APPLICATION OF MATHEMATICAL PROGRAMMING TECHNIQUES IN KENYA: A SURVEY OF MANUFACTURING SECTOR

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DECLARATION

I declare that this research project is my own original work and has not been presented for examination in any other university.

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This research project has been submitted for examination with my approval as the University Supervisor.

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DEDICATION

This work is dedicated to my loving mother, Rose O. Aluoch, and to my wife Lilian B. Cherotich together with my children Berna T. Sangina and Riek A. Sangina who are the inspiration in my life.

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And ultimately my wife deserves special recognition for the many days and nights that I spent locked away in books as she patiently carried more than her fair share, and I am also grateful to the almighty God for his graciousness.

ABSTRACT

This thesis presents the results of a cross sectional survey to determine the extent of application of mathematical programming techniques in the manufacturing sector in Kenya. The questionnaire used was designed to determine the awareness of mathematical programming techniques in the manufacturing sector, the types of mathematical programming techniques applied in the manufacturing sector and the factors affecting application of mathematical programming techniques in the manufacturing sector. The study has shown that awareness of mathematical programming techniques in the manufacturing sector in Kenya is still very low. Findings of the study show that lack of required expertise, inadequate knowledge and difficulty in mastering the subject ranks high among factors affecting application of the techniques in the manufacturing sector. Application of mathematical programming techniques in developed countries show significant benefits to firms in the manufacturing sector. The study view development of awareness creation programs, technical and financial instruments as key in enhancing adoption of mathematical programming techniques in Kenyan manufacturing sector to achieve greater efficiency and productivity.

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CHAPTER ONE: INTRODUCTION

1.1 Background of the Study

Poverty alleviation and job creation have been in the frontline priorities of successive governments since Kenya gained her independence in 1963. Growth of the manufacturing sector has always been considered a major solution to poverty alleviation and job creation. Earlier studies by Kuznets (1966) and Clark (1983) provide ample evidence of the association between sustained shift in the share of economic activities from agriculture to manufacturing and industrialization. A study undertaken by Sanyu et al. (2007) indicates that Kenyan manufacturing sector is yet to catch up with the process of industrialization due mainly to lack of competitiveness.

Penrose (1959) sees a manufacturing firm as a basic unit for the organization of production. For a manufacturing firm to compete effectively in the global market, it is essential for management to make correct economical decisions, one of the necessary managerial skills in that regard is the ability to allocate and utilize resources appropriately to achieve optimal performance. The exercise of allocating scarce resources to a set of tasks is a problem basically encountered in all manufacturing firms (Mallik et al., 2014). One of the knowledge areas, which can help managers of manufacturing firms to make effective decisions to achieve efficiency, increase productivity and overall corporate performance, is operations research (Salome, 2013).

Operations research is defined by the Operational Research Society of Great Britain as "the application of the methods of science to complex problems arising in the direction and management of large systems of men, materials and money in industry, business, government and defense. The distinctive approach is to develop a scientific model of the system, incorporating measurements of factors such as chance and risk, with which to predict and compare the outcome of alternative decisions, strategies or controls. The purpose is to help management to determine its policy and actions scientifically".

Operations research techniques enhance value and decision making (Vorha, 2010), and has been applied extensively in the developed world to solve certain characteristic problems of allocation, queuing, inventory, routing, replacement, search, sequencing and coordination, which are common to manufacturing firms.

An important Knowledge area of operations research that has proved valuable and widely used in the manufacturing sector analysis is mathematical programming, which is also referred to in other literature as constrained optimization (Xiang, 2013). The focus of this study is on the extent of application of mathematical programming techniques, which include linear programming, integer programming, dynamic programming and goal programming as the main subjects of the survey aimed at determining the extent of their application in the manufacturing sector in Kenya.

1.1.1 Mathematical Programming

Snyman (2005) describes mathematical programming as "the science of determining the best solutions to mathematically defined problems, which may be models of physical reality or of manufacturing and management systems". According to Dantzig (1963), Industrial production and the flow of resources in the economy together with the exertion of military effort in a war theater are all interrelated activities with unique complexities. And that although differences may exist in the goals to be achieved by these complex activities and in the particular processes involved as well as in the magnitude of effort, it is however possible to abstract the underlying essential similarities in the management of these seemingly disparate systems.

Dantzig (1963) argues that to abstract the essential similarities in these seemingly desperate systems entails a look at the structure and state of the system and at the objective to be fulfilled to be able to construct a statement of the actions to be performed, their timing, and their quality, referred to as a "program" or "schedule", which will allow the system to move from a given status toward the defined objective. In the same vein, if the system exhibits a structure that can be represented by a mathematical equivalent in the form of a mathematical model, and if the objective can also be framed in a similar manner, then some computational method may be conjured for choosing the best schedule of actions among alternatives; such use of mathematical models is termed mathematical programming (Dantzig, 1963).

1.1.2 Types of Mathematical Programming Techniques

Rao (2009) provides a comprehensive list of mathematical programming techniques available for use to solve various problems in economics or even social life. Under the banner of mathematical programming techniques, referred to in other words as optimization techniques, Rao (2009) include calculus methods, calculus of variations, nonlinear programming, geometric programming, quadratic programming, linear programming, dynamic programming, integer programming, stochastic programming, separable programming, multi-objective programming network methods (CPM and (PERT) and game theory.

Other mathematical programming techniques also listed by Rao (2009) include modern or nontraditional mathematical programming techniques, such as genetic algorithms, simulated annealing, ant colony optimization, particle swarm optimization, neural networks and fuzzy mathematical programming.

1.1.3 Manufacturing Sector

A manufacturing firm is defined in this study as an organization seeking to fulfill customer demand by transforming raw materials or sub-assemblies into a final product using specific resources in order to make a profit. The manufacturing sector in Kenya is made of many different industries using a wide range of technologies in their activities. Based on the Central Bureau of Statistics data, the manufacturing sector contributes 10% to the gross domestic product and the number of formal firms in the sector is 480 according to Kenya Association of Manufacturers data.

The manufacturing sector currently has a workforce of 254,000 people, which represents 13 percent of total formal employment in Kenya. The vision 2030, a planning document of the government of Kenya envisages a growth rate in the region of 30% for the country in thirty years' time. And the manufacturing sector is a key pillar in that vision (Onuonga et al., 2011). The manufacturing sector in Kenya is dominated by food and consumer goods; very little in the way of machinery manufacturing is ongoing except for minor motor vehicle parts.

The manufacturing sector in Kenya operate in an environment where policies and regulations are scattered in different documents such as the Acts of Parliament, sessional papers, development plans and sectoral strategies, and in addition various trade associations also have their own governing regimes that are not necessarily aligned to those of the government and its agencies.

Sanyu et al. (2007) study report whose goal was to promote the industrial development of Kenya with a focus on the manufacturing sector attempts to give an outlook on the sector since the collapse of the East African Community in 1977. The manufacturing sector assumed great significance to the government for spearheading industrialization of the country, however over the years, since 1977, the manufacturing sector performance as failed to live up to expectation with economies in Asia such as Singapore and Korea, which had similar gross domestic product to that of Kenya making great strides towards industrialization. Therefore as part of a comprehensive vision to jumpstart industrialization, the manufacturing sector needs to find ways of streaming its operational activities along the path of global competitiveness.

1.2 Research Problem

Many decisions by managers are prone to failure because they lack scientific approach in their execution. Intuitive, judgmental and experiential approaches are being utilized to a great extent as the easy way out in decision making with detrimental outcomes to efficiency and competitiveness (Murty, 2003). Manufacturing firms that operate at suboptimal levels are therefore more likely to exit from the market with consequences in terms of loss of employment, income and aggregate economic growth to the country (Bangert, 2012).

The per capita income of Kenya has been growing slowly since independence in 1963 and continues to be among the lowest in the world. Growth of the manufacturing sector has for long been considered instrumental in economic development and accounts for 11 percent of the gross domestic product of Kenya, which is low compared to most middle income countries. Furthermore suboptimal production systems most prevalent in the manufacturing sector may have contributed to a large extent to the poor record of Kenyan manufactured goods in the global market, especially in the developed countries.

