as fast as the market requirements. Since 1999, there has not been any officially gazetted number of analytical laboratories in Kenya through the environmental management and coordination Act of 1999. In the Kenyan field of Analytical Chemistry, there were a few key issues that greatly affect the operations of the laboratories and their reliability to be efficient in delivering of their co-mandate objectives whether it's in drug development, forensic analysis, toxicology or quality assurance (Kenya Gazette 1999).

Firstly, there was a general lack of proper infrastructure in this field in terms of state of the art scientific equipment. As of 2013, there are only two Nuclear Magnetic Resonance Equipments that available for research purposes in the Kenyan Universities and of the two only one is operational. As a result, only theoretical knowledge of these equipments is taught in our tertiary level institutions which results in lack of practical knowledge that is demanded by the job market. Additionally, having an efficient economic infrastructure is very important for growing research and development in Kenya and Africa especially in the analytical laboratories industry (Wandega,2011).

Furthermore, Analytical laboratories have human resources that have been trained in a curriculum that is not aligned with the market needs (Schneidman, Dacombe, and Carter, 2014) this results in under performances and lack of the ability to differentiate whether deliverables are rightly set and whether they are done the right way.

In Kenya, Professional bodies and societies that are aligned with Analytical laboratories are very few, so far there is only one society in Kenya called the Kenya Chemical Society and it was only formed in 2007 and it's through these bodies that this field is marketed and standardization of procedures and policies is achieved (Gachanja, 2015).

Currently in the field of analytical chemistry, there is a popular and fast-growing area of innovation called 'Nano analytics' which involves the developing of concepts, principles and methods of application of Nano-technologies and properties of the Nano-sized matter to be used in chemical analysis (Shtykov, 2014). To apply this latest wave of innovation in Kenya, we need to have the most efficient processes in our laboratories if we want to compete in quality testing and assurance globally, which is critical to the economy.

1.2 Research Problem

There was a need to largely investigate and come up with efficient process designs for analytical laboratories that drive growth and development of consistent competitive advantages for Kenyan analytical laboratories. Adopting the right process designs can not only effectively reduce costs and eliminate wastes in laboratories but it can also be a factor for having a competitive edge against other organizations' locally and globally. Analytical laboratories mainly have an aim to analyze samples in an economic, reliable, safe and efficient manner (Wallace and Clarkson, 1999).

Research on how the Kenyan analytical laboratories process designs are established and the relationship on how they affect the laboratories performances in terms of operational efficiency will enable identification of bottlenecks, integration and streamlining of the processes to develop competitive advantages of these laboratories and enable them to even compete globally. Efficient analytical laboratories processes are geared to eliminate data analysis problems that comes with having various workstations with different analysts having different capabilities and instruments. Additionally, analytical laboratories generally have complex working environments due to the different number of instruments in the laboratory ranging from Gas Chromatographs to Spectrophotometers, determining the most efficient process designs in Kenyan laboratories will eliminate these problems. Analytical laboratories that do not have efficient process designs are said to have long service throughputs, high overhead costs and operate on high risks (Brown, 2009)., research needs to be carried out to ascertain if this applies to Kenyan analytical laboratories, hence the reason for this research

Recent studies by Schneidman, Dacombe and Carter (2014), on laboratory human resources and the skills they need to have is some of the research carried out in this area but how these professionals are integrated into the processes was not indicated or researched on. Further research on how analytical laboratories process layouts are designed has been discussed by Rob Skilton (2014) but process design types or how they fit into the layouts was not discussed and hence more reason to research on process designs of analytical laboratories. Matlin and Abegaz in their publication, Chemistry for development (2011), stated that practical chemistry processes are very important to national development and therefore a conducive environment for chemistry research needs to be respected and the products of these researches need to be utilized.

Additionally, Oketch (2014), investigated pharmaceutical firms' performances in Kenya but she did not look at how the pharmaceutical laboratories in the pharmaceutical companies contribute to the overall performance of these firms. Mutunga (2014), researched on design practices in relation to the supply chain performances of milk processing firms in Kenya, where she highlighted that performance measures are important for effective management of organizations, she majorly concentrated in supply chain processes of milk firms and they can be improved, research on key decision areas like the quality assurance laboratories in these milk firms was not thoroughly researched on and therefore there exists a research gap. Lastly, Mutua (2014), also conducted a research on quality management practices and financial performances of cement manufacturing firms in Kenya, where his research concluded that employing quality management practices in these firms increases their financial performances, but he never covered how the quality assurance laboratories in these cement firms are designed and their individual contributions to their financial performances.

In summary, this study was based on an attempt to answer the following research questions, what are the different types of service process designs that analytical laboratories in Kenya develop and operate with? What are the levels of efficiency of operations of analytical laboratories in Kenya? is there a relationship between the different types of service process designs and analytical laboratories efficiency performances? Lastly, what are the contributions of analytical laboratories to the Kenyan economy?

1.3 Objectives of the Study

i. To identify the different types of process designs of analytical laboratories in Kenya.
ii. To determine the efficiency of Kenyan analytical laboratories.
iii. To determine if there is a relationship between process design and analytical laboratories performances in terms of efficiency in Kenya.
iv. To determine the contribution of analytical laboratories to the Kenyan economy.

1.4 Value of the Study

The reason and importance of this study was to identify and evaluate Kenyan analytical laboratories performances through effectively and efficiently investigating their process designs and their ability to employ processes that drive their competitive advantages.

Additionally, the analytical laboratories process designs enable them to adapt to evolving market needs, hence researching about their process designs enables them to identify their weaknesses and not be negatively affected by the ever-evolving market needs. The other importance of this study is to encourage proper government policies and investments to be made in process designs of analytical laboratories.

Analytical Laboratories or in Lehman's terms 'testing laboratories' are found in almost all industries ranging from manufacturing industries to fast moving consumer goods industries and play a very vital role of quality assurance and standards maintenance. Therefore, majority of quality and standard decisions in these industries solely depend on analytical laboratories results and hence the need to have these laboratories operating at the highest levels of competence so that the information disseminated is always reliable, consistent and reproducible at most convenient manner possible. This high level of efficiency in analytical laboratories needs to be investigated if its dependent on the various types process designs, thus the importance of this study.

CHAPTER TWO: LITERATURE REVIEW

2.1 Introduction

This chapter discusses the theories that were adopted for this research, processes as important components of operations management, what makes an analytical laboratory, practices of process design in relation to analytical laboratories, the levels of efficiency associated with analytical laboratories, the importance of these laboratories globally and in Kenya and lastly identify some key knowledge gaps that are associated with analytical laboratory studies.

2.2 Theoretical Foundations of the Study

In Operations management, there are generally three component levels of operations management: Strategies, Systems and Processes. Processes are further comprised of three operations management knowledge areas, and these are; Process design, Project Management and lastly Planning and Control. These processes are basically the main drivers of efficiency and effectiveness when it comes to operations. It is important to note that these three component levels work together or are combined to achieve the desirable high levels of competitive advantage. For example, systems are required for integrating process elements (Okwiri, 2015). It is therefore important to look at process designs of both services and products and see how best they bring about organizational efficiencies and effectiveness to even organizations like analytical Laboratories. Scientific theories are used in research because they allow the researcher to make links and connections in relation to try to explain the relationships involved between the variables under investigation. Theories also reduce and arrange knowledge to draw comparisons between the abstract and the concrete (Sunday, 2012).

2.2.1 Work Process Theory

This concept or approach addresses the specific coordination and arrangement of work activities across time and place, where and when the activities start and end, clearly defined inputs and outputs and lastly the structure involved (Garvin, 1998). It concentrates on accomplishing the work activities involved in the organizations processes through linked chains of the activities. This theory addresses operational types of processes; which are processes that create, produce products or services that customers need. It also addresses processes that do not produce outputs but are important for running businesses, they are called administrative processes. This study referred to this theory because it involved the use or adoption of sequences of linked, interdependent activities that transformed the inputs, which were the process time measures into an output that was operational efficiencies of the Kenyan analytical laboratories. Additionally, this theory is based on focusing on the need to redesign processes to improve their quality, cut-costs and reduce their cycle-times for the main purpose of enhancing operating performance (Davenport, 1993) which is relevant to this study.

2.2.2 Technical Efficiency Theory

This theory was derived from the economic theory and it measures an organization's success using optimal sets of inputs that maximize the outputs (Donnell, Coelli, Battese and Rao, 2005). Relating to this study, the inputs are again the process time measures and they are investigated to maximize the output which is the operating efficiency level of the Kenyan analytical laboratories. The technical efficiency concept is about obtaining the highest output or identifying the best ways to obtain the best output using a given set inputs. If a technically inefficient process can be replaced by a technically efficient process, then there is saving of resources. There is a need to acknowledge that inputs that vary in nature can have either a positive or negative cost to the firm, so it is important to try to save on these costs as much as possible.

