A RESEARCH PROJECT

IN PART FULFILMENT OF MASTER OF
BUSINESS AND ADMINISTRATION (M.B.A.)

TITLE

"AN APPLICATION OF A TRANSPORTATION MODEL TO THE KENYA BREWERIES LIMITED DISTRIBUTION SYSTEM"

AUTHOR

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Soft,

Bringing back
Cattle from
Grazing fields to the
sheds → that time.

SUPERVISOR

DR. DAVID KOHLER

JUNE, 1981

DECLARATION

THIS RESEARCH PROJECT IS MY ORIGINAL WORK AND HAS NOT BEEN PRESENTED FOR A DEGREE IN ANY OTHER UNIVERSITY

JKTangus

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CANDIDATE

THIS RESEARCH PROJECT HAS BEEN SUBMITTED FOR EXAMINATION WITH MY APPROVAL AS THE UNIVERSITY SUPERVISOR

David Kohler

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ABSTRACT

Kenya Breweries Ltd. being one of the largest companies in this Republic, plays a major role in the economy of this country. It will soon be operating five breweries in Mombasa, Nairobi and Kisumu. They are Tusker and Allsopps both in Ruaraka, and one in industrial area, all in Nairobi, one at Mombasa and one to be completed soon (early 1982) in Kisumu. Currently the Nairobi breweries produce all the six brands of beer namely, Tusker, Tusker Export, Tusker Premium, Pilsner, White Cap and Guiness Stout. Only four of these are produced in Mombasa brewery, these are Tusker, Tusker Export, Pilsner and White Cap, but there is a plan that will enable it to produce all the six brands in future.

All these products have got to be distributed all over the Republic so as to reach the final consumers. This distribution activity costs a lot of money to the company, hence raising the operating expenses of the entire organization. Due to the current inflation all over the world and the continuous rise in oil prices the transportation rate has also been rising, thus making this important activity of distribution to be very costly. This increase in transportation cost threatens the company's profit performance and therefore the management is seeking ways of trying to improve the transportation system so as to minimize costs.

So in this project, the author makes an attempt to determine through the use of a linear programming technique, called a transportation problem, that optimal scheduling of products from various sources (breweries) to the numerous destinations (depots).

Such an optimal plan may not only minimize costs but may also improve the quality of services and the image of the organization to the public.

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INTRODUCTION

1.2 STATEMENT OF THE PROBLEM

The expenditure of goods and passenger transport by road in Kenya is very high, hence I can safely say, is a significant percentage of our gross national product (GNP). The problem at hand is the high cost of transporting products from their sources to the numerous destinations. In this huge industry (transport), it is natural to believe that there is great scope for the use of modern operations research techniques in order to obtain optimal plans. Such plans could be found in the following vital activities: vehicle scheduling, depot siting and fleet planning. This has been made more useful by the introduction of computers which are fast and accurate. The following are some important quotations from various OR specialists and top managers about the vitality of controlling transportation costs.[1]

There have been a general outcry about the soaring cost of distribution and companies, faced with rising fuel and labour costs, are paying closer attention to their transport function. "Physical distribution has far too long been regarded as a backroom-type operation", says Onnik S. Tuygil, Turkish-born Chairman of Monsanto Europe SA. "We found that not only was the distribution cost rising year by year, but

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1 Refer to International Management Magazine, August 1975, Volume 30, "Controlling the Soaring Cost of Distribution".

that it was rising at a disproportionate rate to the rest of the company", says Raymond Horsley, distribution director of Rank Radio International Ltd. in the UK. "It can be shown mathematically that, unless some action were taken quickly, the cost of distribution would rapidly become an unacceptable burden on the activities of the company as a whole". "Most companies are now looking at the whole of physical distribution in the context of overall corporate strategy and objectives", reports J.H. Van der Hoop, an independent Dutch consultant specializing in this area.

Van der Hoop also noted that distribution until now has involved only junior managers solving tactical problems, such as vehicle scheduling or routing of goods, but now senior managers recognize that the solution is more likely to be found in long-term research and strategy. That is where the opportunities for making real savings lie.

Other factors affecting transportation are warehousing, transit depots, labour costs, packaging, insurance, inventory holdings and cashflow. But for this project I will be mainly concerned with the reduction of transportation costs through the application of a transportation model that will enable us to get an optimal plan for the Kenya Breweries.

1.3 THE OBJECTIVES OF THE STUDY

1. To investigate the transportation system of the company and then try to arrive at an optimal or near optimal plan i.e. to try to minimize the distribution costs of the company.

2. To show the management of the company how some of the OR techniques can be utilized in solving some of the real world problems such as the one at hand, so that they can be applying them in the future.

3. To improve my knowledge in this particular field of study and to give myself a chance of practically applying the theoretical techniques in solving real world problems like the one at hand.

4. To show that there is always room for improvement in any business activity, and to alert the management to think more seriously of various ways of improving their operational efficiency.

1.4 IMPORTANCE OF THE STUDY

This study falls under distribution planning and the following are some of its important contributions:

a) It means orderly progress in the execution of other activities related to it.

b) It is one of the most effective methods known for ascertaining the best utilization and coordination of the company's resources towards profit and growth.

c) It makes the management think of potential ways of reducing costs by application of modern techniques.

d) It encourages systematic thinking ahead by management and enhances readiness to take care of the future.

e) It brings about effective communication among persons working towards a common goal, like say people in the marketing department are forced to share ideas and information with people in the distribution and transportation department.

f) It focuses attention on the company objectives, as all planning is directed towards achieving the organization objectives and offers effective control.

g) It minimises costs because of the emphasis it places on efficient operations and consistency of approach which results in more economical operations.

1.5 SCOPE AND METHODOLOGY

In scope, this project involves mainly library literature review and field work research. The literature review covers mainly a survey of the concept of distribution planning, the application of operations research techniques and more specifically the Transportation Model. This part of the project is intended to provide a theoretical background of the transportation model.

The research is conducted in Kenya Breweries Ltd. fields of operations including the Head Office, the various breweries and distribution centres.

The instruments to be used in data collection are:

1. Personal interviews
2. Questionnaires
3. Secondary sources such as Company

Reports i.e. Minutes, Financial and Chairman's Speeches.

As regards methodology, the project will start with an introductory chapter which includes the statement of the problem, objectives and importance of the study and its limitations. This will be followed by chapters on background of the company (object of the study), the model iteself and application, evaluation and then summary and recommendations (conclusion).

1.6 LIMITATIONS OF THE STUDY

1. We have the general limitations of all the other linear programming techniques, which are mentioned in the literature review below.
2. The most important constraint for this study has been the time period available. It is too short to do as much as one would have liked to cover so as to make the study to be of maximum usefulness.
3. Most of the information used is current, but it would have been more useful if the future projected ones could be utilized, after all a plan is for the future, not now or the past.
4. One of the Breweries that is included in the plan is the Kisumu Brewery, which is expected to start operations early in 1982. Hence the ultimate plan will be applicable to Kenya Breweries Ltd. in 1982.
5. Transportation costs have been assumed proportional to distance between source and destination. This is in practice an oversimplification as road conditions are not necessarily uniform over the country.

CHAPTER I

1.1 THE BACKGROUND OF KENYA BREWERIES LTD.

This chapter will include the inception, expansion and some of the difficulties of the Kenya Breweries Ltd. upto the time when the study was undertaken. An attempt is also made to highlight the difficulties the company has faced as a result of inflation and rise of petrol prices since 1972, the issues that would warrant the kind of solution sought in this project.

Started in 1914, before the end of World War I there was no local brew in Kenya. After the war two brothers Hurst George and Charles came to Kenya and bought land at Kitale, Soy Farm. They used to drink imported beer and they didn't like it. So they formed what later was to be KBL which now ranks as among the greatest private under-takings in Kenya, and one of the largest brewing concerns in Africa. With the help of another friend H.A. Dawding who had connections with Edu Malt Extract Co. in England the two brothers pulled efforts together to start a brewery. They bought land at Ruaraka because of permanent stream to supply water. They contributed K.£2,500 each and a Company known as KBL was formally registered on the 8th December, 1922, and production began on the 14th December, 1922.

George Hurst was killed in 1923 by an elephant while hunting - hence the name Tusker was adopted in memory of this sad occasion to the Kenya Breweries.

First year of operations company's trading sales was K£2,000 and a profit of K.£40. By 1930 it had started producing and exporting Lager beer. In these early years the company encountered two major problems. The heavy rail charges precluded large export business and during the post war periods, its product was faced with stern competition from beers imported from England, Denmark, Germany, Australia, Holland, South Africa and Japan.

In order to overcome transportation problems the company started establishing other breweries in East Africa. In 1932, it opened one at Dar es Salaam which was to serve Tanganyika and also Mombasa area.

In 1935 Kenya Breweries Ltd. went public and acquired assets of Tanganyika Breweries Ltd. after which both were incorporated into East African Breweries Ltd. With the outbreak of World War II the company was yet to gain, hence they expanded facilities to meet demand. During that time Ruaraka production was 35,000 gallons a month and 12,000 gallons at Dar es Salaam. Troops from South Africa, Britain and India arrived at Mombasa, and beer became as important as ammunitions. Immediate expansion were made but still the demand couldn't be coped with.

The beer shortage was so acute that the War Supply Board had to convene a meeting with brewers and suppliers, where a percentage split of output and supplies for military and civilian resulted. Wartime difficulties led to some lasting benefits for the company and the farmers of Kenya. Farmers were encouraged to grow Barley since by 1942 it was hard to get it from overseas.[2] By 1944, Mombasa Brewery was

[2] Little R., Barley Production in Kenya, The Brewer December, 1978 pp. 462-466

opened. Two British brewing companies, Ind. Coope and Allsopps were also attracted to brewing industry in East Africa.

In 1959 East African Breweries Ltd. acquired substantial holdings in Uganda Breweries Ltd. At the same time Dar es Salaam Breweries was transferred to newly formed Tanganyika Breweries Ltd. which was to operate as an entity throughout Tanganyika.

During this time Allsopps (E.A.) Ltd., also situated at Ruaraka and an upcoming competitor began to work for a larger slice of the beer market by conducting a series of weekly beer testing competitions to determine the preferences of the local beer consumers. The result of these competitions was Allsopps Pilsner Lager which was then introduced into the market.

In 1962, EABL entered into discussions with Allsopps and eventually acquired the whole of its ordinary stock. Steps were also taken to convert EABL into a holding company by transferring its assets and liabilities relating to the Tusker Breweries Nairobi and Mombasa together with the maltings at Nairobi industrial area to a new subsidiary Kenya Breweries Ltd. During 1964, and at the cost of £208,000, 40% of the equity of Kilimanjaro Breweries at Arusha was acquired from the Madhivani Group. And when Guiness (E.A.) Ltd. was Incorporated in Kenya (1965) EABL secured 49% of its issued capital; the other half being owned by Guiness Overseas Ltd.

In 1968 KBL introduced Tusker Export in order to explore the export market in dumpy-non-returnable bottles. The mass production of international competitors made it hard to match prices. But over time the lager had gained popularity in local, shipping and airline markets. It is now exported to USA, Britain and the Middle East.

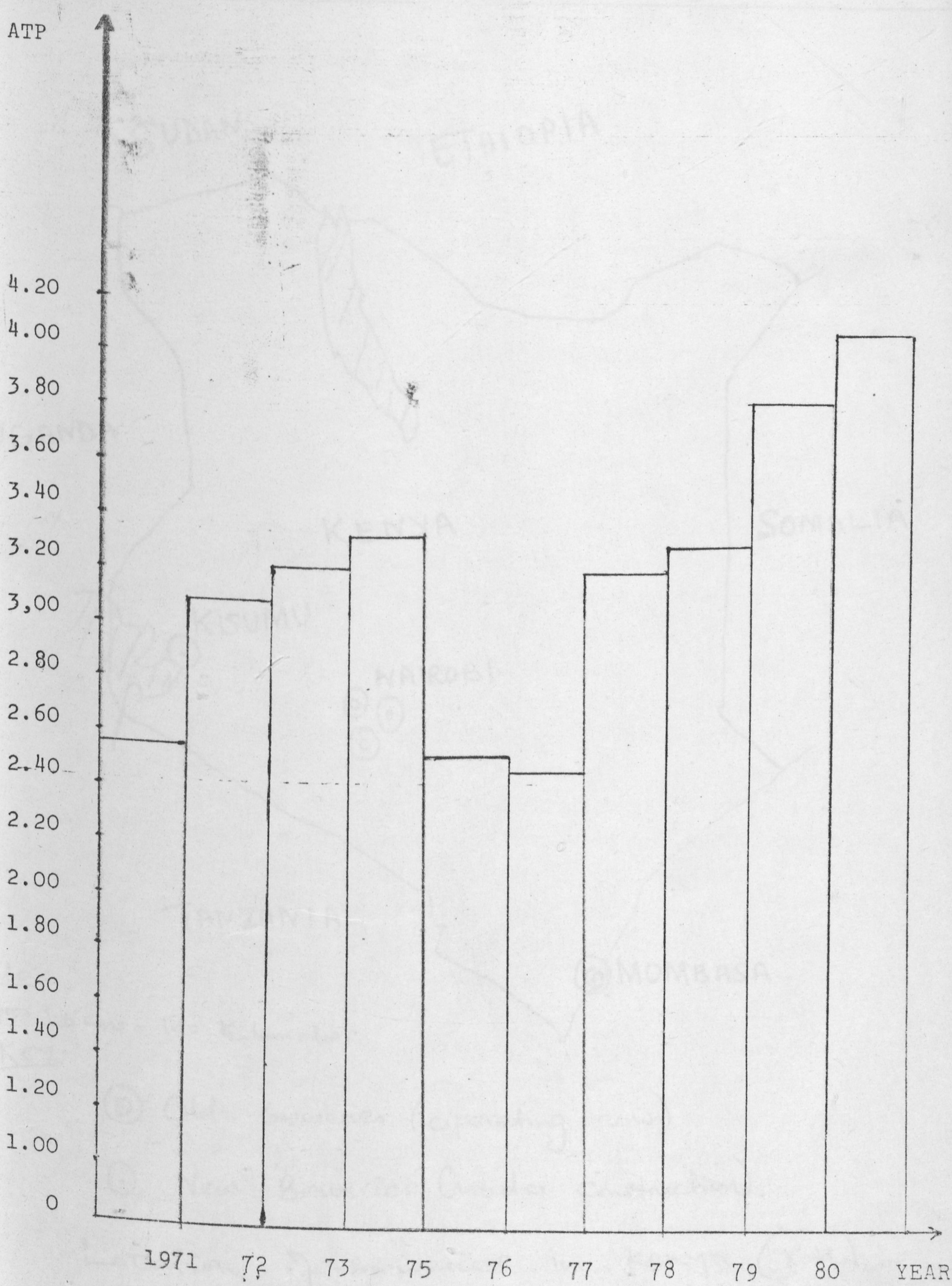
In 1969 KBL purchased the City Breweries Ltd. In 1972 the company had already acquired a modest minority interest of K£15,000 in Seychelles Breweries Ltd. in partnership with Hoase of Germany and Guiness Overseas Ltd.

During 1972 operations became tough going due, to Government tax policies and control, and great increase in production costs resulting from inflation (Ref. to reports of the Chairman from 1972 onwards). Periods between 1971 to 1975 were full of hardships due to inflation and Government policy changes both in Kenya and Tanzania. This can be seen to have affected the profitability of the company around that same time, look at the chart overleaf. This problem of rising costs has continued upto now and it will persist into the future, that is why such a problem should be looked into by the management.