In view of the preceding observations, the manufacturing sector in Kenya will be better equipped to drive industrialization in Kenya as well as vision 2030 if it is globally competitive, which in essence requires the adoption of scientific approaches to making critical business decisions, some of which include mathematical programming techniques that if appropriately applied to resource allocation problems have been shown to enhance effectiveness and efficiency of production systems and quality of goods and services.

1.3 Research Objective

The overall objective of the study was to establish the extent of application of mathematical programming techniques in the manufacturing sector in Kenya. Specific objectives were as follows:

i. To determine extent of mathematical programming techniques awareness in the manufacturing sector

ii. To determine types of mathematical programming techniques applied in the manufacturing sector

iii. To establish factors affecting application of mathematical programming techniques in the manufacturing sector

1.4 Value of the Study

This study aimed to contribute to the operations management literature by providing new evidence from the manufacturing sector concerning some of the bottlenecks of global competitiveness.

The study could also serve as an eye opener to captains of industry on the opportunities provided by mathematical programming for improving strategic, tactical and operational decisions in the firms they lead. In the final analysis the manufacturing sector would have insight on how to cut costs, enhance efficiency and product quality through better resource allocation. The manufacturing sector could also be in a much better position to drive industrialization and vision 2030 agenda in Kenya if policy makers gain a clear picture of the competitive edge derivable from mathematical programming techniques.

CHAPTER TWO: LITERATURE REVIEW

2.1 Introduction

This chapter discusses the theoretical foundation of the study, which includes the classical economic theory of the firm, organizational theory and resource based theory, decision theory and optimization theory. The next sections reviews previous studies based on challenges of mathematical programming techniques, resource allocation problems and thereafter the importance of mathematical programming techniques, adoption of mathematical programming techniques and finally the conclusion of the chapter.

2.2 Theoretical Foundation of the Study

2.2.1 Classic Economic Theory of the Firm

In the classical economic theory, firms are generally viewed as organizations whose main objective is profit maximization. In a manufacturing set up, a production function is described in terms of maximum output that can be produced from a specified set of inputs given a set of technology (Bonini, 1963). This theory that is designed to explain the allocation of resources within the firm works quite well when managers actively engage in discovery and use of dispersed knowledge (Sautet, 2000).

2.2.2 Organizational Theory and Resource based Theory

The organizational theory and resource based theory focus on how organizations can create and deploy resources with the purpose of achieving competitive edge (Leonard and Barton, 1992). In essence, organizational theory may be viewed as a product of application of behavioral theory to economics. As an alternative to agency theory, the organizational theory focuses on the phenomena of decision making process and lateral intra organizational relationships. On the area of decision making process, actors take decisions that are rationality constrained (Simon, 1945), therefore decision out comes tend to yield satisfactory outcomes instead of optimal.

2.2.2 Decision Theory

Decision theory encompass different problem solving techniques where the decision maker must select among possible alternatives that yield various profits or costs (Lehmann, 1950). Bazerman (2002) views decision making as an interdependent exchange between a decision maker and an external environmental event or agent where feedback derived from the external environment enables the decision maker to form a judgment on what decision action is required in order to respond to, control or change the external environment of concern.

Stevenson et al. (1990) differentiates decision from judgment by defining judgment as cognitive assessment of preference among alternatives. Goodwin et al. (1997) distinguishes decision making and problem solving, whereby decision making concerns selection of an alternative from a set of alternatives given, and problem solving as it were emphasizes cognitive making of new alternatives to resolve a problem.

Decision making under certainty assumes that all relevant information required to make decision is certain in nature and is well known. It uses a deterministic model that is complete knowledge, stability and no ambiguity. To make effective decisions, a manager requires knowledge of the strategies available and their payoff. The decision making may be of single objective or of multiple objectives, (Murthy, 2007). Mathematical programming is used when an optimization decision has constraints that limit decisions such as when a business is required to allocate scarce resources optimally.

2.2.3 Optimization Theory

Optimization is about making the best possible choice out of a set of alternatives, the context to which the term usually refers is the mathematically expressed maximization or minimization of some function, the objective function or criterion function; the set of alternatives is frequently restricted by constraints on values of the variables, (Bullock et al., 1988).

Dutta et al. (2004) define optimization as essentially the art, science and mathematics of choosing the best among a given set of finite or infinite alternatives. Rao (2009) defines optimization as the process of finding the conditions that give the maximum or minimum value of a function, and that addition multiplication or division of the function and addition or subtraction of a positive constant from the function does not change the optimum solution,

Snyman's (2005) conception of Mathematical Optimization is that it is the science of determining the best solutions to problems that can be mathematically defined; these may be models of physical reality or manufacturing and management systems. Snyman (2005) argued that algorithms' presently existing are tailored to a particular type of optimization problem and that it is often the user's responsibility to choose an appropriate algorithm for a specified application. Snyman (2005) submitted that each existing algorithm's author has numerical examples that demonstrate the efficiency and accuracy of the developed method and therefore practitioners ought to take note as they select to use a particular method.

The optimization approach is particularly useful at balancing conflicting objectives wherever there are many alternatives actions available to the decision maker. In optimization, many ways that include resource allocation techniques have been developed for getting the optimal solution. The application of mathematical programming techniques, as the quantitative technique of choice in optimization of manufacturing systems, is wide spread in the developed economies and they have been credited by many manufacturing firms for increasing the efficiency and productivity of business operations. In different surveys of businesses, many managers indicate that they use mathematical programming techniques and the outcomes are very good (INFORMS, 2005).

2.3 Previous Studies

2.3.1 Resource Allocation and Mathematical Programming Techniques

Donohue (2006) views resource allocation problem as a problem that requires decision makers to allocate a limited resource, which may include a budget, investment funds, energy, time and self identity between competing alternative choices such as a project, investment options, activities and employment options in order to maximize some objective that may be a profit, benefits, productivity, employment, job satisfaction and well-being.

The study of resource allocation problem in decision theory normally assumes that the decision maker has an initial fixed amount of limited resources available for use, and that all possible alternatives from which to select from are known to the decision maker, in addition the decision maker is required to satisfy only one objective rather than several mutually exclusive objectives or conflicting ones; and that the criteria for judging the value of the objective is that the outcome obtained be maximized in some manner (Bazerman, 2000).

Luptacik (2010) maintains that the basic economic problem of allocating scarce resources among competing factors has three components: first, there are the factors whose values can be chosen by the economic agent such as a consumer or a producer, which are referred to a the decision variables in the problem; secondly, the scarcity of the resources is represented by the opportunity set or the set of feasible values from which to choose; and finally, the competing ends are described by some criterion function, which is referred to as the objective function and gives the value attached to each of the alternative decisions: how to choose the factors within the opportunity set so as to maximize or minimize the objective function is the resource allocation problem.

Mathematical programming techniques are commonly used to get solutions for resource allocation problems that have optimization or minimization of particular objectives as the aim, among the techniques , Rao (2009) include calculus methods, calculus of variations, nonlinear programming, geometric programming, quadratic programming, linear programming, dynamic programming, integer programming, stochastic programming, separable programming, multi-objective programming network methods (CPM and (PERT) , game theory, genetic algorithms, simulated annealing, ant colony optimization, particle swarm optimization, neural networks and fuzzy mathematical programming.

2.3.2 Challenges of Mathematical Programming Technique Application

Munisamy (2012) in a study of corporate operations research practice, which surveyed public listed companies in Malaysia, using self-administered on line questionnaires as well as post, observed that Lack of required expertise, high software cost, theory and practice do not meet, underestimation of needed work, resources and data, high training cost, inadequate knowledge of methods, not user friendly interface, lack of enthusiasm, interest and commitment among managers, interpretation of results is difficult, not applicable to this business and complicated and heavy to master were cited as the main reasons that hamper the use of mathematical programming techniques in Malaysia.

White et al. (2009) in a study of mathematical programming techniques in developing countries noted that issues of appropriateness is a common factor that influence application of mathematical programming in firms. One such issue that white et al. (2009) consider to be significant is the role education in mathematical programming techniques plays in developing countries. In that those teaching the subject may not have relevant practical experience in application of the mathematical programming techniques to practical problems of the developing countries and as such the material disseminated tend to concentrate on mathematical techniques rather than the entire process, and that there is also little incentive in many academic institutions in developing countries for involvement with business, commercial and government communities.