2.3 Process design in Analytical Laboratories

Process design is the explanation and development of procedures that are followed in service delivery and how these procedures interact with relevant materials and equipment. It's not only about these procedures but how these procedures link processes and sub-processes to bring about the whole service delivery. Studies have shown that operational process designs for service delivery organizations are factored by two major parameters; Volume of activities performed per period per unit and the variety of tasks to be carried out by a certain number of people. As a result, there are generally four types of service processes in operations management, namely; Capability, Commodity, Simplicity and Complex processes. Each of these processes vary in relation to the volume of services offered and the variety of these services. Analytical laboratories generally also adopt one of these type of service processes depending on their set objectives, mandates and organizational structure (Johnstone, 2006).

Capability processes are those processes that have high service variety and low volume service units, they are known to be more flexible and don't have a clear service concept (Clark, 2006). Their flexibility is in relation to their outputs and service delivery. They are associated with having staff with very high skill levels and the activities undertaken mostly comprise of average standard activities and non-standard activities that can appear as a one-off project. In Kenya, analytical laboratories that can or employ this type of process must have highly knowledgeable and skilled analysts that own the process completely. Additionally, these laboratories must be receiving unique customer requests that are varied in nature and those activities cannot be automated to offer high volume outputs. An example is the Kenya Government Chemist laboratory based in Nairobi that can be linked to this type of process, because the analysts working in that institution are very highly qualified Chemists, micro-biologists or bio-chemists that receive unique customers' requests that might range from DNA testing to forensic analysis of highly sensitive samples and due to these non-standard customer requests the laboratory has to always maintain a certain level of flexibility to be able to meet all these customer demands.

This is a type of service process that deals with high volume of consumer services with rigid or little variety of the services offered. It has a very clear service concept and the activities carried out are mainly standardized. Analytical laboratories in Kenya that might be associated with this type of process are mostly pharmaceutical laboratories in Pharmaceutical Companies like Regal Pharmaceuticals and Dawa Pharmaceuticals. This is because of the large number of drugs produced and therefore large volumes of batch samples of drugs need to be tested for quality assurance purposes. The testing methodology is fairly standardized with little room for flexibility of the parameters being used to analyze or test the drugs (Quality Systems Approach to Pharmaceuticals, 2006).

Simplicity service processes are normally characterized with low service variety and low volume of services offered, these kinds of processes are mostly used for incubation purposes or when running a pilot service (Johnstone, 2006). The type of analytical laboratories associated with simplicity processes are generally start-up laboratories or consultancy laboratories that don’t have a very large customer base.

Complexity processes are normally the opposite of simple processes, where they have relatively high volume and variety of services. These kinds of processes are very difficult to manage and require a lot of balancing of resources to bring out their efficiencies and effectiveness. Most analytical laboratories that are employing these types of processes tend to strike a balance between having a simple process or a complex process. In Kenya, the laboratories that might employ these kinds of processes are mostly referral or regulatory laboratories like KEBS, KEPHIS or KEMRI.

2.4 Efficiency of Analytical Laboratories

According to Michael Shulver (2012), a seamless process service must be able process customers’ requests, files or orders in a smooth manner with no breaks or gaps. Additionally, the staff should own the process and respective customers together with managers understanding the end-to-end process and lastly those managers should fully understand their role in that process and be able to work cross-functionally to improve the design process. To have an efficient laboratory that offers optimal laboratory services, careful management of the work-force, processes in relation to capacities, systems, equipments and building utilities must take place (Frank, 2012).

It is the laboratory management’s responsibility to ensure that the organization is legally identified according to the laws of the country it is operating on, a quality management system is in place where set processes that maintain quality are established, the laboratory has document control and contract review measures, there is existence qualified personnel, quality and technical records such as standard operating procedures and lastly the environment is conducive for favorable for operations (Frank, 2012).

According to Bradrick (2012), an efficient laboratory is a NICE laboratory, where the NICE is an acronym with N, standing for no or minimal overhead costs, I, meaning initial time of process cycle to be clearly stated and adhered to, C, standing for current or state of the art equipments used in laboratory operations and lastly E, meaning everything concerning parameters to be clearly set together with the limits of those parameters properly defined.

Depending on which type of analytical laboratory different detailed work-flow steps are normally established, but generally all analytical laboratories follow a process design that is divided into 3 stages; Pre-analytic processes, analytic processes and post-analytic processes. For example an environmental analytical laboratory that mainly analyses environmental samples like soil and water have has the following process work-flow: Step one, involves sample collection, step two, storage of samples collected, step 3, sample transportation to the relevant work-stations in the laboratory, step 4, sample pre-treatment for example like pH adjustment of the sample to make the analysis easier, step 5, sample extraction from the sample matrix, step 6, sample analysis, step 7, review of results in terms of acceptance levels, precision and accuracy, step 8, results approval by management and last step 9 is final report generation (Waters-Corporation, 2009).

To fully understand process designs and manage them efficiently, there is need to understand the key decision areas and the level of involvement of the customer in the processes, i.e. whether the processes are front office processes, back office processes or customer processes (Clutterbuck, 1993). Customer processes are those processes that involve the customer in the service delivery while front office processes involve activities related to the service delivery taking place in-front of the customer, back office processes are those processes that deal with service delivery without the customer involvement or his or her presence (Larsson and Bowen, 1989). All analytical laboratories are associated with back office processes because most of the services offered take place in the laboratories where the customer is not involved in the sample analysis neither are they present when the analysis is carried out. Therefore, the key decision area for analytical laboratories must involve the back-process areas.

Applying process designs capabilities to core business activities has the potential to transform the way in which an organization conducts key areas of the business, such as customer service or supply chains. This will enable business activities to operate in more streamlined processes, organizations can reduce costs, increase productivity and efficiency, obtain market insight, reduce risk and become more responsive to continually changing business climates (IBM Corporation, 2011).

Process time measures in service process designs are used for analysis of how efficient the designs are and additionally are used to identify improvement opportunities. This is specifically done by classifying work activities into value adding activities and non-value adding activities. The criteria for classifying these work activities is determined using process time measures. The process time measures involved include, processing times, waiting times, transportation times, set-up times, inspection times and Re-work times. From the calculation of respective process time measures and obtaining the cycle times involved in each process, measures of efficiency are obtained from the determining of the ratio of value adding process times to related cycle times (Okwiri, 2015).

2.5 Analytical Laboratories and Their Importance

Analytical laboratories are complex designs systems that generally serve the purpose of analytical testing, which is a broad term that employs various analytical techniques to identify chemical characteristics of a sample (Mathias, 2016). Broadly analytical laboratories can be categorized into 5 groups: Clinical analytical laboratories, this where samples like blood and urine of patients are tested or analyzed. Environmental analytical laboratories, that normally analyze samples like soil and water. Forensic analytical laboratories, that usually conduct sample testing like human DNA. Organic analytical laboratories, that are responsible for sample analysis of things like plant tissues, etc. and lastly Quality Control or Assurance analytical laboratories that generally are used by industries to ensure quality standards of their products are met.

Analytical laboratories may differ in terms of what they are mandated to analyze, but generally they either serve as regulatory or quality conformance entities. A regulatory analytical laboratory is purposed to oversee and control a certain level of sample standard while a quality analytical laboratory serves the purpose of quality assurance of the different types of product samples that is mandated to analyze. Some of the services that are offered by analytical laboratories are, chemical testing and analysis, materials analysis, polymer and plastics analysis, petro-chemical testing, forensic and organic testing (Intertek, 2016). The techniques that are commonly used by these laboratories are spectrometry, luminescence, electro-analytic and chromatographic techniques (Drees and Wu, 2008).

A good analytical laboratory must generally have a testing facility that has a well-established organization structure and qualified personnel, proper accreditation, proven protocols and standard operating procedures (SoPs'), performance standards, method development and validation and lastly limits of detection and quantification (Jiang, 2005). Analytical laboratories depending on which industry they are in always play a very important role, in the medical industry for example, about 70% of medical decisions rely or are solely based on clinical analytical laboratory results.