CHART I

KENYA BREWERIES LTD. AFTER TAX PROFIT (ATP) FOR 1971-1980

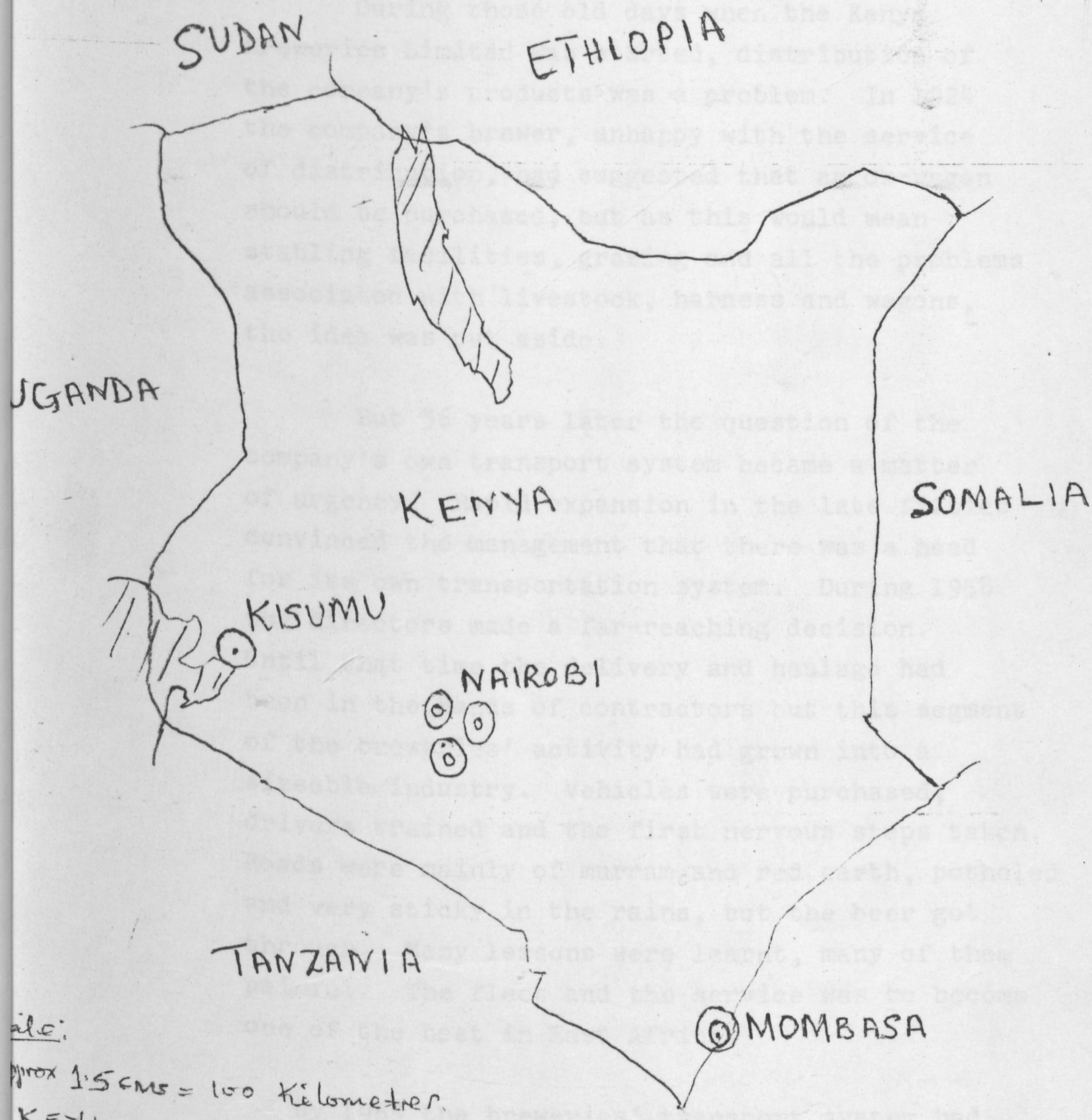
(UNITS IN K.£ M.)



Source: Kenya Breweries Annual Reports for the years 1971 to 1980

MAP 1

KENYA: LOCATION OF BREWERIES



ale:
prox 1.5 cms = 100 Kilometres.

KEY:

⊙ Old Breweries (operating now)

⊙ New Breweries (under construction).

Location of Breweries in Kenya (KBL)

(Source my own drawing)

1.2 KENYA BREWERIES LTD. DISTRIBUTION SYSTEM

During those old days when the Kenya Breweries Limited was started, distribution of the company's products was a problem. In 1924 the company's brewer, unhappy with the service of distribution, had suggested that an ox-wagon should be purchased, but as this would mean stabling facilities, grazing and all the problems associated with livestock, harness and wagons, the idea was put aside.

But 36 years later the question of the company's own transport system became a matter of urgency. Rapid expansion in the late fifties convinced the management that there was a need for its own transportation system. During 1958 the directors made a far-reaching decision. Until that time the delivery and haulage had been in the hands of contractors but this segment of the breweries' activity had grown into a sizeable industry. Vehicles were purchased, drivers trained and the first nervous steps taken. Roads were mainly of murram and red earth, potholed and very sticky in the rains, but the beer got through. Many lessons were learnt, many of them painful. The fleet and the service was to become one of the best in East Africa.

By 1965 the breweries' transport system had developed to include a fleet of 194 units in Kenya. Eight years after the first brewery vehicles had taken to the roads, the group was proud of the fact that their mile/ton cost and the vehicle utilisation rate were among the most efficient in Africa and equated favourably to similar industries in more advanced countries despite the obvious cost disadvantages of operating on rough terrain. Vehicles of the East African Breweries group operating in Kenya alone travelled more than 3,000,000 miles a year hauling beer, empty bottles, raw materials, machinery and equipment.

The current operations is divided between Nairobi breweries and the Mombasa brewery. But soon Kisumu brewery will be supplying Western parts of Kenya, where this means west of Nakuru. The Mombasa brewery supplies beers to the whole of Coast Province, while the rest parts of Kenya is supplied from Nairobi breweries. For those brands that are not being produced in Mombasa like Guiness Stout and Tusker premium, they are first of all taken from Nairobi to Mombasa before they are distributed to the various depots. So in cases like that of Voi, which is on the way to Mombasa from Nairobi, they will never receive their supplies directly from Nairobi unless specifically authorized. They will always get it from Mombasa so as to maintain the existing internal control against theft of beer. (look at maps No. 2 and 3).

There are 110 lorries with trailers that operate from Nairobi to other parts of the country and each one of them can carry an average of 930 Metric cases of beer (load capacity officially allowed) when full but for empties the capacity is 1016 Metric cases. A lorry alone without a trailer has a capacity of 540 Metric cases when full and 716 cases for empties. In Mombasa there are 10 vehicles, these are 7 lorries, 2 lorries with trailers and 1 small van. All the breweries vehicles have one driver assigned to them. They have their own maintenance departments where they service and repair their vehicles. There is a big garage in Ruaraka and there is another one in Mombasa. The Kenya breweries uses only road transport for their distribution of products and materials within the Republic of Kenya because they are cheap, fast and flexible to use and have wide coverage. They buy most of their big lorries from Italy, the Fiat company. The Transport and Distribution Manager, Mr. Burugu argues that the Fiat vehicles are relatively cheaper, more efficient in their operations and easier to maintain. The supply market is readily available and the supply of spare parts is excellent. (see the maps No.2 and 3).

KENYA BREWERIES TOTAL TRANSPORTATION COSTS FOR THE YEARS 1977-1980 (IN K.£)

YEAR	COST:
1977	2,467,000
1978	3,837,000
1979	3,400,000
1980	4,320,000

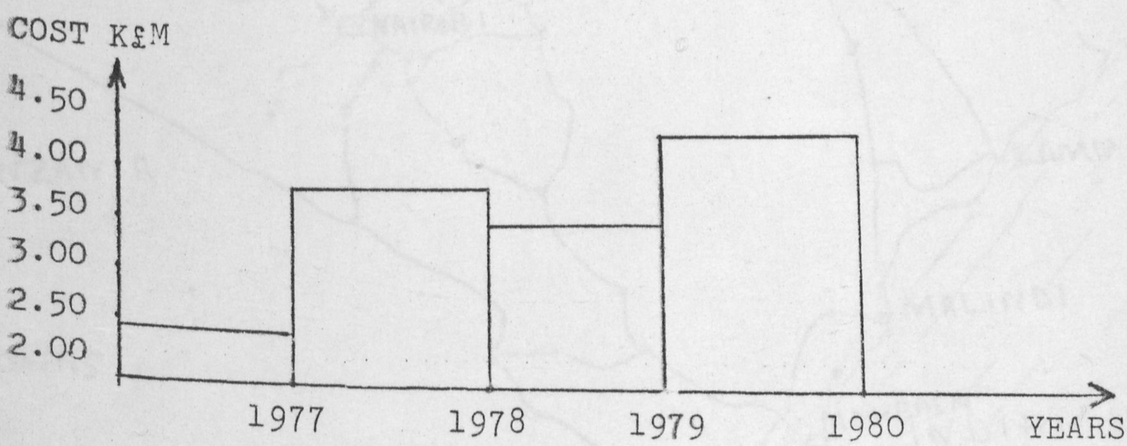
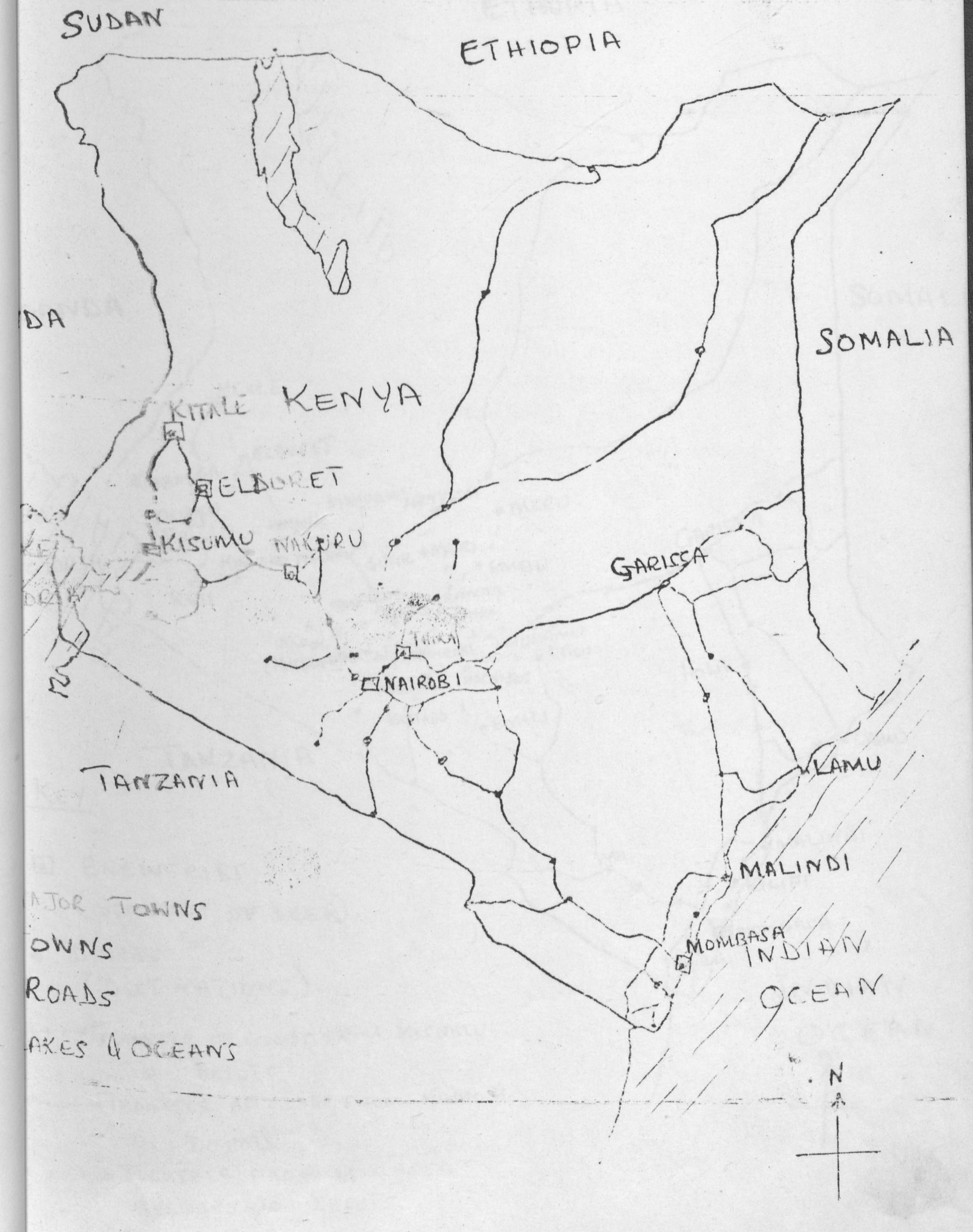


CHART 2

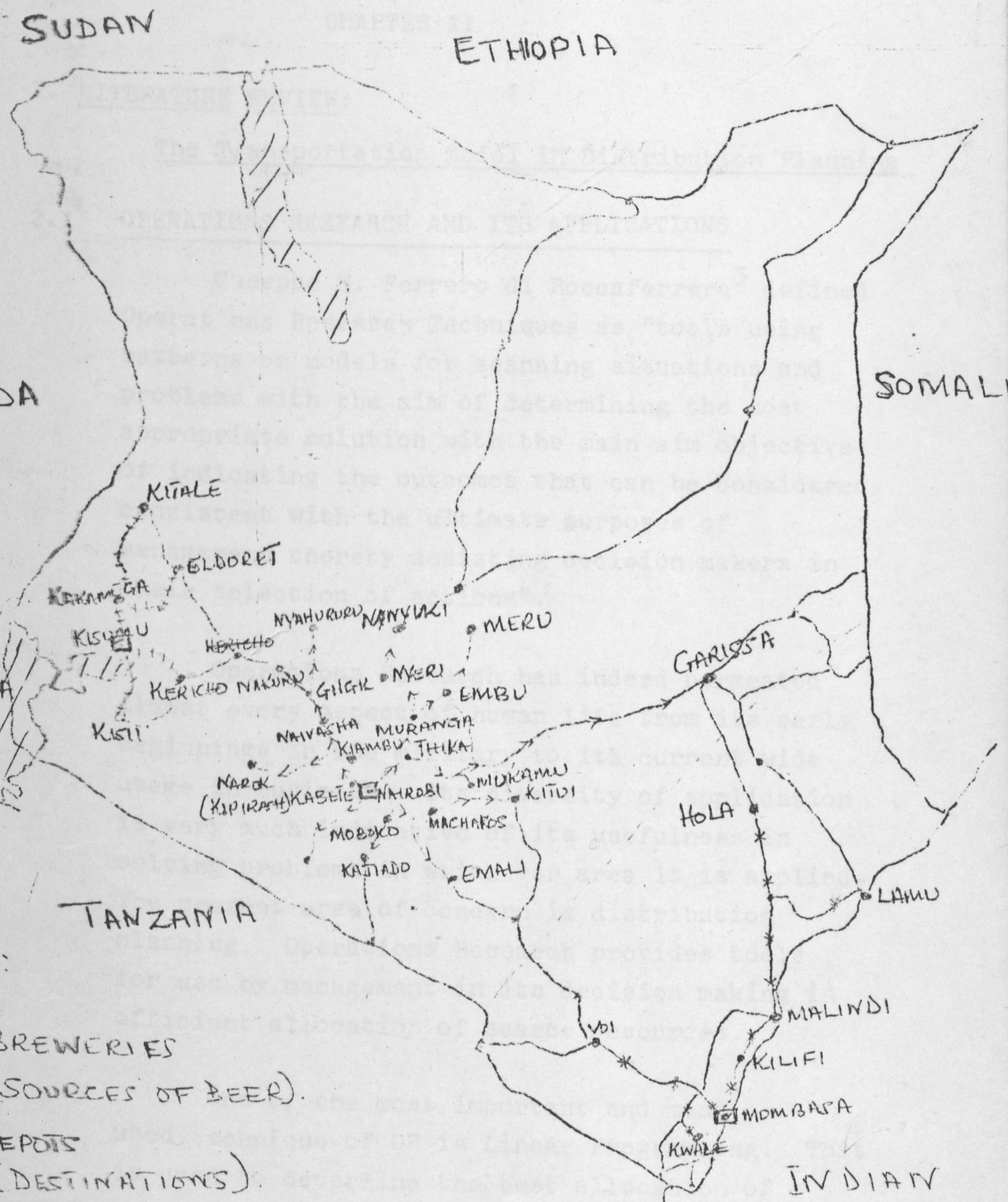
MAP 2

KENYA: PHYSICAL NETWORK OF THE ROAD TRANSPORTATION SYSTEM



MAP 3

KENYA BREWERIES LTD DISTRIBUTION SYSTEM PLAN BEFORE THE APPLICATION OF THE TRANSPORTATION MODEL.



KEY:

⊡ BREWERIES (SOURCES OF BEER).

• DEPOTS (DESTINATIONS)

⊡-+-+-+-• TRANSFER OF GOODS FROM KISUMU TO DEPOTS

⊡——→——• TRANSFER OF GOODS FROM NAIROBI TO DEPOTS

⊡-*-*-*-• TRANSFER FROM MOMBASA BREWERY TO DEPOTS.

- - - - DEMARCATION LINE BETWEEN DISTRIBUTION ZONES, DETERMINED ARBITRARY.

CHAPTER II

2. LITERATURE REVIEW:

The Transportation Model in Distribution Planning

2.1 OPERATIONS RESEARCH AND ITS APPLICATIONS

Giuseppe M. Ferrero di Roccaferrera[3] defined Operations Research Techniques as "tools using patterns or models for scanning situations and problems with the aim of determining the most appropriate solution with the main aim objective of indicating the outcomes that can be considered consistent with the ultimate purposes of management thereby assisting decision makers in their selection of actions".