Jeffrey et al. (1995) in the study of operational research practitioner's use of operational research tools in which 380 respondents out of a population of 395 were surveyed. challenges enumerated by respondents included problems associated with describing complex models to senior management, incongruence between model and reality, experiential issues, data quality issues, efficiency issues and communication issues.

In the study of Nigerian private firms, Ehie et al. (1994) noted that the top three problems encountered in the application of mathematical programming techniques according to professionals using the techniques in their workplace included insufficient number of trained personnel, need for software development and lack of appropriate software packages.

Richu et al. (2013) in a study of challenges in the implementation of operations research techniques that surveyed Nakuru County based logistics service providers. and covered 92 respondents drawn from a population of 100 staff and customers observed that the use of mathematical programming techniques have not yet been fully utilized by business firms and that inadequate human capital and absence of qualified human capital, lack of professional input, insufficient platform for developing and training professionals and lack of motivation and recognition as some of the key challenges that deterred implementation of mathematical programming techniques.

2.3.3 The Importance of Mathematical Programming Techniques

One of the main characteristic of a successful mathematical programming application is the savings generated and also the opportunity provided by it (Richu et al., 2013). There are a lot of studies that show the potential benefits of using mathematical programming in the manufacturing sector to gain competitive advantage provided by improved operational prowess and ability to manufacture a wide range of products at high volumes without a significant increase in costs or penalties. In addition mathematical programming techniques have the potential of increasing productivity, reducing direct labour costs, rework costs, and work in progress inventories, and establishing closer and more responsive links to markets (Luis, 2013).

Fourie (2007) however argues that the existing evidence indicating these benefits is surprisingly scanty and highly diverse. For example, whereas some studies infer a significant relationship between use of mathematical programming and manufacturing or even firm performance some others do not indicate any. Despite these contradictory results, Agrawah (2010) submits that a considerable number of managers still consider mathematical programming techniques useful in various ways to the manufacturing sector and other sectors as a competitive tool and even invest in it: and further more posit that more firms are likely to invest in mathematical programming techniques in the future.

Bornstein (1990) and Richu et al. (2013) describe four key factors affecting successful implementation of mathematical programming techniques in the manufacturing sector as technical, economic and political in nature, although Datta et al. (1994) suggests that this can also be as a result of inappropriate attention being given to human aspects. Further more successful implementation can also be attributed to absence of an operational research champion.

The potential benefits of mathematical programming techniques are widely reported in the literature (Mwangi, 2013 and Wiendahl et al., 2004), however, findings about the relationship between mathematical programming techniques and performance have been contradictory and inconsistent in many instances. In contrast, Barney (1991) notes significant impact of mathematical programming techniques on manufacturing firms' performance.

Eiselt et al. (2010) found that there is a relationship between mathematical programming techniques and patterns of growth, profitability, and flexibility. Yarmish (2014) reports that firms with higher performance use mathematical programming techniques more than firms with lower performance do, Yarmish (2014) further finds that mathematical programming techniques have a significant impact on both the operational and the organizational performance. There for it is imperative for managers of manufacturing firms to have certain competencies of mathematical programming to be able to achieve the desired results of the organizations they manage.

2.3.4 Adoption of Mathematical Programming Techniques

Fabozzi (1976) in a survey of mathematical programming in American companies found that seventy four percent of the sample firms employed linear programming, while only 37 percent and 28 percent reported using nonlinear and dynamic programming respectively. Firms in this study also gave various reasons for adopting the technique they used, which predominantly included reducing costs and providing decision makers with greater insight into operations. The survey further asked respondents to select whether success achieved with each technique employed was "good", "fair", "poor" or "uncertain," and of the three techniques, linear programming, nonlinear and dynamic programming, linear programming had the greatest success.

Thomas et al. (1979) in a survey of corporate operations research, the largest 100 industrial firms in California included, found that 93% of the firms used statistical analysis, 84% used simulation, 78% used linear programming and 70% used program evaluation and review techniques or critical path method. This represented a growth from the previous surveys on application of mathematical programming techniques to industrial decision processes.

Chen et al. (2002) surveyed the practice of operational research in Taiwanese companies and the questions that were asked included specific techniques being used, application areas, reasons for using operations research techniques, reasons for not using, difficulties encountered and future perspectives. Results for 262 respondents provided several informative findings. Compared with a 1995 survey of Kao et al. the Chen et al. survey found that the percentage of companies that had used operations research techniques increased from 62.7% in 1995 to 76.7% in 2001. Furthermore during the same period the Taiwan government supported educational and training programs. In essence the survey indicated that Taiwanese companies recognize operations research techniques as an efficient management tool for economic development.

Bandyopadhyay (1980) in a study of operations research applications in manufacturing industries in India noted that decision makers were aware of its power of analysis, however they had very little faith and confidence in its applicability to Indian situations. The study also indicated that most of the private firms and family based firms used practically no operations research techniques.

Munisamy (2012) in a survey of corporate operations research practice in Malaysia found that 64% of the companies had a special department for operations research activities. In comparison to a survey by Kwong in 1986 in Malaysia, which had reported only 4 out of 198 organizations that is 2% as having a formal operations research department, there has been a clear trend to centralize the operations research activities as a specific responsibility and function in the companies. The survey also showed that 83% of the companies applied some form of operations research tools to tackle business problems. A clear indication of greater awareness that operations research can enable a company to gain competitive advantage in today's unpredictable business environment.

Ike et al. (1994) surveyed operations research utilization by companies in Lagos, Nigeria, and of the 954 questionnaires mailed, 93 were returned for a response rate of 9.7%. Although the response rate was low, the survey showed that operations research is still in its infancy in Nigeria and that the use of the techniques may increase with the availability of technical and financial support.

2.4 Conclusion

The literature reviewed indicate that use of mathematical programming techniques is quite well documented in developed countries, but barely so in Sub Saharan African countries such as Nigeria, Kenya, Zambia, Uganda and Tanzania except for South Africa (Ike et al., 1994). The literature reviewed also indicate that studies thus undertaken highlight some of the challenges in mathematical programming implementation and the benefits that can be gained if appropriately applied to problems of the manufacturing sector, however most of the surveys undertaken so far focus on the broader field of operations research and there are very few studies, especially in Africa and Kenya in particular focusing on usage of mathematical programming techniques, which as it were are pivotal in optimization of productivity.

Since no study had been performed before in Kenya, to determine the extent of application of mathematical programming techniques in the manufacturing sector, this study therefore set out to ascertain the extent of awareness and usage of mathematical programming techniques in the manufacturing sector in Kenya. Furthermore the study may expand the current local awareness of the potency of mathematical programming techniques in optimization of manufacturing sector productivity and competitiveness in the global market.

CHAPTER THREE: RESEARCH METHODOLOGY

3.1 Introduction

The first part of the chapter discuses research design followed by a discussion of methods used to arrive at the population of study. Thereafter the chapter provides an explanation of the manner in which data was collected and analyzed.

3.2 Research Design

The research design for this study was cross sectional survey and non experimental in nature. The survey focused on determining awareness and application of mathematical programming techniques in the manufacturing sector in Kenya as well as factors affecting application of the techniques.

3.3 Population of the Study

In this study the unit of analysis was the manufacturing firm. However since the manufacturing firm could not give the answers sort after, it was the people who work in the firm that provided the information on that firm. The managers served as informants for each set of information required. Table 3.3.1 provides the distribution structure of the population.

In this study, a sample of firms was selected from a population of 480 members of the Kenya Association of Manufacturers based on the following calculations: n has the sample size, was equal to 62, 12% of the population. 12% was chosen due to logistical constraints, the barest minimum being 10% based on Gay et al. (1992). N was the population frame, which was equal to 480, and r the number of firm distribution in the given sub sectors. The number of samples selected per sub sector was given by r divide by N and then multiplied by n.