According to Kenya Bureau of Standards (2016), analytical laboratories exist or are established to ensure set standards are met and even surpassed. The importance of testing these standards is to enable production of quality goods and services, reduce the cost of production, protect the environment, increase productivity and lastly bring about competitiveness. While Intertek, a South African based company with operations in Kenya dealing with offering laboratory services, states that the importance of offering analytical laboratory services is to provide quality assurance to its clients' products and services, reduce costs, minimize health, safety and security risks. Additionally, their reliable testing and certification will enable faster regulatory approval in the concerned areas.

In Kenya, the analytical laboratories are generally spread out across the manufacturing, pharmaceutical, environmental, educational and clinical industries. Furthermore, they can be divided into private owned analytical laboratories and government owned laboratories. The government owned analytical laboratories mostly act as regulatory or referral bodies with some taking on individual clients that need analytical laboratory services. The major Government owned analytical laboratories in Kenya are: Government Chemist of Kenya,

Kenya Bureau of Standards, Kenya Industrial Research and Development Institute (KIRDI), Kenya Agricultural Research Institute (KARI), Kenya Plant Health Inspectorate Services (KEPHIS), Kenya Medical Research Institute (KEMRI) among others (Kenya Gazette,2015). Some of the privately owned analytical laboratories in the Kenya are: Kenya Breweries Limited analytical laboratory that is responsible for quality assurance of processed beer, Consol Glass Kenya chemical laboratory which is responsible for chemical testing of glass making raw materials and the manufactured glass bottles, Regal Pharmaceuticals laboratories which test the quality of drugs manufactured, etc.

2.6 Summary and Research Gaps

The empirical literature review discusses the importance of analytical laboratories globally and locally and different the types of analytical laboratories, what elements or characteristics are to be found in analytical laboratories and how these characteristics play a crucial role in differentiating between an efficient analytical laboratory and an inefficient one. The chapter also looks at different types of processes designs and how these processes are present in analytical laboratories, depending on the type, objectives and core-mandates of the analytical laboratories operating in Kenya and through their designing and management, high levels of efficiency is brought out. Lastly, the chapter looks at the key decision areas associated with analytical laboratories.

Studies done by Brown (2009), were on how to facilitate fast analysis and decision making in analytical laboratories but he failed to address the root cause on how these types of analyses and decisions are dependent on the process design in place, therefore, further research needs to be carried out on how efficiencies of analytical laboratories are related to their process designs and how the different kinds of processes can affect different aspects of analytical laboratories performances. Not a lot of research has really been done on process designs of technical service industries like laboratories, studies relating to analytical laboratories have been done by many researchers like Skilton (2009), on laboratory general layout designs, Dotto and Yusif (2012), on work flow maximization and delay causes of clinical analytical laboratories and Kimengech, Waithaka, Onyuka and Kigondu (2017), on errors that affect quality of laboratory services in clinical chemistry laboratories. Out of all these researches, not a lot of process design associated with laboratories research has been done thus there exists a research gap that needs to be considered, hence the reason for my undertaking this research topic.

2.7 Conceptual Framework

A conceptual framework is a network of the applicable associated variables developed from the research problem and is normally rationally developed, explained and elaborated by using processes like interviews, observations and literature reviews (Sekaran, 2003).

Independent Variables **Dependent Variables**

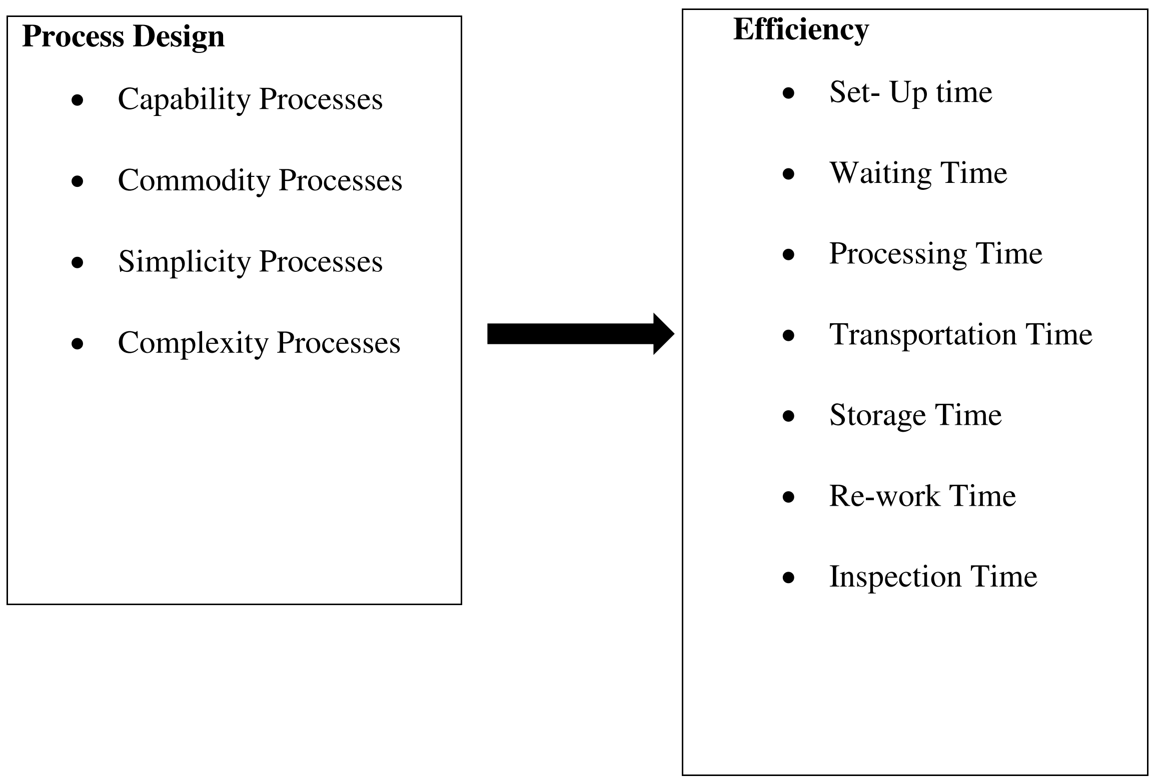

Fig 1.0: Conceptual Framework, Source (Researcher, 2017)

CHAPTER THREE: RESEARCH METHODOLOGY

3.1 Introduction

This chapter discusses the research design involved, the population of where the samples were drawn from, the data collection instruments, the data collection technique and finally the data analysis method and presentation.

3.2 Research Design

The research design was a descriptive study because there was a need to describe the characteristics of the variables of interest (Sekaran, 2003), which were service process designs as independent variables and efficiency being the dependent variable. A descriptive study is versatile in applying it across various management disciplines and the data involved could be incorporated both qualitatively and quantitatively. The study was also a cross-sectional study because it was carried out once.

3.3 Population of the Study

The population of the study covered non-clinical government and private laboratories, pharmaceuticals laboratories, manufacturing and process industry laboratories, environmental laboratories and fast-moving consumer goods laboratories. There are 50 analytical laboratories operating in Kenya either as independent laboratories or under companies operating in the above stated industries (Kenya Business Directory, 2015 and Kenya Association of Manufacturers, 2017). A census study of all the 50 analytical laboratories in Kenya was used (Appendix II). This was because of the relatively small number of these firms.

3.4 Data Collection

Primary data collection was employed where the sampling instrument was a semi-structured questionnaire that had have four parts: Part A, had general questions on, the participants position in the organization and the number of years the participant has worked in the organization. Part B, had multiple choice-single response measurement questions on the number of employees working in the laboratory, the number of samples analyzed, the number of the different type of samples analyzed, the number of equipments used in the laboratory and the level of education of the employees working in the laboratory. Part C, had questions on process time measures that were used to calculate efficiency levels and Part D, had multiple choice-single response questions on analytical laboratories contribution to the Kenyan economy. The questionnaires were physically delivered by use of a research assistant to the participants and an agreed time to collect them was also agreed upon. The targeted respondents were employees working in the Laboratories. Follow ups about the questionnaires were through e-mails and phone calls with the respective participants.

3.5 Data Analysis

In achieving the objective of determining the type of service process designs analytical laboratories in Kenya employed (Objective I), service process design determinants; the number of employees working in the laboratory, the number of samples analyzed, the number of the different type of samples analyzed, the number of equipments used in the laboratory and the level of education of the employees working in the laboratory were analyzed using Microsoft Excel Software to obtain their measures of means and standard deviations.

The objective of determining the efficiency of analytical laboratories in Kenya (Objective II) was done through gathering of information on the work-flow steps involved in the respective analytical laboratories of respondents and the times each work-flow step took to be completed. From the work-flow steps separation of value-adding and non-value adding work activities or steps was done. Process time measures in relation to processing, waiting, transportation, set-up, inspection and re-work times was analyzed using the respondents' answers in the questionnaire and process cycle time analysis of the data was carried out, using Microsoft Excel software. The measures of efficiency were determined using the ratio of value adding steps or processing times to the total process or work-flow cycle time (Okwiri, 2015).

