SCHEDULING AND CONTROL OF TRANSPORT, LABOUR FORCE AND MATERIAL IN NAIROBI CITY COUNCIL'S WATER DEPARTMENT

VEENA R. GUPTA

"A thesis submitted in part fulfilment for the degree of Master's in Business Administration in the University of Nairobi."

April 1981

This thesis is my original work and has not been presented for a degree in any other University.

This thesis has been submitted for examination with my approval as University Supervisor.

TABLE OF CONTENTS

FIGURES AND TABLES

A B S T R A C T

This study concentrates on the repair and maintenance work performed by the Operations and Maintenance Section of Nairobi City Council's Water and Sewerage Department. The research shows that the present system is operating inefficiently and it also highlights the inefficient areas. Recommendations are made for improvements, especially in the communications system and in the scheduling and control of transport, labour and material.

A C K N O W L E D G E M E N T

I am extremely grateful for the help I have received from Mr. C. Hurst, the Chief Assistant Engineer (Operations and Maintenance) at the time of the study, and Dr. D. Kohler, my supervisor who conceived the project and who guided me through all stages of it. His good advice, constructive criticism and guidance were of great help to me. I would also like to thank Professor Chandra Das for so willingly supervising my work while Dr. Kohler was on leave.

My special thanks go to Mr. Moche, the General Manager of the Water and Sewerage Department for granting me permission to do the research. Without his permission this thesis would never have been possible.

I am very grateful to Mr. James Wagura who assisted me very generously in my field work. I would also like to extend my gratitude to the entire staff of the Operations and Maintenance Section for their constant willingness to help me in all possible ways. Everyone was very friendly and co-operative especially Mr. A. Diosi, Mr. C. Mbici, Mr. F.N. Bennetts, Mr. J.S. Flora, Mr. E.G. Gitei, and Mr. John Apat.

In the end I would like to thank Mrs. M. Shehe for typing my thesis.

CHAPTER 1

INTRODUCTION

This study was conducted at the Water and Sewerage Department of Nairobi City Council, specifically the Operations and Maintenance Section at the Kampala Road Depot. The study was requested by the Chief Assistant Engineer, of the Operations and Maintenance Section, Mr. Charles Hurst, who thought that the existing system was not operating efficiently. My supervisor, Dr. David Kohler approved of the idea and then permission to carry out the research was granted by the Nairobi City Council.

It is the job of the Operations and Maintenance Section to find sources of water, get water from those sources, treat it (or purify it) and then distribute it among the people of Nairobi through a well maintained distribution system.

Faults such as leaks, burst mains, blocked meters and so on - occur in Nairobi City Council's water supply system, and the responsibility for repairing them lies with the Operations and Maintenance Section. To carry out these repair functions there is a large labour force, considerable supplies and a number of vehicles with radio communication. Even with all these available facilities the section is operating inefficiently; many complaints remain unattended and there is a lot of delay and wastage of both time and money.

The purpose of this study was to find where these inefficiencies lie and why. Then I was to suggest ways of improving the inefficiencies of this Section particularly in its use of transport, labour and material, and of making better use of its communication system.

This research was carried out in a number of steps and is described in the thesis in the following manner.

After the introduction the second chapter of the thesis describes the historical background of the Nairobi City Council and its Water Department. This chapter shows us how Nairobi and its Water Department came into existence and the various developments that took place thereafter.

The third chapter consists of an account of the present organization of the whole section, giving details of the functions and problems of each subsection.

Chapter four reviews some literature related to the thesis topic. The literature is concentrated on vehicle scheduling problems and methods.

The following chapter is a detailed account of the methodology used to collect the necessary data for the study.

The next chapter, chapter six then analyses and intepprets the data collected in the previous chapter.

And finally the last chapter of the thesis gives a description of the various recommendations made to improve the present system. It also gives the amount of improvement the recommendations are likely to make. Lastly some suggestions are made for further research.

CHAPTER 2

HISTORICAL BACKGROUND

2.1 BIRTH OF NAIROBI AND THE CITY COUNCIL

The birth of Nairobi coincided with the building of a railways headquarters between Uganda and Mombasa. Originally Nairobi was a Masai land known to the Masai as "Nakusontelon" meaning "the beginning of all beauty". "Nakusontelon" was bisected by a small stream which the Masai called Uaso Nairobi "a place of cold water", and it was that name which most people preferred to use. The Uaso Nairobi came to be known later as the Nairobi River and the place as Nairobi. At the time the railway arrived, Nairobi was no more than a bleak swampy stretch of landscape, devoid of human habitation of any sort, the resort of thousands of wild animals of various species.

Nairobi was chosen as the site of the railway's main depot between Mombasa and Lake Victoria for two reasons: there was adequate water available there and it was the last stretch of level ground before reaching the Rift Valley. Before the end of 1899 Nairobi not only became the staging place for the railway but also for hunters, traders and settlers. Soon after, in 1901, the headquarters of the British East African Protectorate were moved from Machakos to Nairobi, and this had the effect of further swelling its population.

The regulations of the Nairobi Municipal Committee were published on the 16th April 1900, and it officially commenced operation in 1901. The Nairobi Municipality Regulations defined the township of Nairobi as "the area comprised within a radius of one-mile-and-a half of the railway station". The city boundaries were extended in 1928, then again in 1963, and a further extension is projected in the future, as shown in Figure 1.

2.2 THE NAIROBI WATER WORKS

In the early nineteen hundreds the railway authorities discovered the first water supply, the Nairobi River, and obtained water by means of two concrete dams and two pipe-lines. But this water proved to be of poor quality and supply. The railway authorities then built a large and deep reservoir with sufficient capacity to provide over a million gallons per day and laid a pipe line to convey the water into service tanks which distributed the supply in the township area.

The railway authorities supplied water to Nairobi township via various stand-pipes which they erected. This turned out to be a very profitable investment, a nominal rate of five rupees (equal to approximately 6 shillings) per month being charged for each stand pipe. The railway continued to own and control Nairobi's main water supply until 1921 when they sold these interests to the Nairobi Town Council for a sum of £20,000, payable with interest in twenty annual instalments of £1,743. For the first five years the Railway was supplied with water for all purposes free of charge, and at cost price after that period. There was also an obligation on the Council to supply water at equitable terms to government departments when required to do so. By 1921 the water supply was insufficient to meet demand and so the Council opened additional springs at Kikuyu which cost them £2,300. The Council also purchased a private water scheme - the Muthaiga Estate supply - which cost them a further £6,500 in 1923.

Figure 1

CHANGES IN THE NAIROBI CITY BOUNDARY

Nairobi Dam was completed in 1946 and by 1950 it was providing ¼ million gallons of water daily to Nairobi for consumption. Work on the Ruiru Dam had been going on, when on November 1946 it was decided to raise the height of that dam to increase the safety margin in future dry seasons. By 1950 Ruiru Dam was completed.

In the mid 1940's there were two schools of thought on Nairobi's water problems. Nairobi's future water supply could either be brought from a great distance or pumped from a great depth: dams or deep wells was the issue. Some were in favour of sinking large boreholes in the municipal area. However, when the preliminary gauging of the Chania River was completed in October 1946 everything else was subordinated to the Chania Scheme and early in 1947 it was adopted as the long term solution. The other dam sites were abandonned and the idea of deep well-boring was dropped.

Around 1948 the plans for the Chania-Sasumua Scheme were completed. The dam to be constructed would hold 1,000,000,000 gallons of storm flows from the Chania and Sasumua Rivers; the water would be piped forty miles to Nairobi and the scheme, which would cost approximately £750,000, would augment Nairobi's water supply by four million gallons daily when completed in 1952. This is what was scheduled at that time but in fact the Chania-Sasumua Scheme was completed four years later in 1956.

In 1955 the City obtained supplies from Kikuyu Springs, Nairobi Dam, and Ruiru Dam. At that time, storage and purification took place at Kabete and at Hill Tank. Once the Chania-Sasumua Scheme was completed in 1956, the water supply was also obtained from the Sasumua Dam. Then purification of water took place at the Sasumua Dam and Kabete, and this treated water was then stored at Kabete and Hill Tank. Nairobi Dam was closed sometime after 1961. The Nairobi City Council's water supplies by 1970 are shown in Figure 2.

A number of developments took place after 1970, as can be seen from the diagramatic layout of Nairobi Water Works in Figure 3. The Middle Chania Water Supply Phase I started operating in 1974. From here water is taken to a reservoir in Gigiri by a 36 kilometer pipe. Kampala Road Depot was built in 1974 and was responsible for all the operations and maintenance of the Nairobi Water Works. By 1976, the Middle Chania Water Supply Scheme Phase I, the Chania Water Supply Phase I Distribution, and the Chania Water Supply Phase III Distribution were operating.

2.3 WATER AND SEWERAGE DEPARTMENT AS AN ORGANIZATION

The Water and Sewerage Department became a Department of the Nairobi City Council in 1970. Before that, part of it was under the City Engineer's Department and a part under the City Treasurer's Department. The Water and Sewerage Department was set up on 1st April 1970 as a result of successful negotiations between the International Bank for Reconstruction and Development (World Bank) and the City Council of Nairobi. By setting up this department all the engineering, financial and administrative activities concerning water and sewerage were brought under one management, for convenience and efficiency. The responsibilities of this department were to

(i) plan its future expansion;

(ii) plan and manage its operations and affairs;