Operations Research has indeed permeated almost every aspect of human life from its early beginnings in the military to its current wide usage in business. Its diversity of application is very much indicative of its usefulness in solving problems in whichever area it is applied. The present area of concern is distribution planning. Operations Research provides tools for use by management in its decision making in efficient allocation of scarce resources.

One of the most important and most used technique of OR is Linear Programming. This is used to determine the best allocation of resources. It deals with either minimization or

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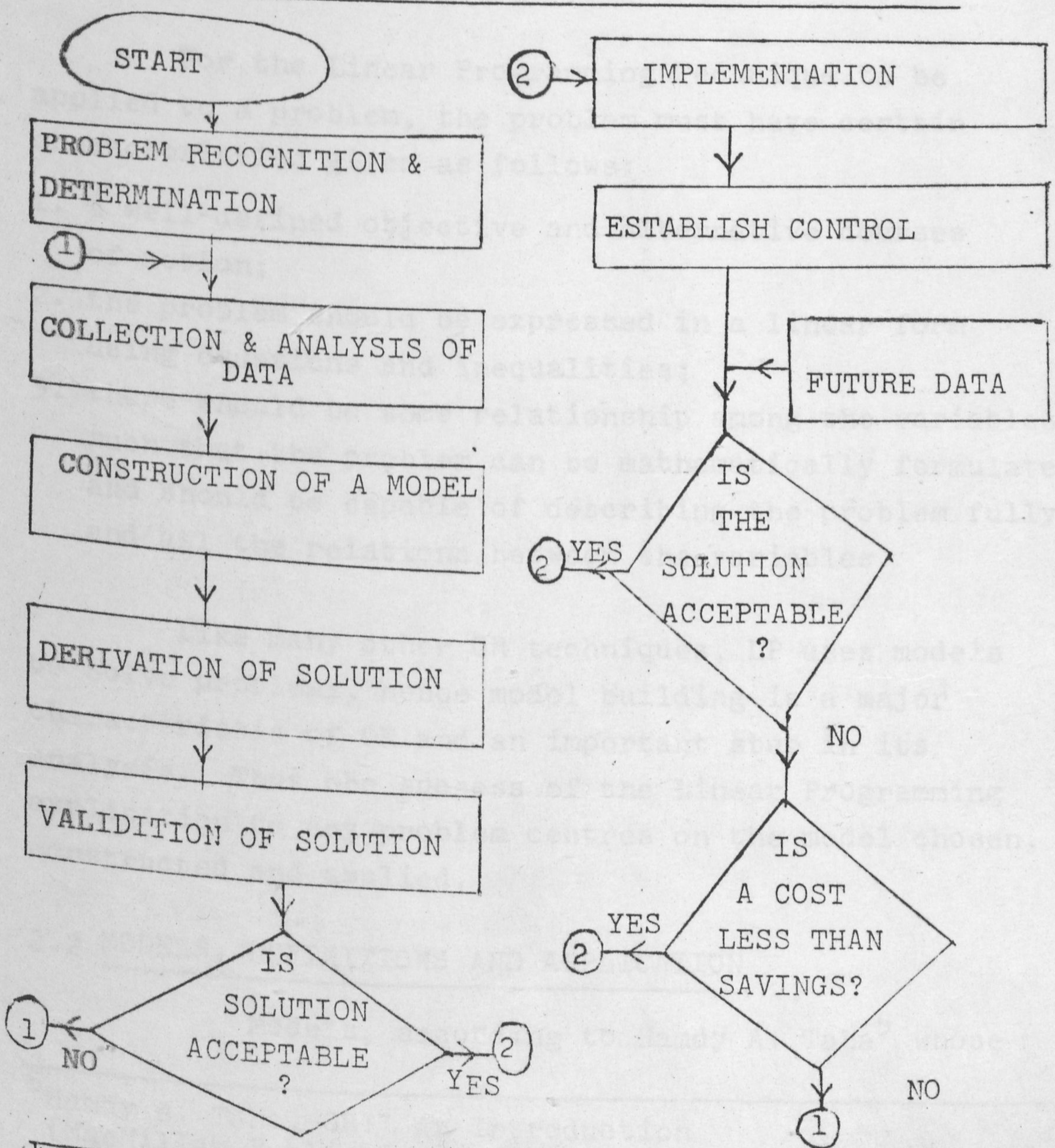
[3] Ginseppe M. Ferrero di Roccaferrera, Operations Research Models for Business and Industry, (South Western Publishing Company, Cincinnati, 1964), Chapter I, pp. 19-20.

maximization problems; subject to certain constraints. On the whole, LP is a management tool for seeking the solution of problems in conformity with the firm's clearly defined objectives. In its many valuable applications, J.L. Heskett[4] contends that LP has lent itself effectively to the Analysis of Movement (transportation) Systems. *

OPERATIONS RESEARCH APPROACH TO MANAGEMENT DECISION MAKING: - FLOWCHART (CHART 3)



[4] Heskett, J.K., "Business Logistics", Encyclopedia of Management, Edited by Carl Heyel, (Ronhold Book Corp. USA (1963) Pg. 85

OR is defined as the application of Scientific Methods, Techniques and Tools to Problems involving the Operations of Systems to provide those in control (managers) of the operations with optimum solutions to the problems (As by Ackoff - Rivett). There are other definitions like that of the OR groups which says is the application of methods of science to complex problems arising in the direction and management of large system of machines, materials, men and money in industry, government, business and defence.

For the Linear Programming Technique to be applied to a problem, the problem must have certain characteristics given as follows:

1. a well-defined objective and alternative courses of action;
2. the problem should be expressed in a linear form using equations and inequalities;
3. there should be some relationship among the variables such that the problem can be mathematically formulated and should be capable of describing the problem fully and all the relations between the variables.

Like many other OR techniques, LP uses models to solve problems, hence model building is a major characteristic of OR and an important step in its analysis. Thus the success of the Linear Programming application to any problem centres on the model chosen, constructed and applied.

2.2 MODELS, DEFINITIONS AND APPLICATION

Models, according to Hamdy A. Taha[5] whose

[5] Hamdy A. Taha, OR: An Introduction (MacMillan Publishing Company Inc. New York, 1971), Page 2.

definition is that adopted in this project, are "an idealised representation of a real life system". He adds that if the system is in existence, "the objective of the Model is to provide means for analyzing the behaviour of the system for the purpose of improving its performance". Models are derived on the basis of the main characteristics of the problem; only significant variables pertaining to the problem have to be included in it. The effectiveness of the model in respect of how it solves the problem at hand is thus the basic factor in its choice. This effectiveness depends on the objective being sought. These objectives must be clearly defined and kept up to date to be referred to any time, and they should not conflict.

Models are of many kinds but of our immediate concern is the mathematical or symbolic model. This has been known to be the most abstract model and by far the most applied in OR. It employs mathematical symbols to represent decision variables of the system. The variables are related together to describe the behaviour of the system. The decision variables are unknowns which are to be determined from the solution of the model. Also we have known or given variables in the model. The model further contains constraints which limit the decision variables to their feasible values in order to let the model account for the physical limitations of the system. Lastly, there is the objective function which defines the measure of effectiveness of the system as a mathematical function of its decision variables. The function acts as an indicator for the achievement of the optimum solution when the model is being applied.

Models offer several advantages or benefits, they are easier in manipulation or analysis than the real system. They enhance carrying out varied experimentation efficiently in terms of cost and risk. As P.J. Robinson[6] puts it, model application permits a determination of how one or more phases of the system may be changed to accomplish some well-defined objective. Robert S. Weinsberg[7] adds that the model assists the planner in reaching a conclusion; it does not provide, nor is it intended to provide, a final judgement-free mechanical answer. Mathematical models are of many types but of major interest here, however, is the Transportation Model.

The model defines the existence of several supply-points (sources) and destinations plus the unit cost of transport from each source to each destination. Also specified is the quantity of goods available for transportation or distribution at each source and the quantity required at each destination. In scope, the Transportation Model becomes applicable only when two or more sources of supply are distributing one commodity to two or more destinations. There are various ways of doing this but our main concern here is the simplex method.

There are various methods for solving the transportation problem -namely VAM, MODI and Simplex Computational method. In this project I was mainly

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[6] P.J. Robinson, "The Management Sciences", Handbook of Business Administration by H.B. Maynard (MacGraw-Hill Inc. N.Y. 1967) Section 1, Chapter 5 pp. 62-63.

[7] Robert S. Weinsberg, "Management Science and Marketing Strategy, Marketing and the Computer by Wroe Alderson and Stauley J. Shapiro (Prentice Hall Inc. Englewood Cliffs, N.J., 1963) Part II, Chapter 1, pp. 98-127.

concerned with the use of Simplex Method, which is used for choosing the optimal feasible programme and which was developed by the end of summer 1947.

The development of this method was made more fruitful when electronic digital computers were developed, which made the application of LP to be easy. Since 1952, when the first successful solution of an LP problem on a high-speed computer occurred, the simplex algorithm or its variations have been coded for practically all general purposes electronic computers.

2.3 APPLICATIONS OF LP MODELS

LP has been applied in solving many management and industrial problems. Among the areas of its application are production planning, smoothing, inventory control, financial planning and Transportation planning.[8] The Transportation problem has been modified to handle other managerial decisions like the assignment and the contract award decisions.

2.4 CHARACTERISTICS OF LP MODELS

The basic requirements before an LP technique can be employed in the solution of practical problems namely:

a) There must be a scarcity of resources.
b) The decision variables in the problem must be interrelated, and it should be possible to express this interrelationship into mathematical formulations.

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[8] Salkingard Kornbluth J. - LP in Fin. Planning

c) There must be an alternative course of action.
d) An objective function must be clearly defined mathematically.
e) The objective function and its constraints must be expressed in a linear form.

For the model to work, there are assumptions that must be made before employing the LP technique, these are:

a) Proportionality - this is the quantities of the inflow and outflow of a system are always proportional to the level of activity.
b) Non-Negativity - All activities are assumed to be carried out at a positive level i.e. no negative units.
c) Additivity and Accountability of Resources. It should be possible to establish proper balances between inputs and outputs for all activities.
d) Divisibility of Activities and Resources. So that any positive level of units is possible and any proportion of each resource can be utilized.
e) Linearity of the constraint Equations and the objective function - Here we assume that all equations are of the first degree that would be plotted as straight lines.
f) Deterministic Assumption - Certainty. It is assumed that all the coefficiencies of the variables as well as the constraining values are known with certainty. In reality these values may neither be known accurately nor do they remain constant.

2.5 THE ADVANTAGES OF USING LP TECHNIQUE

a) Its use leads to the optimum use of the scarce productive factors within an organization.

b) It leads to improved quality of management decisions. The user becomes more objective in dealing with problems. The user concentrates in those factors that affects the problem only and hence puts a clear picture of the happenings within the basic restrictions and the elements involved in the problem puts the user in a better position to understand both the problems and their solutions.

c) It offers a substantial means for improving the knowledge and skill of the user resulting from the analytical exercise that he goes through before finding the solution.

d) The technique is not rigid, and is not a substitute for the manager in deciding the best action to be taken, hence it is always the responsibility of the user to accept or modify the solution before using it.

e) LP highlights bottlenecks that are found in operations which may otherwise not be known before generating an optimal solution.

2.6 THE LIMITATIONS OF LP

1. A number of the basic requirements and assumptions may not be satisfied.
2. The size and quality of data available, the amount of data that can be handled by a computer, time limitation in collecting and transforming information into mathematical notations before solving the problem.

3. Monetary costs of carying out a research, up-dating information and reprogramming may be prohibitive.

4. It can solve problems with only one objective functions while we know now that organizations pursue more than one objective.

Although we have such advantages and limitations of LP, we can still argue that it is the best technique so far for solving such problems as stated above and they give optimal solutions given at any prevailing circumstances.

CHAPTER III

THE TRANSPORTATION PROBLEM (TP)

One of the earliest and most fruitful applications of Linear Programming techniques has been the formulation and solution of the transportation problem as a linear-programming problem. The basic TP was originally stated by Hitchcock[9] and later discussed in detail by Koopmans[10].

The General Transportation Problem

A homogenous product is to be shipped in the amounts a_1, a_2, a_3 ... a_m, respectively from each of M shipping origins and received in amounts of b_1, b_2, b_3, ... b_n, respectively, by each of n shipping destinations.

The cost of shipping a unit amount from i^{th} source to the j^{th} destination is C_{ij} and is known for all combinations (i,j). The problem is to determine the amount X_{ij}, to be shipped over all routes (i,j) so as to minimize the total cost of transportation.

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[9] Hitchcook, F.L. Distribution of a Product from Several sources to Numerous Localities, Journal of Mathematical Physics, Vol. 20, 1941.

[10] Koopmans, J.C. Optimum Utilization of the Transportation System, Econometrica, Vol. 17, Supplement, 1949.

Below is a simplified tableau of a transportation problem. (Table 3.1). In this table we have M sources plus 1 dummy source for any shortages and n destinations plus 1 dummy destination for any surplus goods. The total cost of shipping X_{ij} goods (units) is given as $C_{ij}X_{ij}$. Since there is no negative shipment, we restrict our $X_{ij} \geqslant 0$. So from the table we have the mathematical statement of the transportation problem: Find values for X_{ij} which minimizes the total cost.

TABLE 3.1

DESTINATIONS

SOURCES: i \ j	1	2	j	n	n + 1	SOURCE CAPACITIES
1	C_{11} X_{11}	C_{12} X_{12}	C_{1j} X_{ij}	C_{1n} X_{1n}	$C_1(n+1)$ $X_1(n+1)$	a_1
2	C_{21} X_{21}	C_{22} X_{22}	C_{2j} X_{2j}	C_2 X_{2n}	$C_2(n+1)$ $X_2(n+1)$	a_2
i	C_{i1} X_{i1}	C_{i2} X_{i2}	C_{ij} X_{ij}	C_{in} X_{in}	$C_i(n+1)$ $X_i(n+1)$	a_i
M	C_{M1} X_{M1}	C_{M2} X_{M2}	C_{Mj} X_{Mj}	C_{Mn} X_{Mn}	$C_M(n+1)$ $X_M(n+1)$	a_M
M+1	$C_{(M+1)1}$ $X_{(M+1)1}$	$C_{(M+1)2}$ $X_{(M+1)2}$	$C_{(M+1)j}$ $X_{(M+1)j}$	$C_{(M+1)n}$ $X_{(M+1)n}$	$C_{(M+1)(n+1)}$ $X_{M+1(n+1)}$	a_{M+1}
DESTI-NATION REQUIRMT	b_1	b_2	b_j	b_n	b_{n+1}	A

3.1 $$\sum_{i=1}^{m+1} \sum_{j=1}^{n+1} C_{ij} X_{ij}$$

Subject to the following constraints

3.2 $$\sum_{j=1}^{n+1} X_{ij} \leqq a_i, \; i = 1, 2, \ldots M, M+1$$

3.3 $$\sum_{i=1}^{m+1} X_{ij} \geqq b_j, \; j = 1, 2, \ldots, n, n+1$$

and

3.4 $$X_{ij} \geqq 0$$

In order for the above to be consistent we must have the sum of equations (3.2) equal to the sum of equations (3.3) that is:

$$\sum_{i=1}^{m+1} \sum_{j=1}^{n+1} X_{ij} = \sum_{i=1}^{n+1} \sum_{j=1}^{M+1} X_{ij} = \sum_{i=1}^{n+1} a_i = \sum_{j=1}^{M+1} b_j = A$$

Where A could be either the total available or total requirements, whichever is the bigger of the two. The system of equatinns (3.1) to (3.4) is a linear-programming problem with (M + 1) + (n + 1) equations in (M + 1) (n +1) variables.

Hence from the above literature the Transportation problem is a minimization problem, that can be solved by the use of any of the following methods when they are the most appropriate, simplex method , Stepping-Stone or Vogel Approximation method, or Modified Distribution Method. It therefore searches for the optimum quantities of units to ship from each factory (brewery) to each warehouse (depot) for a least cost solution.

In this project the simplex algorithm is useful, because of a wide range of depots involved, which makes the choices to be numerous so as to require the use of computer services.

A digital computer can be used whether it be in a batch or a real time processing made to arrive at a final solution. This is one of the reasons why the linear programming approach is widely used in the industry today.