Multiple regression analysis was used to identify if there any relationships between process designs and efficiencies of analytical laboratories as stated in objective III, this was done using SPSS.

Determining the contribution of analytical laboratories to the Kenyan economy (Objective IV) was done through analysis of frequencies, percentages, means and standard deviations where the respondents were required to answer to what percentages are analytical laboratories playing a role in their contribution to the Kenyan economy in relation to Pharmacy and Drug control, Agriculture, Food Safety, Environment, Research and Development.

CHAPTER FOUR: DATA ANALYSIS, RESULTS AND DISCUSSION

4.1 Introduction

This chapter presents the data analysis results, their interpretation and discussion of the findings. The study had four objectives: to determine the different types of service process designs that Kenyan analytical laboratories employ, to determine the efficiency of Kenyan analytical laboratories, to determine if there is a relationship between process design and analytical laboratories performances in terms of efficiency in Kenya and lastly to determine the contribution of analytical laboratories to the Kenyan economy. Data analysis was done using means, standard deviations, frequencies, percentages and regression. Results are presented in tables.

4.2 Response Rate

The table 1.0 below shows the respondents rate of response, from the 50 sample questionnaires administered, 28 were answered. The 28 answered represents 56% of the administered questionnaires and the reason for this 56% response rate is that 44% of the respondents did not respond due to their organizations policies of not allowing the answering of questionnaires. According to McNulty (2008) a 50% or more response rate is considered or regarded as acceptable when conducting a research survey study. Therefore, a response rate of 56% is appropriate for this study.

Sample Size	No. of Respondents	Response Rate
50	28	56%

Table 1.0: Research Response Rate.

Additionally, from the 28 respondents, 5 responses were from government analytical laboratories, 5 were from multi-nationals' laboratories, 10 were from privately owned manufacturing and processing laboratories and 8 were from also privately owned fast-moving consumer goods laboratories this is attributed to the fact that there are more privately owned analytical laboratories operating in Kenya than government owned.

4.3 Descriptive Determination of the Different Types of Process Designs used by Kenyan Analytical Laboratories

No. of Employees in the Laboratory	**1-10**	**11-20**	**21-30**	**31-40**	**Other (>40)**
Frequency	7	13	4	2	2
%	25	46.5	14.3	7.1	7.1
Mean = 17.57					
S.D = 10.52					
No. of Samples Analyzed Per Day	**1-10**	**11-20**	**21-30**	**31-40**	**Other (>40)**
Frequency	1	11	7	1	8
%	3.6	39.2	25.0	3.6	28.6
Mean = 36.00					
S.D = 29.07					
Different types of Samples Analyzed Per Day	**1-5**	**6-10**	**11-15**	**16-20**	**Other (>20)**
Frequency	9	8	6	2	3
%	32.2	28.6	21.4	7.1	10.7
Mean = 20.18					
S.D = 6.81					

No. of Equipments in the Laboratory	1-5	6-10	11-15	16-20	Other (>20)
Frequency	2	4	9	8	5
%	7.1	14.3	32.2	28.6	17.8
Mean = 16.11					
S.D = 9.48					
Level of Employees Education	**Diploma**	**Higher Diploma**	**Degree**	**Masters**	**Other (>Masters)**
Frequency	7	1	12	8	0
%	25.0	3.6	42.8	28.6	0

Table 2.0: Composition of Kenyan Analytical Laboratories Employees and their level of Education, the Number and different types of samples and the number of Equipments present in their operations.

The first objective of the study was to determine the different types of process designs used by Kenyan Analytical Laboratories and from the data collected, many of the employees working in the laboratories are between 11 and 20 with a percentage rate of 46.5 and only 7.1 percent of the laboratories have employees above 40, this could be because of automation of analysis processes resulting in less number of employees needed in these laboratories (American chemical Society, 2017). Furthermore, the number of equipments mostly used in Kenyan Analytical Laboratories was found to be in the range of 11 to 15 representing a percentage of 32.2. Additionally, from the data collected, the number of samples mostly analyzed by laboratory analysts is 11-20 samples that represents 39.2 percent and looking at the different types of samples analyzed, 1 to 5 is the most common range with a percentage of 32.2. Lastly, most of employees' level of education that work in these laboratories are degree holders that represent 42.8 percent of the samples and followed closely by Masters' holders with a percentage of 28.6, these figures can be attributed to the possibility that most Kenyan analytical laboratories employees have few job responsibilities and their tasks lack job sophistication. Additionally, the results could be explained by the fact that these types of laboratories are trying to be cost effective thus the reason for the low numbers and variety of samples analyzed. From the analyzed data, Kenyan Analytical Laboratories can be explained to mostly operate with simple processes and commodity processes. From the data analyzed, there is clearly a low volume of number of samples analyzed where majority of samples analyzed is between 11 and 20 samples a day representing the highest percentage of 39.2 and additionally a low variety of samples analyzed of between 1 to 5 a day representing the highest percentage value of 32.2, these are clear characteristics associated with simplicity processes (Johnstone, 2005). Kenyan Analytical Laboratories are also associated with commodity type of service processes because the levels of education associated with them are mostly from diploma, higher diploma, degree and masters' level employees with percentage rates of 25, 3.6, 42.8 and 28.6 respectively. Commodity processes are characterized with reducing reliance on an individual knowledge and skills and hence the reason of having no employees working that are doctorate holders and professors (Clark, 2005). These findings explain that most Kenyan analytical laboratories have simple job tasks and responsibilities, there is a lot of automation and that the laboratories are generally cost-effective or do not have appropriate financial infrastructures to support their own operations.

4.4 Determining the efficiency levels of Kenyan Analytical Laboratories

In achieving the second objective which was determining efficiency levels of the Kenyan analytical laboratories, the first step involved the calculation of process time measures; processing times, transportation times, storage times, re-work times, inspection times and delay times, these were obtained by summation of respective work-activities as summarized by table 3.0 below. The determination of the processing times involved the summation of times in minutes to carry out work activities or process flow steps 1, 2, 5, 6, 7 and 11 (refer to Appendix I) that were answered by the respondents (Evans and Lindsay, 2002). Moreover, the transportation times involved in the process was obtained by getting the time taken in minutes to complete work activity or process flow step 4.

Furthermore, the determination of the storage time was obtained from the summation of process work flow steps 3 and 12. Lastly, the inspection times was a summation of process flow steps 8 and 10. Lastly, the re-work times was obtained from process work flow step 9.

Process Flow Type	No. of Steps	Actual Process Steps	Total	% of Steps	% of Processing Time
Processing Time	6	1,2,5,6,7,11	9270	50	44.3
Transportation	1	4	1500	8.3	7.2
Storage	2	3,12	4310	16.7	20.6
Re-work	1	9	2880	8.3	13.8
Inspection	2	8,10	2960	16.7	14.1
Delay	0	0	0	0	0
Total	**12**	**12**	**20920**	**100**	**100**

Table 3.0: Data summary of the Kenyan Analytical Laboratories Process Times Measures.

The second step was obtaining the process time measures for each sample and summing them all up to obtain their respective cycle times. Summary of the process cycle times data is tabulated below in table 4.0.

Sample	Processing Time (Mins)	Transportation Time (Mins)	Storage Time (Mins)	Re-work Time (Mins)	Inspection (Time)	Delay Time (Mins)	Total/ Cycle Time
1	70	0	0	0	10	0	**80**
2	160	30	60	10	60	0	**320**
3	430	150	120	150	300	0	**1150**
4	300	180	190	30	60	0	**760**
5	210	10	90	60	120	0	**490**

Sample	Processing Time (Mins)	Transportation Time (Mins)	Storage Time (Mins)	Re-work Time (Mins)	Inspection (Time)	Delay Time (Mins)	Total/ Cycle Time
6	580	10	270	10	40	0	**910**
7	80	0	270	10	20	0	**380**
8	580	10	120	270	270	0	**1250**
9	510	10	60	270	330	0	**1180**
10	290	60	90	270	90	0	**800**
11	840	270	280	60	60	0	**1510**
12	120	0	280	30	0	0	**430**
13	340	10	30	0	330	0	**710**
14	170	60	40	30	40	0	**340**
15	210	60	70	150	10	0	**500**
16	90	30	0	0	180	0	**300**
17	1140	0	540	270	420	0	**2370**
18	90	10	280	0	40	0	**420**
19	670	10	40	270	150	0	**1140**
20	480	10	420	270	60	0	**1240**
21	390	10	420	270	40	0	**1130**
22	200	90	180	30	40	0	**540**
23	150	90	90	60	70	0	**460**
24	270	270	10	240	10	0	**800**
25	100	90	40	30	60	0	**320**
26	390	10	20	30	20	0	**470**
27	70	10	280	30	40	0	**430**
28	340	10	20	30	90	0	**490**
Total	**9270**	**1500**	**4310**	**2880**	**2960**	**0**	**20920**

Table 4.0: Process cycle time analysis.