City Council of Nairobi – Water Supplies IN 1970

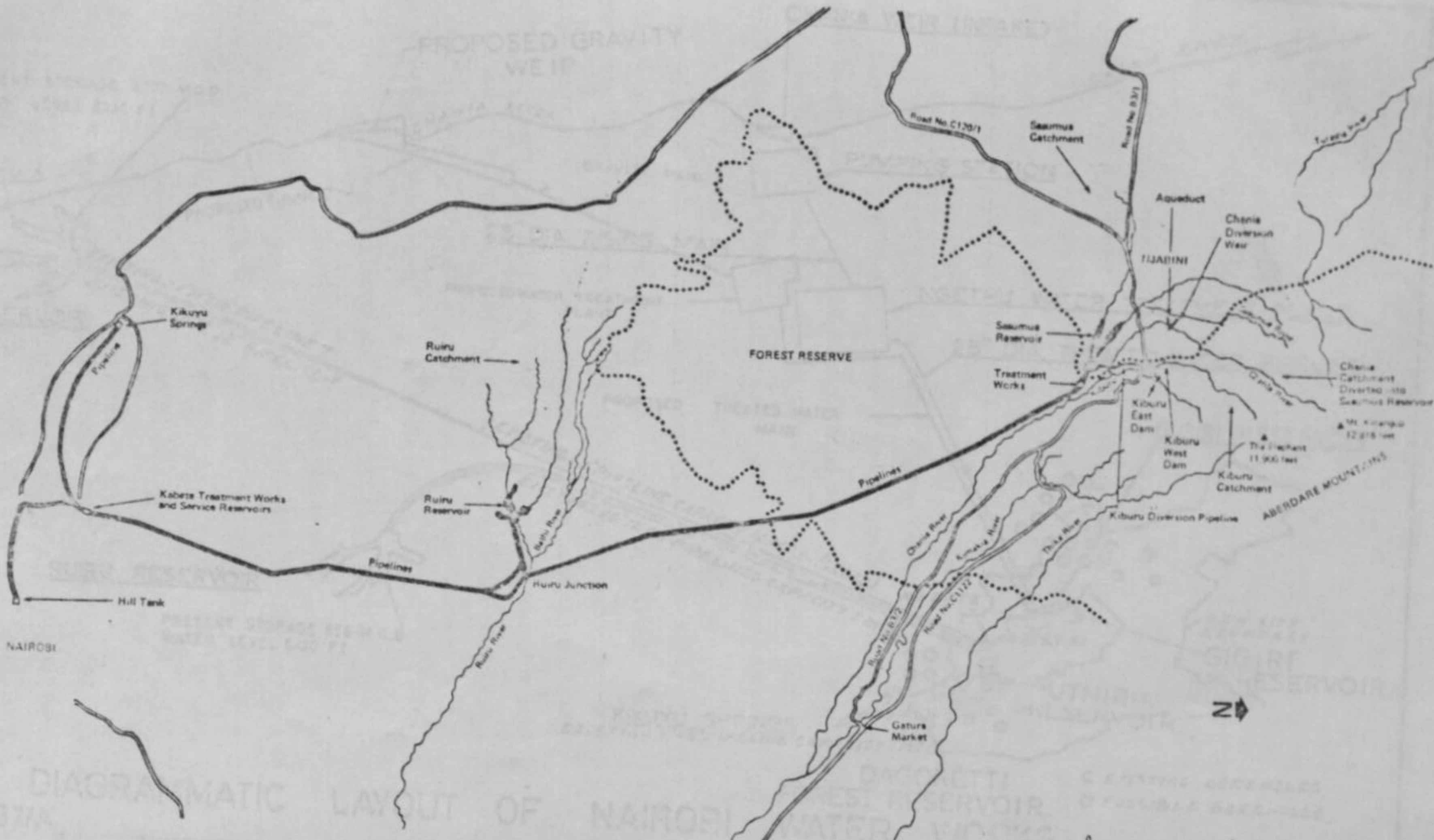
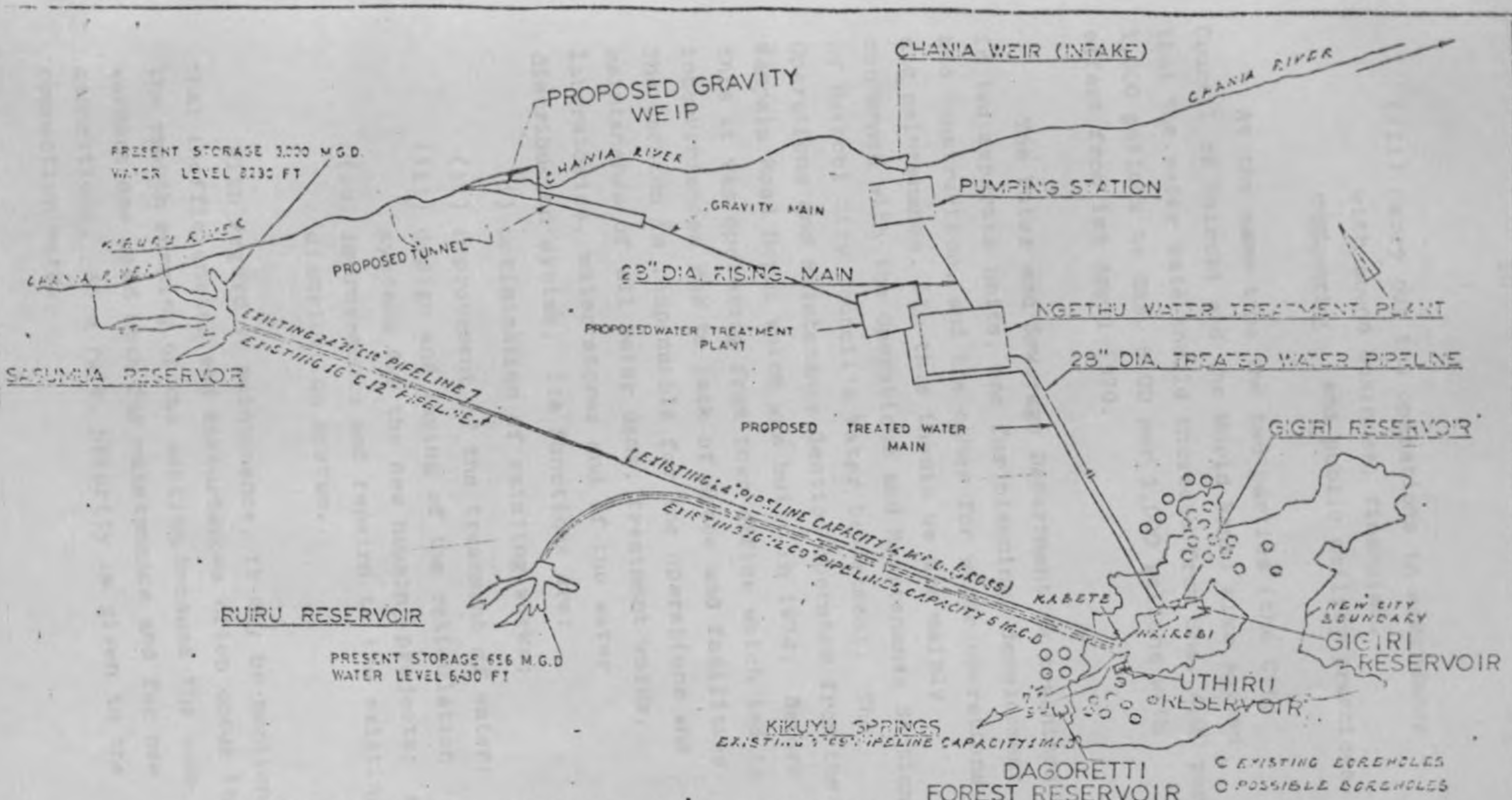


Figure 3



DIAGRAMMATIC LAYOUT OF NAIROBI WATER WORKS

DG. NO. W/1357/A

(iii) carry out its operations in accordance with sound business, financial, engineering and public utility practices.

At the same time the two parties (the City Council of Nairobi and the World Bank) also agreed that the water rate should increase from Shs. 4.00 per 1,000 gallons to Shs. 5.00 per 1,000 gallons with effect from 1st April 1970.

The Water and Sewerage Department is organized in two separate units, one for planning, development and construction, and the other for water operations and maintenance. In this thesis we are mainly concerned with the Operations and Maintenance Section of Nairobi City Council's Water Department. The Operations and Maintenance Section operates from the Kampala Road Depot which was built in 1974. Before this it was operating from town office which led to inconveniences due to lack of space and facilities. The section is responsible for the operations and maintenance of all water dams, treatment works, laboratories, water stores and of the water distribution system. Its functions are:

(i) optimization of existing works;

(ii) improvement of the treatment of water;

(iii) design and laying of the reticulation systems for the new housing projects; and

(iv) improvements and repairs to the existing distribution system.

With regard to maintenance, it may be mentioned that inefficiencies and disturbances often occur in the smooth running of the section because the same workers are used both for maintenance and for new connections. As a rule, priority is given to the connection work.

Until 1973 40,000 water meters had been connected. Meters were connected on a rent basis from 1969. The income from water increased steadily over the years 1970-1972:

	1970	1971	1972
Revenue	£1,137,000	1,303,000	1,748,000
Less Expenses	£ 395,000	415,000	478,000
Net Revenue	£ 742,000	888,000	1,270,000

Despite these developments in the Nairobi Water Works and its organization it is becoming increasingly difficult to meet the City's increasing demand for water. Figure 4 shows the increase in population and Figure 5 shows the corresponding increase in water consumption over the years from 1950-1980.

The population of Nairobi went up almost 7 times from 1950 to 1980. This increase in population arose because of various factors (migration, births, expansion, etc.). The demand for water went up 12.3 fold in the same period and the City Council of Nairobi was hard pressed to cope with this rising demand.

Looking at the financial side of the Water Department, it has always shown positive net revenue over the years. Due to the high rise in various costs of water supply the water charges also rose at a considerable rate. The Nairobi City Council's water charges , it's overall expenses, revenue and surplus over the years are shown in Table 1.

Figure 4

GROWING POPULATION OF NAIROBI

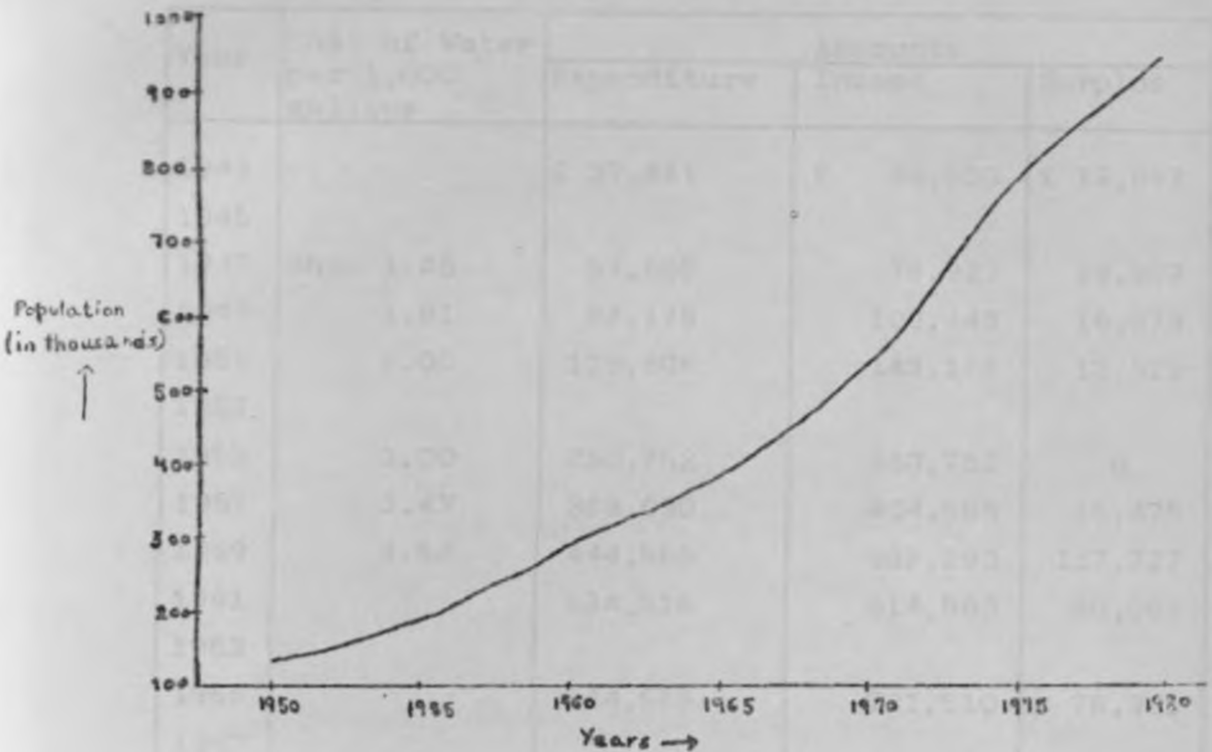


Figure 5

DAILY WATER DEMAND

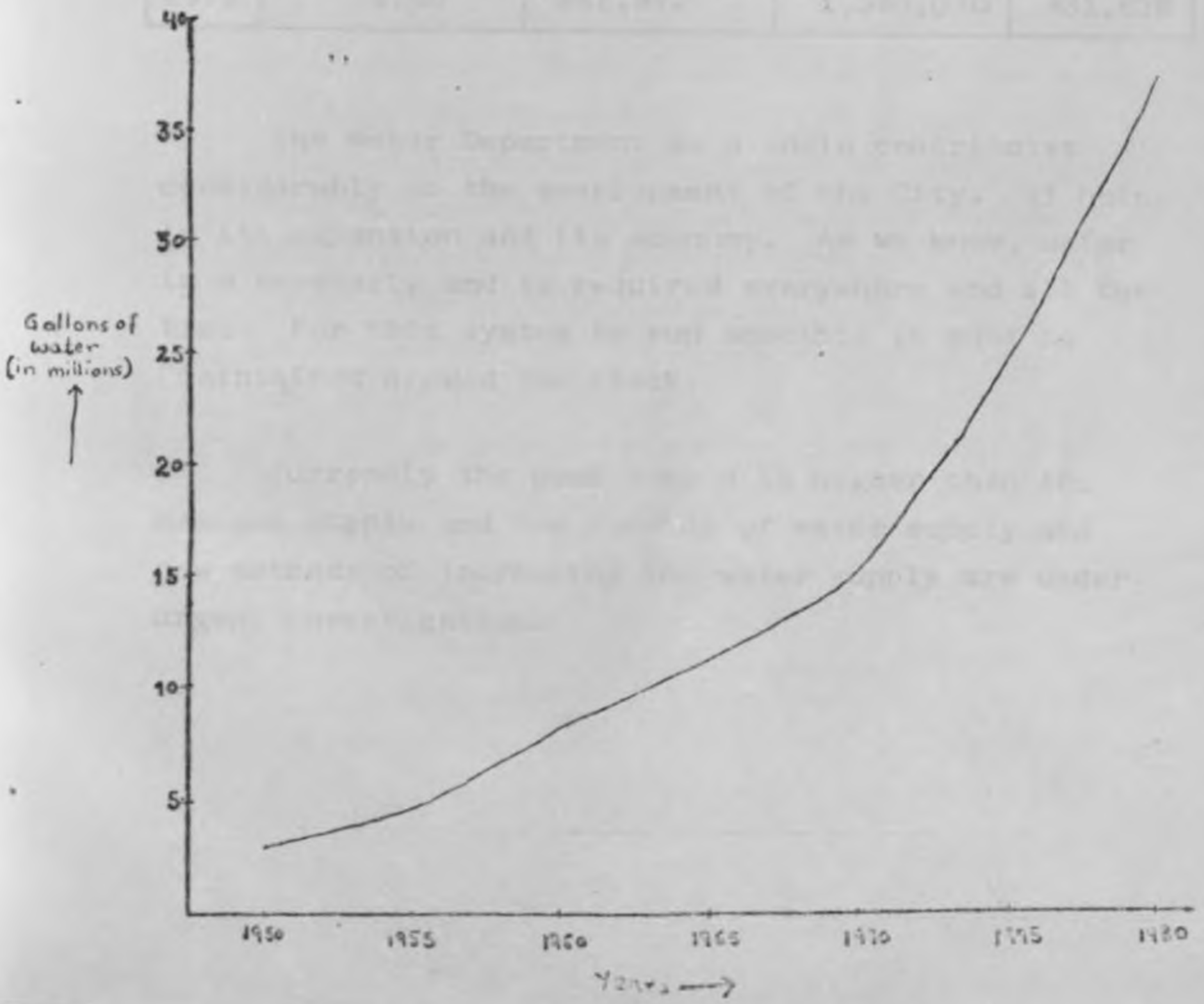


Table 1

FINANCIAL ACCOUNT OF THE WATER DEPARTMENT

Year	Cost of Water per 1,000 gallons	Accounts		
		Expenditure	Income	Surplus
1943		£ 37,411	£ 56,503	£ 19,092
1945				
1947	Shs. 1.46	57,605	76,927	19,322
1949	1.81	84,175	100,448	16,273
1951	2.00	129,806	143,128	13,322
1953				
1955	3.00	260,752	260,752	0
1957	3.47	389,090	404,565	15,475
1959	3.54	444,566	562,293	117,727
1961		534,516	614,583	80,067
1963				
1965		644,589	721,510	76,921
1967				
1969	4.00	837,996	883,486	45,490
1970	5.00	968,675	1,136,638	167,963
1972	6.50	951,382	1,383,020	431,638

The Water Department as a whole contributes considerably to the development of the City. It helps in its expansion and its economy. As we know, water is a necessity and is required everywhere and all the time. For this system to run smoothly it must be maintained around the clock.