CHAPTER IV

A THE APPLICATION OF A TRANSPORTATION MODEL TO THE CURRENT KENYA BREWERIES LTD. DISTRIBUTION SYSTEM

A.4.1 The Data:

As mentioned earlier, the data and information relevant to the transportation problem includes the sources of supply (the breweries) and the quantities of product available at each of the sources (a_i), the destinations (depots) and their respective demands or requirements (b_j), and the unit transportation costs (C_{ij}) from each source to each destination. All these data are available except the last one whereby the transportation rate was not obtainable. But this problem can be taken care of by the use of what we called Parametric programming. We shall treat our transportation rate to be a parameter called (C), then go ahead and derive the unit transportation costs.

A.4.1.a Sources of Supply and Quantities Available

The sources of supply are the three Breweries one in Nairobi (Ruaraka), Kisumu and the one in Mombasa. The Kisumu brewery is not yet complete and is expected to start operations in 1982. So we shall be concerned with the projected operations of all the above breweries by the year 1982. These three breweries and their capacities (a_{ij}) are shown in Appendix 1(A).

A.4.2.b Destinations and Their Capacities

The destinations in this project are the depots. These are the centres where the Kenya Breweries Ltd. vehicles offload their beers so that the agents can collect for distribution to various areas where they are consumed. The destinations are forty (40) in all and these and their requirements (b_js) can be seen in Appendix II (A).

A.4.1.c Unit Transportation Costs

This has been arrived at by multiplying the various distances between the breweries and the depots by the transportation rate per case per kilometre. This rate has not been available and instead we are using a parameter (C) for our purposes. In Appendix III (A) we see the various distances from breweries to depots in kilometres. In Appendix IV(A) we find the unit transportation costs that has been derived as stated above in Kenya Shillings. So that the figures we see in Appendix IV(A) shows the cost in Kenya Shillings of transporting one case of beer from a brewery to a depot.

So in order to find the best or optimal pattern of distribution of beer in order to satisfy the demands promptly and at minimum cost; we have to use the relevant data shown in Appendices I(A) to IV(A).

A.4.2 The Transportation Model and the Kenya Breweries Ltd. Distribution Problem

The transportation Model as already provided is a basic model, but may not exactly suit the situation and minor adjustments are usually expected before being applied.

The formulation of the problem can be read from Appendices V(A) and VI(B). The slack (Dummy) column in the destinations have been added because we found out that we had more beer available in the breweries stores than could be consumed. After this formulation then the next move is now to put down the objective function to be minimized and that is the total cost of transportation.

$$\text{Min. Total Cost} = \sum_{i=1}^{M+1} \sum_{j=1}^{n+1} C_{ij} X_{ij}$$

$$= \sum_{i=1}^{3} \sum_{j=1}^{41} C_{ij} X_{ij},$$

where C_{ij} is unit transportation cost and X_{ij} is the optimal quantity of units transported as explained earlier.

Subject to:

A. Brewery capacities constraints

$$\sum_{j=1}^{41} X_{ij} \leqq a_{ij}, \text{ for } i = 1,2, \text{ and } 3$$

B. Depot requirements constraints

$$\sum_{i=1}^{5} X_{ij} \geqq b_{ij}, \text{ for } j = 1,2,3\ldots, \text{ and } 41$$

C. Non Negativity Constraints

$$X_{ij} \geqslant 0$$

When solving our problem we can remove our parameter variable "C" from the objective function without affecting the optimal solution by dividing the objective equation by "C", which we can put back after obtaining the optimal plan by multiplying it with the final figure of cost.

THE FOLLOWING ARE REPRESENTATIONS OF QUANTITIES TO BE SHIPPED FROM THE THREE BREWERIES TO THE DEPOTS

Let X_{ij} represent that quantity shipped from Brewery i to depot j, where i = 1, ..., 3 and j = 01, ..., 41 i.e. X_{101} represent that quantity shipped from Brewery 1 (Ruaraka) to depot 01 (Kisii), See Appendix V(A) and VI(A).

All the quantities from Row 1 comes from Ruaraka, Row 2 comes from Mombasa and Row 3 from Kisumu brewery. All depots are numbered from 01 to 40. SL represent slacks for the brewery capacities.

The optimum solution must satisfy the column requirements which are equal conditions, and the row requirements, which are equal or less than conditions. With the addition of Slack Variables (SL) we have an equal to condition for the rows too.

4.3.A The Computer Linear Programming Package and its Use

4._.a. The Package

A package is usually a devise which takes in parameters and processes them following a particular pattern that has been established.

In the University of Nairobi Computer, an XDLA package that can be used for solving Linear Programming and Transportation problems is available. For full details consult ICL Reference Manuals 4147 - Linear Programming MK3 and 4288 - Linear Programming MK3., guide copies of which are readily available in the Institute of Computer Science Library, Chiromo.

4.3.b. Use of the Package

After the formulation of the problem has been completed as shown above then using the instructions given in the mentioned manuals we can start coding the information ready for punching. After coding the information on coding sheets then all that information will be punched on cards in the correct format. The punched cards are taken into the card reader which reads them for running in the computer package. All these were done and after some iterations which are not shown in this research paper the optimal solution was found, that can be read from the computer printout given here as Appendix VII(A) which will be explained later.

A.4.4. THE SOLUTION TO THE CURRENT KENYA BREWERIES DISTRIBUTION PLAN

After the application of the ICL Linear Programming package as explained above, the solution was found which is shown in pages 58 to 59 (Appendix VII (A)). On this computer printout we have five columns and one hundred and twenty four rows, representing the variables and the objective value.

The interpretation is done as follows, in the first column we find letter "B", which signifies that row contains the basic variable, that is to say the variable that appears in the optimal solution. Following that column down the first letter "B" appears in row 2, so that we know that variable X_{102} is a basic variable and it appears in the optimal solution. As explained earlier this variable denotes the amount of beer (in metric cases) that is shipped from brewery 1 (Ruaraka) to depot 2 (Nyeri). To summarise the interpretation I will give the meaning of each column. In column 1 if there is a letter B, then this shows that the variable is present in the optimal solution, and if there is nothing then it means that the variable is not present in the final solution. In column 2 we have the variables given in ascending order, their meaning was explained earlier, with the title name. In column 3 we have the value of the variables (in this case in units of metrix cases of beer except for the objective value which is the total cost of the optimal distribution plan). In column 4 entitled objective, we have the cost of transporting a case of beer from a brewery to a depot as the case may be. In column 5 we have the extra cost (i.e. the additional costs of transporting a case from a berwery to a depot) if we were to do so.

So that if we take the first non-basic variable in the first row, we do not have a letter B which indicates that the variable X_{101} is non-basic and will not appear in the optimal solution, and this is why we have figure zero in the 3rd column under the title value, the zero means no beers are shipped from brewery 1 (Ruaraka) to depot 1 (Kisii). If one unit was shipped then the cost would be K.Shs. 615C, made up of the normal cost of K.Shs. 364C plus an additional cost of K.Shs 251C so that by not shipping anything from Ruaraka to Kisii we are in effect saving K.Shs.251C per case. The rest of the non-basic variables will be interpreted in a similar manner.

Taking the first basic variable which is in row 2, in the first column we have letter B, which shows that it is in the optimal solution and in column 2, we find that the variable is X_{102}. Following that row we find that in column 3 under value column we have figure 75000, which is interpreted as the total amount of beer in metric cases shipped from Ruaraka to Nyeri at the cost of K.Shs. 155C per case, the figure shown in column 4 under the objective column. In the last column we have figure zero which means that there is no extra cost above the normal cost of K.Shs. 155C of transporting one case of beer between the two places. The same interpretation is applied to the rest as explained above. After interpreting the computer printout as it is given above then we draw up an optimal plan that is shwn in Appendix VIII(A). This summary which is presented in the form of a table shows all the breweries and all the depots. This gives the quantity of beer that is shipped from a brewery to a depot. So that each cell, say for example the first one, shows that no beer is shipped from Ruaraka to Kisii, because this would have been a less economical operation than the one given which shows that the most economical way of supplying Kisii depot is from Kisumu. Hence from this table we find that all the Kisii requirements is satisfied by the supply from

Kisumu brewery alone. Kisumu brewery supplies 40000 cases of beer to Kisii and this is the total demand of Kisii depot. The rest of the cells are interpreted in the same way.

Therefore Appendix VIII(A) shows the recommended distribution plan of Kenya Breweries in the form of a matrix which can be read very easily. It is possible to have two breweries supplying the same depot due to limited supply from the brewery that could supply at a cheaper cost, like in the case of Hola in our problem here, where 9000 cases is being supplied by Mombasa brewery and the other 1000 cases of the total requirement is being supplied by Ruaraka brewery at a higher cost per case. This is so because the Mombasa brewery supply has been exhausted so the next best alternative is to supply from Ruaraka. So the optimal solution is the best we can do under the given conditions prevailing at the time of planning.

In this optimal solution we find that most of the excess beer is in Kisumum brewery which amounts to 32000 cases, while in Ruaraka we have only 2000 cases and none in Mombasa brewery. In such a case when it comes to implementation the execution of the plan will rely on the management's judgement or alternatively a certain minimum safety stock could be established and incorporated into the plan, hence acting as another constraint. In our case we would have done so by setting the three variables concerned as given below: $X_{141} \geqslant X_1$, $X_{241} \geqslant X_2$, and $X_{341} \geqslant X_3$,
Where X_1 is the amount of beer that will at least remain in brewery 1 (Ruaraka), X_{141} is the variable which gives the amount of beer that remains in brewery 1, because depot 41 is interpreted to mean the same brewery and the others are interpreted in the same manner.

The distribution plan can be read very easily in Map 4, which shows the various routes that will be used according to the optimal plan. On this map we find the optimal plan will divide Kenya into three distribution zones, namely Western, Central and Eastern. The Western Zone will be supplied by Kisumu brewery, the Central Zone by Ruaraka and the Eastern Zone by Mombasa brewery. This demarcation of Kenya into Zones of distribution is applicable only under the current conditions otherwise when conditions are changed it might change a bit. But the point to note is that a depot will be supplied by a brewery that will do so at the most economical costs subject to the given constraints.

If we compare the old plan and the optimal plan we find that the new plan costs K.Shs. 13098600OC, while the old one would have costed an extra amount due to the extra cost that would have been incurred due to the shipment of (i) 15000 cases from Kisumu to Kipirash instead of shipping them from Ruaraka, (ii) shipment of 1000 cases from Mombasa to Hola, which would mean transporting them from Ruaraka to Mombasa first, before shipping to Hola due less capacity in Mombasa instead of shipping them directly from Ruaraka, (iii) shipment of 15000 cases from Mombasa to Voi instead of the direct shipment from Ruaraka then being brought back to Voi. So from these few instances we can rightly conclude that the present optimal plan will definitely cost less than the old system that was summarised in Map 2.

B. THE APPLICATION OF A TRANSPORTATION MODEL TO AN HYPOTHETICAL KENYA BREWERIES LTD. DISTRIBUTION SYSTEM

B.4.1 The Data

This is the same as given above in A.4.1, the differences will be shown below.

B.4.1.a. Sources of Supply and Quantities Available

The sources of supply are five for this hypothetical problem situated in Ruraka (Nairobi), Mombasa, Nakuru, Kisumu and Kitale. Look at Appendix 1(B), which shows the Breweries and their capacities (a_{is})

B.4.1.b. Destinations and Their Capacities

There are 40 depots, these can be seen in Appendix II(B) which shows the various depots and their requirements (b_{js}).

B.4.1.c. Unit Transportation Costs

This can be seen in Appendix III(B) and IV(B) which shows distances and unit transportation costs respectively. These have been arrived at as described in (A)4.1.c. above. Refer also to Appendix V(A).

From the above information we can now formulate the transportation problem in its standard form by the use of Table given in Appendix V(B).

B.4.2 <u>The Transportation Model and the Hypothetical Kenya Breweries Ltd. Distribution Problem</u>

The formulation of the whole transportation problem in its standard form has been demonstrated in (A) above and the same procedure is used in (B). Refer to (A) 4.2 for further explanations which are generally applicable in both situations.

As follows below is the formulated hypothetical problem of the Kenya Breweries distribution system.

First is the objective function which is a minimization problem:

$$\text{Minimize Total Cost}(Z) = \sum_{i=1}^{m+1} \sum_{j=1}^{n+1} C_{ij}X_{ij}$$

$$= \sum_{i=1}^{5} \sum_{j=1}^{41} C_{ij}X_{ij}$$

Where C_{ij} is unit transportation cost and X_{ij} is the optimal quantity of units transported from brewery i to depot j.

Subject to:

A. Brewery capacities constraints

$$\sum_{j=1}^{41} X_{ij} \leqq a_{ij}, \text{ for } i = 1, 2, 3, 4, \text{ and } 5$$

B. Depot requirements constraints

$$\sum_{i=1}^{5} X_{ij} \geqslant b_{ij}, \text{ for } j = 1, 2, 3, \ldots, 41$$

C. Non-Negativity constraints

$$X_{ij} \geqslant 0$$

Note: That the representations are just the same as those given above in problem (A), except for the addition of two other hypothetical breweries given as Nakuru and Kitale, numbered 4 and 5 respectively.

B.4.3 The Computer Linear Programming Package and Its Use

This was explained in (A) above and so reference could be made if need arises. The same procedure was done for the hypothetical problem hence the computer output is shown in Appendix VI(B).

B.4.4. The Solution to the Hypothetical Kenya Breweries Distribution Plan

After a simiilar application of ICL package as explained in (A) above, the solution was found which can be read on pages 70 to 74 (Appendix VI B), given in the form of a computer printout. Its format and interpretation is just done as explained in (A) above.

A summary of the computer printout is shown in Appendix VII B, which shows the various quantities shipped from one brewery to a depot and how all the depots and brewery constraints are satisfied.

In this particular optimal distribution plan we find very interesting recommendation such as other breweries supplying depots located nearer to other breweries, because this will be the cheapest way to distribute beer from breweries

THE HYPOTHETICAL KENYA BREWERIES TRANSPORTATION PROBLEM FORMULATED

THE OBJECTIVE FUNCTION

MINIMIZE TOTAL COST (Z) $= 364cX_{101} + 155cX_{102} + 87cX_{103} + 19cX_{104} + 139cX_{105} + 42cX_{106} + 200cX_{107} + 290cX_{108} + 334cX_{109} + 193cX_{110} + 266cX_{111}$
$+ 604X_{112} + 35$[illegible]$X_{113} + 13cX_{114} + 156cX_{115} + 402cX_{116} + 349cX_{117} + 312cX_{118} + 195cX_{119} + 160cX_{120} + 65cX_{121} + 84cX_{122} + 13cX_{123} + 14cX_{124} + 15cX_{125} +$
$27cX_{126} + 2$[illegible]$X_{127} + 51cX_{128} + 148cX_{129} + 12cX_{130} + 380cX_{131} + 116cX_{132} + 107cX_{133} + 497cX_{134} + 493cX_{135} + 492cX_{136} + 516cX_{137} + 543cX_{138} + 536cX_{139}$
$+ 826cX_{140} +$ [illegible] $+ 844cX_{201} + 640cX_{202} + 572cX_{203} + 504cX_{204} + 634cX_{205} + 527cX_{206} + 685cX_{207} + 775cX_{208} + 157cX_{209} + 583cX_{210} + 751cX_{211} + 119cX_{212}$
$+ 866cX_{213} + 455cX_{214} + 641cX_{215} + 887X_{216} + 834cX_{217} + 797cX_{218} + 433cX_{219} + 325cX_{220} + 455cX_{221} + 574cX_{222} + 472cX_{223} + 471cX_{224} + 470cX_{225} + 458cX_{226}$
$+ 511cX_{227} +$ [illegible]$cX_{228} + 633cX_{229} + 473cX_{230} + 468cX_{231} + 601cX_{232} + 535cX_{233} + 12cX_{234} + 8cX_{235} + 7cX_{236} + 31cX_{237} + 58cX_{238} + 317cX_{239} + 341cX_{240} + 0X_{241} +$
$113cX_{301} + 40$[illegible]$cX_{302} + 436cX_{303} + 330cX_{304} + 488cX_{305} + 391cX_{306} + 112cX_{307} + 502cX_{308} + 683cX_{309} + 315cX_{310} + 183cX_{311} + 953cX_{312} + 1$[illegible]$cX_{313} + 376cX_{314} + 117cX_{315}$
$+ 53cX_{216} + 5$[illegible]$cX_{317} + 158cX_{318} + 544cX_{319} + 509cX_{320} + 414cX_{321} + 260cX_{322} + 336cX_{323} + 335cX_{324} + 384cX_{325} + 376cX_{326} + 375cX_{327} + 400cX_{328} + 201cX_{329} +$
$337cX_{330} +$ [illegible] $+ 233cX_{332} + 456cX_{333} + 846cX_{334} + 842cX_{335} + 841cX_{336} + 865cX_{337} + 892cX_{338} + 880cX_{339} + 1175cX_{340} + 0X_{341} + 207cX_{401} + 276cX_{402} +$
$243cX_{403} +$ [illegible]$X_{404} + 295cX_{405} + 198cX_{406} + 219cX_{407} + 309cX_{408} + 490cX_{409} + 122cX_{410} + 110cX_{411} + 760cX_{412} + 225cX_{413} + 143cX_{414} + 4cX_{415} + 240cX_{416}$
$+ 198cX_{417} +$ [illegible]$cX_{418} + 351cX_{419} + 316cX_{420} + 22cX_{421} + 57cX_{422} + 143cX_{423} + 142cX_{424} + 141cX_{425} + 183cX_{426} + 182cX_{427} + 207cX_{428} + 73cX_{429} +$
$168cX_{430} + 53$[illegible]$X_{431} + 40cX_{432} + 263cX_{433} + 653cX_{434} + 649cX_{435} + 648cX_{436} + 672cX_{437} + 694cX_{438} + 687cX_{439} + 982cX_{440} + 0X_{441} + 316cX_{501} + 501cX_{502}$
$+ 468cX_{503} +$ [illegible]$X_{504} + 520cX_{505} + 423X_{506} + 444cX_{507} + 534cX_{508} + 715cX_{509} + 347cX_{510} + 233cX_{511} + 985cX_{512} + 3cX_{513} + 368cX_{514} + 222cX_{515} +$
$142cX_{516} + 195cX_{517} + 69cX_{518} + 915cX_{519} + 54$[illegible]$cX_{520} + 446cX_{521} + 292cX_{522} + 368cX_{523} + 267cX_{524} + 366cX_{525} + 408cX_{526} + 407cX_{527} + 432cX_{528} +$
$293cX_{529} + 369cX_{530} + 761cX_{531} + 265cX_{532} + 468cX_{533} + 876cX_{534} + 874cX_{535} + 873cX_{536} + 897cX_{537} + 924cX_{538} + 912cX_{539} + 1207cX_{540} + 0X_{541}$