The final step was the calculation of the efficiency levels of each of the samples that represented the analytical laboratories operating in Kenya. This was achieved by calculating the ratio of processing times which represent the value adding time activities to the cycle times or total time (Okwiri, 2015). Table 5.0 illustrates the different efficiency levels obtained for the respective samples obtained from the respondents.

Sample	Efficiency	% Efficiency
1	0.875	87.5
2	0.500	50.0
3	0.374	37.4
4	0.395	39.5
5	0.429	42.9
6	0.637	63.7
7	0.211	21.1
8	0.464	46.4
9	0.432	43.2
10	0.363	36.3
11	0.556	55.6
12	0.279	27.9
13	0.479	47.9
14	0.500	50.0
15	0.420	42.0
16	0.300	30.0
17	0.481	48.1
18	0.214	21.4
19	0.588	58.8
20	0.387	38.7
21	0.345	34.5
22	0.370	37.0
23	0.326	32.6
24	0.338	33.8
25	0.313	31.3
26	0.830	83.0
27	0.163	16.3

Sample	Efficiency	% Efficiency
28	0.694	69.4
Average	**0.438**	**43.8**

Table 5.0: Efficiency levels of respective samples from respondents.

From the table above, we can clearly observe that Kenyan Analytical Laboratories are operating at a relatively low efficiency level of an average percentage mean of 43.8 and standard deviation of 17.14. Out of the 28 samples only 8 representing 28.6 percent are operating at efficiencies above 50 percent, meaning that 71.4 percent of the analytical laboratories are below the 50 percent operating efficiency level. According to Pazko (2003), different types of analytical laboratories ranging from wet chemistry laboratories to in-organic laboratories all should operate at efficiency levels above 50 percent. This therefore means that Kenyan analytical laboratories are operating at efficiency levels that are below the internationals standards.

4.5 Determining the relationship between Kenyan Analytical Laboratories Process Designs and their Efficiency Levels

To determine if there is a relationship between process design and analytical laboratories performances in terms of efficiency in Kenya. Multiple regression analysis was carried out with efficiency levels being the dependent variables and number of employees, the number of samples analyzed, the different types of samples analyzed and the number of equipments being the independent variables. According to Clark and Johnstone (2005), the type of service process designs adopted by an organization is dependent on the volume of services offered and the variety offered. They further explain that in determining whether an organization’s type of service design in relation to whether they are commodity processes, capability processes, simple processes or complex processes, factors like the number of employees, the volume of transactions, the different types of transactions and equipments available at the organization play a crucial role in identifying the service process designs types. Therefore, justifying the reason for using the number of employees, the volume of samples analyzed, the different types of volume analyzed and lastly the number of equipments present in the Kenyan Analytical Laboratories.

4.5.1 Analysis of the Variance (ANOVA) Table

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	.040	4	.010	.308	.870[b]
	Residual	.753	23	.033		
	Total	.793	27			

a. Dependent Variable: Efficiency

b. Predictors: (Constant), No_Equipments, Type_Sample, No_Employees, No_Samples

Table 6.0: ANOVA Table

The Null Hypothesis is that there is no supported relationship between the independent variables (service process design factors of Kenyan Analytical Laboratories) and the dependent variable being the efficiency levels of Kenyan Analytical Laboratories at 95% confidence levels. From table 6.0, p-value = .870 which is greater than α =0.05. This indicates that the model is statistically insignificant and that the identified factors have a statistically insignificant relationship with Kenyan Analytical Laboratories efficiency levels. Because of the p-value of .870 which is greater than α =0.05, we fail to reject the Null Hypothesis, therefore the null hypothesis stands.

4.5.2 Model Summary

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change
1	.225[a]	.051	-.114	.18093	.051	.308	4	23	.870

a. Predictors: (Constant), No_Equipments, Type_Sample, No_Employees, No_Samples

Table 7.0 Multiple Regression Model Summary

From table 7.0, The coefficient of multiple determination is 0.051; meaning, about 5.10% of the variation in the efficiency levels of Kenyan Analytical Laboratories is explained by the number of employees, number of equipments, number of samples analyzed and the number of the different types of samples analyzed present in the analytical laboratories. The regression equation appears to be not useful for making predictions since the value of R^2 is not close to 1 but at 0.051.

4.5.3 Determining the Multiple Regression Equation for the Data

Coefficients[a]

Model		Unstandardized Coefficients B	Unstandardized Coefficients Std. Error	Standardized Coefficients Beta	t	Sig.	95.0% Confidence Interval for B Lower Bound	95.0% Confidence Interval for B Upper Bound	Collinearity Statistics Tolerance	Collinearity Statistics VIF
1	(Constant)	35.231	9.756		3.611	.001	15.050	55.413		
	Type_Sample	-.047	.071	-.152	-.659	.516	-.195	.101	.778	1.285
	No_Equipments	.283	.387	.156	.731	.472	-.517	1.083	.902	1.109
	No_Samples	.069	.134	.119	.511	.614	-.209	.347	.766	1.305
	No_Employees	.150	.339	.092	.441	.663	-.552	.852	.942	1.062

a. Dependent Variable: Efficiency

Table 8.0 Model Summary of the Multiple Regression Equation Coefficients.

From table 8.0, the multiple regression equation for this data is explained as Y being the Dependent variable which is efficiency, the constant having a figure of 35.23 and respective coefficients of the dependent variables; type of sample, number of equipments, number of samples and number of employees as -0.047, 0.283, 0.069 and 0.150 respectively. Therefore, the equation obtained is as follows.

$Y = a + b_1X_1 + b_2X_2 + b_3X_3 + b_4X_4 + E$

Where;

Y= Dependent Variable (Efficiency)

a = Constant

X_1= Independent Variable 1 (Type of Sample Analyzed)

X_2= Independent Variable 2 (Number of Equipments)

X_3= Independent Variable 3 (Number of Samples Analyzed)

X_4= Independent Variable 4 (Number of Employees)

E = Error Term

Therefore, the equation observed from the data is illustrated below.

$Y = 35.231 – 0.047X_1 + 0.283X_2 + 0.069X_3 + 0.150X_4$

From the table 8.0 all the independent variables in the above model are; however, insignificant since all of them have p-values of greater than 5%. This means that this model does support any relationship between the efficiency levels of Kenyan analytical laboratories and the stated independent variables. The factors that might greatly affect the efficiency levels of Kenyan analytical laboratories and are not accounted for by this model could be the analytical methodologies applied in the laboratories, innovation and technology adoption and training. Training might involve on the job specifications that are only unique to the specific laboratory work-activities.

4.6 Analyzing the Contribution of Kenyan Analytical Laboratories to the Kenyan Economy

Table 9.0 below summarizes 5 key contributions that are related to Analytical Laboratories in relation to the Kenyan economy; namely, Pharmacy and Drug control, Agricultural standards maintenance, Food safety, Environment pollution control, Research and Development. From the data, Pharmacy and Drug Control has its highest percentage contribution rate at between 61-80 which represents a 39.3 percent of a total of 28 responses. Agricultural standards maintenance also has its highest percentage contribution rated at 61-80 which represents 38.5 percent of a total of 26 responses. Furthermore, Food safety has its highest percentage contribution rate at 81-100 which represents 35.7 percent of a total of 28 responses. Additionally, Environment pollution control has its highest percentage contribution rate at 61-80 which represents 40 percent of a total of 25 responses. Lastly, Research and Development has its highest percentage contribution rate at also 61-80 representing a 42.3 percent of 26 responses.