Table 3.3.1 Members Distribution per Sector:

Sector	**Members**	**Number Of Samples**
Building, Construction & Mining	15	2
Chemicals & Allied	58	7
Energy, Electrical & Electronics	30	4
Food & Beverages	94	12
Leather & Footwear	14	2
Metal & Allied	52	7
Motor Vehicle & Accessories	21	3
Paper & paper Board	52	7
Pharmaceutical & Medical Equipment	19	2
Plastics & Rubber	54	7
Textiles & Apparels	58	7
Timber, Wood & Furniture	13	2
Total	**480**	**62**

Source: (Research data, 2014)

3.4 Data Collection

In this study, questionnaire was used to collect data and personal interviews in some cases undertaken. Personal interviews entailed one on one conversation with the respondents while questionnaires addressed the key objectives of the study. The questionnaire was administered using the drop and pick method. The questionnaire was designed so that each question would obtain replies that could be summarized in a manner that was capable of answering questions implied by the study objectives.

3.5 Data Analysis

Data analysis involved a mixture of quantitative and qualitative analyses. Qualitative analysis basically focused on content analysis of responses with a view to identifying the main themes that emerged from respondents. Content analysis entailed recording and critical analysis of each questionnaire and responses from the respondents and identifying emerging trends.

CHAPTER FOUR: DATA ANALYSIS AND INTERPRETATION OF THE FINDINGS

4.1 Introduction

In this chapter, the results obtained from respondents with the use of the questionnaires developed and distributed as explained in chapter 3 is analysed and interpreted. The research results are based on the responses of 48 used questionnaires representing the views of a population of 480 manufacturing firms in Kenya. This was achieved by sending out 62 questionnaires through the drop and pick method together with follow-up clarifications over the telephone in some instances. Based on the response rate, 77% of the questionnaires were filled while 23% were unfilled. Table 4.1 indicates the response rate.

Table 4.1.1 Response Rate

Number of Questionnaires	Frequency	Percentage
Filled questionnaires	48	77%
Unfilled questionnaires	14	23%
Total	62	100

Source: (Research data, 2014)

Of the 48 usable questionnaires, 4% represented building, construction & mining, 15% represented chemicals and allied, 8% represented energy, electrical and electronics, 19% represented food and beverages, 2% represented leather and footwear, 8% metal and allied, 6% motor vehicle and accessories, 8% paper and paper board, 4% pharmaceuticals and medical equipment, 12 % plastic and rubber, 10%

textile and apparels, timber whereas 4% wood and furniture. Tables 4.1.2 indicate representation of each sector.

As indicated by the resulting data, the respondents represent 10% of the population, which is satisfactory for analytical purposes of the survey.

Table 4.1.2 Response Rate by Sector

Sector	**Sample**	**Respondents**	**Percentage**
Building, Construction & Mining	2	2	4%
Chemicals & Allied	7	7	15%
Energy, Electrical & Electronics	4	4	8 %
Food & Beverages	12	9	19%
Leather & Footwear	2	1	2%
Metal & Allied	7	4	8%
Motor Vehicle & Accessories	3	3	6%
Paper & paper Board	7	4	8%
Pharmaceutical & Medical Equipment	2	2	4%
Plastics & Rubber	7	6	12%
Textiles & Apparels	7	5	10%
Timber, Wood & Furniture	2	2	4%
Total	62	48	100%

Source: (Research data, 2014)

4.2 Awareness of Mathematical Programming Techniques

The first question in the survey dealt with awareness of mathematical programming techniques in the manufacturing sector and table 4.2.1 gives the response rate. The respondents responses showed that out of the 48 usable questionnaires linear programming had the highest number of good responses at 18, integer programming had the highest reasonably good responses at 13, particle swam optimization had the highest no answer response while simulated annealing had the highest not good response and ant colony optimization the highest lacking response.

Table 4.2.1 Awareness Response Rating

Mathematical Programming Techniques	Good	Reasonably Good	No Answer	Not Good	Lacking
Calculus Methods	15 (31.20%)	12 (25.00%)	7 (14.60%)	9 (18.80%)	5 (10.40%)
Nonlinear Programming	13 (27.10%)	8 (16.70%)	10 (20.80%)	6 (12.50%)	11 (22.90%)
Geometric Programming	10 (20.80%)	11 (22.90%)	5 (10.40%)	7 (14.60%)	15 (31.20%)
Quadratic Programming	8 (16.70%)	6 (12.50%)	4 (8.30%)	13 (27.10%)	17 35.40%)
Linear Programming	18 (37.50%)	12 (25.00%)	7 (14.60%)	6 (12.50%)	5 (10.40%)
Dynamic Programming	14 (29.10%)	11 (22.90%)	6 (12.50%)	10 (20.80%)	7 (14.60%)
Integer Programming	17 (35.40%)	13 (27.10%)	5 (10.40%)	8 (16.70%)	5 (10.40%)
Stochastic Programming	9 (18.80%)	10 (20.80%)	3 (6.20%)	14 (29.10%)	12 (25.00%)

Separable Programming	6 (12.50%)	3 (6.20%)	11 (22.90%)	15 (31.20%)	13 (27.10%)
Multi-Objective Programming	8 (16.70%)	7 (14.60%)	7 (14.60%)	10 (20.80%)	16 (33.30%)
Network Methods (CPM And (PERT)	13 (27.10%)	11 22.90%)	5 10.40%)	9 18.80%)	10 20.80%)
Game Theory	10 (20.80%)	8 (16.70%)	6 (12.50%)	13 (27.10%)	11 (22.9%)
Genetic Algorithms	0 (0%)	0 (0%)	10 (20.80%)	18 (37.50%)	20 (41.70%)
Simulated Annealing	0 (0%)	1 (2.10%)	8 (16.70%)	21 (43.70%)	18 (37.50%)
Ant Colony Optimization	0 (0%)	0 (0%)	11 (22.90%)	9 (18.80%)	28 (58.30%)
Particle Swarm Optimization	1 (2.10%)	0 (0%)	26 54.20%)	10 20.80%)	11 22.90%)
Neural Networks	0 (0%	0 (0%	15 (31.20%	7 (14.60%	26 (54.20%
Fuzzy Mathematical Programming	0 (0%)	2 (4.20%)	13 (27.10%)	19 (39.60%)	14 (29.10%)

(Research data, 2014)

The analysis of the responses on extreme ends of the rating scale indicated that linear programming, based on the rating of good, had the highest value at 37.50% followed by integer programming at 35.40% and calculus methods at 31.20%, while on the other end of the scale lacking rating had the highest percentage response of ant colony optimization at 58.30% followed by neural networks at 54.20% and genetic algorithm at 41.70% respectively.

Based on the observed findings, 62.50% (that is the sum of good and reasonably good ratings) of the respondents believed their awareness of linear programming and integer programming was good. This is followed by calculus and dynamic programming respectively at 56.20% and 52%. While the most negative response came from simulated annealing at 79.20%, ant colony optimization 77.10% followed by neural networks at 68.80% on the not good and the lacking ratings.

4.3 Types of Mathematical Programming Techniques Applied in the Manufacturing Sector

The second question in the survey sought to find out the level of application of mathematical programming techniques, and table 4.3.1 provide the result of the survey question. The results indicated that the mathematical programming techniques that had the highest response out of 48 usable questionnaires based on the always applied rating are calculus methods at 5 followed by non linear programming at 4 and integer programming at 3. While the rating for never applied scale indicate that ant colony, particle swam optimization and fuzzy mathematical programming tied at 48 each followed by game theory and neural networks also tied at 47 and genetic algorithms at 46. And the rating of sometimes applied indicated linear programming highest at 18 followed by network methods at 9 and calculus methods at 8 responses.

The analysis of the types of mathematical programming techniques applied indicate that calculus had the highest application at 10.40% together with linear programming at 10.40% while non linear followed at 8.30%, integer programming, network methods and multi objective programming tied with 6.20% respectively.

The rating for never applied indicate that ant colony optimization, particle swam optimization and fuzzy mathematical programming had the highest percentage of respondents at 100% while neural networks and game theory had 97% and genetic algorithms had 95%.