SUBJECT TO THE FOLLOWING CONSTRAINTS

(A) BREWERY CAPACITIES, ROW CONSTRAINTS:

ROW 1: $X_{101} + X_{102} + X_{103} + X_{104} + X_{105} + X_{106} + X_{107} + X_{108} + X_{109} + X_{110} + X_{111} + X_{112} + X_{113} + X_{114} + X_{115} + X_{116} + X_{117} + X_{118} + X_{119} + X_{120} + X_{121} + X_{122} + X_{123}$
$+ X_{124} + X_{125} + X_{126} + X_{127} + X_{128} + X_{129} + X_{130} + X_{131} + X_{132} + X_{133} + X_{134} + X_{135} + X_{136} + X_{137} + X_{138} + X_{139} + X_{140} + X_{141} \leqq 1201000$

ROW 2: $X_{201} + X_{202} + X_{203} + X_{204} + X_{205} + X_{206} + X_{207} + X_{208} + X_{209} + X_{210} + X_{211} + X_{212} + X_{213} + X_{214} + X_{215} + X_{216} + X_{217} + X_{218} + X_{219} + X_{220} + X_{221} + X_{222}$
$+ X_{223} + X_{224} + X_{225} + X_{226} + X_{227} + X_{228} + X_{229} + X_{230} + X_{231} + X_{232} + X_{233} + X_{234} + X_{235} + X_{236} + X_{237} + X_{238} + X_{239} + X_{240} + X_{241} \leqq 161000$

ROW 3: $X_{301} + X_{302} + X_{303} + X_{304} + X_{305} + X_{306} + X_{307} + X_{308} + X_{309} + X_{310} + X_{311} + X_{312} + X_{313} + X_{314} + X_{315} + X_{316} + X_{317} + X_{318} + X_{319} + X_{320} + X_{321} + X_{322} + X_{323}$
$+ X_{324} + X_{325} + X_{326} + X_{327} + X_{328} + X_{329} + X_{330} + X_{331} + X_{332} + X_{333} + X_{334} + X_{335} + X_{336} + X_{337} + X_{338} + X_{339} + X_{340} + X_{341} \leqq 340000$

ROW 4: $X_{401} + X_{402} + X_{403} + X_{404} + X_{405} + X_{406} + X_{407} + X_{408} + X_{409} + X_{410} + X_{411} + X_{412} + X_{413} + X_{414} + X_{415} + X_{416} + X_{417} + X_{418} + X_{419} + X_{420} + X_{421} + X_{422} + X_{423} +$
$X_{424} + X_{425} + X_{426} + X_{427} + X_{428} + X_{429} + X_{430} + X_{431} + X_{432} + X_{433} + X_{434} + X_{435} + X_{436} + X_{437} + X_{438} + X_{439} + X_{440} + X_{441} \leqq 174000$

ROW 5: $X_{501} + X_{502} + X_{503} + X_{504} + X_{505} + X_{506} + X_{507} + X_{508} + X_{509} + X_{510} + X_{511} + X_{512} + X_{513} + X_{514} + X_{515} + X_{516} + X_{517} + X_{518} + X_{519} + X_{520} + X_{521} + X_{522} + X_{523} + X_{524}$
$+ X_{525} + X_{526} + X_{527} + X_{528} + X_{529} + X_{530} + X_{531} + X_{532} + X_{533} + X_{534} + X_{535} + X_{536} + X_{537} + X_{538} + X_{539} + X_{540} + X_{541} \leqq 124000$

(B) DEPOT REQUIREMENTS (DEMAND), COLUMN CONSTRAINTS:

COL 1. $X_{101} + X_{201} + X_{301} + X_{401} + X_{501} \geqq 48000$
2. $X_{102} + X_{202} + X_{302} + X_{402} + X_{502} \geqq 83000$
3. $X_{103} + X_{203} + X_{303} + X_{403} + X_{503} \geqq 107000$
4. $X_{104} + X_{204} + X_{304} + X_{404} + X_{504} \geqq 37000$
5. $X_{105} + X_{205} + X_{305} + X_{405} + X_{505} \geqq 48000$
6. $X_{106} + X_{206} + X_{306} + X_{406} + X_{506} \geqq 78000$
7. $X_{107} + X_{207} + X_{307} + X_{407} + X_{507} \geqq 24000$
8. $X_{108} + X_{208} + X_{308} + X_{408} + X_{508} \geqq 96000$
9. $X_{109} + X_{209} + X_{309} + X_{409} + X_{509} \geqq 21000$
10. $X_{110} + X_{210} + X_{310} + X_{410} + X_{510} \geqq 30000$
11. $X_{111} + X_{211} + X_{311} + X_{411} + X_{511} \geqq 44000$
12. $X_{112} + X_{212} + X_{312} + X_{412} + X_{512} \geqq 24000$
13. $X_{113} + X_{213} + X_{313} + X_{413} + X_{513} \geqq 40000$
14. $X_{114} + X_{214} + X_{314} + X_{414} + X_{514} \geqq 117000$
15. $X_{115} + X_{215} + X_{315} + X_{415} + X_{515} \geqq 72000$
16. $X_{116} + X_{216} + X_{316} + X_{416} + X_{516} \geqq 65000$
17. $X_{117} + X_{217} + X_{317} + X_{417} + X_{517} \geqq 116000$
18. $X_{118} + X_{218} + X_{318} + X_{418} + X_{518} \geqq 47000$
19. $X_{119} + X_{219} + X_{319} + X_{419} + X_{519} \geqq 25000$
20. $X_{120} + X_{220} + X_{320} + X_{420} + X_{520} \geqq 30000$
21. $X_{121} + X_{221} + X_{321} + X_{421} + X_{521} \geqq 36000$
22. $X_{122} + X_{222} + X_{322} + X_{422} + X_{522} \geqq 20000$
23. $X_{123} + X_{223} + X_{323} + X_{423} + X_{523} \geqq 178000$
24. $X_{124} + X_{224} + X_{324} + X_{424} + X_{524} \geqq 130000$
25. $X_{125} + X_{225} + X_{325} + X_{425} + X_{525} \geqq 81000$
26. $X_{126} + X_{226} + X_{326} + X_{426} + X_{526} \geqq 32000$
27. $X_{127} + X_{227} + X_{327} + X_{427} + X_{527} \geqq 28000$
28. $X_{128} + X_{228} + X_{328} + X_{428} + X_{528} \geqq 23000$
29. $X_{129} + X_{229} + X_{329} + X_{429} + X_{529} \geqq 22000$
30. $X_{130} + X_{230} + X_{330} + X_{430} + X_{530} \geqq 36000$
31. $X_{131} + X_{231} + X_{331} + X_{431} + X_{531} \geqq 11000$
32. $X_{132} + X_{232} + X_{332} + X_{432} + X_{532} \geqq 10000$
33. $X_{133} + X_{233} + X_{333} + X_{433} + X_{533} \geqq 8000$
34. $X_{134} + X_{234} + X_{334} + X_{434} + X_{534} \geqq 29000$
35. $X_{135} + X_{235} + X_{335} + X_{435} + X_{535} \geqq 40000$
36. $X_{136} + X_{236} + X_{336} + X_{436} + X_{536} \geqq 58000$
37. $X_{137} + X_{237} + X_{337} + X_{437} + X_{537} \geqq 29000$
38. $X_{138} + X_{238} + X_{338} + X_{438} + X_{538} \geqq 18000$
39. $X_{139} + X_{239} + X_{339} + X_{439} + X_{539} \geqq 19000$
40. $X_{140} + X_{240} + X_{340} + X_{440} + X_{540} \geqq 10000$
41. $X_{141} + X_{241} + X_{341} + X_{441} + X_{541} \geqq 30000$

(C) NON NEGATIVITY CONSTRAINT

$X_{101}, X_{102}, X_{103}, X_{104}, \ldots\ldots X_{541} \geqq 0$

to depots when we look at them in totality. That is when we control all the various breweries for the benefit of the whole organization. This sort of a thing is seen in such recommendations like supplying Nyali directly from Ruaraka and yet Nyali is situated very near to Mombasa brewery. The other examples are Kisumu brewery which supplies Nyahururu and Naivasha which are beyond Nakuru brewery and very far from Kisumu brewery itself. The same case applies to Nakuru brewery which supplies Meru depot which is beyond Ruaraka to the opposite side. And Kitale brewery which supplies Nakuru depot that is situated very near the Nakuru brewery.

All these funny recommendations and the one that was mentioned earlier that of the same depot being supplied by more than one brewery is possible due to the relationships between breweries capacities and the depots requirements.

Therefore without such an application of a transportation model to find the optimal plan we can never make such recommendations which can be seen here to be going to minimize costs hence maximizes the profits of the firm.

Again we could have incorporated safety stocks in our model so that we shall remain with some beer in the various breweries as explained in (A) above.

The hypothetical distribution plan has been summarized in Map 5, which is self explainatory and hence is easy to read and understand. In this case not like in problem A, we are not able to demarcate the various distribution zones because of the complexities of the distribution plan. However, we can see that the plan is a straight forward one and is clearly shown by the markings given.

In comparison with the old plan, a similar procedure could be shown as it was done in problem A, that will lead to showing that the optimal plan is really the cheaper of the two.

CHAPTER V

SUMMARY AND CONCLUSIONS

Subject to various limitations mentioned earlier, this study has been carried out successfully. I am happy to say that, despite the time pressure that I was subjected to, I have been able to complete the study as required by the MBA regulations and at the same time been able to satisfy all the objectives that were listed earlier in the introductory part of this research paper.

I have been able to carry out an investigation about the transportation system of the Kenya Breweries Ltd. and showed how a transportation model could be applied to give an optimal plan of the distribution system. Such a plan can make the whole management to function as one group, so that it enhances coordination and communication in the organization for better efficiency.

I have also shown how such operations research knowledge can be utilized in solving real world problems such as the one in question. This study has also shown that there is always room to improve the operational efficiency of any organization at all operational levels.

It is also my hope that the Breweries Management will take the study seriously and consider various ways of trying to implement it. This is because after the analysis of the problem and a plan of action has been drawn up, the next inevitable stage towards solving the problem is to implement the plan. This has been defined as the translation of the plan or results into detailed operating instructions geared at solving the problem at hand.

It is very important that those who will be executing the plan should thoroughly understand how it was arrived at, hence it is a necessity that proper and close communication should be maintained between the planners and the executors. In implementation of the optimal plan other administrative considerations will be brought in which might lead to small adjustments of the plan, so that we do not hold the plan to be rigid.

In addition, whereas this plan looks a permanent solution to the Kenya Breweries Ltd. distribution problem, the management should realise that it reflects what should be done only so long as the existing conditions holds otherwise better data can always be incorporated and a better plan arrived at, when the environment changes over time, since this world has got a dynamic environment.

Two optimal plans were arrived at, one was relevant to the current situation while the other one was an hypothetical problem. Which by holding other things constant and varying the demand and the number of breweries, tried to show how the optimal distribution plan could be affected. A study of a similar nature could be carried out to find the best locations of breweries and their capacities in future, so as to reap optimal benefits. Operations Research techniques such as the one at hand can be effectively utilized in carrying out such an analysis and managers of all types of industries should take serious approach to knowing these techniques and how best to apply them to improve the operations of their organizations.

The possible areas of application of Linear

Programming techniques in the Kenya Breweries Ltd are:

1. Production Scheduling - here the production capacities of the various breweries will be analysed in relation to the total demand and its future.

2. Breweries and Depots Siting - here an application of Linear Programming techniques can come up with optimal plans of the locations of the breweries and depots.

3. Capital Budgeting - here we find that the Kenya Breweries Ltd. is either acquiring new capital assets or expanding on the existing ones, in either way an application of Linear Programming techniques can give optimal solutions.

4. Policy Change - here we find that a future change in policy can effectively be arrived at by an application of LP techniques, this could be done in such areas like changing the mode of transport, say from roads to that of using railway lines. This could be possible if the breweries can carry out a research to find out the effect of building big or what I would call primary depots (which will feed the secondary depots) along the railway lines and at strategic positions that will minimize costs in the long run. This will be a realistic possiblity in future considering the fact that the cost of fuel and vehicles is continuing to rise every year. It will come to a time when using the present mode of transport will be uneconomical, when compared to some form of mixed modes such as the one suggested above. If such a plan or project could be done, then the Breweries will build these primary depots along the railway lines and then the Railway Corporation will also build what I will

call railway sidelines, whereby the trains carrying the beer wagons could pass through and drop the wagons before continuing on their journeys.

When coming back they pick the empties and carry them back to their sources. Although this will be a big investment initially, in the long run it can be found to be cheaper. From these primary depots the Breweries lorries can then pick the beers and transport to the secondary depots (final destinations).

Such a change of policy if researchers will find it to be cheaper, will help to solve the Government restrictions of road maximum load that cannot allow the Breweries to use bigger vehicles than what they are currently using and will reduce the number of vehicles required for their transportation.department.

5. <u>Vehicle Scheduling and Fleet Planning</u> - this is the next stage after getting an optimal distribution plan. Here you will equate the number of vehicles, their carrying capacities and the amounts to be shipped from various Breweries to various depots, so as to minimize cost, by using the smallest number of vehicles to meet the requirements at the lowest cost.

There could be other possible areas where Linear Programming techniques could be applied, because these techniques have proved to be applicable almost in all fields of management operations, and it should be noted that it is hard to mention all of them.