Percentage	0-20	21-40	41-60	61-80	81-100	
Pharmacy and Drug Control Frequency of Contribution	2	3	4	11	8	Mean=64.75 SD=23.90
% of Frequency Distribution	7.1	10.7	14.3	39.3	28.6	
Percentage	**0-20**	**21-40**	**41-60**	**61-80**	**81-100**	
Agricultural Standards Frequency of Contribution	4	2	5	10	5	M=58.12, SD=26.21
% of Frequency Contribution	15.4	7.7	19.2	38.5	19.2	
Percentage	**0-20**	**21-40**	**41-60**	**61-80**	**81-100**	
Food Safety Frequency of Contribution	3	3	4	8	10	M=64.02, SD=26.86
% of Frequency Contribution	10.7	10.7	14.3	28.6	35.7	
Percentage	**0-20**	**21-40**	**41-60**	**61-80**	**81-100**	
Environmental Pollution Control Frequency of Contribution	2	3	6	10	4	M=59.26, SD=22.77
% of Frequency	8.0	12.0	24.0	40.0	16.0	

Contribution						
Percentage	**0-20**	**21-40**	**41-60**	**61-80**	**81-100**	
Research and Development Frequency of Contribution	2	4	4	11	5	M=50.40 SD=31.78
% of Frequency Contribution	7.7	15.4	15.4	42.3	19.2	

Table 9.0: Kenyan Analytical Laboratories Contribution to the Kenyan Economy.

The high percentage rate or uniqueness of Kenyan analytical laboratories contribution to food safety at between 81 to 100 percent could be as a result that majority of the Kenyan analytical laboratories are in the category of quality assurance and control types of analytical laboratories and these types of laboratories mostly are associated with food, processed and manufactured type of sample analyses.

CHAPTER FIVE: SUMMARY OF FINDINGS, CONCLUSIONS AND RECOMMENDATIONS

5.1 Introduction

This chapter summarizes and concludes the research data analyzed, gives recommendations and further research studies opportunities that might be explored in future and lastly highlights some of the limitations encountered while carrying out the research.

5.2 Summary of Findings

From the 50 sample questionnaires administered to the respondents, 28 responses were obtained. This represented a 56 percent response rate and according to Richardson (2005) this was enough for a descriptive analysis to be carried out. Additionally, 5 responses were from government analytical laboratories, 5 were from multi-nationals' laboratories, 10 were from privately owned manufacturing and processing laboratories and 8 were from also privately owned fast-moving consumer goods laboratories this was attributed to the fact that there are more privately owned analytical laboratories operating in Kenya than government owned.

In analyzing the first objective of determining the different types service process designs used by Kenyan Analytical Laboratories, the measuring determinants used were; the number of employees working in the laboratories, the different type of samples analyzed, the number of samples analyzed, the number of equipments used in the laboratories and the level of education of employees working in the laboratories. Through these determinants the volume and variety of work activities and skills involved was used as a criterion to determine whether the Kenyan Analytical laboratories employ commodity, capability, simplicity or complexity process designs (Johnstone and Clark, 2005). From the data the laboratories were found to employ commodity and simplicity service process designs, due to their low variety and volume of samples analyzed and the education levels of the employees. These findings were used to explain that Kenyan analytical laboratories are associated with simple job tasks and responsibilities, are automated and lack proper financial resources hence are employing cost-effective measures.

In analyzing the second objective of determining the efficiency levels of Kenyan Analytical Laboratories, the work-flow activities or steps involved in the process were divided into value adding activities and non-value adding activities. The value adding activities times were summed up to obtain the processing times and the efficiency levels were obtained from dividing the total work-flow activities times by the processing times (Evans and Lindsay, 2002). From the data, the average operating efficiency levels of Kenyan analytical Laboratories was 43.8 percent and only 28.6 percent of the laboratories were operating at efficiency levels above the 50 percent mark, these are low efficiency levels compared to other global laboratories. This means that these laboratories could be operating with a lot of bottlenecks like obsolete equipments, in-accurate methodologies applied during analysis and lack of innovation and technology adoption.

In determining if there is a relationship between Kenyan Analytical Laboratories service process designs and their efficiency levels, multiple regression analysis was carried out. The model summary for the regression model had a correlation coefficient of 0.225 which is a positive but a weak correlation of efficiency of Kenyan Analytical Laboratories being the dependent variables and the number of employees, the number of samples, the different number of samples and the number of equipments in the laboratories being the independent variables. The coefficient of multiple determination was 0.051; this meant that, about 5.10 percent of the variation in the efficiency levels of Kenyan Analytical Laboratories was explained by the number of employees, number of equipments, number of samples analyzed and the number of the different types of samples analyzed present in the analytical laboratories. The 95 percent could be attributed to other factors like methodology selection and application, innovation and technology adoption, management systems in place or even job specification training.

In analyzing the contribution of Kenyan Analytical Laboratories to the Kenyan Economy, out of the 5 key contributions, namely; Pharmacy and Drug Control, Agricultural Standards and Maintenance, Food Safety, Environmental Pollution and Control and lastly Research and Development. The first 4 were all averaging at a 61-80 percentage contribution rate as their highest respondents' rate of 39.3, 38.5, 40.6 and 42.3 percent respectively. Food safety was the exception with a highest percentage contribution rate of 81-100 at 35.7 percent of the respondents. This is because majority of Kenyan analytical laboratories are quality assurance and control type of analytical laboratories with majority of them analyzing food, processed and manufacturing samples.

5.3 Conclusion

From the above findings, Kenyan Analytical Laboratories mostly employ commodity and simplicity types of process designs this can be due to many reasons; simple job responsibilities and tasks, automation and employment of cost-effective measures. Their operating efficiency levels were low averaging at 43.8 percent with only 28.6 percent operating at efficiency levels above 50 percent, this is low compared to global analytical laboratories and this low efficiency level could be as a result of bottlenecks causing a lot of inefficiencies. These bottlenecks could be wrong methodology selection and application, obsolete equipments used and lack of technology and innovation adoption. There also was no supported relationship between the different types service process designs employed by these laboratories and their operating efficiency levels, this means that the model proposed does not affect the efficiency levels of the Kenyan analytical laboratories this could be due to the fact that other factors affecting their operating efficiency levels like methodology selection and application, innovation and technology adoption, management systems in place or even job specification training. Lastly, Food safety was the highest contribution by Kenyan Analytical Laboratories to the Kenyan economy with a percentage contribution rate of between 81-100. This is because of majority of Kenyan analytical laboratories are quality assurance and control type of analytical laboratories with majority of them analyzing food, processed and manufacturing samples.

5.4 Recommendations

From the above conclusions, the following recommendations were arrived at for managers and decision makers involved in the Kenyan analytical laboratory industry: Kenyan analytical Laboratories should not rely on the types of service process designs to increase their operating efficiency levels as from the study it was clearly seen how an analytical laboratory level of efficiency is relatively not affected by the type of service process design they employ but should look at other factors that might affect their operating efficiency levels, these other factors are methodology selection and application, innovation and technology adoption, management systems in place or even job specification training.

Additionally, to the government, they should create an enabling environment by encouraging policies and laws that the will enable the analytical laboratories to play a more contributing role to the Kenyan economy in relation to Pharmacy and drug control, Agricultural standards maintenance, Environmental pollution and control and lastly Research and development.

To researchers, they should carry out research on what other factors affect the efficiency levels of Kenyan analytical laboratories as from the study it was clearly seen the determinants of service process designs do not affect these types of laboratories efficiency levels.

5.5 Limitations of Study

The Kenyan Analytical Laboratories, some of them operate under very strict confidentiality policies, therefore some of the laboratories could not provide answers to the questionnaires provided and this posed a challenge to this research.

Due to the different practices and operating procedures employed by the different types of laboratories operating in Kenya, this research was only limited to analytical laboratories and not at all other types of laboratories like medical laboratories.

5.6 Further Studies

Further research studies can be conducted to other different types of laboratories like the medical laboratories to further identify if there is a relationship in the type of process designs they employ and their operating efficiency levels.

Further research can additionally be conducted to analyze whether product oriented organizations and their process designs affect their operating efficiency levels, because this research was based on service process designs not product designs.

Furthermore, factors that might affect the efficiency levels of the Kenyan analytical laboratories like, methodology selection and application, innovation and technology adoption, management systems in place or even job specification training should be investigated, and the level of relationship clearly defined and determined.

Further studies can be carried out to investigate the accreditation process of the Kenyan analytical laboratories, its effectiveness to the Kenyan analytical industry and whether this accreditation process affects their operating efficiency levels and quality.

Lastly, research can be carried out to determine the reasons for the slow growth of analytical laboratories in Kenya, and comparisons made to other countries, regionally and even internationally, additionally, research on factors that favour their growth.

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Appendix 1: Sample Questionnaire

The following is a questionnaire by Mr. Munene Jayson Kaguta, having D61/80348/2015 as his Registration number (University of Nairobi), for purposes of collection of data in conducting a research project on PROCESS DESIGN AND EFFICIENCY OF ANALYTICAL LABORATORIES IN KENYA. Year of research is 2017. This research is done as partial part of fulfilment of requirements for award of a Masters' (Operations Management) of Business Administration in the University of Nairobi.