Table 4.3.1 Types Applied Response Rating

Mathematical Programming Techniques	Never applied	Sometimes applied	Always applied
Calculus Methods	35 (72.90%)	8 (16.50%)	5 (10.40%)
Nonlinear Programming	39 (81.20%)	5 (10.40%)	4 (8.30%)
Geometric Programming	44 (91.70%)	3 (6.20%)	1 (2.10%)
Quadratic Programming	42 (87.50%)	4 (8.30%)	2 (4.20%)
Linear Programming	25 (52.10%)	18 (37.50%)	5 (10.40%)
Dynamic Programming	43 89.60%)	3 6.20%)	2 4.20%)
Integer Programming	41 (85.40%)	4 (8.30%)	3 (6.20%)
Stochastic Programming	39 (81.20%)	7 (14.60%)	2 (4.20%)
Separable Programming	45 (93.70%)	3 (6.20%)	0 (0%)
Multi-Objective Programming	40 (83.30%)	5 (10.4%)	3 (6.20%)
Network Methods (CPM And (PERT)	37 (77.10%)	9 (18.70%)	2 (6.20%)
Game Theory	47 (97.90%)	0 (0%)	1 (2.10%)
Genetic Algorithms	46 (95.80%)	2 (4.20%)	0 (0%)
Simulated Annealing	43 (89.6%)	5 (10.40%)	0 (0%)
Ant Colony Optimization	48 (100.00%)	0 (0%)	0 0%)
Particle Swarm Optimization	48 (100.00%)	0 (0%)	0 (0%)
Neural Networks	47 97.90%)	1 2.10%)	0 0%)
Fuzzy Mathematical Programming	48 (100.00%)	0 (0%)	0 (0%)

(Research data, 2014)

On the rating, sometimes applied, network method had the highest response at 18.7% followed by calculus methods at 16.50% and stochastic programming at 14.6% respectively.

4.4 Factors affecting application of mathematical programming techniques

This section sought to determine the factors affecting application of mathematical programming techniques in the manufacturing sector and table 4.4.1 provide the result of the survey. Out of the 48 usable questionnaires, lack of required expertise factor had strongly agreed rating highest at 39.60% and the lowest rating on disagree at 6.30%. While 68.80% agreed lack of required expertise affects application of mathematical programming techniques and 16.70% disagreed.

On the inadequate knowledge of methods factor, strongly disagree and don't know both had the lowest rating at 8.30%. While the highest rating was 31.30% on agree. Generally 72.90% agreed inadequate knowledge of methods affects application of mathematical programming techniques while 18.70% disagree.

on the high training cost factor, the highest rating was on agree rating at 31.30% while the lowest rating was on don't know rating at 12.50%. High training cost factor, however, had 50.10% agreeing it affects application of mathematical programming techniques while 37.50% disagreed.

On high software costs factor, the highest response was on agree rating while the lowest response on strongly agree rating at 12.50%. However, 54.10% are in agreement that high software costs affects application of mathematical programming techniques while 39.60% disagreed.

On the lack of enthusiasm, interest and commitment among managers factor, the highest response was on agree rating while the lowest on strongly agree rating. However, 56.30% agreed that lack of enthusiasm, interest and commitment among managers affects application of mathematical programming techniques while 25% disagreed.

On the factor, interpretation of results is difficult, the highest response was on agree rating at 35.40% while the lowest on strongly disagree rating at 10.40%. However, 54.20% agreed interpretation of results affected application of mathematical techniques while 22.90% disagreed.

On the factor, it is complicated and heavy to master, the highest response was on strongly agree rating at 37.50% while the lowest rating on strongly disagree rating at 6.20%. Further analysis of data indicated that 62.50% agreed that application of mathematical programming techniques is complicated and heavy to master while 22.90% disagreed.

On the factor, Not applicable to this firm, disagree rating was lowest at 8.30% while the highest was agree rating at 31.30%. Further analysis indicated that 51.20% agreed that mathematical programming techniques was not applicable to the firms while 20.80% disagreed.

Table 4.4.1 Factors Affecting Application Response Rating

Factors	Strongly Disagree	disagree	Don't Know	Agree	Strongly Agree
Lack of required expertise	5 (10.40%)	3 (6.30%)	7 (14.60%)	14 (29.20%)	19 (39.60%)
Inadequate knowledge of methods	4 (8.30%)	5 (10.40%)	4 (8.30%)	20 (41.60%)	15 (31.30%)
High training cost	8 (16.70%)	10 (20.80%)	6 (12.50%)	15 (31.30%)	9 (18.80%)
high software costs	6 (12.50%)	13 (27.10%)	3 (18.80%)	16 (33.30%)	10 (20.80%)
Lack of enthusiasm, Interest and commitment among managers	5 (10.40%)	7 14.60%)	9 (18.80%)	14 (29.20%)	13 (27.10%)
Interpretation of results is difficult	5 (10.40%)	6 (12.50%)	11 (22.90%)	17 (35.40%)	9 (18.80%)
It is complicated and heavy to master	3 (6.20%)	8 (16.70%)	7 (14.60%)	12 (25.00%)	18 (37.50%)
Not applicable to this firm	6 (12.50%)	4 (8.30%)	13 (27.10%)	15 (31.30%)	10 (20.80%)

(Research data, 2014)

CHAPTER FIVE: SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

5.1 Introduction

The aim of this survey was to determine the extent of mathematical programming techniques awareness in the manufacturing sector, and to determine types of mathematical programming techniques applied in the manufacturing sector and to establish factors affecting application of mathematical programming techniques in the manufacturing sector. This chapter presents the summary of findings and recommendations. Further research areas are also proposed at the end of the chapter.

5.2 Summary of the Findings

The survey findings indicated that awareness of mathematical programming techniques, which includes calculus methods, calculus of variations, nonlinear programming, geometric programming, quadratic programming, linear programming. dynamic programming, integer programming, stochastic programming, separable programming, multi-objective programming network methods (CPM and (PERT) and game theory, genetic algorithms, simulated annealing, ant colony optimization, particle swarm optimization, neural networks and fuzzy mathematical programming is still very low, although some techniques like linear programming, dynamic programming and network methods showed slightly higher awareness in the manufacturing sector generally, but application is significantly low as well.

The types of mathematical programming techniques that find some use in the manufacturing sector in Kenya, although sparingly, include calculus methods, linear programming methods, integer programming, network methods, multi objective programming and non linear programming. Other techniques are mostly not used at all, and even those that are used, based on the extent, are unlikely to have the full benefit of the technique in question due to a range of challenges inherent in the degree skill set, but also awareness of the value.

Findings also indicated that the manufacturing sector in Kenya also acknowledge certain challenges in application of mathematical programming techniques, which include lack of required expertise, inadequate knowledge of methods, high training cost, high software costs, lack of enthusiasm on the part of decision makers, interest and commitment among managers, difficulty in interpretation of results, complicatedness and difficulty in mastering the techniques highly.

These findings closely reflect the literature reviewed about the findings of other studies that have been done in developing countries such as Nigeria. This is an indication that generally Africa is as yet to appreciate the value of mathematical programming techniques in enhancing efficiency, productivity and competitiveness of their manufacturing sector.

Furthermore application of mathematical programming techniques in the manufacturing sector in Kenyan firms has been found to be very low indeed, although it has been proven in developed countries as a potent tool for optimization of a wide range of process and systems within organizations leading to greater value for share holders. Various theories that were reviewed in the literature are also associated with optimization of processes and systems within organizations, as such it can be concluded that most manufacturing firms in Kenya operate in sub optimal state and therefore may not be in the foreseeable future reach the desired competitiveness envisioned in various development plans of Kenya unless drastic transformation of perceptions takes place in the sector.

5.3 Conclusions

The manufacturing sector in Kenya is still far from appreciating the importance of mathematical programming techniques has is evident from the survey. Mathematical programming techniques have a history of wide application in solving practical problems and improving the efficiency of many firms and organizations in the developed world and to some extent in the developing world.

This study set out to survey application of mathematical programming techniques in the manufacturing sector in Kenya, and aimed to determine the extent of mathematical programming techniques awareness, to determine types of mathematical programming techniques applied in the manufacturing sector and to establish factors that affect application of mathematical programming in the manufacturing sector if any.

A sample population of 480 manufacturing firms was used to select a sample size of 62 from which a set of questionnaires seeking to find the degree of awareness of mathematical programming techniques, types of mathematical programming techniques being applied and factors affecting application of mathematical programming techniques was distributed, 48 responded.