APPENDIX 1 (A)

MONTHLY BEER SUPPLY (IN METRIC CASES):
QUANTITY AVAILABLE FOR DISTRIBUTION

BREWERY	QUANTITY AVAILABLE
1. RUARAKA (NRB)	1201000
2. MOMBASA	161000
3. KISUMU	340000
TOTAL SUPPLY	1702000

APPENDIX II (A)

MONTHLY BEER DEMAND: IN METRIC CASES

THE DEPOT'S CAPACITIES PER MONTH

	DEPOT	CAPACITY		DEPOT	CAPACITY
1.	KISII	40000	21	MACHAKOS	30000
2.	NYERI	75000	22	NAIVASHA	15000
3.	MURANGA	100000	23	NARARASHI	170000
4.	KABETE	30000	24	RWATHIA	125000
5.	EMBU	40000	25	MWAMBA	75000
6.	THIKA	70000	26	MABOKO	25000
7.	NANYUKI	15000	27	NGONG	20000
8.	MERU	90000	28	MUKAMU	15000
9.	VOI	15000	29	KIPIRASH	15000
10.	NYAHURURU	22000	30	AFCO(EASTLEIGH)	30000
11.	KERICHO	33000	31	GARISA	4000
12.	MALINDI	15000	32	GILGIL	3000
13.	KITALE	25000	33	MAGADI	2000
14.	KIAMBU	110000	34	NYALI	22000
15.	NAKURU	65000	35	KIZINGO	33000
16.	KAKAMEGA	60000	36	MIJIKENDA	50000
17.	KISUMU	110000	37	KWALE	20000
18.	ELDORET	40000	38	KILIFI	10000
19.	KITUI	15000	39	HOLA	10000
20.	EMALI	22000	40	LAMU	2000

APPENDIX III (A)

DISTANCE IN KILOMETRES BETWEEN EACH BREWERY AND EACH DEPOT

DEPOT	BREWERY	RUARAKA(NRB.)	MOMBASA	KISUMU
1.	KISII	364	849	113
2.	NYERI	155	640	469
3.	MURANGA	87	572	436
4.	KABETE	19	504	330
5.	EMBU	139	624	488
6.	THIKA	42	527	391
7.	NANYUKI	200	685	412
8.	MERU	290	775	502
9.	VOI	334	151	683
10.	NYAHURURU	198	683	315
11.	KERICHO	266	751	83
12.	MALINDI	604	119	953
13.	KITALE	381	866	195
14.	KIAMBU	13	498	336
15.	NAKURU	156	641	197
16.	KAKAMEGA	402	887	53
17.	KISUMU	349	834	5
18.	ELDORET	312	797	158
19.	KITUI	195	433	544
20.	EMALI	160	325	509
21.	MACHAKOS	65	458	414
22.	NAIVASHA	89	574	260
23.	NARARASHI	13	472	336
24.	RWATHIA	14	471	335
25.	MWAMBA	15	470	334
26.	MABOKO	27	458	376
27.	NGONG	26	511	375
28.	MUKAMU	51	444	400
29.	KIPIRASH	148	633	201
30.	AFCO (EASTLEIGH)	12	473	337
31	GARISA	380	468	729
32.	GILGIL	116	601	233

APPENDIX III (A) (Continued)

DEPOT \ BREWERY		RUARAKA(NRB.)	MOMBASA	KISUMU
33.	MAGADI	107	538	456
34.	NYALI	497	12	846
35.	KIZINGO	493	8	842
36.	MIJI KENDA	492	7	841
37.	KWALE	516	31	865
38.	KILIFI	543	58	892
39.	HOLA	536	317	880
40.	LAMU	826	341	1175

APPENDIX IV (A)

COST IN K.SHS. OF TRANSPORTING ONE METRIC CASE OF BEER FROM EACH BREWERY TO EACH DEPOT (COST MATRIX)

DEPOT	BREWERY	RUARAKA(NRB.)	MOMBASA	KISUMU
1.	KISII	364C	849C	113C
2.	NYERI	155C	640C	469C
3.	MURANGA	87C	572C	436C
4.	KABETE	19C	504C	330C
5.	EMBU	139C	624C	488C
6.	THIKA	42C	527C	391C
7.	NANYUKI	200C	685C	412C
8.	MERU	290C	775C	502C
9.	VOI	334C	151C	683C
10.	NYAHURURU	198C	683C	315C
11.	KERICHO	266C	751C	83C
12.	MALINDI	604C	119C	953C
13.	KITALE	381C	866C	195C
14.	KIAMBU	13C	498C	336C
15.	NAKURU	156C	641C	197C
16.	KAKAMEGA	402C	887C	53C
17.	KISUMU	349C	834C	5C
18.	ELDORET	312C	797C	158C
19.	KITUI	195C	433C	544C
20.	EMALI	160C	325C	509C
21.	MACHAKOS	65C	458C	414C
22.	NAIVASHA	89C	574C	260C
23.	NARARASHI	13C	472C	336C
24.	RWATHIA	14C	471C	335C
25.	MWAMBA	15C	470C	334C
26.	MABOKO	27C	458C	376C
27.	NGONG	26C	511C	375C
28.	MUKAMU	51C	444C	400C
29.	KIPIRASH	148C	633C	201C
30.	AFCO(EASTLEIGH)	12C	473C	337C
31.	GARISA	380C	468C	729C

APPENDIX IV (A) Continued

DEPOT \ BREWERY		RUARAKA(NRB.)	MOMBASA	KISUMU
32.	GILGIL	116C	601C	233C
33.	MAGADI	107C	538C	456C
34.	NYALI	497C	12C	846C
35.	KIZINGO	493C	8C	842C
36.	MIJI KENDA	492C	7C	841C
37.	KWALE	516C	31C	865C
38.	KILIFI	543C	58C	892C
39.	HOLA	536C	317C	880C
40.	LAMU	826C	341C	1175C

APPENDIX V (A)

THE FOLLOWING ARE THE DEPOTS/BREWERIES AND THEIR SHORT NAMES

1. KISII - - KI	16. KAKAMEGA -KK	31. GARISA - GA
2. NYERI - NY	17. KISUMU(DP)-KS	32. GILGIL GI
3. MURANGA - MU	18. ELDORET EL	33. MAGADI - MG
4. KABETE - KA	19. KITUI -KU	34. NYALI - NL
5. EMBU - EM	20. EMALI -EA	35. KIZINGO- KZ
6. THIKA - TH	21. MACHAKOS -MC	36. MIJI KENDA - MI
7. NANYUKI - NA	22. NAIVASHA -NI	37. KWALE - KW
8. MERU - ME	23. NARARASHI -NR	38. KILIFI - KL
9. VOI - VO	24. RWATHIA -RW	39. HOLA - HO
10. NYAHURURU - NH	25. MWAMBA -MW	40. LAMU - LA
11. KERICHO - KO	26. MABOKO -MB	41. RUARAKA- RU
12. MALINDI - MA	27. NGONG -NG	42. MOMBASA - MO
13. KITALE - KT	28. MUKAMU -MK	43. SLACK - SL
14. KIAMBU - KM	29. KIPIRASH -KP	44. KISUMU(BR.)- KB
15. NAKURU - NK	30. AFCO (EASTLEIGH-AF	45. KITALE(BR.) KE
		46. NAKURU(BR.)- NU

APPENDIX VI (A)

THE CURRENT KENYA BREWERIES LTD TRANSPORTATION PROBLEM IN A TABLEAU

DEPOT / BREWERY	1 KI	2 NY	3 MU	4 KA	5 EM	6 TH	7 NA	8 ME	9 YO	10 NH	11 KO	12 MA	13 KT	14 KM	15 NK	16 KK	17 KS	18 EL	19 RU	20 EA	21 MC	22 NL	23 NR	24 RW
RU (ROW1)	364c X_{101}	155c X_{102}	87c X_{103}	14c X_{104}	139c X_{105}	42c X_{106}	200c X_{107}	290c X_{108}	334c X_{109}	198c X_{110}	266c X_{111}	604c X_{112}	381c X_{113}	13c X_{114}	156c X_{115}	402c X_{116}	349c X_{117}	312c X_{118}	195c X_{119}	160c X_{120}	65c X_{121}	89c X_{122}	13c X_{123}	14c X_{124}
MO (ROW2)	849c X_{201}	640c X_{202}	572c X_{203}	504c X_{204}	624c X_{205}	527c X_{206}	685c X_{207}	775c X_{208}	151c X_{209}	683c X_{210}	751c X_{211}	119c X_{212}	866c X_{213}	498c X_{214}	641c X_{215}	887c X_{216}	834c X_{217}	797c X_{218}	433c X_{219}	325c X_{220}	458c X_{221}	574c X_{222}	472c X_{223}	471c X_{224}
KB (ROW3)	113c X_{301}	409c X_{302}	436c X_{303}	330c X_{304}	488c X_{305}	341c X_{306}	412c X_{307}	502c X_{308}	683c X_{309}	315c X_{310}	83c X_{311}	953c X_{312}	195c X_{313}	336c X_{314}	197c X_{315}	53c X_{316}	5c X_{317}	156c X_{318}	544c X_{314}	509c X_{320}	414c X_{321}	260c X_{322}	336c X_{323}	335c X_{324}
DEPOT REQUIREMENTS (bj)	40000	75000	100000	30000	40000	70000	15000	90000	15000	22000	33000	15000	25000	110000	65000	60000	110000	40000	15000	22000	30000	15000	170000	125000

	25 MW	26 MB	27 NG	28 MK	29 KP	30 AF	31 GA	32 GI	33 MG	34 NL	35 KZ	36 MI	37 KW	38 KL	39 HO	40 LA	41 SL	BREWERY CAPACITY (ai).
	15c X_{125}	27c X_{126}	26c X_{127}	51c X_{128}	148c X_{129}	12c X_{130}	380c X_{131}	116c X_{132}	167c X_{133}	497c X_{134}	493c X_{135}	492c X_{136}	516c X_{137}	543c X_{138}	536c X_{139}	826c X_{140}	0 X_{141}	1201000
	470c X_{125}	458c X_{226}	511c X_{227}	444c X_{228}	633c X_{229}	473c X_{230}	468c X_{231}	601c X_{232}	538c X_{233}	12c X_{234}	8c X_{235}	7c X_{236}	31c X_{237}	58c X_{238}	317c X_{239}	341c X_{240}	0 X_{241}	161000
	334c X_{325}	376c X_{326}	375c X_{327}	400c X_{328}	201c X_{329}	337c X_{330}	729c X_{331}	233c X_{332}	456c X_{333}	846c X_{334}	842c X_{335}	841c X_{336}	865c X_{337}	892c X_{338}	880c X_{339}	1175c X_{340}	0 X_{341}	340000
	75000	25000	20000	15000	15000	30000	4000	3000	2000	22000	33000	50000	20000	10000	10000	2000	34000	1702000

APPENDIX VII (A)

PROBLEM ... MATRIX SOLUTION

DUMP/JUMP RIGHT HAND SIDE

OBJECTIVE COST

COLUMN INFORMATION

	NAME		VALUE	OBJECTIVE	REDUCED COST
	X101	*	0	504.0000	251.0000
B	X102	*	25000.0000	155.0000	0
B	X103	*	100000.0000	37.0000	0
B	X104	*	30000.0000	19.0000	0
B	X105	*	40000.0000	139.0000	0
B	X106	*	70000.0000	42.0000	0
B	X107	*	15000.0000	230.0000	0
B	X108	*	90000.0000	290.0000	0
B	X109	*	15000.0000	354.0000	0
B	X110	*	22000.0000	173.0000	0
	X111	*	0	265.0000	133.0000
	X112	*	0	604.0000	265.0000
	X113	*	0	381.0000	135.0000
B	X114	*	110000.0000	13.0000	0
B	X115	*	65000.0000	155.0000	0
	X116	*	0	402.0000	349.0000
	X117	*	0	547.0000	344.0000
	X118	*	0	312.0000	154.0000
B	X119	*	15000.0000	195.0000	0
B	X120	*	22000.0000	160.0000	0
B	X121	*	30000.0000	65.0000	0
B	X122	*	1000.0000	89.0000	0
B	X123	*	170000.0000	13.0000	0
B	X124	*	125000.0000	14.0000	0
B	X125	*	75000.0000	15.0000	0
B	X126	*	25000.0000	27.0000	0
B	X127	*	20000.0000	26.0000	0
B	X128	*	15000.0000	51.0000	0
B	X129	*	[illegible].0000	143.0000	0
B	X130	*	3000.0000	12.0000	0
B	X131	*	4000.0000	360.0000	0
B	X132	*	3000.0000	116.0000	0
B	X133	*	2000.0000	107.0000	0
	X134	*	0	497.0000	266.0000
	X135	*	0	493.0000	266.0000
	X136	*	0	492.0000	266.0000
	X137	*	0	516.0000	266.0000
	X138	*	0	543.0000	265.0000
B	X139	*	1000.0000	536.0000	0
	X140	*	0	636.0000	264.0000
B	X141	*	2000.0000	[illegible]	0
	X201	*	0	649.0000	763.0000
	X202	*	0	640.0000	704.0000
	X203	*	0	572.0000	704.0000
	X204	*	0	604.0000	704.0000
	X205	*	0	624.0000	704.0000
	X206	*	0	627.0000	704.0000
	X207	*	0	635.0000	704.0000
	X208	*	0	775.0000	704.0000
	X209	*	0	151.0000	[illegible].0000

PROBLEM — LP MATRIX — SOLUTION

DUMP: DUMP — RIGHT HAND SIDE R — OBJECTIVE COST

COLUMN INFORMATION

	NAME		VALUE	OBJECTIVE	REDUCED COST
	X211	+	0	683.0000	704.0000
	X_11	+	0	751.0000	637.0000
B	X212	+	15000.0000	114.0000	
	X213	+	0	683.0000	670.0000
	X214	+	0	478.0000	704.0000
	X215	+	0	641.0000	704.0000
	X216	+	0	687.0000	1095.0000
	X217	+	0	334.0000	1042.0000
	X218	+	0	797.0000	855.0000
	X219	+	0	433.0000	457.0000
	X220	+	0	329.0000	564.0000
	X221	+	0	653.0000	612.0000
	X222	+	0	574.0000	704.0000
	X223	+	0	472.0000	673.0000
	X224	+	0	471.0000	673.0000
	X225	+	0	479.0000	674.0000
	X226	+	0	498.0000	690.0000
	X227	+	0	511.0000	704.0000
	X228	+	0	444.0000	612.0000
	X229	+	0	633.0000	794.0000
	X230	+	0	473.0000	680.0000
	X231	+	0	468.0000	507.0000
	X232	+	0	601.0000	704.0000
	X233	+	0	538.0000	650.0000
B	X234	+	22000.0000	12.0000	
B	X235	+	35000.0000	8.0000	0
B	X236	+	50000.0000	7.0000	
B	X237	+	30000.0000	31.0000	
B	X238	+	15000.0000	58.0000	0
B	X239	+	9000.0000	317.0000	
B	X240	+	2000.0000	341.0000	0
	X241	+	0	0	219.0000
B	X301	+	45000.0000	113.0000	0
	X302	+	0	469.0000	314.0000
	X303	+	0	456.0000	349.0000
	X304	+	0	330.0000	311.0000
	X305	+	0	458.0000	347.0000
	X306	+	0	391.0000	347.0000
	X307	+	0	412.0000	212.0000
	X308	+	0	503.0000	212.0000
	X309	+	0	683.0000	349.0000
	X310	+	0	315.0000	117.0000
B	X311	+	35000.0000	33.0000	0
	X312	+	0	953.0000	613.0000
B	X313	+	25000.0000	195.0000	
	X314	+	0	336.0000	325.0000
	X315	+	0	197.0000	411.0000
B	X316	+	60000.0000	25.0000	
B	X317	+	110000.0000	9.0000	
B	X318	+	40000.0000	[illegible]	

PROBLEM LP MATRIX SOLUTION

DUMP: DUMP 4 RIGHT HAND SIDE R
OBJECTIVE COST

COLUMN INFORMATION

NAME		VALUE	OBJECTIVE	REDUCED COST
X319	+	0	544.0000	349.0000
X320	+	0	509.0000	349.0000
X321	+	0	414.0000	349.0000
X322	+	0	260.0000	171.0000
X323	+	0	338.0000	325.0000
X324	+	0	335.0000	321.0000
X325	+	0	334.0000	317.0000
X326	+	0	376.0000	349.0000
X327	+	0	375.0000	349.0000
X328	+	0	400.0000	349.0000
X329	+	0	201.0000	53.0000
X330	+	0	337.0000	325.0000
X331	+	0	729.0000	349.0000
X332	+	0	233.0000	117.0000
X333	+	0	436.0000	349.0000
X334	+	0	846.0000	615.0000
X335	+	0	842.0000	615.0000
X336	+	0	841.0000	615.0000
X337	+	0	839.0000	615.0000
X338	+	0	892.0000	615.0000
X339	+	0	880.0000	344.0000
X340	+	0	1175.0000	615.0000
B X341	+	52000.0000	0	0
OBJECTIVE		130985999.9999		