The questionnaire contains 4 parts; Part A, B, C and D respectively.

PART A

This part contains administration questions and are necessary for identifying the participants and the positions they hold in their respective organizations.

Participant's position ____

Participant's no. of years in the organization ___________________________________

PART B

This part contains measurement questions that are structured as multiple choice – single response questions that are meant to identify the type of service process design that is used by the participants analytical laboratories.

Instructions:

The questions require a one answer solution and if the multiple answer choices provided do not have the desirable answer, the closest approximation of the desired answer should be filled in the other option provided.

1. What is the number of employees working in laboratory/ laboratories?

1-10	11-20	21-30	31-40	Other (Specify)

2. What is the number of samples analyzed in the laboratory/ laboratories in a day?

1-10	11-20	21-30	31-40	Other (Specify)

3. What is the number of different types of samples tested in the laboratory/laboratories (E.g. soil samples, water samples, plant samples etc.)?

1-5	6-10	11-15	16-20	Other (Specify

4. What is the number of analytical equipments found in the laboratory/ laboratories (E.g. HPLC, AAS, Alcolysers, etc.)?

1-5	6-10	11-15	16-20	Other (Specify)

5. What is the level of education of majority of the analyst working in the laboratory/ laboratories?

☐ Primary level ☐ Secondary level ☐ Certificate level☐ Diploma level

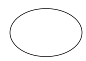
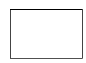
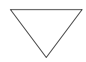
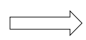
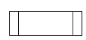
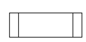
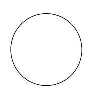
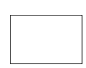
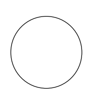
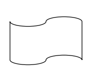
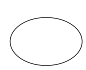
☐ Higher diploma level ☐ Degree level ☐ Masters level ☐ Doctorate level

☐ Professor level

PART C

This part contains measurement questions that are structured using the *general* work-flow steps of how analytical laboratories operate from the beginning of the analysis to the end. The participant is required to select ONLY the work-steps that are found in their laboratories' operations respectively. The participant is to select the time taken for the work flow steps present in their laboratories to be implemented or performed (an estimate may be selected if the available choices do not cover the participant's work-flow time).

The purpose of this part of questionnaire is to collect data on process time measures that will be used to analyze the efficiency of the analytical laboratory process.

Work flow step	Process symbol	Time taken
1. ☐ Test request by customer.		☐ 10min ☐ 30min ☐ 1hr ☐ 1.30hrs ☐ 2hrs ☐ 2.30hrs ☐ 3hrs ☐ 3.30hrs ☐ 4hrs ☐ 4.30hrs
2. ☐ Sample collection.		☐ 10min ☐ 30min ☐ 1hr ☐ 1.30hrs ☐ 2hrs ☐ 2.30hrs ☐ 3hrs ☐ 3.30hrs ☐ 4hrs ☐ 4.30hrs
3. ☐ Sample storage.		☐ 10min ☐ 30min ☐ 1hr ☐ 1.30hrs ☐ 2hrs ☐ 2.30hrs ☐ 3hrs ☐ 3.30hrs ☐ 4hrs ☐ 4.30hrs
4. ☐ Sample transportation.		☐ 10min ☐ 30min ☐ 1hr ☐ 1.30hrs ☐ 2hrs ☐ 2.30hrs ☐ 3hrs ☐ 3.30hrs ☐ 4hrs ☐ 4.30hrs
5. ☐ Sample pre-treatment.		☐ 10min ☐ 30min ☐ 1hr ☐ 1.30hrs ☐ 2hrs ☐ 2.30hrs ☐ 3hrs ☐ 3.30hrs ☐ 4hrs ☐ 4.30hrs
6. ☐ Sample extraction.		☐ 10min ☐ 30min ☐ 1hr ☐ 1.30hrs ☐ 2hrs ☐ 2.30hrs ☐ 3hrs ☐ 3.30hrs ☐ 4hrs ☐ 4.30hrs
7. ☐ Sample analysis.		☐ 10min ☐ 30min ☐ 1hr ☐ 1.30hrs ☐ 2hrs ☐ 2.30hrs ☐ 3hrs ☐ 3.30hrs ☐ 4hrs ☐ 4.30hrs
8. ☐ Sample review (acceptance, precision, accuracy).		☐ 10min ☐ 30min ☐ 1hr ☐ 1.30hrs ☐ 2hrs ☐ 2.30hrs ☐ 3hrs ☐ 3.30hrs ☐ 4hrs ☐ 4.30hrs
9. ☐ Result re-analysis.		☐ 10min ☐ 30min ☐ 1hr ☐ 1.30hrs ☐ 2hrs ☐ 2.30hrs ☐ 3hrs ☐ 3.30hrs ☐ 4hrs ☐ 4.30hrs
10. ☐ Results approval.		☐ 10min ☐ 30min ☐ 1hr ☐ 1.30hrs ☐ 2hrs ☐ 2.30hrs ☐ 3hrs ☐ 3.30hrs ☐ 4hrs ☐ 4.30hrs
11. ☐ Final reporting.		☐ 10min ☐ 30min ☐ 1hr ☐ 1.30hrs ☐ 2hrs ☐ 2.30hrs ☐ 3hrs ☐ 3.30hrs ☐ 4hrs ☐ 4.30hrs
12. ☐ Sample archiving.		☐ 10min ☐ 30min ☐ 1hr ☐ 1.30hrs ☐ 2hrs ☐ 2.30hrs ☐ 3hrs ☐ 3.30hrs ☐ 4hrs ☐ 4.30hrs

PART D

This part involves a single choice answering of a quantitative question on the percentage level of analytical laboratories contributions to the Kenyan Economy.

You are provided with 5 key contributions that are related to analytical laboratories in relation to the Kenyan economy; namely, Pharmacy and Drug control, Agricultural standards maintenance, Food safety, Environment pollution control, Research and Development. Please select one appropriate answer, that best describes the percentage level that each contribution plays in relation to the Kenyan Economy.

Percentage / **Contribution**	0-20%	21-40%	41-60%	61-80%	81-100%
Pharmacy and drug control					
Agricultural Standards maintenance					
Food Safety					
Environment Pollution Control					
Research and Development					

If there are any other key analytical laboratories contributions to the Kenyan economy and their estimated percentage levels of their contribution, please indicate them below.

……………………………………………………………………………………………
……………………………………………………………………………………………
……………………………………………………………………………………………
………………………

Appendix II: List of Analytical laboratories in Kenya

1. Kenya Plant Health Inspectorate Service (KEPHIS) Laboratories
2. Kenya Bureau of Standards (KEBS) Laboratories
3. National Quality Control Laboratories (NQCL)
4. Kenya Agriculture and Livestock Research Organization (KALRO) Laboratories
5. Kenya Agricultural Research Institute (KARI) Laboratories
6. Kenya Breweries Limited (KBL) Laboratories
7. GlaxoSmithkline Kenya Laboratories
8. Mumias Sugar Factory Laboratory
9. Homegrown Microbiology Laboratories
10. Nestle Food Kenya Laboratories
11. SGS Laboratories
12. Dawa pharmaceuticals Laboratories
13. Government Chemist Laboratories
14. Analabs Laboratories
15. Intertek Limited Laboratories
16. Polucon Services Laboratories
17. Karlsmarts Laboratories
18. Quest Laboratories
19. Prolab Limited Laboratories
20. Nairobi Bottlers Limited Laboratories
21. ABS TCM limited Laboratories
22. Bora Biotech Laboratories
23. Kenya Forest Research Institute Laboratories
24. Kenya Industrial Research and Development Institute (KIRDI) Laboratories
25. VETLABS Laboratories
26. Kenya Pipeline Corporation Laboratories
27. Kenya Electricity Generating Company Limited Laboratories (KENGEN)
28. Dupont Limited Laboratories

29. BASF East Africa Limited Laboratories
30. GMP Limited Laboratories
31. Orbit Chemicals Laboratories
32. Consol Glass Kenya Laboratories
33. Regal Pharmaceutical Laboratories
34. National Oil Laboratories
35. Nairobi Water and Sewerage Company Laboratories
36. Bamburi Cement Company Laboratories
37. Savannah Cement Company Laboratories
38. Athi River Mining Cement Laboratories
39. Brookside Dairies Company Laboratories
40. New Kenya Co-operative Creameries Company Laboratories
41. Biodeal Laboratories
42. Cosmos Laboratories
43. Beyer East Africa Company Laboratories
44. Crown Paints Laboratories
45. Sadolin Paints laboratory
46. Thika Power Plant Laboratory
47. Delmonte Company Laboratories
48. Twiga Chemical Laboratories
49. Keroche Breweries Laboratories
50. Laboratory and Allied Company Laboratories

Appendix III: Permission Letter

UNIVERSITY OF NAIROBI
SCHOOL OF BUSINESS

Telephone: 020-2059162
Telegrams: "Varsity", Nairobi
Telex: 22095 Varsity

P.O. Box 30197
Nairobi, Kenya

DATE 12/10/2017

TO WHOM IT MAY CONCERN

The bearer of this letter MUNENE JAYSON KARUTA

Registration No. D61/80348/2015

is a bona fide continuing student in the Master of Business Administration (MBA) degree program in this University.