Currently the peak demand is higher than the maximum supply and new sources of water supply and new methods of increasing the water supply are under urgent investigation.

CHAPTER 3

PRESENT ORGANIZATION

3.1 THE ORGANIZATION CHART

City Council of Nairobi as a local authority manages for the public well-being what are essentially local as opposed to national affairs. Services provided by the City Council of Nairobi are - public control, licensing, entertainment, interpretation of City Council by-laws, roads, sewers, sewage disposal, drains, bridges, street lighting, town planning, highways, building inspection and control, quantity surveying, parks, refuse removal and disposal, fire services, ambulance services, car parks, playing fields and open air spaces, control of swimming baths, cemeteries and crematories, food and drugs inspection, health services, nursing and midwifery, registration of births, maternity and child welfare, inoculation, communicable disease control, housing, public welfare of the aged, handicapped and mentally disturbed, day nurseries, libraries, recreation halls, markets and water supply. From these numerous services offered by the City Council of Nairobi, the only one of importance for this study is the water supply service provided to the City. This particular service comes under the Water and Sewerage Department.

The head of the City Council is the Mayor who is elected to that position by the public. Directly below him comes the Town Clerk who is permanently appointed and who deals with the administration of the six major departments of the City Council of Nairobi. These departments are - Housing and Development, Education, Water and Sewerage, City Engineers, Social Services and Housing, and City Treasurer. Each department has a General Manager reporting directly to the Town Clerk.

The Water and Sewerage Department of the City Council of Nairobi is headed by a General Manager. There are two deputies to the General Manager, one dealing with the engineering aspects and the other with the commercial aspects of the department.

The Deputy General Manager (Engineering) has under him three main sections: Planning, Design and Construction, Sewerage and Operations and Maintenance. Each of the sections is headed by a Chief Assistant Engineer. The Deputy General Manager (Commercial) has under him various accountants and clerical officers dealing with the water and sewerage bills and accounts.

The Division of work and lines of authority are defined according to the position in the hierarchy shown in the Organization Chart in Figure 6. The Chart shows each and everyone's exact position in the organization.

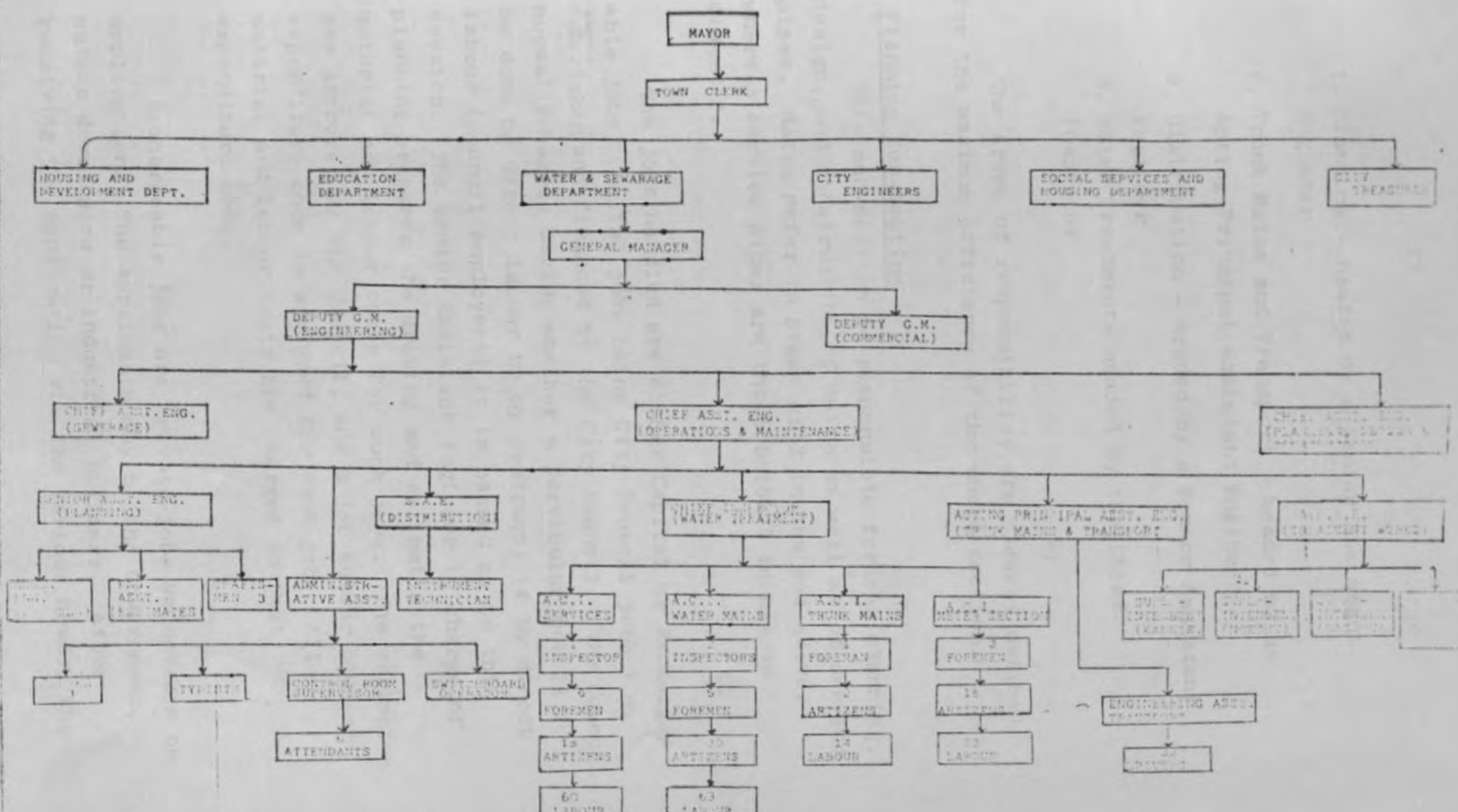
3.2 OPERATIONS AND MAINTENANCE SECTION

This section operates from Kampala Road Depot, in the Industrial Area of Nairobi. It is responsible for the collection of rain water and its treatment and distribution to consumers. In carrying out this task, the section also looks after trunk mains, storage and service reservoirs, distribution mains as well as service pipes, meters and all the other apparatus associated with such works.

The section is headed by a Chief Assistant Engineer, and under him, as shown in the organization chart, there are five sub-sections. The sub-sections are:

Figure 6

ORGANIZATION CHART



1. Planning - headed by a Senior Assistant Engineer
2. Trunk Mains and Transport - headed by an Acting Principal Assistant Engineer
3. Distribution - headed by a Senior Assistant Engineer
4. Water Treatment- headed by the Chief Inspector

The areas of responsibility are clearly defined for the maximum efficiency of the whole section.

3.2.1 Planning Sub-Section

This sub-section is responsible for the planning, design, and construction of mains as well as of service pipes. Mains refer to pipes of 3 inches and above, whereas service pipes are those below 3 inches in diameter.

The jobs handled are either Capital or Rechargeable jobs, Capital jobs being City Council jobs i.e. undertaken and financed by the City Council. The Council normally has to decide whether a particular job is to be done by direct labour or by contract; if by direct labour (council employees) it is passed on to this section. The Senior Assistant Engineer in charge of planning prepares the drawing and estimates the material and labour costs for such jobs. The estimates are approved by the Council, and a job number plus an expenditure code is assigned for each job. All material and labour costs are charged to that expenditure code.

Rechargeable jobs are private jobs undertaken on application. The applicants may be the Government, estate developers or industrial builders. After receiving the application via the various heads, the

Senior Assistant Engineer prepares the drawings and estimates the cost of the job, as for the capital jobs, except for an additional 20% charge over the basic charge for administration. The applicant is then called upon to deposit this estimated amount, and upon payment, a job number is assigned to his particular job. All costs incurred in doing this job are charged to that job number. The Commercial Section is also furnished with a copy of the estimates, and afterwards it is informed of all the material and labour hours spent on the job for the final costing. On completion of the job, the applicant is called upon to meet any extra costs, if the actual costs are more than the original estimate, or is refunded the excess of estimate over the actual cost.

The Senior Assistant Engineer (S.A.E.) works in close contact with the Chief Inspector who provides the workers for carrying out the actual construction. Jobs which do not need close supervision - especially routine jobs, are normally passed on to the Chief Inspector, who sees to it that they are done. Non-routine jobs require the S.A.E. to exercise personal control.

In carrying out his job, the S.A.E. is faced with a number of problems. First, there is a shortage of transport for men and material to the various sites. Men are often taken to the site and stay idle waiting for the foremen to bring the material, and idle time is charged to the jobs just as normal working time so long as the men are on the site. Secondly, the administration of the labour force is such that men have to report at the depot in the morning, and before they leave for the various sites, at about nine O'clock. By the time they arrive at their working place it is nearly ten O'clock. They have to be picked up from their working place before 3 O'clock so as to return their tools before 4 O'clock. So on average they work for 4 to 5 hours each day whereas the job is charged for an 8 hour working day.

3.2.2 Distribution Sub-Section

This sub-section is in charge of water distribution from the various reservoirs and tanks. The S.A.E. together with his men look after pressure problems and general consumer complaints to ensure that everyone in the city is properly supplied with water. Enough pressure has to be maintained in the whole system, and where pressure from the tanks and reservoirs is not great enough to send water to higher ground, water pumps are constructed along the distribution mains to build up the necessary pressure. Leaks and bursts along the main and service pipes have to be repaired when and where they occur, and it is the responsibility of this sub-section to perform such jobs.

Along the various pipes there are valves for regulating the flow and pressure of water in the pipes. Sluice valves (3 inches and above in diameter) are used on the mains and gate valves (below 3 inches) on the service pipes. In addition there are special valves, the main ones being - air valves for letting trapped air out especially in hilly places, and fire hydrant valves for drawing water by fire fighters. While sluice and gate valves are used to control the flow of the water, a special valve, the pressure reducing valve (PRV) is used to reduce pressure in the pipes if necessary. All these valves have to be operated, maintained and replaced when necessary, and it is the responsibility of this sub-section to do so.

Another task of this sub-section is to repair and replace faulty meters. A meter shop is operated at Kampala Road Depot where all the disconnected meters are cleaned, ready for reconnection. Meters are also cleaned on the site, when consumers complain of no water or very little water in their taps, and the meter is found to be blocked.

New works have to be taken over from the Planning sub-section, or from the Planning, Development and Construction Section; (see the Organization Chart) when completed, and from there on maintenance is an on-going task.

In carrying out his function the Senior Assistant Engineer is often faced with a number of problems.

First there is the problem of identifying and responding to consumer complaints. A typical complaint is lack of water, and when such a complaint comes in, it is often difficult for the S.A.E. to decide what the problem is - whether it is a blocked meter, or a leak along the pipe, or some other cause. Problems in pinpointing the exact source of the trouble contribute to the slowness of the sub-section in answering consumer complaints. The organization of repair teams into mains, services and meter men delays the response even more.

Secondly, the feedback system on the jobs completed is rather faulty, especially because the S.A.E. for this section does not control the labourers directly. If they do not fill action sheets promptly and accurately, the S.A.E. is often at a loss as to which jobs have been completed and which remain.

Thirdly, co-ordination with Planning, Development and Construction on the new works to be taken over is often far from perfect; and this sub-section has often to do a lot of work in compiling proper records - for such new schemes.

Finally this sub-section has to keep a continuous record of water levels in the reservoirs and the tanks, to ensure there is enough water for distribution. If levels are dangerously low, some consumers are shut-off, and complaints keep on coming especially during dry seasons when less water is received from the sources.

3.2.3 Trunk Mains and Transport Sub-Section

This sub-section of the Operations and Maintenance Section is headed by an Acting Principal Assistant Engineer (A.P.A.E.). He is responsible for all the trunk mains and transport.