UNIVERSITY OF NAIROBI
Institute of Computer Science

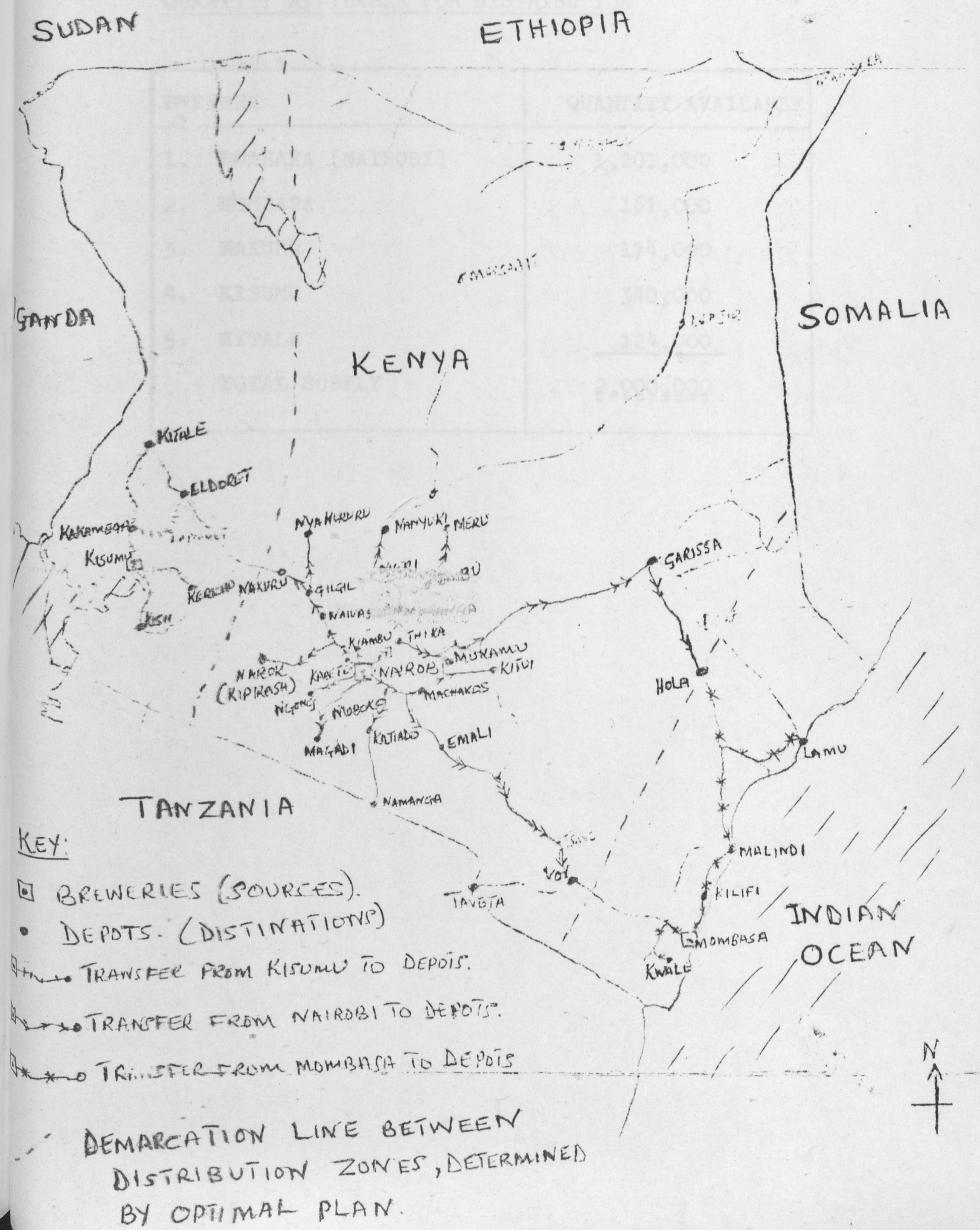
APPENDIX VIII (A)

MATRIX SUMMARY OF SOLUTION (RECOMMENDED DISTRIBUTION PLAN)

BREWERY/ DISTRIBUTION DEPOT	1 RUARAKA	2 MOMBASA	3 KISUMU	TOTAL SUPPLIED
1. Kisii			40000	40000
2. Nyeri	75000			75000
3. Muranga	100000			100000
4. Kabete	30000			30000
5. Embu	40000			40000
6. Thika	70000			70000
7. Nanyuki	15000			15000
8. Meru	90000			90000
9. Voi	15000			15000
10. Nyahururu	22000			22000
11. Kericho			33000	33000
12. Malindi		15000		15000
13. Kitale			25000	25000
14. Kiambu	110000			110000
15. Nakuru	65000			65000
16. Kakamega			60000	60000
17. Kisumu			110000	110000
18. Eldoret			40000	40000
19. Kitui	15000			15000
20. Emali	22000			22000
21. Machakos	30000			30000
22. Naivasha	15000			15000
23. Nararashi	170000			170000
24. Rwathia	125000			125000
25. Mwamba	75000			75000
26. Maboko	25000			25000
27. Ngong	20000			20000
28. Mukamu	15000			15000
29. AFCO (Eastleigh)	30000			30000
30. Kipirash	15000			15000
31. Garisa	4000			4000
32. Gilgil	3000			3000
33. Magadi	2000			2000
34. Nyali		22000		22000
35. Kizingo		33000		33000
36. Miji Kenda		50000		50000
37. Kwale		20000		20000
38. Kilifi		10000		10000
39. Hola → 2.	(1000)	9000		19000
40. Lamu		2000		2000
Excess Supply	2000		32000	34000
TOTAL PRODUCED	1201000	161000	340000	1702000

MAP 4

THE OPTIMAL CURRENT KENYA BREWERIES DISTRIBUTION PLAN



APPENDIX I (B)

MONTHLY BEER SUPPLY (IN METRIX CASES)

QUANTITY AVAILABLE FOR DISTRIBUTION

BREWERY	QUANTITY AVAILABLE
1. RUARAKA (NAIROBI)	1,201,000
2. MOMBASA	161,000
3. NAKURU	174,000
4. KISUMU	340,000
5. KITALE	124,000
TOTAL SUPPLY	2,000,000

APPENDIX II (B)

MONTHLY BEER DEMAND: (IN METRIX CASES)

THE DEPOT'S REQUIREMENT PER MONTH

DEPOT	REQUIREMENT	DEPOT	REQUIREMENT
1. KISII	48,000	21. MACHAKOS	36,000
2. NYERI	83,000	22. NAIVASHA	20,000
3. MURANGA	107,000	23. NARARASHI	178,000
4. KABETE	37,000	24. RWATHIA	130,000
5. EMBU	48,000	25. MWAMBA	81,000
6. THIKA	78,000	26. MABOKO	32,000
7. NANYUKI	24,000	27. NGONG	28,000
8. MERU	96,000	28. MUKAMU	23,000
9. VOI	21,000	29. KIPIRASH	22,000
10. NYAHURURU	30,000	30. AFCO(EASTLEIGH)	36,000
11. KERICHO	44,000	31. GARISA	11,000
12. MALINDI	24,000	32. GILGIL	10,000
13. KITALE	40,000	33. MAGADI	8,000
14. KIAMBU	117,000	34. NYALI	29,000
15. NAKURU	79,000	35. KIZINGO	40,000
16. KAKAMEGA	65,000	36. MIJI KENDA	58,000
17. KISUMU	116,000	37. KWALE	29,000
18. ELDORET	47,000	38. KILIFI	18,000
19. KITUI	27,000	39. HOLA	19,000
20. EMALI	30,000	40. LAMU	10,000

APPENDIX III (B)

DISTANCE IN KILOMETRES BETWEEN EACH BREWERY AND EACH DEPOT

DEPOT \ BREWERY	RUARAKA	MOMBASA	KISUMU	NAKURU	KITALE
1. KISII	364	849	113	208	316
2. NYERI	155	640	469	276	501
3. MURANGA	87	572	436	243	468
4. KABETE	19	504	330	137	362
5. EMBU	139	624	488	295	520
6. THIKA	42	527	391	198	423
7. NANYUKI	200	685	412	219	444
8. MERU	290	775	502	309	534
9. VOI	334	151	638	490	715
10. NYAHURURU	198	683	315	122	347
11. KERICHO	266	751	83	110	233
12. MALINDI	604	119	953	760	985
13. KITALE	381	866	195	225	3
14. KIAMBU	13	498	336	143	368
15. NAKURU	156	641	197	4	222
16. KAKAMEGA	402	887	53	240	142
17. KISUMU	349	834	5	198	195
18. ELDORET	312	797	158	156	69
19. KITUI	195	433	544	351	576
20. EMALI	160	325	509	316	541

APPENDIX III (B) Continued

BREWERY DEPOT	RUARAKA	MOMBASA	KISUMU	NAKURU	KITALE
21. MACHAKOS	65	458	414	221	446
22. NAIVASHA	89	574	260	67	292
23. NARARASHI	13	472	336	143	368
24. RWATHIA	14	471	335	142	367
25. MWAMBA	15	470	334	141	366
26. MABOKO	27	458	376	183	408
27. NGONG	26	511	375	182	407
28. MUKAMU	51	444	400	207	432
29. KIPIRASH	148	633	201	73	298
30. AFCO (EASTLEAIGH)	12	473	337	168	369
31. GARISA	380	468	729	536	761
32. GILGIL	116	601	233	40	265
33. MAGADI	107	538	456	263	488
34. NYALI	497	12	846	653	878
35. KIZINGO	493	8	842	649	874
36. MIJI KENDA	492	7	841	648	873
37. KWALE	516	31	865	672	897
38. KILIFI	543	58	892	699	924
39. HOLA	536	317	880	687	912
40. LAMU	826	341	1175	982	1207

APPENDIX IV (B)

COST MATRIX: COST IN K.SHS. OF TRANSPORTING ONE METRIC CASE OF BEER FROM EACH BREWERY TO EACH DEPOT

DEPOT \ BREWERY	RUARAKA	MOMBASA	KISUMU	NAKURU	KITALE
1. KISII	364C	849C	113C	208C	316C
2. NYERI	155C	640C	469C	276C	501C
3. MURANGA	87C	572C	436C	243C	468C
4. KABETE	19C	504C	330C	137C	362C
5. EMBU	139C	624C	488C	295C	520C
6. THIKA	42C	527C	391C	198C	423C
7. NANYUKI	200C	685C	412C	219C	444C
8. MERU	290C	775C	502C	309C	534C
9. VOI	334C	151C	683C	490C	715C
10. NYAHURURU	198C	683C	315C	122C	347C
11. KERICHO	266C	751C	83C	110C	233C
12. MALINDI	604C	119C	953C	760C	985C
13. KITALE	381C	866C	195C	225C	3C
14. KIAMBU	13C	498C	336C	143C	368C
15. NAKURU	156C	641C	197C	4C	222C
16. KAKAMEGA	402C	887C	53C	240C	142C
17. KISUMU	349C	834C	5C	198C	195C
18. ELDORET	312C	797C	158C	156C	69C
19. KITUE	195C	433C	544C	351C	576C
20. EMALI	160C	325C	509C	316C	541C
21. MACHAKOS	65C	458C	414C	221C	446C
22. NAIVASHA	89C	574C	260C	67C	292C
23. NARARASHI	13C	472C	336C	143C	368C
24. RWATHIA	14C	471C	335C	142C	367C
25. MWAMBA	15C	470C	334C	141C	366C
26. MABOKO	27C	458C	376C	183C	408C
27. NGONG	26C	511C	375C	182C	407C
28. MUKAMU	51C	444C	400C	207C	432C
29. KIPIRASH	148C	633C	201C	73C	298C
30. AFCO (EASTLEIGH)	12C	473C	337C	168C	369C
31. GARISA	380C	468C	729C	536C	711C
32. GILGIL	116C	601C	233C	40C	265C

APPENDIX IV (B) Continued

DEPOT \ BREWERY	RUARAKA	MOMBASA	KISUMU	NAKURU	KITALE
33. MAGADI	107C	538C	456C	263C	488C
34. NYALI	497C	12C	846C	653C	878C
35. KIZINGO	493C	8C	842C	649C	874C
36. MIJI KENDA	492C	7C	841C	648C	873C
37. KWALE	516C	31C	865C	672C	897C
38. KILIFI	543C	58C	892C	699C	924C
39. HOLA	536C	317C	880C	687C	912C
40. LAMU	826C	341C	1175C	982C	1207C

APPENDIX V (B)

THE HYPOTHETICAL KENYA BREWERIES LTD TRANSPORTATION PROBLEM IN A TABLEAU

DEPOT / BREWERY	1 KI	2 NY	3 MV	4 KA	5 EM	6 TH	7 NA	8 ME	9 VO	10 MH	11 KO	12 MA	13 KT	14 KM	15 NK	16 KK	17 KS	18 EL	19 KU	20 EA	21 MC	22 NI	23 NR	24 RW
RU (ROW 1)	364c X_{101}	155c X_{102}	87c X_{103}	19c X_{104}	139c X_{105}	42c X_{106}	200c X_{107}	290c X_{108}	334c X_{109}	148c X_{110}	266c X_{111}	604c X_{112}	381c X_{113}	13c X_{114}	156c X_{115}	402c X_{116}	349c X_{117}	312c X_{118}	195c X_{119}	160c X_{120}	65c X_{121}	89c X_{122}	13c X_{123}	14c X_{124}
MO (ROW 2)	849c X_{201}	640c X_{202}	572c X_{203}	504c X_{204}	624c X_{205}	527c X_{206}	685c X_{207}	775c X_{208}	151c X_{209}	683c X_{210}	751c X_{211}	1119c X_{212}	866c X_{213}	498c X_{214}	641c X_{215}	887c X_{216}	834c X_{217}	797c X_{218}	433c X_{219}	325c X_{220}	458c X_{221}	574c X_{222}	472c X_{223}	471c X_{224}
KB (ROW 3)	113c X_{301}	469c X_{302}	436c X_{303}	330c X_{304}	488c X_{305}	391c X_{306}	412c X_{307}	502c X_{308}	683c X_{309}	315c X_{310}	83c X_{311}	953c X_{312}	195c X_{313}	336c X_{314}	197c X_{315}	53c X_{316}	5c X_{317}	158c X_{318}	544c X_{319}	509c X_{320}	414c X_{321}	260c X_{322}	336c X_{323}	335c X_{324}
NU (ROW 4)	208c X_{401}	276c X_{402}	243c X_{403}	137c X_{404}	295c X_{405}	198c X_{406}	219c X_{407}	309c X_{408}	490c X_{409}	122c X_{410}	110c X_{411}	760c X_{412}	225c X_{413}	143c X_{414}	4c X_{415}	240c X_{416}	198c X_{417}	156c X_{418}	351c X_{419}	316c X_{420}	221c X_{421}	67c X_{422}	143c X_{423}	142c X_{424}
KE (ROW 5)	316c X_{501}	501c X_{502}	468c X_{503}	362c X_{504}	520c X_{505}	423c X_{506}	444c X_{507}	534c X_{508}	715c X_{509}	347c X_{510}	233c X_{511}	985c X_{512}	3c X_{513}	368c X_{514}	222c X_{515}	142c X_{516}	195c X_{517}	69c X_{518}	576c X_{519}	541c X_{520}	446c X_{521}	292c X_{522}	368c X_{523}	367c X_{524}
DEPOT REQUIREMENT (b_j)	48000	83000	107000	37000	48000	78000	24000	96000	21000	30000	44000	24000	40000	117000	72000	65000	116000	47000	25000	30000	36000	20000	178000	130000

CONTINUE	25 MN	26 MB	27 NG	28 MK	29 KP	30 AF	31 GA	32 GI	33 MG	34 NL	35 KZ	36 MI	37 KW	38 KL	39 HO	40 LA	41 SL	BREWERY CAPACITY (a_i)
	15c X_{125}	27c X_{126}	26c X_{127}	351c X_{128}	148c X_{129}	112c X_{130}	380c X_{131}	116c X_{132}	107c X_{133}	497c X_{134}	493c X_{135}	492c X_{136}	516c X_{137}	543c X_{138}	536c X_{139}	826c X_{140}	0 X_{141}	1201000
	470c X_{225}	458c X_{226}	511c X_{227}	444c X_{228}	633c X_{229}	473c X_{230}	468c X_{231}	601c X_{232}	538c X_{233}	12c X_{234}	8c X_{235}	7c X_{236}	31c X_{237}	55c X_{238}	317c X_{239}	341c X_{240}	0 X_{241}	161000
	334c X_{325}	376c X_{326}	375c X_{327}	400c X_{328}	201c X_{329}	337c X_{330}	729c X_{331}	233c X_{332}	456c X_{333}	846c X_{334}	842c X_{335}	841c X_{336}	865c X_{337}	892c X_{338}	880c X_{339}	1175c X_{340}	0 X_{341}	340000
	141c X_{425}	183c X_{426}	182c X_{427}	207c X_{428}	73c X_{429}	168c X_{430}	536c X_{431}	40c X_{432}	263c X_{433}	653c X_{434}	649c X_{435}	648c X_{436}	672c X_{437}	699c X_{438}	687c X_{439}	982c X_{440}	0 X_{441}	174000
	366c X_{525}	408c X_{526}	407c X_{527}	432c X_{528}	298c X_{529}	369c X_{530}	761c X_{531}	265c X_{532}	488c X_{533}	878c X_{534}	874c X_{535}	873c X_{536}	897c X_{537}	924c X_{538}	912c X_{539}	1207c X_{540}	0 X_{541}	124000
	81000	32000	28000	23000	22000	36000	11000	10000	8000	29000	40000	55000	29000	18000	19000	10000	30000	2000,000