On analysis of the data, it was found that generally awareness of mathematical programming techniques is very low. This low level of awareness can be explained to some varying degrees by factors, which include lack of require expertise, inadequate knowledge, high training cost, high software costs, Lack of enthusiasm, Interest and commitment among managers and difficulty in interpretation of results.

5.4 Recommendations

Most respondents reported low levels of awareness of mathematical programming techniques. It is therefore recommended that some instruments of creating enhanced awareness be developed within the manufacturing sector in Kenya.

Application of mathematical programming techniques in individual manufacturing firms in Kenya is also very low despite lack of awareness. It is therefore recommended that some form of technical as well as financial support be made readily available for the manufacturing sector to enhance uptake and achievement of greater efficiency in productive activities of the firms.

More importantly, practitioner of operations research in Kenya may be better positioned to spearhead programs for creating awareness and enhanced adoption of mathematical programming techniques through a membership association.

5.5 Areas for Further Studies

This study was generally constrained for time and resources, the study therefore settled on the barest minimum sample size of 12%. The researcher therefore recommends a more comprehensive study with enhanced sample size to assess the application of mathematical programming techniques in the manufacturing sector in Kenya. In addition the researcher also recommends a holistic survey of application of operations research in the manufacturing sector or in Kenya generally.

5.6 Limitation

The study had limitation of financial capacity to undertake a study of a much bigger sample, which could have greatly enhanced the quality of inferential analyses; further more challenges of the number of personnel that could be used to collect data, and materials and equipment for the purpose were also some of the limitations. Time was also a limiting factor, and disallowed similar benefits advanced over financial capacity.

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APPENDICES

Appendix I: Questionnaire

This survey is being done to find out the extent of awareness and usage of Mathematical Programming Techniques in the manufacturing sector in Kenya. All information you give will be treated confidential and used for academics only.

(Kindly tick any of the boxes that best answers the question and fill in the gaps where needed)

Section A: Awareness of mathematical programming techniques

1. **How would you rate your awareness of mathematical programming techniques?**

(On a scale of 1 = good, 2 = reasonably good, 3 = no answer, 4 = not good, 5 = lacking: place an X in the appropriate box for each technique)

Mathematical Programming Techniques	**Good (1)**	**(2)**	**(3)**	**(4)**	**Lacking (5)**
Calculus Methods					
Nonlinear Programming					
Geometric Programming					
Quadratic Programming					
Linear Programming					
Dynamic Programming					
Integer Programming					
Stochastic Programming					
Separable Programming					
Multi-Objective Programming					
Network					

Methods (CPM And (PERT)					
Game Theory					
Genetic Algorithms					
Simulated Annealing					
Ant Colony Optimization					
Particle Swarm Optimization					
Neural Networks					
Fuzzy Mathematical Programming					

Section B: Application of Mathematical Programming Techniques.

1. **On average, how often do you apply mathematical programming techniques in your work or firm?**

(On a scale of 1 = never used, 2 = sometimes used, 3 = always used: place an X in the appropriate box for each technique)

Mathematical Programming Techniques	**Never applied (1)**	**Sometimes applied (2)**	**Always applied (3)**
Calculus Methods			
Nonlinear Programming			
Geometric Programming			
Quadratic Programming			
Linear Programming			
Dynamic Programming			
Integer Programming			
Stochastic Programming			

Separable Programming			
Multi-Objective Programming			
Network Methods (CPM And (PERT)			
Game Theory			
Genetic Algorithms			
Simulated Annealing			
Ant Colony Optimization			
Particle Swarm Optimization			
Neural Networks			
Fuzzy Mathematical Programming			

Section C: Factors affecting application of mathematical programming Techniques

1. **This section seeks to find out the factors affecting application of mathematical programming techniques in your firm.** (On a scale of 1 = strongly disagree, 2 = disagree, 3 = don't know, 4 = agree, 5 = strongly agree: please place an X in the appropriate box)

Factors	1	2	3	4	5
Lack of required expertise					
Inadequate knowledge of methods					
High training cost					
high software costs					
Lack of enthusiasm/interest/commitment among managers					
Interpretation of results is difficult					

It is complicated and heavy to master					
Lack of computing facilities					
Not applicable to this firm					

THANK YOU FOR TAKING TIME OUT OF YOUR BUSY SCHEDULE TO ANSWER THIS QUESTIONNAIRE

Appendix II: List of Sample Population

1.BASCO PRODUCTS
2.BAYER EAST AFRICA
3.BOC KENYA
4.BUYLINE INDUSTRIES
5.CARBACID
6.COATES BROTHERS
7.COIL PRODUCTS
8.COLGATE PALMOLIVE
9.COOPER KENYA
10.CROWN BERGER KENYA
11.DESBRO KENYA
12.DIAMOND INUDSTRIES
13.EAST AFRICA HEAVY CHEMICALS
14.EASTERN CHEMICAL INDUSTRIES
15.GALAXY PAINTS AND COATING COMPANY
16.GRAND PAINTS
17.HENKEL KENYA
18.INTERCONSUMER PRODUCTS
19.JOHNSON DIVERSEY EAST AFRICA
20.KAPI
21.KEL CHEMICALS
22.KEMIA INTERNATIONAL
23.KEN NAT INK AND CHEMICALS
24.MAGADI SODA COMPANY
25.METOXIDE AFRICA
26.MILY GLASS WORKS
27. OASIS
28.ORBIT CHEMICAL INDUSTRIES
29. OSHO CHEMICALS
30.POLYCHEM EAST AFRICA
31.PROCTER AND GAMBLE EAST AFRICA
32.PYRETHRUM BOARD OF KENYA
33.PZ CUSSIONS AND COMPANY
34.RAYAT TRADING COMPANY
35.]RECKITT BENCKISER EAST AFRICA
36.ROSIN KENYA
37.SADOLIN PAINTS EAST AFRICA
38.SARA LEE HOUSEHOLD AND BODY CARE KENYA
39.SAROC
40.SOILEX CHEMICALS
41.STRATEGIC INDUSTRIES
42.SUPA BRITE
43.SUPER FOAM
44.SYNRESINS
45.TRI-CLOVER INDUSTRIES
46.UNILEVER KENYA
47.VITAFOAM PRODUCTS

48.A.I RECORDS KENYA
49.AMEDO CENTRE KENYA
50.ASSA ABLOY EAST AFRICA
51.BAUMANN ENGINEERING
52.CHEVRON
53.EAST AFRICA CABLES
54.EVEREADY BATTERIES KENYA
55.FRIGOREX EAST AFRICA
56.HOLMAN BROTHERS EAST AFRICA
57.INTERNATIONAL ENERGY TECHNIK
58.KENWESTFAL WORKS
59.KENYA PETROLEUM REFINERIES
60.KENYA POWER AND LIGHTING COMPANY
61.KENYA SCALE COMPANY/AVERY KENYA
62.KENYA SHELL
63.MANUFACTURING AND SUPPLIES KENYA
64.MARSHALL FOWLER ENGINEERING
65.MECER EAST AFRICA
66.METLEX INDUSTRIES
67.METSEC
68. MOBILE OIL KENYA
69.OPTIMUM LUBRICANTS
70.PENTAGON AGENCIES
71.POWER ENGINEERING INTERNATIONAL
72.POWER TECHNICS
73.RELIABLE ELECTRICAL ENGINEERING
74.SANYO ARMCO KENYA
75.SOCABELEC EAST AFRICA
76.SOLLATEK ELECTRONICS KENYA
77.TEA VAC MACHINERY
78.AFRICA SPIRITS
79.AGRINER AGRICULTURAL DEVELOPMENT
80.AGRO CHEMICAL AND FOOD COMPANY
81.ALLIANCE ONE TOBACCO KENYA
82.ALPHA FINE FOODS
83.ALPINE COOLERS
84.ANNUM TRADING COMPANY
85.AQUAMIST
86.ARKAY INDUSTRIES
87.BELFAST MILLERS
88.BIDCO OIL COMPANY
89.BIO FOODS PRODUCTS
90.BOGANI INDUSTRIES
91.BRITISH AMERICAN TOBACCO KENYA
92.BROADWAY BAKERY
93.BROOKSIDE DAIRY
94.C. CZARNIKOW SUGAR EAST AFRICA
95.CADBURY KENYA
96.CANDY KENYA
97.CAPWELL INDUSTRIES