Trunk Mains: Trunk Mains carrying treated water are laid from Sasumua to Kabete and from Ngethu to Gigiri. From Ruiru to Kabete trunk mains carry untreated water. This sub-section deals with all these trunk mains, their maintenance, repairs, easement maintenance, etc. These trunk mains are very important for the amount of water flowing through them is very large e.g. Ngethu - 11.7 m.g/d (M.g/d - million gallons per day), Sasumua - 13 m.g/d and Ruiru - 4.5 m.g/d. So a small problem with any of these trunk mains can lead to a lot of damage. For example a leak in a trunk main can lead to reduced water supply in Nairobi. This in turn will cause all sorts of problems for the consumers - and of course the City Council - and at the same time the City Council will be losing a lot of revenue.

Due to the above reasons great care is

taken of the trunk mains,e.g. there are sixteen men patrolling the Sasumua pipeline to Kabete and nine men patrolling the pipeline from Ngethu to Gigiri. These men clean the valves, look for any damage, leaks etc. and clear the rubbish around the pipeline. There are radios and vehicles at each station. The daily report of the pipelines, the flow of water, etc. is given from these various stations to the control room through the radio, so that the A.P.A.E. can keep a continuous check and can take action when necessary.

The maintenance of all the service reservoirs (these are all the water tanks, towers and reservoirs) also comes under this sub-section.

<u>Transport</u>: The A.P.A.E. is also responsible for all the transport belonging to the Water and Sewerage Section. The Engineering Assistant of Transport is responsible for the transport. In this sub-section they deal with the maintenance, repairs, accident repairs, drivers and allocation of the transport, but they do not deal with its utilization. All the transport belongs to the Water and Sewerage Department and not to any particular section. All the vehicles are "non-pool" vehicles i.e. not assigned to the City Council.

There are supposed to be 63 vehicles and 22 motorbikes but at present 5 motorbikes and 23 vehicles are broken down and in the garage, due to which the number of vehicles operating is 40 and the number of motorbikes operating is 17. The vehicles and motorbikes are allocated more or less permanently according to the sections, Mains, Services, and Meters. Changes in the allocation of vehicles usually arise when a certain vehicle has to be withdrawn from a section e.g. because of breakdown, maintenance or accident, etc. When withdrawn a vehicle is not always replaced and so a section has occasionally to do with less than the originally assigned number of vehicles, which causes certain problems.

Once the vehicles are taken into the City Council garage for repairs they take a very long time before they come out. Some vehicles have been in the garage for years now, which is a large waste of resources and revenue. Payment by the City Council is slow and consequently suppliers often refuse to supply parts. Replacement of vehicles on the other hand is a very slow and long procedure.

The allocation of operational vehicles at the time of the study is as shown below in Table 2.

Table 2

Water and Sewerage Department - Vehicle Allocation

SECTION	NON-POOL VEHICLES
City Hall	302, 320, 333, KRC 929
Mains, Distribution	294, 325, 311, 313
Services, Distribution	293, 309, 326, 310, 312
Meter Section	209, 315, 316, 318, 210
Trunk Mains	306
Sasumua	301, 324
Ngethu	305
Ruiru	323
Sewer Section	277, 288, 276
Kabete	304
Kariobangi	308
Survey	295, 307, 245
Commercial Section	201
Electrical	207
Depot/Engineering	322, 271, 179
Eastleigh	-
Dandora	292
Chief Inspector	319
New Connections	-

Most of the motorbikes are assigned to the Commercial Section. Most of the vehicles leave the depot at around 8.30 a.m. and come back at 4 O'clock p.m. Petrol is given twice a day at 9.30 a.m. and 4.00 p.m. The petrol pump and allocation of petrol and oil comes under the Stores.

The permanent allocation for the 63 vehicles shown below in Table no.3. The present alterations can be seen by comparing Table 3 with the previous table.

Table 3

Water and Sewerage Department - Vehicle Allocation

SECTION	NON-POOL VEHICLES
City Hall	302, 320, 333, KRC 929
Mains, Distribution	325, 311, 313, 296, 275, 256
Services, Distribution	326, 310, 312, 292, 294, 262
New Schemes	199, 369
Meter Section	209, 314, 203, 315, 316, 318, 319, 204
Trunk Mains	306, 194, 188, 323, 198
Waste Detection	293
Sasumua	266, 301
Ngethu	305
Ruiru	206
Sewer Section	146, 324, 277, 288, 259
Kabete	233, 263, 41 UN 11K
Kariobangi	308
Surveys	295, 307, 337, 245
Commercial Section	276, 208, 202
Electrical	207
Depot/Engineering	271, 261, 195, 210, 304, 179
Eastleigh	274
Dandora	322
Chief Inspector	317
New Connections	201
Total	63 Vehicles

3.2.4 Treatment Works Sub-Section

Treatment Works is a sub-section of the Operations and Maintenance Section. It is headed by an Acting Principal Assistant Engineer. The A.P.A.E.'s main job is supervision of the whole of the waterworks, its operations, maintenance and repairs; and the provision of chemicals. He also checks and collects the daily reports on the flow and quality of water supplied to the customers.

This sub-section deals with the treatment of raw water. The water supplied to Nairobi is treated at various places: Sasumua, Kikuyu Springs, Ngethu and Kabete. Kabete receives raw water from Ruiru dam. It also receives treated water from Sasumua and Kikuyu springs. Treated water from Ngethu goes to Gigiri. From Kabete and Gigiri water is further distributed ready for use by the customers.

At Kabete, Sasumua and Ngethu there are treatment plants where the raw water is treated in order to make it clear, pure and healthy. Water is treated by checking the colour and turbidity of the water, its colour should be approximately 5 and turbidity approximately 1 in jackson units. If colour and turbidity are not approximately as stated above, then the water is treated by chemical procedures. After that chlorine is added to the water to make it disinfective. At each treatment plant there are superintendents, chemists, etc. There is a large laboratory at Kabete which is independent and the head-quarters for the chemical side of Waterworks. It is called the Central Laboratory.

Most of the information about flow and quality of water is received by the A.P.A.E. through the control room by radio from Sasumua, Ngethu and Kabete. The chemical stocks are also checked by radio so that the required action can be taken accordingly. But this information flow is not coming in regularly and is not smooth. So it becomes difficult to keep the records updated and take action immediately. Whenever anyone has a problem they consult the A.P.A.E. who acts as a technical supervisor.

Transport is used to supply the required chemicals at the treatment plants. Some chemicals are supplied directly from the firm to the treatment plant. They have some problems with unreliable suppliers for the supply of chemicals is done on a contract basis and the contract is given to the cheapest tender. They also have some problems with chemicals which are not locally produced, such as chlorine which is imported from India; here time becomes a major problem.

3.2.5 Water Treatment Sub-Section

This sub-section controls all the labour force. It is headed by the Chief Inspector (C.I.) who controls all the manual workers e.g. the assistant chief inspectors, inspector, foremen, artisans and labourers. The line of authority can be seen clearly from the organization chart. This sub-section works in close co-ordination with the other sub-sections for the labour is actually used by the whole section: the Planning Sub-Section uses the labour for new jobs, the Distribution Sub-Section uses the labour for the repair and maintenance of main and service pipes and meters, whereas the Trunk-Mains and Transport Sub-Section depends on labour for the repairs, and maintenance of the trunk mains. They all work as a team.

The S.A.E. of Planning does the design, drawings and estimate of the job which then goes through several committees and when approved is passed to the C.I. of water treatment, who carries out the practical side of the job. The S.A.E. supervises the job whereas the C.I. supervises the men doing the job. The foremen are required to know about the schemes and estimates in order that they can try to do the job within the estimated cost. The Assistant Chief Inspector's job is to see that the job is being done properly, is being done as estimated (cost, hours etc.) and to control the worker's overtime.

Most of the labour is unskilled when first-hired and therefore have to be trained on the job. Jobs are done according to priority. According to priority the jobs are categorized as -

1. Bursts and leaks
2. New supplies or new connections
3. Others e.g. repairs, small schemes etc.

The labour is paid as shown below:

Artizans - K.Shs. 10.30/hour

Permanent labour - K.Shs. 23.90/day

Overtime: Week days - 1½ times the normal
Week ends and public holidays - 2 times the normal

Normal Working hours: Week days - 8.00 a.m. to 4.00 p.m.
Saturdays - 8.00 a.m. to 12.30 p.m.

The C.I. tries to maintain good industrial relations so that the workers work properly. The labour is handled with care in order to make them work efficiently.

The labour is collected from different areas of the City in the morning and brought to the depot. The labour and artizans leave the depot with a foreman in a lorry at around 8.30 a.m. or 8.45 a.m. and sometimes even later. The foreman then takes attendance, allocates work and then drops groups of men and artizans at different jobs in different areas. These jobs can often be very far from eachother, so usually by the time he drops the last batch of men it is already 10.30 a.m. or 11.00 a.m. The foreman then goes around to supervise these various jobs. Each batch of men are allocated to one job only, so for example, if one of the batch of workers completes their job early they sit idle for they do not know what to do next. The foreman starts picking up the workers at around 2.30 p.m. in order to get back to the depot by 3.30 p.m., which is the reporting time at the depot. Then the workers are taken back to the various areas in the city where they are dropped to go home. From the above account it is clear that on average the labour is working only 4 to 5 hours a day whereas the job is charged for 8 hours a day. This leads to inefficiency and waste of time and resources.

The foremen work in a particular area so that they are familiar with the place, roads, pipes, fittings etc. The stores open at 10.00 O'clock due to which the foremen cannot carry the material in the morning when they go on site. The foreman drops the men at the site and comes back to the depot and collects the required material and then drops the material needed at each site. Most of the time is utilized in travelling. The inspectors follow later on to the sites to inspect the work going on.

The C.I. does not interfere with the allocation of the labour. The A.C.I. does the allocation of the labour. This allocation is done by 4.30 in the evening for the next day. Changes in this allocation only occur in case of emergency or absentees.

The Control Room is open and at service 24 hours every day. For late emergencies and holidays there is a foreman, one artizan, three labour and one driver housed in town. The transport for them is supplied from the Kampala Road Depot. They are paid on contract basis; that is, only when they do a job.

The main problem this sub-section is facing is due to transport. Usually only 50% or less vehicles are operating. This is due to poor maintenance of vehicles. Some vehicles have been in the garage for a number of years now. The problem arises because the department is not independent and has to take vehicles to the city garage where they join the queue of city vehicles awaiting repair. Buying too many vehicles is uneconomical but if the vehicles are too few then there is little output and no proper use of labour. The labour depends very much on transport, for if there is no transport the labour cannot go to the site. Sometimes some foremen do not go to the site due to lack of transport.

The vehicles are allocated according to the sections, and the allocation is more or less permanent. If all vehicles could be on the road the efficiency could increase incredibly.

Delegation of power is practiced to a large extent. This causes some problems but it is also desirable especially during emergencies - e.g. trunk or main bursts. The feedback is not very good which leads to inefficiencies. There is not enough control over the labour for the C.I. does not know where the labour is and when they were picked up from the job, for they reach the depot at 3.30 even if they were picked up at 1.00 O'clock. There are security men attached to each section.

3.2.6 Control Room

This room is the centre of communication to and from Kampala Road Depot. There are three telephones and two radios, manned by a foreman, four attendants and two trainees. They work around the clock in three shifts, each attendant doing one eight-hour shift. The morning shift runs from 6.00 a.m. to 2.00 p.m., the afternoon shift is from 2.00 p.m. to 10.00 p.m. and the night shift runs from 10.00 p.m. to 6.00 a.m. While three attendants are on duty one attendant is off. The foreman is there during regular working hours - i.e. from 8.00 a.m. to 4.30 p.m., and the trainees come in the morning shift or take the place of an absent attendant.

Telephones are used just like other ordinary telephones though most of the time is spent in receiving consumer complaints and messages from various points in the water system where there are telephones.

Radios are for communicating with men on the working sites and with the outer stations like Sasumua, Ngethu and Ruiru. One set (a Yellow set) is for communicating with the outer stations, whereas the other set (the Blue set) is for the Nairobi area only. Similar to this blue set in the Control Room there are other blue sets fitted into vehicles (10 at present) and it is through these sets that the men on the site are able to communicate with the headquarters (the depot).

The men on sites can also communicate between themselves but they have to be connected by the headquarters. In addition to those fitted in the vehicles, there are also two portable blue sets, one at Karura and the other at Loresho reservoir.

Outer stations apart from possessing a yellow set for communication with the headquarters, have red sets for their own internal (local) communication. Each colour set uses a different frequency.

When consumer complaints come in, they are recorded on a "waterworks", like the one shown below in Figure 7.