He/she is required to submit as part of his/her coursework assessment a research project report on a management problem. We would like the students to do their projects on real problems affecting firms in Kenya. We would, therefore, appreciate your assistance to enable him/her collect data in your organization.

The results of the report will be used solely for academic purposes and a copy of the same will be availed to the interviewed organizations on request.

Thank you

UNIVERSITY OF NAIROBI
SCHOOL OF BUSINESS
12 OCT 2017
P.O. BOX 30197-00100, NAIROBI

PATRICK NYABUTO
SENIOR ADMINISTRATIVE ASSISTANT
SCHOOL OF BUSINESS

Appendix IV: Sampled Answered Questionnaire

Appendix 1: Sample Questionnaire

The following is a questionnaire by Mr. Munene Jayson Kaguta, having D61/80348/2015 as his Registration number (University of Nairobi), for purposes of collection of data in conducting a research project on PROCESS DESIGN AND EFFICIENCY OF ANALYTICAL LABORATORIES IN KENYA. Year of research is 2017. This research is done as partial part of fulfilment of requirements for award of a Masters' (Operations Management) of Business Administration in the University of Nairobi.

The questionnaire contains 4 parts; Part A, B, C and D respectively.

PART A

This part contains administration questions and are necessary for identifying the participants and the positions they hold in their respective organizations.

Participant's position LABORATORY TECHNICIAN

Participant's no. of years in the organization 4 YEARS

PART B

This part contains measurement questions that are structured as multiple choice – single response questions that are meant to identify the type of service process design that is used by the participants analytical laboratories.

Instructions:

The questions require a one answer solution and if the multiple answer choices provided do not have the desirable answer, the closest approximation of the desired answer should be filled in the other option provided.

1. What is the number of employees working in laboratory/ laboratories?

1-10	11-20	21-30	31-40	Other (Specify)
✓				

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2. What is the number of samples analyzed in the laboratory/ laboratories in a day?

1-10	11-20	21-30	31-40	Other (Specify)
			✓	

3. What is the number of different types of samples tested in the laboratory/laboratories (E.g. soil samples, water samples, plant samples etc.)?

1-5	6-10	11-15	16-20	Other (Specify
✓				

4. What is the number of analytical equipments found in the laboratory/ laboratories (E.g. HPLC, AAS, Alcolysers, etc.)?

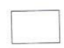
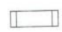
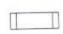
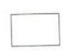
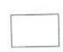
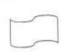
1-5	6-10	11-15	16-20	Other (Specify)
		✓		

5. What is the level of education of majority of the analyst working in the laboratory/ laboratories?

☐ Primary level ☐ Secondary level ☐ Certificate level ☐ Diploma level
☐ Higher diploma level ☑ Degree level ☐ Masters level ☐ Doctorate level
☐ Professor level

PART C

This part contains measurement questions that are structured using the *general* work-flow steps of how analytical laboratories operate from the beginning of the analysis to the end. The participant is required to select ONLY the work-steps that are found in their laboratories' operations respectively. The participant is to select the time taken for the work flow steps present in their laboratories to be implemented or performed (an estimate may be selected if the available choices do not cover the participant's work-flow time). The purpose of this part of questionnaire is to collect data on process time measures that will be used to analyze the efficiency of the analytical laboratory process.

Work flow step	Process symbol	Time taken
1. ☐ Test request by customer.		☐ 10min ☐ 30min ☐ 1hr ☐ 1.30hrs ☐ 2hrs ☐ 2.30hrs ☐ 3hrs ☐ 3.30hrs ☐ 4hrs ☐ 4.30hrs
2. ☑ Sample collection.		☐ 10min ☐ 30min ☐ 1hr ☑ 1.30hrs ☐ 2hrs ☐ 2.30hrs ☐ 3hrs ☐ 3.30hrs ☐ 4hrs ☐ 4.30hrs
3. ☐ Sample storage.		☐ 10min ☐ 30min ☐ 1hr ☐ 1.30hrs ☐ 2hrs ☐ 2.30hrs ☐ 3hrs ☐ 3.30hrs ☐ 4hrs ☐ 4.30hrs
4. ☑ Sample transportation.		☑ 10min ☐ 30min ☐ 1hr ☐ 1.30hrs ☐ 2hrs ☐ 2.30hrs ☐ 3hrs ☐ 3.30hrs ☐ 4hrs ☐ 4.30hrs
5. ☑ Sample pre-treatment.		☐ 10min ☐ 30min ☐ 1hr ☑ 1.30hrs ☐ 2hrs ☐ 2.30hrs ☐ 3hrs ☐ 3.30hrs ☐ 4hrs ☐ 4.30hrs
6. ☑ Sample extraction.		☐ 10min ☐ 30min ☐ 1hr ☑ 1.30hrs ☐ 2hrs ☐ 2.30hrs ☐ 3hrs ☐ 3.30hrs ☐ 4hrs ☐ 4.30hrs
7. ☑ Sample analysis.		☐ 10min ☐ 30min ☐ 1hr ☐ 1.30hrs ☐ 2hrs ☐ 2.30hrs ☐ 3hrs ☐ 3.30hrs ☐ 4hrs ☑ 4.30hrs
8. ☑ Sample review (acceptance, precision, accuracy).		☐ 10min ☐ 30min ☐ 1hr ☐ 1.30hrs ☐ 2hrs ☐ 2.30hrs ☐ 3hrs ☐ 3.30hrs ☐ 4hrs ☑ 4.30hrs
9. ☑ Result re-analysis.		☐ 10min ☐ 30min ☐ 1hr ☐ 1.30hrs ☐ 2hrs ☐ 2.30hrs ☐ 3hrs ☐ 3.30hrs ☐ 4hrs ☑ 4.30hrs
10. ☑ Results approval.		☐ 10min ☐ 30min ☐ 1hr ☑ 1.30hrs ☐ 2hrs ☐ 2.30hrs ☐ 3hrs ☐ 3.30hrs ☐ 4hrs ☐ 4.30hrs
11. Final reporting. ☑		☐ 10min ☐ 30min ☐ 1hr ☑ 1.30hrs ☐ 2hrs ☐ 2.30hrs ☐ 3hrs ☐ 3.30hrs ☐ 4hrs ☐ 4.30hrs
12. ☑ Sample archiving.		☐ 10min ☐ 30min ☐ 1hr ☑ 1.30hrs ☐ 2hrs ☐ 2.30hrs ☐ 3hrs ☐ 3.30hrs ☐ 4hrs ☐ 4.30hrs

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PART D

This part involves a single choice answering of a quantitative question on the percentage level of analytical laboratories contributions to the Kenyan Economy.

You are provided with 5 key contributions that are related to analytical laboratories in relation to the Kenyan economy; namely, Pharmacy and Drug control, Agricultural standards maintenance, Food safety, Environment pollution control, Research and Development. Please select one appropriate answer, that best describes the percentage level that each contribution plays in relation to the Kenyan Economy.

Percentage / **Contribution**	0-20%	21-40%	41-60%	61-80%	81-100%
Pharmacy and drug control				✓	
Agricultural Standards maintenance				✓	
Food Safety				✓	
Environment Pollution Control			✓		
Research and Development			✓		

If there are any other key analytical laboratories contributions to the Kenyan economy and their estimated percentage levels of their contribution, please indicate them below.

....

....

....

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Appendix V: Work Plan and Budget

Time	**2017**											
Month Activity	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**
Proposal Development												
Proposal Defense												
Data Collection												
Data analysis												
Research Project Writing												

ITEM	**TOTAL**
Stationery	20,000
Data Collection Research Assistant	10,000
Data (Internet)	10,000
Transport	5,000
Binding and printing	5,000
Contingencies	10,000
TOTAL	**60,000**