98.CARLTON PRODUCTS EAST AFRICA
99.CHAI TRADING COMPANY
100.CHEMELIL SUGAR COMPANY
101.CHIRAG KENYA
102.COASTAL BOTTLERS
103.COCA COLA EAST AFRICA
104.CONFEC INDUSTRIES EAST AFRICA
105.CORN PRODUCTS KENYA
106.CROWN FOODS
107.CUT TOBACCO KENYA
108.DEEPA INDUSTRIES
109.DEL MONTE KENYA
110.DOMINION FARMS
111.E & A INDUSTRIES
112.EAST AFRICA SEA FOOD
113.EQUATOR BOTTLERS
114.ERDEMAN COMPANY KENYA
115.EXCELL CHEMICALS
116.FARMERS CHOICE
117.FRIGOKEN
118.GILOIL COMPANY
119.GLACIER PRODUCTS
120.GLOBAL ALLIED INDUSTRIES
121.GLOBAL BEVERAGES
122.GONAS BEST
123.HAIL & COTTON DISTILLERS
124.HIGHLANDS CANNERS
125.HIGHLANDS MINERAL WATER COMPANY
126.HOMEOIL
127.INSTA PRODUCTS EPZ
128.JAMBO BISCUITS KENYA
129.JAMES FINLAY KENYA
130.JETLAK FOODS
131.KAPA OIL REFINERIES
132.KARIRANA ESTATE
133.KENAFRIC INDUSTRIES
134.KENBLEST
135.KENCHIC
136.KENSALT
137.KENYA BREWERIES
138.KENYA NUT COMPANY
139.KENYA SWEETS
140.KENYA TEA DEVELOPMENT AGENCY
141.KENYA TEA PACKERS, KETEPA
142.KENYA WINE AGENCIES
143.KEROCHE INDUSTRIES
144.KEVIAN KENYA
145.KIBOS SUGAR AND ALLIED INDUSTRIES
146.KISII BOTTLERS
147.KRYSTALLINE SALT

148.KWALITY CANDIES & SWEETS
149.L.A.B INTERNATIONAL KENYA
150.LONDON DISTILLERS KENYA
151.MAFUKOP INIDUSTRIES
152.MASTERMIND TOBACCO KENYA
153.MAYFAIR HOLDINGS
154.MELVIN MARSH INTERNATIONAL
155.MENENGAI OIL REFINERIES
156.MILLY FRUIT PROCESSORS
157.MINI BAKERIES NAIROBI
158.MIRITINI KENYA
159.MOMBASA SALT WORKS
160.MOMBASA MAIZE MILLERS
161.MOUNT KENYA BOTTLERS
162.MUMIAS SUGAR COMPANY
163.NAIROBI BOTTLERS
164.NAIROBI FLOUR MILLS
165.NAS AIRPORT SERVICES
166.NESTLE FOODS KENYA
167.NJORO CANNING FACTORY KENYA
168.PALMAC OIL REFINERS
169.PATCO INDUSTRIES
170.PEARLE WATERS
171.PEMBE FLOUR MILLS
172.PREMIER FLOUR MILLS
173.PREMIER FOOD INDUSTRIES
174.PROCTOR & ALLAN EAST AFRICA
175.PROMASIDOR KENYA
176.PWANI OIL PRODUCTS
177.RAFIKI MILLERS
178.RAZCO
179.RIFT VALLEY BOTTLERS
180.SIGMA SUPPLIES
181.SMASH INDUSTRIES
182.SOFTA BOTTLING COMPANY
183.SPECTRER INTERNATIONAL
184.SPICE WORLD
185.SPIN KNIT DAIRY
186.SUPER BAKERY
187.SWAN INDUSTRIES
188.UNGA GROUP
189.UDV KENYA
190.UNITED MILLERS
191.UZURI FOODS
192.VALLEY BAKERY
193.VALUEPAK FOODS
194.W.E. TILLEY
195.WANAINCHI MARINE PRODUCTS
196.WEST KENYA SUGAR COMPANY
197.WESTERN KENYA EXPRESS SUPLIERS

198.WRIGLEY COMPANY EAST AFRICA
199.ALPHARAMA
200.BATA SHOE COMPANY
201.BUDGET SHOES
202.C&P SHOES INDUSTRIES
203.LEATHER INDUSTRIES OF KENYA
204.NEW MARKET LEATHER FACTORY
205.METAL & ALLIED
206.AFRICAN MARINE & GENERAL ENGINEERING COMPANY
207.ALLIED METAL SERVICES
208. ALLOY STEEL CASTINGS
209.APEX STEEL
210.ASL
211.ASP COMPANY
212.ATHI RIVER STEEL PLANT
213.BOOTH EXTRUSIONS
214.BROLLO KENYA
215.CITY ENGINEERING WORKS
216.COLOUR PACKAGING
217.COOK 'N LITE
218.CORRUGATED SHEETS
219.CRYSTAL INDUSTRIES
220.DEVKI STEEL MILLS
221.DOSHI ENTERPRISES
222.EAST AFRICA SPECTRE
223.EAST AFRICAN FOUNDRY WORKS
224.ELITE TOOLS
225. FARM ENGINEERING INDUSTRIES
226.FRIENDSHIP CONTAINER MANUFACTURERS
227.GENERAL ALUMINIUM FABRICATORS
228.GOPITECH KENYA
229.GREIF KENYA
230.HOBRA MANUFACTURING
231.INSTEEL
232.J.F. MCCLOY
233.KALUKWORKS
234.KENS METAL INDUSTRIES
235.KHETSHI DHARAMSHI & COMPANY
236.MECOL
237.METAL CROWNS
238.MORRIS & COMPANY
239.NAILS & STEEL PRODUCTS
240.NAMPAK KENYA
241.NAPRO INDUSTRIES
242.NARCOL ALUMINIUM ROLLING MILLS
243.NDUME
244.ROLMIL KENYA
245.SANDVIK KENYA
246.SHAMCO INDUSTRIES
247.SONI TECHNICAL SERVICES

248.SOUTERN ENGINEERING COMPANY
249.STANDARD ROLLING MILLS
250.STEEL STRUCTURES
251.STEELMAKERS
252.STEELWOOL AFRICA
253.SUPER STEEL & TUBES
254.TARMAL WIRE PRODUCTS
255.TONONOKA STEEL
256.TRITEX INDUSTRIES
257.VIKING INDUSTRIES
258.WARREN ENTERPRISES
259.WELDING ALLOYS
260.WIRE PRODUCTS
261.ASSOCIATED BATTERY MANUFACTURERS
262.ASSOCIATEDD VEHICLE ASSEMBLERS
263.AUTO ANCILLARIES
264.AUTO SPRING MANUFACTURERS
265.AUTOMOTIVE & INDUSTRIES BATTERY MANUFACTURERS
266.BANBROS
267.BHACHU INDUSTRIES
268.CHI AUTO SPRING INDUSTRIES
269.GENERAL MOTORS EAST AFRICA
270.IMPALA GLASS INDUSTRIES
271.KENYA GRANGE VEHICLE INDUSTRIES
272.KENYA VEHICLE MANUFACTURERS
273.LABH SINGH HARNAM SINGH
274.MEGH CUSHION INDUSTRIES
275.MUTSIMOTOK MOTOR COMPANY
276.PIPE MANUFACTURERS
277.SOHANSONS
278.THEEVAN ENTERPRISES
279.TOYOTA EAST AFRICA
280.UNIFILTERS KENYA
281.VARSANI BRAKELININGS
282.ATHI RIVER MINING
283.BAMBURI CEMENT
284.BAMBURI SPECIAL PRODUCTS
285.CENTRAL GLASS INDUSTRIES
286.EAST AFRICA PORTLAND CEMENT COMPANY
287.HOMA LIME COMPANY
288.JOY BATHROOMS
289.KARSAN MURJI & COMPANY
290.KENBRO INDUSTRIES
291.KENYA BUILDERS & CONCRETE
292.MALINDI SALTWORKS
293.MANSON HART KENYA
294.ORBIT ENTERPRISES
295.SAJ CERAMICS
296.AJIT CLOTHING FACTORY
297.ALLPACK INDUSTRIES