Figure 7

Waterworks

CITY COUNCIL OF NAIROBI

WSD/W/I **WATERWORKS** No. 82695

Situation ____________ Date ____________ 19 ____

Road/Street ____________

Plot No. ____________

To. Chief Inspector/Water Stores Please attend to the following	To. General Manager Action taken
WATER STORES RECEIVED.......... REFERRED TO No.......... FOR ACTION	
..............................Signed	..............................for Chief Inspector

One copy of the "Waterworks" is passed on to the relevant person (inspector or foreman) for action. Most of the complaints are sent either to Mains, Services or the Meter Section. When action is taken (e.g. the necessary repair), the worker who has done the job, fills the "ACTION TAKEN" side of the "Waterworks" and returns it to the Control Room for filing. The Control Room also maintains a book, having the number of columns as shown below in Figure 8, where the complaints are recorded.

Figure 8

Daily Complaint Book

Date	Time	Address	Complaint	Waterworks No.	Passed To	Completed By

Reports are also received in the Control Room about various problems or faults in the water system. Major problems like bursts of the main are reported directly by radio to the men in the field (preferably those working near the burst) for quick action.

Control Room attendants have other duties apart from receiving general and particular consumer complaints. They do compile a few records and pass them on to the relevant people. Among such records are -

(i) A record of flows (in gallons per day) in and out of the reservoirs together with the levels of water in the reservoirs at particular intervals; these records are forwarded to the Distribution Section.

(ii) A daily laboratory analysis report of water from Kabete laboratory, which is forwarded to the Acting Principal Assistant Engineer for Treatment Works.

(iii) A record of radios and to which vehicles they have been fitted.

The Control Room is a busy place in terms of the incoming and outgoing calls; and the number of people coming in to send or receive messages (mainly the section heads and Inspectors) over the radio is quite large. Others come in to check on the map the location of their assigned jobs. The room is quite noisy around nine O'clock, when nearly all the telephones are used simultaneously, and on top of that map checkers are also talking. Too much noise in the Control Room causes difficulty and confusion, on both sides of the telephones and radios.

Other problems experienced by the Control Room include having to leave the Control Room unattended in order to go out and call various officers required on the radio by their men in the field. Secondly when an attendant is alone, he can occasionally find more than two calls (either on the radios or telephones) coming in simultaneously, and he has to keep some callers waiting or leave them unattended. Thirdly, they at times find it difficult to know the exact nature of the consumer's complaint and therefore at times send the "waterworks" to the wrong section e.g. to the Mains Section instead of sending it to the Service or Meter Section. This leads to extra delay in taking the right action. Furthermore when an emergency occurs, they are often unable to know the right vehicle to contact for action because no continuous record is kept of the whereabouts of vehicles and men. Finally the map with plot numbers is out of date, in terms of street and estate names and plot numbers, and the current map is too small and the plot numbers are missing on the map. This makes it difficult for the attendants to guide men in the field in locating the problematic spots.

The Water Tanker is also controlled by the Control Room and directed as to where to take the emergency water supply.

3.2.7 Stores

The stores for the whole of Water and Sewerage Department is situated at the Kampala Road Depot. This consists of a sheltered area and also a large open area. In the sheltered area small materials and chemicals are stored, whereas the open ground is used for the pipes, joints, T's etc. The stores come under the Commercial Section. The stores are headed by an Assistant Stores Superintendent. Under the A.S.S. comes the Assistant Store Keeper and an Accountant Grade III. Below them is a Senior Clerk Officer and below him in hierarchy are two Clerk Officers Grade II. There are also three labourers and a cleaner working under the Assistant Stores Keeper.

The stores controls and records all the materials e.g. valves, pipes, meters etc. A record of petrol and chemicals is also kept at the stores. The material and petrol is supplied to the Stores on a yearly tender basis. The demand for materials for the forthcoming year is prepared by the S.A.E. (Planning). These figures are then sent to the P.D. and C. Department. This is then advertised inviting tenders. The tender usually accepted is the cheapest one. The tender documents are prepared by the P.D. and C Department and copies are forwarded to the Stores. This supply may be in bulk or piecemeal. The suppliers are requested to supply the material over the year - in required amounts, but usually this is not practised for the suppliers tend to supply the material all at once which causes storage problems. Sometimes some suppliers even fail to supply the material. Very few orders for materials originate from the Stores. The maximum amount allowed for direct order of material is K.Shs. 3,000/= per order.

Each material has a different N.C.C. Stock card on which is recorded the particulars of the item, the name of the item, its unit, commodity code (issued by the stores), the amount coming in and going out, etc. The record of an item is kept as in Figure 9.

Figure 9

Nairobi City Council's Stock Card

<table>
<tr><th rowspan="2">DATE</th><th rowspan="2">SRS NO.</th><th rowspan="2">SIV NO.</th><th colspan="2">QUANTITIES</th><th rowspan="2">BALANCE</th><th rowspan="2">AUDIT</th></tr>
<tr><th>IN</th><th>OUT</th></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td colspan="2">DESCRIPTION OF ITEM</td><td>UNIT</td><td>MINIMUM</td><td>MAXIMUM</td><td colspan="2">COMMODITY CODE</td></tr>
</table>

They do not record the minimum or maximum stock levels at the moment but it is assumed that they should be recording these details soon.

Petrol and oil are also supplied on a yearly contract basis just like the material. It is also recorded in exactly the same manner as shown above. They usually request for petrol and oil supply when they are left with about a seven day's stock. The forecasted demands are shown in Table 4.

Table 4

Average Fuel Utilization

Type	Maximum Store	Average Utilization Period
Regular	9,000 litres	2 or 2½ weeks
Diesel	4,500 litres	3 to 4 weeks
Oil	630 litres	6 months

When supply of any material is needed the department head prepares a requisition for a local purchase order. This goes to the Commercial Section for certification that the money is available. After this the requisition goes to the Purchasing Section (which is under the City Treasurer). They then prepare the purchase order. A copy of the purchase order is given to the Stores to await the delivery of goods.

The timings of the issuing of materials and petrol are as follows:

STORE TIMINGS

Issuing of Material	Issuing of Petrol
Week Days	Week Days
10.00 a.m. to 12.30 p.m. and 2.00 p.m. to 3.30 p.m.	9.30 a.m. to 10.30 a.m. and 3.00 p.m. to 3.45 p.m.
Saturdays	Saturdays
10.00 a.m. to 11.00 a.m.	9.00 a.m. to 11.00 a.m.
Sundays and Public Holidays	Sundays and Public Holidays
Closed	Closed

To obtain material from the Stores, the foreman must fill in a Stores Issue Voucher. In the voucher he fills the expenditure code, material required, in which unit and how much. This voucher then must be signed by one of the few persons who are authorized to sign these vouchers. Now the foreman can get the required material from the Stores. One of the store keepers issues the material, fills in the amount of material issued and signs the voucher. On receipt of the material the voucher is signed by the foreman. There are three copies of this voucher one (the original) copy goes to the Commercial Section where they use it for actual job costing. The second copy is kept with Stores as a record and the third copy is retained by the foreman and is used as a gate pass, and left at the gate. At the gate, all the material carried out of the depot is checked with the Stores Issue Voucher. The person at the gate notes the voucher number and passes the copy to the Stores Issue Voucher to the Engineering Section for records and job costing purposes. A Stores Issue Voucher is as shown inFigure 10.

Figure 10

Stores Issue Voucher

CITY COUNCIL OF NAIROBI

CT/COSTING/7

STORES ISSUE VOUCHER

(FOR USE IN ALL STORES EXCEPT KINGSTON ROAD AND TRANSPORT DEPOT)

Expenditure Code or Job No. must be given and a Separate Voucher used for each allocation

DETAILS OF JOB

TYPE	DEPT No	VOUCHER No
Col 1	Col 2	Col 3 - 7
5		14244

[illegible]	[illegible]

DESCRIPTION	UNIT	QUANTITY REQUIRED	[illegible]	[illegible]	BALANCE

To Storekeeper,

Please issue the above stores to be charged to the account shown.

.... DATE .... FOR HEAD OF DEPARTMENT

CERTIFIED ISSUED .... STOREKEEPER

RECEIVED .... DATE ....

For the material that has been issued but is not used a Stores Return Voucher is filled out and the material is returned. This also has three copies, one goes to the Commercial Section, other to the Stores and the third copy goes to the administration.

For issue of petrol each vechile has it's own petrol issue card. This card has the following particulars on it, as shown in Figure 11.

Figure 11

Petrol Issue Card

Vehicle Code No.

Date of Issue	Vehicle Registr-ation No.	Speedometer Reading	Petrol	Diesel	Oil	Drivers Signature

Some speedometers are not working, so it becomes difficult to control the petrol and see if it is being used properly or not. The vehicles are not sent to the garage for repair of the speedometer, for once any vehicle goes into the garage it takes a long time for it to come out.

The Stores have the following problems: Sometimes they run out of stock for a particular material but that is not very often; and sometimes the suppliers fail to supply the material. The sheltered area of the stores is very small and therefore some of the items that should be kept in the stores are laid out in the open; Due to the shortage of storage area they have some storage problems when very large orders arrive.

If the Stores are closed or on holidays and the foreman needs some material, he takes it from the outside and sometimes forgets to give the voucher to the storekeeper once the Stores open again. Consequently they have difficulty in trying to trace the missing material and account for it. They then get into trouble when the audit is done at the end of the year.

3.3 SUMMARY OF ACTIVITIES AND PROBLEMS

Overall the main activities of the Water Department can be listed as below -

1. Control over water distribution system, water mains and trunk mains.

2. Co-ordination and activities of water distribution, with activities carried out through other public works division.

3. Supervision of Stores and Workshops and stock of equipment.

4. Requisition of materials for operation and maintenance.

5. Purchase of water distribution materials by tender.

6. Control over assets.

7. Maintenance of distributing and collecting systems.

8. Maintenance and testing of fire hydrants.

9. Direction of activities of artizans.

10. Supervision of leak detection, inspection, cleaning and maintenance of pipelines.

11. Resolving of consumer complaints, pipe bursts, disconnections, reconnections.

12. Supervision of capital works carried out by direct labour.

13. Review of staff establishment and organization of staff training.

14. Data collection and preparation of reports.

15. Preparation of accurate records of Mains, Service connections and other installations.

16. Preparation of preliminary budget estimates.

17. Consumption and pressure survey in the Distribution System including records of district meters.

Even though each sub-section seems to have its own problems, all the problems are ultimately related and concentrate in the areas of labour, transport and material. The major inefficiencies lie in the organization of labour, transport and material along with inadequate control. This can be described as follows - the men (labourers) in the morning are picked up from their places of residence and brought to the depot where attendance is taken and the allocation of jobs is done. There is a great deal of confusion at the depot in the morning. After they have left the depot the foremen drop the various teams of labourers and artizans at their places of work one by one. These sites can be situated anywhere in the city. Some foremen don't go to the sites due to shortage of vehicles for two foremen do not like to go in the same vehicle. On paper the Water Department has many vehicles but usually a large number of these vehicles are not operating and are in the city garage for some repair job. Some of the department vehicles have been in the garage for a number of years now. There is no control over such an activity.

Once the men are dropped at their places of work the vehicles usually come back to the depot with the foremen to collect material needed to complete the jobs. It often happens that from the time the labourers and artizans are dropped at the sites, and while the foreman goes to the depot, collects the material and then goes back to supply the material at the various sites the men are just idle. This is a great amount of man hours wasted. The vehicles also seem to be travelling back and forth unnecessarily; the foremen are supposed to supervise the men on the job as much as possible. The vehicles start collecting the men to return to the depot by 3.30 p.m. and it is the practice of the department to drop the men at their residential areas. Due to this manner of organization it seems that large amounts of time are wasted both in labour and vehicle hours; money is also wasted in unnecessary travelling of vehicles. This is also due to the inconvenient opening and closing hours of the stores.

The Senior management and the Control Room staff have no control over the vehicles or the men in the field for they have no feedback or idea of their whereabouts at any time. Each vehicle travels almost all over the city during the day; it has no allocated route or area.

The consumer complaints come in through the Control Room where they are noted on a small piece of paper called a waterwork, and this is then forwarded to either the Mains, Services or Meter Sections to act upon. If this waterworks is lost or misplaced or is not acted upon, there is no check which will detect this fact. So actually no one knows which complaints are coming in, which are being worked on, which have been acted upon and which ones are pending.

Numerous consumer complaint calls come in through the Control Room everyday. It is usually very difficult to assess the exact nature of the complaint from the consumer's account and so a series of delays often occur, such as the waterworks being given to the wrong section. In case of an emergency complaint, since the Control Room staff don't know where the vehicles are, they have to ask all the vehicles for their positions and then ask one of them to go to the emergency site.

What one needs here is detailed and optimal planning, scheduling and routing of the vehicles and also a proper control system to maintain the plan in the long run.

CHAPTER 4

RELATED LITERATURE REVIEW

4.1 INTRODUCTION

This chapter reviews some work done by various writers in the field of scheduling. This chapter includes in brief what scheduling is, the importance of scheduling, different methods of scheduling and why none of these methods can be used for scheduling vehicles in this particular case.