OPTIMAL SOLUTION
DUMP= DUMP 5 OBJECTIVE= [illegible]

PROBLEM LP MATRIX SOLUTION

[illegible] RIGHT HAND SIDE R
OBJECTIVE COST

COLUMN INFORMATION

	NAME		VALUE	OBJECTIVE	REDUCED COST
	X101	+	0	364.0000	463.0000
B	X102	+	83000.[illegible]	155.0000	0
B	X103	+	107000.0000	87.0000	0
B	X104	+	[illegible]7000.0000	17.0000	0
B	X105	+	48000.0000	139.0000	0
B	X106	+	78000.0000	42.0000	0
B	X107	+	24000.0000	200.0000	0
B	X108	+	2000.0000	290.0000	0
B	X109	+	21000.0000	334.0000	0
	X110	+	0	176.0000	95.0000
	X111	+	0	266.0000	395.0000
	X112	+	0	604.0000	0
	X113	+	0	381.0000	615.00[illegible]
B	X114	+	117000.0000	13.0000	0
	X115	+	0	156.0000	171.0000
	X116	+	0	402.0000	[illegible]61.0000
	X117	+	0	349.0000	556.0000
	X118	+	0	312.0000	430.0000
B	X119	+	25000.0000	195.0000	0
B	X120	+	30000.0000	160.0000	0
B	X121	+	36000.0000	65.0000	0
	X122	+	0	69.0000	41.0000
B	X123	+	17[illegible]000.0000	13.0000	0
B	X124	+	1[illegible]0000.0000	14.0000	0
B	X125	+	81000.0000	15.0000	0
B	X126	+	[illegible]	27.0000	0
B	X127	+	[illegible]	26.0000	0
B	X128	+	[illegible]	31.0000	0
	X129	+	0	148.0000	139.0000
B	X130	+	36000.0000	12.0000	0
B	X131	+	11000.0000	380.0000	0
	X132	+	0	110.0000	75.0000
B	X133	+	8000.0000	107.0000	0
B	X134	+	29000.0000	497.0000	0
	X135	+	0	495.0000	0
	X136	+	0	492.0000	0
B	X137	+	10000.0000	516.0000	[illegible]
	X138	+	0	543.0000	0
B	X139	+	19000.0000	536.0000	0
	X140	+	0	826.0000	0
	X141	+	0	0	237.0000
	X201	+	0	849.0000	1433.0000
	X202	+	0	640.0000	970.0000
	X203	+	0	572.0000	970.0000
	X204	+	0	504.0000	970.0000
	X205	+	0	324.0000	970.0000
	X206	+	0	527.0000	970.0000
	X207	+	0	685.0000	970.0000
	X208	+	0	775.0000	970.0000
	X209	+	0	151.0000	302.0000

PROBLEM LP MATRIX SOLUTION

DUMP=DUMP 5 RIGHT HAND SIDE R

OBJECTIVE COST

COLUMN INFORMATION

NAME		VALUE	OBJECTIVE	REDUCED COST
X210	*	0	683.0000	1065.0000
X211	*	0	751.0000	1365.0000
B X212	*	24000.0000	119.0000	0
X213	*	0	866.0000	1585.0000
X214	*	0	498.0000	970.0000
X215	*	0	641.0000	1141.0000
X215A	*	0	887.0000	1531.0000
X217	*	0	834.0000	1526.0000
X218	*	0	797.0000	1450.0000
X219	*	0	453.0000	723.0000
X220	*	0	325.0000	650.0000
X221	*	0	463.0000	873.0000
X222	*	0	574.0000	1011.0000
X223	*	0	472.0000	944.0000
X224	*	0	471.0000	942.0000
X225	*	0	470.0000	940.0000
X226	*	0	458.0000	916.0000
X227	*	0	511.0000	970.0000
X228	*	0	444.0000	878.0000
X229	*	0	530.0000	1129.0000
X230	*	0	473.0000	946.0000
X231	*	0	468.0000	573.0000
X232	*	0	601.0000	1065.0000
X233	*	0	558.0000	916.0000
X234	*	0	12.0000	0
B X235	*	40000.0000	9.0000	0
B X236	*	58000.0000	7.0000	0
B X237	*	11900.0000	21.0000	0
B X238	*	13000.0000	58.0000	0
X239	*	0	517.0000	256.0000
B X240	*	13000.0000	341.0000	0
X241	*	0	0	722.0000
B X301	*	46000.0000	113.0000	0
X302	*	0	469.0000	102.0000
X303	*	0	436.0000	137.0000
X304	*	0	330.0000	79.0000
X305	*	0	480.0000	137.0000
X306	*	0	371.0000	137.0000
X307	*	0	412.0000	0
X308	*	0	502.0000	0
X309	*	0	683.0000	137.0000
B X310	*	[illegible]	315.0000	0
B X311	*	44000.0000	33.0000	[illegible]
X312	*	0	953.0000	137.0000
X313	*	0	195.0000	217.0000
X314	*	0	336.0000	111.0000
X315	*	0	197.0000	0
B X316	*	[illegible]	53.0000	0
B X317	*	11[illegible]000.0000	5.0000	0
X318	*	0	193.0000	114.0000

PROBLEM LP MATRIX SOLUTION

DUMP:DUMP 3 RIGHT HAND SIDE R

OBJECTIVE COST

COLUMN INFORMATION

	NAME		VALUE	OBJECTIVE	REDUCED COST
	X319	+	0	544.0000	137.0000
	X320	+	0	507.0000	137.0000
	X321	+	0	414.0000	137.0000
B	X322	+	30000.0000	260.0000	0
	X323	+	0	336.0000	111.0000
	X324	+	0	335.0000	109.0000
	X325	+	0	334.0000	107.0000
	X326	+	0	376.0000	137.0000
	X327	+	0	375.0000	137.0000
	X328	+	0	400.0000	137.0000
B	X329	+	22000.0000	201.0000	0
	X330	+	0	337.0000	113.0000
	X331	+	0	729.0000	137.0000
	X332	+	0	233.0000	0
	X333	+	0	456.0000	137.0000
	X334	+	0	646.0000	137.0000
	X335	+	0	842.0000	137.0000
	X336	+	0	341.0000	137.0000
	X337	+	0	865.0000	137.0000
	X338	+	0	692.0000	137.0000
	X339	+	0	880.0000	132.0000
	X340	+	0	1175.0000	137.0000
	X341	+	0	0	25.0000
	X401	+	0	203.0000	238.0000
	X402	+	0	276.0000	102.0000
	X403	+	0	243.0000	137.0000
	X404	+	0	137.0000	99.0000
	X405	+	0	295.0000	137.0000
	X406	+	0	193.0000	137.0000
	X407	+	0	219.0000	0
B	X408	+	74000.0000	309.0000	0
	X409	+	0	490.0000	137.0000
B	X410	+	5000.0000	122.0000	0
	X411	+	0	110.0000	220.0000
	X412	+	0	760.0000	137.0000
	X413	+	0	285.0000	440.0000
	X414	+	0	143.0000	111.0000
B	X415	+	38000.0000	4.0000	0
	X416	+	0	240.0000	380.0000
	X417	+	0	198.0000	336.0000
	X418	+	0	156.0000	305.0000
	X419	+	0	351.0000	137.0000
	X420	+	0	318.0000	137.0000
	X421	+	0	221.0000	137.0000
	X422	+	0	67.0000	0
	X423	+	0	143.0000	111.0000
	X424	+	0	142.0000	137.0000
	X425	+	0	141.0000	137.0000
	X426	+	0	[illegible]	137.0000
	X427	+	0	132.0000	137.0000

PROBLEM LP MATRIX SOLUTION

DUMP:DUMP 3

RIGHT HAND SIDE R
OBJECTIVE COST

COLUMN INFORMATION

	NAME		VALUE	OBJECTIVE	REDUCED COST
	X428	+	0	207.0000	137.0000
	X429	+	0	73.0000	65.0000
	X430	+	0	168.0000	137.0000
	X431	+	0	536.0000	137.0000
B	X432	+	10000.0000	40.0000	0
	X433	+	0	253.0000	137.0000
	X434	+	0	653.0000	137.0000
	X435	+	0	649.0000	137.0000
	X436	+	0	648.0000	137.0000
	X437	+	0	672.0000	137.0000
	X438	+	0	699.0000	137.0000
	X439	+	0	657.0000	132.0000
	X440	+	0	962.0000	137.0000
	X441	+	0	0	215.0000
	X501	+	0	316.0000	176.0000
	X502	+	0	501.0000	139.0000
	X503	+	0	468.0000	144.0000
	X504	+	0	362.0000	106.0000
	X505	+	0	520.0000	144.0000
	X506	+	0	425.0000	144.0000
	X507	+	0	444.0000	7.0000
	X508	+	0	534.0000	7.0000
	X509	+	0	715.0000	144.0000
	X510	+	0	547.0000	7.0000
	X511	+	0	233.0000	125.0000
	X512	+	0	935.0000	144.0000
	X513	+	40000.0000	3.0000	0
	X514	+	0	368.0000	118.0000
	X515	+	7000.0000	222.0000	0
	X516	+	0	142.0000	64.0000
	X517	+	0	195.0000	165.0000
	X518	+	47000.0000	57.0000	0
	X519	+	0	576.0000	144.0000
	X520	+	0	541.0000	144.0000
	X521	+	0	446.0000	144.0000
	X522	+	0	272.0000	7.0000
	X523	+	0	368.0000	118.0000
	X524	+	0	367.0000	116.0000
	X525	+	0	366.0000	114.0000
	X526	+	0	400.0000	144.0000
	X527	+	0	407.0000	144.0000
	X528	+	0	432.0000	144.0000
	X529	+	0	278.0000	72.0000
	X530	+	0	369.0000	120.0000
	X531	+	0	751.0000	144.0000
	X532	+	0	255.0000	7.0000
	X533	+	0	455.0000	144.0000
	X534	+	0	873.0000	144.0000
	X535	+	0	874.0000	144.0000
	X536	+	0	875.0000	144.0000

UNIVERSITY OF NA

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LP MATRIX
                                   SOLUTION
MP:DUMP
                                   RIGHT HAND SIDE  R
                                   OBJECTIVE        COST
UMN INFORMATION

NAME                VALUE          OBJECTIVE      REDUCED COST
537        *                0       897.0000        144.0000
538        *                0       924.0000        144.0000
539        *                0       912.0000        139.0000
540        *                0      1227.0000        144.0000
541        *    3000[illegible].0000            0               0
ECTIVE       1[illegible]45000[illegible].0000
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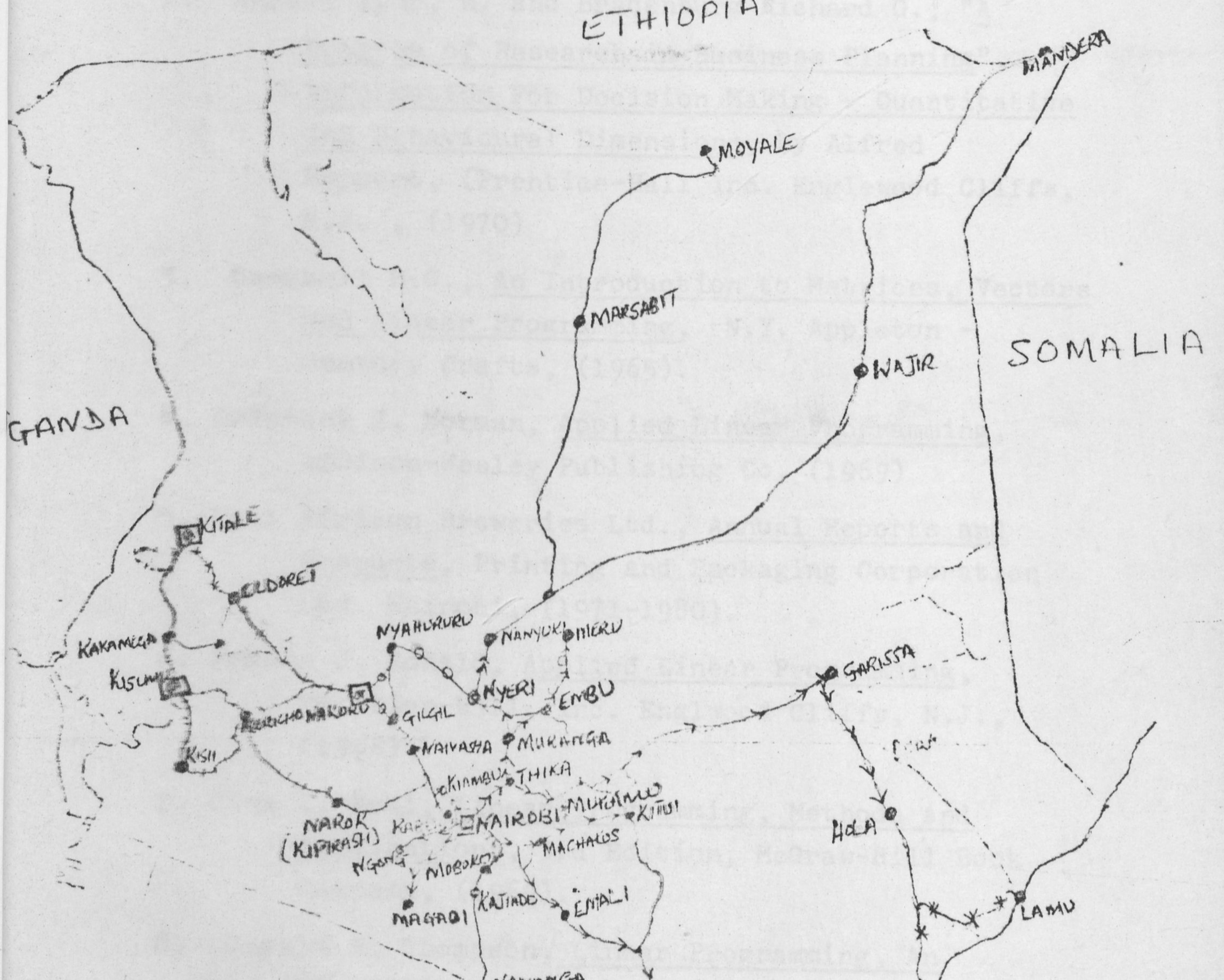
APPENDIX VII (B)

MATRIX SUMMARY OF SOLUTION (RECOMMENDED DISTRIBUTION PLAN)

Brewery/ Distribution Depot	1 uaraka	2 Mombasa	3 Kisumu	4 Nakuru	5 Kitale	Total (Demand) Supplied
1. Kisii			48000			48000
2. Nyeri	83000					83000
3. Muranga	107000					107000
4. Kabete	37000					37000
5. Embu	48000					48000
6. Thika	78000					78000
7. Nanyuki	24000					24000
8. Meru	2000			94000		96000
9. Voi	21000					21000
10. Nyahururu			25000	5000		30000
11. Kericho			44000			44000
12. Malindi		24000				24000
13. Kitale					40000	40000
14. Kiambu	117000					117000
15. Nakuru				65000	7000	72000
16. Kakamega			65000			65000
17. Kisumu			116000			116000
18. Eldoret					47000	47000
19. Kitui	25000					25000
20. Emali	30000					30000
21. Machakos	36000					36000
22. Naivasha			20000			20000
23. Nararashi	178000					178000
24. Rwathia	130000					130000
25. Mwamba	81000					81000
26. Maboko	32000					32000
27. Ngong	28000					28000
28. Mukamu	23000					23000
29. Kipirash			22000			22000
30. AFCO (Eastleigh)	36000					36000
31. Garisa	11000					11000
32. Gilgil				10000		10000
33. Magadi	8000					8000
34. Nyali	29000					29000
35. Kizingo		40000				40000
36. Mjji Kenda		58000				58000
37. Kwale	18000	11000				29000
38. Kilifi		18000				18000
39. Hola	19000					19000
40. Lamu		10000				10000
Excess Supply					30000	30000
Total Produced	1201000	161000	340000	174000	124000	2000000

MAP 5

THE OPTIMAL HYPOTHETICAL KENYA BREWERIES DISTRIBUTION PLAN



KEY:

⊡ BREWERIES (SOURCES)

• DEPOTS (DISTINATIONS)

⊡+—+—• TRANSFER FROM KISUMU TO DEPOTS

⊡o—o—• TRANSFER FROM NAKURU TO DEPOTS

⊡→—→—• TRANSFER FROM NAIROBI TO DEPOTS

⊡×—×—• TRANSFER FROM KITALE TO DEPOTS

⊡*—*—• TRANSFER FROM MOMBASA TO DEPOTS.

Note: Depots, Nevarashi, Rusathia and Musamba are in Nairobi
Depots, Nyali, Kizingo and Miji Kenda are in Mombasa

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