298.ANDIKA INDUSTRIESS
299.ASSOCIATED PAPERS & STATIONERY
300.AUTOLITHO
301.BAG AND ENVELOPE CONVERTERS
302.BAGS & BALERS MANUFACTURERS
303.BUSINESS FORMS & SYSTEMS
304.CARTUBOX INDUSTRIES
305.CEMPACK
306.CHANDARIA INDUSTRIES
307.COLOUR LABELS
308.COLOURPRINT
309.D.L. PATEL PRESS KENYA
310.DODHIA PACKAGING
311.EAST AFRICA PACKAGING INDUSTRIES
312.ELITE OFFSET
313.ELLAMS PRODUCTS
314.ENGLLISH PRESS
315.FLORA PRINTERS
316.GENERAL PRINTERS
317.GUACA STATIONERS
318.ICONS PRINTERS
319.IMAGING SOLUTIONS KENYA
320.INTERLABELS AFRICA
321.KAKAMEGA PAPER CONVERTERS
322.KARTASI INDUSTRIES
323.KENAFRIC DIARIES MANUFACTURERS
324.KENYA LITHO
325.KEM-FRAY EAST AFRICA
326.KITABU INDUSTRIES
327.KUL GRAPHICS
328.MODERN LITHOGRAPHIC KENYA
329.NATION MEDIA GROUP
330.NATIONAL PRINTING PRESS
331.PACKAGING MANUFACTURERS
332.PAN AFRICAN PAPER MILLS
333.PAPER CONVERTERS KENYA
334.PAPERBAGS
335.PHOENIX MATCHES
336.PRIMEX PRINTERS
337.PRINTPAK MULTI PACKAGING
338.PRUDENTIAL PRINTERS
339.PUNCHLINES
340.RAFFIA BAGS KENYA
341.SIG COMBIBLOC OBELKAN KENYA
342.STATPAACK INDUSTRIES
343.T AWS
344.TETRA PAK
345.THE JOMO KENYATTA FOUNDATION
346.THE PAPER HOUSE OF KENYA
347.THE REGFAL PRESS KENYA

348.THE RODWELL PRESS
349.THE STANDARD GROUP
350.TRANSPAPERE KENYA
351.TWIGS STATIONERS & PRINTERS
352. UNESCO PAPER PRODUCTS
353.UNITED BAG MANUFACTURERS
354.ALPHA MEDICAL MANUFACTURERS
355.BETA HEALTHCARE INTERNATIONAL
356.BIODEAL LABORATORIES
357.BULK MEDICAL
358.COSMOS
359.DAWA
360.ELYS CHEMICAL INDUSTRIES
361.GESTO PHARMACEUTICALS
362.GLAXO SMITHKLINE KENYA
363.KAM PHARMCY
364.LABORARTORY & ALLIED
365.MANHAR BROTHERS KENYA
366.MEDIVET PRODUCTS
367.NOVELTY MANUFACTURING
368.PHARM ACCESS AFRICA
369.PHARMACEUTICAL MANUFACTURING COMPANY
370.REGAL PHARMACEUTICALS
371.UNIVERSAL CORPORATION
372.ACME CONTAINERS
373.AFRO PLASTICS KENYA
374.ALANKAR INDUSTRIES
375.BETATRAD KENYA
376.BOWPLAST
377.BOBMIL INDUTRIES
378.CABLES & PLASTICS
379.COMPLAST INDUTRIES
380.CONTINENTAL PRODUCTS
381.DOSHI IRONMONGERS
382.DUNE PACKAGING
383.ELGITREAD KENYA
384.ESLON PLASTICS OF KENYA
385.FIVE STAR INDUSTRIES
386.GENERAL PLASTICS
387.HACO INDUSTRIES
388.HI-PLAST
389.KAMBA MANUFAACTURERS
390.KINGSWAY TYRES & AUTOMART
391.L.G. HARRIS & COMPANY
392.LANEEB PLASTICS INDUSTRIES
393.METRO PLASTICS KENYA
394.NAIROBI PLASTICS
395.NAV PLASTICS
396.OMBI RUBBER ROLLERS
397.PACKAGING INDUSTRIES

398.PACKAGING MASTERS
399.PLASTICS & RUBBER INDUSTRIES
400.POLYBLEND
401.POLYFLEX INDUSTRIES
402.POLYTHENE INDUSTRIES
403.PRESTIGE PACKAGING
404.PROSEL
405.QPLAST INDUSTRIES
406.RUBBER PRODUCTS
407.SAFEPAK
408.SAMEER AFRICA
409.SANPAC AFRICA
410.SHIV ENTERPRISE
411.SIGNODE PACKAGING SYSTEMS
412.SLIPACK INDUSTRIES
413.SOLVOCHEM EAST AFRICA
414.SUMARIA INDUSTRIES
415. SUPER MANUFACTURERS
416.TECHPAK INDUSTRIES
417.TREADSETTERS TYRES
418.UMOJA RUBBER PRODUCTS
419.UNI-PLASTICS
420.VYATU
421.AFREICAN COTTON INDUSTRIES
422.AFRO SPIN
423.ALTEX EPZ
424.ALPHA KNITS
425.APEX APPARELS EPZ
426.APPAREL AFRICA
427.ASHTON APPAREL EPZ
428.BEDI INVESTMENTS
429.BHUPCO TEXTILE MILLS
430.BLUE BIRD GARMENTS EPZ KENYA
431.BLUE PLUS
432.BROTHER SHIRTS FACTORY
433.CALIFORNIA LINK EPZ
434.EMKE GARMENT
435.FULCHAND MANEK & BROS
436.IMAGE APPARELS
437.J.A.R KENYA EPZ
438.KAMYN INDUSTRIES
439.KEN-KNIT GARMENT EPZ
440.KAPRIC APPARELS
441.KEN-KNIT KENYA
442.KENYA SHIRTS MANUFACTURERS COMPANY
443.LEENA APPARELS
444.LE-STUD
445.LONDRA
446.MEGA GARMENT INDUSTRIES KENYA EPZ
447.MEGA SPIN

448.MICRO TEXTILES EAST AFRICA
449.MIRAGE FASHION WEAR EPZ
450.MRC NAIROBI EPZ
451.NAKURU INDUSTRIES
452.NGKECHA INDUSTRIES
453.PREMIER KNITWEAR
454.PROTEX KENYA EPZ
455.RIZIKI MANUFACTURERS
456.ROLEX GARMENT EPZ
457.SENIOR BEST GARMENT EPZ KENYA
458.SHIN-ACE GARMENTS
459.SILVERSTAR MANUFACTURES
460.SIN LANE KENYA EPZ
461.SINO LINK GARMENTS MANUFACTURERS EPZ
462.SPIN KNIT
463.SPINNERS & SPINNERS
464.STORM APPAREL MANUFACTURERS COMPANY
465.STRAIGHTLINE ENTERPRISES
466.SUMMIT FIBRES
467.SUNFLAG TEXTILE & KNITWEAR MILLS
468. TARPO INDUSTRIES
469.TEITA ESTATE
470.THE KIKOY COMPANY
471.THIKA CLOTH MILLS
472.UNITED ARYAN EPZ
473.UPAN WASANA EPZ
474.VAJA MANUFACTURERS
475.WILDLIFE WORKS EPZ
476.YU-UN KENYA EPZ COMPANY
477.ECONOMIC HOUSING GROUP
478.EDEMA KENYA
479.FURNUTRE INTERNATIONAL LIMITED
480.HWANG SUNG INDUSTRIES

Appendix III: Specimen Letter to Respondents

ATTN: The Manager,

Dear Sir,

I am a postgraduate student at University of Nairobi pursuing a Masters of Business Administration- Operations Management. One of the requirements is to undertake a research relevant to the course of study. I am therefore researching on "Use of Mathematical Programming in Kenya: A Survey of Manufacturing Sector":

So I request your firms' participation in the survey. The information you will give will not be used for any other purpose other than academic and will be treated as confidential. I will appreciate your cooperation.

Yours researcher,

Frederick O. Awich.