4.2 IMPORTANCE

Scheduling problems arise in many practical circumstances and under a wide variety of guises. Many of these scheduling problems are basically optimization problems having the following form: Given a collection of tasks to be scheduled on a particular processing system subject to various constraints, find a feasible schedule that minimizes (or in some cases maximizes) the value of the given objective function[9]. There are various types of scheduling problems: production scheduling, job scheduling, vehicle scheduling, etc. Here we are only concerned with vehicle scheduling.

Transportation probably ranks as the most important economic activity in business logistics, consuming typically two-thirds of a firm's expenditure spent on all logistics activities[16]. Transport decisions are important because of their frequently recurring nature. Constantly changing requirements force continual reconsideration of transport decisions.

One way in which any organization seeks

to improve distribution efficiency is through the maximum utilization of transportation, equipment and manpower. To reduce transportation costs, and also to improve customer service, routings are sought that will minimize time or distance. Two types of routing problems are common. First is the routing through a transportation network where the origin and destination points are the same, as in sequencing the stops for a delivery truck making local product deliveries.

Before the scheduling problem can be attacked, first the trips must be generated, usually by solving a series of routing problems. The routing and scheduling are clearly related, with each problem constraining the other.

Management has become increasingly aware of the need to control the rising costs of the physical distribution activity. The systematic construction of efficient vehicle routes provides an important tool for the control of costs in the short term, for adapting the vehicle fleet-size and composition in the medium-term, and even for the location of depots in the longer term.

4.3 THE VEHICLE SCHEDULING PROBLEM

The development of vehicle routing methodology is important not only if efficient routes are thereby generated to suit local circumstances but also if it leads to an improvement in cost functions for the purpose of major reshaping of depot networks.

When there are several vehicles there is both a problem of allocation of customers to vehicles and a sequencing problem for each vehicle. In the absence of vehicle capacity and route-metric constraints this problem is known as the multiple TSP (traveling salesman problem)[23]

Foster and Ryan[8] state that in its simplest form the vehicle scheduling problem (VSP) is to design a set of routes (from a central depot) to service n customers at known locations with a known quantity of some commodity such that all customers are satisfied and that any restrictions on the capacity of vehicle or the duration of a route are observed. The VSP objective is to construct a schedule of routes satisfying these restrictions using a minimum number of routes, and for this minimum number of routes, a minimized total milage (or time). This objective is one of a number of closely related objectives arising in scheduling problems which are discussed by Christofides and Eilon[5].

In any practical scheduling problem, however, we would expect additions both to the factors contributing to the objective. In particular one extension of the vehicle scheduling problem that regularly occurs in practice is that of scheduling over a planning period of more than one day. In such a case, the maximum number of vehicles employed on one day rather than the total number of routes becomes the dominant objective factor. This extension also introduces new constraints:

(i) deliveries to customers must be made on the day specified;
(ii) deliveries to customers requiring more than one visit should be "evenly spread" over the planning period;
(iii) the daily work load must be "evenly spread" over the planning period; and
(iv) the structure of the routes should be such that new business can be incorporated without a radical revision of schedule[8].

4.4 SCHEDULING METHODS

A number of methods exist for evaluating various routing alternatives and selecting optimum or nearly optimum tours. Some of the methods used are branch and bound[20], graphics[2], heuristics[17], dynamic programming[14], lockset method[26] and sweep method[11], to note a few.

Which to choose is a matter of balancing the efficiency with which the method seeks a solution and the "quality" of the solution obtained. That is, branch and bound procedures guarantee that an optimal solution will be obtained, but they often require a considerable amount of computational time, especially for large-scale problems. In contrast heuristic procedures often provide "good" or nearly optimum solutions, and they are conservative in their requirements for computational time. As Tillman and Cochran note: "... the methods based on heuristic programming are the only algorithmic approaches that are computationally feasible for large problems"[28].

When solving a scheduling problem by any method, various factors have to be taken into consideration, such as number of vehicles to be used, capacity of the vehicles, and the selection of the route itself.

When the tour has many stop-off points and reasonably large quantities are demanded at each point, more than one vehicle is needed to complete the tour, or alternately, a single vehicle must be routed several times to meet the demand requirements of the tour. Vehicle capacity is an important consideration in real-world routing problems. This can be considered in two forms[1]; First, vehicle capacity is a constraint on minimizing the number of vehicles needed to meet demand requirements over time when route distance or travel time is less of a consideration.

One commonly faces the scheduling problem in which a number of customers are to receive deliveries from a central depot, or a freight pickup is to be made at many points and the vehicle returned to a central depot. These delivery or pickup vehicles are routed to minimize travel time, distance, cost, etc. However to serve any of these points a fleet of vehicles with various capacities might be present. Thus, in addition to selecting the most efficient route, one would also like to know which vehicle should be used on the route (tour).

The number of alternative routes and combinations of vehicles for even a small-size problem is staggering and requires some mathematical aid to find the best solution. Several mathematical formulations of the problem and solution methods exist[5], but probably the best all around solution method in terms of accuracy and computation time is the "savings" method by Clark and Wright[7]. In testing several methods, Christofides and Eilon found that the "savings" method required substantially less computational time than comparable methods and on the average produced tours that were only 3.2 percent longer than the optimal tours in the 10 problems tested[5]. The method is simple and is suitable for hand computation or computer programming.

Now here we are going to discuss some vehicle scheduling methods in some detail but leaving out the mathematical models associated with each method.

4.4.1 Heuristic Algorithms

Basically there are two types of algorithms that can be used to solve the vehicle - dispatch problem; exact and heuristic. Exact algorithms are the ones that yield an exact solution in a finite number of steps, in the absence of round - off or other errors. Christofides and Eilon[5] developed an exact algorithm based on a branch-and-bound approach that was limited to problems involving relatively few locations because of the computer time involved. This is generally true of all exact algorithms that solve the vehicle - dispatch problem. They are all restricted by computer time and/or storage. Heuristic Algorithms on the other hand, are quite often faster and capable of obtaining optimum or near-optimum solutions to much larger problems in a reasonable amount of computer time.

The heuristic algorithms are generally considerably faster, but sometimes sacrifice accuracy, whereas exact algorithms may be extremely slow but always get the optimum solution if time permits. Specifically, Lin and Kernighan[19] have developed a heuristic algorithm that will produce an optimum or near-optimum solution to the 100 - location problem in reasonable times. The Held and Karp[15] procedure is an exact method that does rely on a branch and bound procedure. Consequently, the computer times reported are excessive when compared to heuristic results reported by Lin[18].

An algorithm was developed by Mcmohan and Florian[22] in order to minimize maximum lateness, subject to ready times and due dates. The method could be classified as a branch-and-bound, however it has some unusual features.

4.4.2 The Lockset Method

The lockset method of sequential programming is used to route feed delivery trucks and indicate potential distance savings of as much as 20% in comparison to the actual routes used by the business concerns. Using the method, the number of trucks required to make the deliveries can be reduced from the number actually used. The system is computerized to enable a dispatcher to design delivery routes and issue loading instructions for each truck as soon as orders for a given day are known[26].

Often trips involve servicing two or more stops where the sequence of stops is important in determining the length of the route. A principal factor affecting the cost of delivery is the distance travelled per unit of product delivered[6]. Thus, any procedure which will result in driving a shorter distance or spending less time en route while providing the same services can contribute to lower costs and improved market efficiency. The lockset method of truck route section offers considerable promise of being such a procedure[7].

The dispatcher faces a number of alternatives as he schedules deliveries. The calculation of the distance for each possible route is impractical under most actual operating conditions. For example according to Churchman, Ackoff and Arnoff[6] for 20 stops a computer programming one sequence per microsecond and working 8 hours a day, 365 days a year would take about 250,000 years to find a solution. The use of more than one vehicle from a single depot further complicates the situation.

The lockset method of route selection will enable a dispatcher quickly to design delivery routes (1) by selecting a set of stops to be included on a given route, and (2) by finding a sequence for each set. The objective is to minimize the total distance travelled by all carriers; achieving this objective also tends to use the minimum number of carriers. Minimization is not subject to mathematical proof but results can be tested by comparing ex post routings with routings actually used by firms under operating conditions.

Although one computer program can be written to incorporate all constraints, it does not appear to be a practical solution. Each user should actually take into account his special situation and make appropriate modifications to improve the efficiency of the algorithm in his application.

The lockset method is not deterministic in the sense of offering mathematical proof of optimization. In the absence of such proof, it is presumed that it is possible that there is a better solution than the one provided by the lockset method. So, we can say that the lockset method provides a feasible - rationale rather than a feasible - optimum solution. It should be regarded as a tool to aid the dispatcher rather than as a substitute method to take his place.

Even though this method is a feasible rationale, it was tested by the authors[26] by analysing 20 routings of 12 firms. In no case did the management procedure result in a routing with fewer miles than was discoverable by an appropriate version of the lockset method.

Optimization can be defined here as minimizing total travel distance. If total route time for the driver is a factor, the time spent unloading can be included. According to Webb[29] one of the major difficulties in planning journeys is always the estimation of journey time, including allowances for planned stops and other eventualities. Other measures of distance may be used, such as miles, cost and fuel used.

4.4.3 The Sweep Algorithm

For solving medium as well as large-scale vehicle-dispatch problems with load and distance constraints for each vehicle, Gillet and Miller[11] give an efficient algorithm (with description and mathematical model) called the Sweep Algorithm. The problem considered by this algorithm is as follows: The number of Customers located at different locations desire a certain quantity of goods that can be delivered from a single depot. A single vehicle may not be able to supply every demand because of load and distance constraints. The problem then is to determine the number of routes and the paths in each route that will minimize the total distance travelled by all vehicles in supplying all demands, subject to the load and distance constraints on each vehicle. Of course the distance constraint could be replaced by a time constraint without changing the problem.

4.4.4 Other Methods

For a local delivery vehicle routing problem, it is rare that management would require new delivery schedules day by day. Fixed routes are usually operated, being modified in minor respects to accomodate the changes in such cases. Incentive payment schemes operate best in a stable environment and management are better able to schedule planned maintenance of vehicles. Christofides[4] suggests that the set of daily schedules constructed using historic daily orders effectively generates a figure of merit - the frequency of occurance of each individual link. Fixed routes may then be constructed from this ranking of frequently used links, either including or rejecting each link in turn so that the vehicle capacity or route metric constraints are violated with an acceptable probability. O'Brien[24] argues that in most established delivery operations the depot can be held in reserve and need only be assigned anew to take up the slack in the fixed routes which happen to be underloaded on the day in question.

Garey, Graham and Johnson[9] have a different way of solving the scheduling problem. Instead of looking for the best possible route or optimal solution, the analysis of the worst case behavior of an algorithm is the real heart of their approach.

Apart from the methods mentioned above there are many more methods of solving the vehicle scheduling problem. This is only For instance as Schultz[27] has given a practical method for vehicle scheduling based on the ideas of Clark and Wright[7] and Shruben and Clifton. This procedure was tested for about 25 firms in a dozen industries and there was not a single case in which this system failed to find a shorter set of routes than was actually being used by the company. Over half of the firms were able to reduce their fleet size by one or more trucks. Caprera and Orloff[3] describe the General Routing Problem (GRP) approach for solving large scale routing problems. The GRP approach to routing involves several different types of problem reduction processes, some of which can be generalized to other difficult combinatorial problems.

There are various problems that arise when solving or constructing transportation schedules; these are dealt with by Gurevich and Gertsbach. Orloff[25] also gives some insight into the structure of a large class of fleet scheduling problems.

4.5 CONCLUSION

Vehicle scheduling is a very important activity and is a problem almost every organization is faced with in one way or another. As we saw above there are various methods used to solve scheduling problems. Each method is especially geared to a particular type of problem situation. To solve a particular scheduling problem with a particular method, some assumptions must be made and the problem must meet some conditions before it can yield the required results.

The problem that we have at hand here is rather unique. Here we have several vehicles allocated to a number of sections; each section operates as an individual unit as well as in coordination with the other sections. We have a large fleet of vehicles of various capacities, which all operate from the central depot. The vehicles bring men to the depot in the morning, and then carry labour and material to the various sites of work. They also carry the required material from the depot to the various sites during the day and this must be delivered by a certain time of day; that is, material is loaded and unloaded several times. The foreman supervise the various jobs in the same vehicle throughout the day. Finally in the evening men are transported back to the depot and from there back home. The number and location of the sites changes every day and during the day. None of the methods described in the literature is suitable for such a problem as this. The requirement here is for a method which gives maximum utilization of transport, equipment and manpower all at the same time. All these three (transport, manpower and material) are very interrelated in this problem. By maximizing the utility of the three factors we will reduce transportation costs, save time, reduce distance travelled, waste a minimum man hours, and improve services by getting more jobs done on time and efficiently.

Only the manual method described in this report can adequately deal with this complex combination of constraints and objectives.

4.6 REFERENCES

1. Ballou, Ronald H. "Business Logistics Management" Prentice-Hall Inc., Englewood Cliffs, New Jersey, 1973.

2. Barachet, L.L., "Graphic Solution of the Travelling Salesman Problem", Operations Research, Vol. 5 (December 1957) pp.841-45

3. Caprera, David and Orloff Clifford, "Reduction and Solution of Large Scale Vehicle Routing Problems", Transportation Science, Vol. 10, No. 4 (November 1976) pp. 361-373

4. Christofides, N., "Fixed Routes and Areas for Delivery Operations", International Journal of Physical Distribution, 1971, pp. 87-92

5. Christofides, N. and Eilons, S. "An Algorithm for the Vehicle Dispatching Problem", Operational Research Quarterly, Vol. 20.(1969) pp. 309

6. Churchman, C. West, Russell L. Ackoff and Leonard, Arnoff, "Introduction to Operations Research", New York, John Wiley and Sons, Inc. 1957

7. Clark G. and Wright, J.W., "Scheduling of Vehicles from a Central Depot to a Number of Delivery Points", Operations Research, Vol. 12, (July-Aug. 1964) pp. 568-681

8. Foster, B.A. and Ryan, D.M., "An Integer Programming Approach to the Vehicle Scheduling Problem", Operational Research Quarterly, Pergamon Press, Vol. 27 (1976) No. 2(i) pp. 367-384.

9. Garey, M.R. , Graham, R.L. and Johnson, D.S., "Performance Guarantees for Scheduling Algorithms," Operations Research Vol. 26 No. 1 (Jan.-Feb. 1976), pp. 3-21

10. Gaskell, J.J., "Bases for Vehicle Fleet Scheduling", Operations Research Quarterly, Vol. 18 (1967), pp. 281-295

11. Gillett, Billey E. and Miller, Leland R., "A Heuristic Algorithm for the Vehicle Dispatch Problem", Operations Research, Vol. 22, No. 2, (March-April 1974), pp. 340-349

12. Gurevich, Yu. and Gertsback, I., "Constructing an Optimal Fleet for a Transportation Schedule", Transportation Science, Vol. 11, No. 1 (February 1977), pp. 20-36.

13. Hayes, Robert, "The Delivery Problem", Management Science Research Report, Carnegie Institute of Technology No. 106 (1967)

14. Held, M. and Karp, R.M., "A Dynamic Programming Approach to Sequencing Problems", Journal of the Society for Industrial and Applied Mathematics, Vol. 10, (March 1962) pp. 196-210.

15. Held M. and Karp, R.M., "The Travelling Salesman Problem and Minimum Spanning Trees; Part II", Mathematical Programming 1 (1971) pp. 6-25

16. Heskett, J.L., "Macroeconomic Cost of Physical Distribution", in Papers - Third Annual Meeting, American Transportation Research Forum (Oxford, Inc. The Richard B. Cross Co., 1962) pp. 169-89.

17. Karg, Robert L., and Thompson, Gerald L., "A Heuristic Approach to Solving Travelling Salesman Problems", Management Science, Vol. 10 (January 1964), pp. 225-48.

18. Lin, Shen, "Computers Solutions of the Travelling Salesman Problem", Bell Syst. Tech. J. Vol. 44, (1965) pp. 2245-2269.

19. Lin, Shen, and Kerminghan, B.W., "A Heuristic Algorithm for the Travelling Salesman Problem", Computer Science Technology Report No. 1, Bell Labs, April 1972.

20. Little, John D.C., Murty, Katta G., Sweeney, Dura W. and Karel, Caroline, "An Algorithm for the Travelling Salesman Problem", Operations Research, Vol. 11 (November-December 1963), pp. 972-89

21. Maffei, Richard B., "Modern Methods of Local Delivery Route Design", Journal of Marketing, Vol. 29 (April 1965), pp. 13-18.

22. Mcmohan, Graham and Florian, Michael, "On Scheduling with Ready Times and Due Dates to Minimize Maximum Lateness", Operations Research, Vo. 23, No. 3, (May-June 1975), pp. 475-482.

23. Mole, R.H., "A Survey of Local Delivery Vehicle Routing Methodology", Journal of the Operational Research Society, Vol. 30, No. 3, pp. 245-252.

24. O'Brien, H., "Distribution Modes and Transport Planning", Retail and Distribution Management, Vol 3, (1975) pp. 49-52.

25. Orloff, Clifford S., "Route Constrained Fleet Scheduling", Transportation Science, Vol. 10, No. 2 (May 1976), pp. 149-68.

26. Schruben, Leonard W. and Clifton, Ruth E., "The Lockset Method of Sequential Programming Applied to Routing Delivery and Pickup Trucks", American Journal of Agricultural Economics, Vol. 50, No. 4 (November 1968).

27. Schultz, Hilbert K., "A Practical Method for Vehicle Scheduling", Interfaces, Vol. 9, No. 3 (May 1979), pp. 13-19.

28. Tillman, Frank A. and Cochran, Harold, "A Heuristic Approach for Solving the Delivery Problem", Journal of Industrial Engineering, Vol. 14, (July 1968), pp. 354-58.

29. Webb, Michael, "Transporting Goods by Road: Policies, Techniques, and Distribution Efficiency", Operations Research Quarterly, Vol. 25, No. 1 pp. 193-195.

CHAPTER 5

PRELIMINARY INVESTIGATION AND DATA COLLECTION

The preliminary investigation and data collection was carried out in the following steps.

5.1 INITIAL MEETINGS

The study began in July 1979 as a result of discussions between Mr. Charles Hurst, the then Assistant Chief Engineer and Dr. David Kohler, my supervisor. Mr. Hurst mentioned some of the inefficiencies of his section to Dr. Kohler. Dr. Kohler thought it might be an interesting area for research, and asked whether an MBA student might be allowed to investigate the situation and make proposals for improving the efficiency of the section. This proposal was readily agreed to, first by Mr. Hurst and then formally by the General Manager, Mr. Moche.

The problem was initially defined as: to improve the efficiency at Kampala Road Depot, particularly in the use of transport, labour and material distribution, and to make better use of the existing communication system.

In order to ensure that I was accepted and given every assistance by his staff, Mr. Hurst called a meeting of all sub-section heads and inspectors. At this meeting Mr. Hurst introduced me and explained the purpose of the study. He stressed that no-one was to feel threatened by the study and he asked that all staff cooperate fully. I benefited greatly from this meeting for I was introduced to everyone. Everyone in the department was told what was going on, and any doubts or questins were clarified. The support and suggestions given by the staff contributed materially to the success of the project.

5.2 FAMILIARIZATION

Before the formal investigation could begin it was first necessary to familiarize myself with the main features of Nairobi's water system and with the organization, functions and staff of the various sub-sections and operating units. Interviews, of a general discussive nature, were held individually with all sub-section heads and other key staff members, such as those in the Control Room and Stores. In addition, I personally observed every sub-section and operating unit in operation and learnt the technical aspects of the work.

Through these interviews and observations I learnt the day-to-day running of the organization, the activities performed by each sub-section and their role in the section as a whole, and a great deal of technical knowledge about the physical characteristics of pipes, joints, valves, leaks, bursts, meters, etc.

5.3 STUDY OF THE RECORDS

Once I was familiar with the organization and its activities I surveyed the records kept by the various operational units. The records that I thought relevant to the study were these:

(i) Stores Records - A number of records are kept by the stores staff, all with the aim of accounting for the incoming and outgoing material and petrol. I observed discreetly the record keeping procedure in operation, and also compared the stores records with the actual physical stock in some cases. From this I was able to ascertain that the records kept by Stores were quite well up-to-date and were accurate enough for my study.

(ii) Control Room Records - A considerable time was spent studying the records kept in the Control Room. The Control Room is a very busy place with calls coming in from all areas. Virtually all complaints are first reported to the Control Room by telephone. Each complaint is then recorded on a document called a waterwork. This waterwork is then passed on to one of the sections, either Mains, Services or Meters, for action to be taken. Details of each complaint are recorded in the Control Room Record Book. This book carries important information such as:

- the date and time the complaint came in;
- the nature of the complaint e.g. "a leak near the meter", or "a main burst", etc.;
- the location of the complaint in the city;
- which section (Mains, Services or Meters) is assigned to rectify the fault; and
- the date and time when the fault was rectified.

By carefully studying the records of the past several years I was able to obtain a very good impression of the following:

- the way the complaints vary in frequency throughout the year, especially the

peak months;
- the pattern of faults in the various locations of the city;
- the time the complaints occur; according to the time throughout the day and the days of the week;
- the frequency of the type of complaint e.g. 'burst', 'leak' etc.

I plotted graphs which visually summarized this information. All the complaints are recorded in the book as they are received, but often they are not up-dated later on when the fault has been rectified. Due to this incorrect and incomplete record-keeping one never knows which complaints have actually been acted upon and which ones haven't. This indicates the lack of a good feedback and control system.

The Control Room Staff also keep records of the daily inflow and outflow of water in the reservoirs (in gallons per day) and the level of water in the various reservoirs at a particular time. They also compile a daily laboratory water analysis report. These records were not studied in detail since they were not directly relevant to the study.

(iii) Work Allocation Forms - At the beginning of each day the inspectors prepare Work Allocation Forms which indicate:
- the date;
- each artizan's name;
- the type and location of the complaint he and the labourers have to deal with that day; and
- the number of vehicle he will use.

A Work Allocation Form (see Appendix A) is made out for each foreman. One foreman usually takes one vehicle with a number of artizans. The foreman uses that vehicle to drop each artizan at his place of work, to tour each site supervising the work, to collect material and supplies from the depot when required, and also to drop men home or bring them back to the depot at the end of the day.

I found that the way the Work Allocation Forms were completed was very inefficient: each artizan is allocated only one job for the whole day, even when the job is expected to last only one hour. This wastes valuable labour hours and creates confusion and problems. This wasted time could easibly be used to reduce the amount of overtime, finish up a long job or complete another pending job.

In addition to the Work Allocation Form the inspector also keeps records of:

- the total hours worked on each job; and
- the number of overtime hours worked by each man.

These records in turn are used to calculate the cost of jobs in terms of man hours and to compute the workers' overtime pay.

(iv) Vehicle Work Ticket - Another important document which I studied in detail is the Vehicle Work Ticket (see Appendix B). This is completed each day for each vehicle by the foreman in charge of the particular vehicle. This form gives among other things:

- the vehicle number;
- the date and driver's name;
- full details of the route taken, material carried, and purpose of the journey;

- the speedometer readings, and times at the beginning and end of the day, and at arrival and departure from each place of work.

Theoretically one could ascertain from this document a great deal of information relevant to the organization and efficiency of the Operations and Maintenance Section. This form could give information such as:

- the time the vehicle started from the depot;
- the supplies and men the vehicle was carrying;
- the details of the route the vehicle took;
- details regarding what and who was dropped or picked up where and at what time, etc.

So we see that this document could be very useful and important, but I am afraid, however, that it is rarely completed fully and accurately. There may be several reasons why this is so:

- the foremen are not very well educated and feel ill-at-ease with paperwork;
- no one apparently scrutinizes the Vehicle Work Tickets afterwards;
- if the Vehicle Work Tickets were properly filled in, many inefficiencies might be exposed.

(v) Foremen's Records - Each foreman is supposed to keep a record of all the jobs done by him on a daily basis, but when I looked into this, these records were either never kept or very irregular. Some of the foremen had not filled in their books for over a year. The reasons for this are the same as for not filling in the Vehicle Work Ticket properly.

If completed such records could have given some very important and useful information for the study as well as for the organization as such.

(vi) Material and Vehicle Record Book - Another record studied was the Material and Vehicle Record Book. This is filled in by the attendants at the gate of the depot. It records the time each vehicle comes in or goes out of the depot, its purpose and what it is carrying.

The above are the few existing records which were most relevant to my study. I found in general that these records were rarely studied by the operations staff at the Operations and Maintenance Section, and the senior management did not insist on their being completed fully and accurately. This reflects the lack of adequate control.

5.4 THE INFORMATION REQUIRED FOR THE STUDY

Once I had become familiar with the way the Operations and Maintenance Section operated and had studied their records in detail, I was able to identify what further information would be needed for my study:

(i) the mileage each vehicle travelled per day;

(ii) the petrol consumed in litres per day;

(iii) the timings of vehicles entering and leaving the yard;

(iv) the time when the vehicles left to collect the labour and the time they returned to the depot;

(v) the time each artizan reached his place of work;

(vi) the number of workers present each day;

(vii) the number of jobs effected each day;

(viii) the number of man hours and vehicle hours assigned to each job;

(ix) the load the vehicles carried in terms of men and supplies;

(x) the amount of time wasted waiting for supplies to arrive at the place of work;

(xi) the amount and type of material used;

(xii) the number and type of jobs done each day, including their location;

(xiii) the length of time taken to answer a consumer complaint;

(xiv) the number of complaints coming into the Control Room through the telephone and other sources, and their classification according to Sections (Mains, Services and Meters);

(xv) the number of personal radio messages, telephone messages and other distracting low priority calls coming into the Control Room;

(xvi) the number of times a vehicle is diverted from its predetermined route by an urgent radio call;

(xvii) the accuracy of the Control Room staff in diagnosing the nature of consumer complaints.

5.5 THE FIRST DATA COLLECTION EXERCISE

In order to collect this required information, a data collection exercise was planned involving nearly all of the activities. I designed a number of forms to be completed by the various members of staff performing the relevant duties. These forms were all geared towards collection of the required data for the study. I took several precautions to ensure the completion and accuracy of the forms:

- I clearly demonstrated and explained in detail to every one concerned, how to fill in the forms and their use;
- no one was asked to fill in their names and I assured them that they need not fear exposure of individuals and that all information would be treated as confidential;
- data was collected for a period of one week - a period not too short and not too long;
- a daily check on filling the forms was administered.

Even after taking all these precautions this large data collection exercise failed. When I collected these forms at the end of the week I found that half the forms were either not filled in or they were incomplete. Very few forms had been properly filled in. The reason for such a response could be any of the following or some other:

- they were reluctant to fill in the forms for they were not totally convinced as to the use of such information;
- may be they were not exactly assured of their security;
- most men in such a field detested paper work;
- they found these forms time-consuming and extra work.

After this failure I was faced with a problem - how was I to collect the necessary data required to carry out the study.

5.6 THE SECOND DATA COLLECTION EXERCISE

After failure of the first data collection exercise the whole situation was reviewed from the beginning. I found that instead of using all newly designed forms, a large proportion of the information needed could be acquired from the existing records. So for the second data collection exercise I used as many existing forms as I could. Some additions were made to some daily records to suit the requirements of the study and a few new very simple forms were also designed to provide the additional information needed.

This time full care was taken that all forms were filled in accurately and completely. Along with the other precautions taken previously to ensure this, I asked Mr. Hurst the Chief Assistant Engineer to call a meeting of all the inspectors, foremen, Control Room and Stores staffs. I then explained in detail how each form was to be filled in, all doubts were erased and questions clarified. Mr. Hurst asked all men to give me their full co-operation and to fill in the forms completely and accurately. He told them that it was their duty to complete the forms.

The various forms that were used for this data collection exercise can be divided into two classes: the existing records and the newly designed forms.

5.6.1 The Existing Records

A general description of each of the existing records used has been given earlier in this chapter. The following is a more detailed and specific account.

(i) The Vehicle Work Ticket - This was the most important form used in the study. This form was completed in duplicate by the foreman in charge of each vehicle. One copy was submitted to me for data collection and the other one was retained in the book for record keeping. This form gave very useful data regarding:

- the time the vehicle left the depot;
- the men and material it carried;
- the time when men were dropped and picked up from the site - this gave the average number of hours actually at work;
- the details of the route travelled by each vehicle - this pointed out the area covered by the vehicle, the distance travelled in miles and any defects in the route taken;
- the amount of supervision done;
- the number of trips made to and from the depot and their durations;
- by noting the speedometer reading I calculated the distance between each site and the total distance travelled by the vehicle each day;
- the time the vehicle returned to the depot.

(ii) The Daily Allocation Form - A minor addition was made in this form: a column was added to note down the waterwork or querry sheet number carried out by each artizan. This form, apart from giving important information, helped keep a check on the data gathered by the Vehicle Work Ticket. Useful operational facts noted were:

- which artizan travelled in which vehicle;
- where was each artizan dropped with his men and to do what;
- by checking out the waterwork or querry sheet number carried, I found how long it takes to satisfy a consumer complaint;

- how many jobs an artizan performs in a day.

(iii) The Overtime Records - This record of overtime hours worked by labourers, artizans and foremen is kept by the inspectors and was used to find out the total amount of overtime worked daily.

(iv) The Control Room Records - From the Control Room I mainly studied the waterwork records and the Daily Complaint Book. These records helped me learn how the complaints are communicated to the Control Room, what type of complaints come in, and how they are classified according to the Mains, Services and Meters Sections. I also calculated how long it takes to satisfy a consumer complaint from these books.

(v) Stores Records - The Stores Issue Vouchers and Return Vouchers filled in by the foreman in charge gave information regarding the number and type of material most commonly used.

(vi) The Gate Records - The record books kept at the gate record the time each vehicle goes and comes in the depot, its purpose and number of the Stores Issue or Return Voucher carried, if the vehicle is carrying any material. These records keep a good check on:

- the Vehicle Work Ticket, as far as the timings are concerned;
- the Stores Issue Voucher numbers, and the time and type of material issued.

5.6.2 The Specially Designed Forms

Some forms were specially designed to collect the necessary information required for the study. These forms were made as simple as possible (see appendices C,D,E & F):

(i) Material Issued - This form was completed by stores attendant issuing the material. It gave -

- the date;
- the name of the foreman coming to collect the material;
- the time the material was collected; and
- the number of the Stores Issue Voucher.

(ii) Petrol Issued - This was another form designed to be completed by the stores staff on a daily basis. It was used to provide information such as:

- the vehicle number;
- the time the vehicle came in to get fuel;
- the amount of petrol, diesel or oil issued; and
- the speedometer reading at that time.

From this I calculated the total amount of petrol, oil or diesel used by each vehicle and by all vehicles, and the rate of consumption.

(iii) Vehicle Re-Direction Form - This specially designed form was filled in by the Control Room staff to find out how many times a vehicle was diverted from its original route by the Control Room and in what type of situations. The form showed:

- the date and vehicle number;
- the time when the vehicle was contacted by radio;
- the present place of work and type of work; and
- the place and type of job, the vehicle and men are being sent to.

From this form one could determine the priorities of the various types of jobs.

(iv) Daily Work Record - Every foreman is supposed to keep a record of all the jobs they do per day, but as mentioned before this record was never kept. Since this information seemed very useful I designed a form asking for the following information:

- the date;
- the foreman's name and section;
- the location and type of job;
- the number of men working on each job or site;
- whether the job was completed or to be continued and, if not completed, why?

From this information given in the form, the following information could be extracted:

- the total area and jobs one foreman supervises;
- number of jobs completed by number of men per day;
- whether an artizan works on more than one job a day or not; and
- what types of jobs are completed in a day and which ones take more than a day to finish.

5.6.3 Additional Information

Apart from all the records and forms used for data collection, some other important facts and figures were collected on the spot:

- the cost of petrol, oil and diesel per litre at that time;
- the daily attendance record of the labourers and artizans;

- the monthly wages of a labourer and an artizan;
- the official working hours;
- the overtime wage rates;
- the total number of vehicles operating at the time of data collection, and their allocation according to sections; and
- the timings at which the material and fuel were issued.

During this second data collection exercise everyone was very cooperative and helpful. All the forms were completed fully and accurately. I continuously monitored the exercise. Due to everyone's combined effort this data collection exercise proved to be successful. I was able to collect all the necessary data without any major problem. The reference period this time was three days long.

5.7 POST DATA COLLECTION PERIOD

Enough information was gathered from all the records and forms studied, to fully describe the following:

- the daily routine operations performed at the depot;
- the daily routine of the labourers;
- how the vehicles were used;
- the use of the Stores and how the material was withdrawn;

- the role of the Control Room; and
- how consumer complaints come in and are dealt with to completion.

A number of charts, maps and tables were drawn from the information gathered to point out the inefficiencies in a number of different areas of the system.

Once the data was collected, I fully analysed it by hand calculation using averages wherever necessary. On the basis of the analysis and the inefficiencies stated through the analysis, I gave a number of recommendations for improving the system. The financial benefit of each recommendation was calculated and specified.

CHAPTER 6

ANALYSIS AND INTERPRETATION OF THE DATA

All the data collected for the study is divided into three areas, and is analysed according to these areas:

- the movement and use of transport;
- the assignment, workload and utilization of labour; and
- the issue, transport and use of supplies.

6.1 TRANSPORT

The Operations and Maintenance Section has many vehicles of various types and capacities. There are diesel vehicles, petrol vehicles, trucks, lorries, cars, pickups, motorcycles, etc.

All these vehicles are usually allocated on a permanent basis. Here we are only concerned with the vehicles allocated to the three Sections, Mains, Services and Meters. At the time of the study this allocation was as shown in Table 5.

Table 5

Vehicle Allocation

Section	Vehicles (NP Number)
MAINS	NP 311, 325, 296, and 256
SERVICES	NP 326, 312, 309, and 293
METERS	NP 209, 204, 315, 317, 316 and 318

From the Meter Section only two vehicles NP 204 and NP 318 were taken into consideration, for these are the only two vehicles which are used for repair jobs in this section. The other four vehicles are used for meter disconnection, reconnection and new connections, etc. and none of these activities were taken into account in this study.

6.1.1 Utilization of Fuel

Fuel is issued to all the department vehicles from the depot. The issue timings are as follows:

Monday to Friday - from 9.30 a.m. to 10.30 a.m. and from 3.00 p.m. to 3.45 p.m.
Saturday - from 9.00 a.m. to 11.00 a.m.
Sunday - closed.

During the reference period, the total amount of petrol, diesel and oil consumed and its cost was as shown in Table 6.

Table 6

Consumption and Cost of Fuel

	Average Daily Consumption in litres	Cost Per litre in Shillings at the time of Study	Annual Cost in Shillings (based on 312 working days per year
PETROL	300	3.06	259,044
DIESEL	84	2.04	53,477
OIL	2	5.35	3,338
TOTAL			315,859.00

This total annual cost of fuel of Shs. 315,859.00 was only a fraction of the total cost of transportation. This cost figure does not include the cost of repairs, wear and tear and depreciation, which is considered to be a substantial amount.

6.1.2 Mileage Travelled

The distance travelled per day by each of the vehicles under study was as shown in Table 7.

Table 7

Mileage Travelled

Section	Vehicle No. NP	1st Day Kms	2nd Day Kms	3rd Day Kms	Total Kms	Average Kms/Day
MAINS	311	214	223	231	668	223
	325	132	122	193	447	149
	296	135	138	155	428	143
	294	176	173	142	491	164
	256	74	138	0	212	106
SERVICES	326	63	198	222	483	161
	312	111	146	149	406	135
	309	206	175	175	536	179
	293	100	114	114	403	134
METERS	204	107	88	197	292	97
	318	130	190	131	451	150
TOTAL	11				4817	

Therefore the average distance travelled by a vehicle per day is

$$\frac{4817}{33} = 150.53 \text{ Kms per day}$$

Assuming a vehicle runs for 312 days a year the total distance travelled by each vehicle per year is approximately 47,000 Kms on average. The life of these vehicles can therefore be no more than three or four years.

6.1.3 Routing

Taking the second day of the reference period, 15th August 1979, as a reference day, the detailed route covered by each vehicle was found from the Vehicle Work Tickets. These details of the route taken by each vehicle under consideration (11 vehicles) was then plotted on a map starting from the depot and ending at the depot. To avoid over-crowding the vehicles were divided into two sets (one of 6 and the other of 5 vehicles) and then plotted separately on two maps. These maps are shown in figures 12 and 13.

From these maps the inefficiencies could be seen clearly. Some of the more noteworthy of these were as follows:

(i) Vehicles are not restricted to areas but travel to all corners of the City. For example, NP 293 on 15th August 1979 went to Kibera, Runda, City Centre, Mathare and Kariobangi. On the same day, NP 318 visited Eastlands, City Centre, Uthiru, South 'C', Mathare Valley, Kariobangi South, Buru buru, and Westlands.

(ii) Two vehicles often covered more or less the same route e.g. NP 256 and NP 293.

(iii) Vehicle NP 204 was on one site at Ngei Estate from 9.25 a.m. to 2.00 p.m. These men could have been dropped there and NP 204 could then have been used for further repair jobs.

(iv) Many vehicles were present in the same area within an hour e.g. the following vehicles were present at City Centre between 12.00 noon and 1.00 p.m.

NP 296, 311 and 318 were there at 12.00 noon and NP 256 and 293 were at City Centre at 12.40 p.m. Similarly there were three vehicles calling within an hour at Umoja: NP 311 was there at 2.00 p.m., NP 326 at 2.20 p.m. and NP 325 at 3.00 p.m.

(v) Vehicles often come from very far to collect men who could have been picked up by another vehicle nearby. For example, NP 311 went to Loresho from Eastlands to pick up John and Gitumbi at 2.20 p.m. although NP 296 was at Loresho at 2.15 p.m.

(vi) All vehicles travelled almost the same route after 3.00 p.m. to drop men after work, i.e. these vehicles called at Kariobangi, Juja Road, Outer Ring Road, and City Centre.

(vii) Most of the vehicles came at around the same time in the morning and afternoon from various parts of the City to Kampala Road Depot, to collect material.

(viii) On 15th August 1979 there were ten vehicles out of eleven doing overtime: NP 256, 296, 311, 326, 318, 293, 325, 204, 312 and 294. Three of these vehicles - NP 293, 318 and 326 - were at Eastlands between 6.30 p.m. and 7.45 p.m.

(ix) Out of eleven vehicles seven called at Kariobangi, nine called at City Centre and

Figure 12

ROUTES TRAVELLED BY VEHICLES

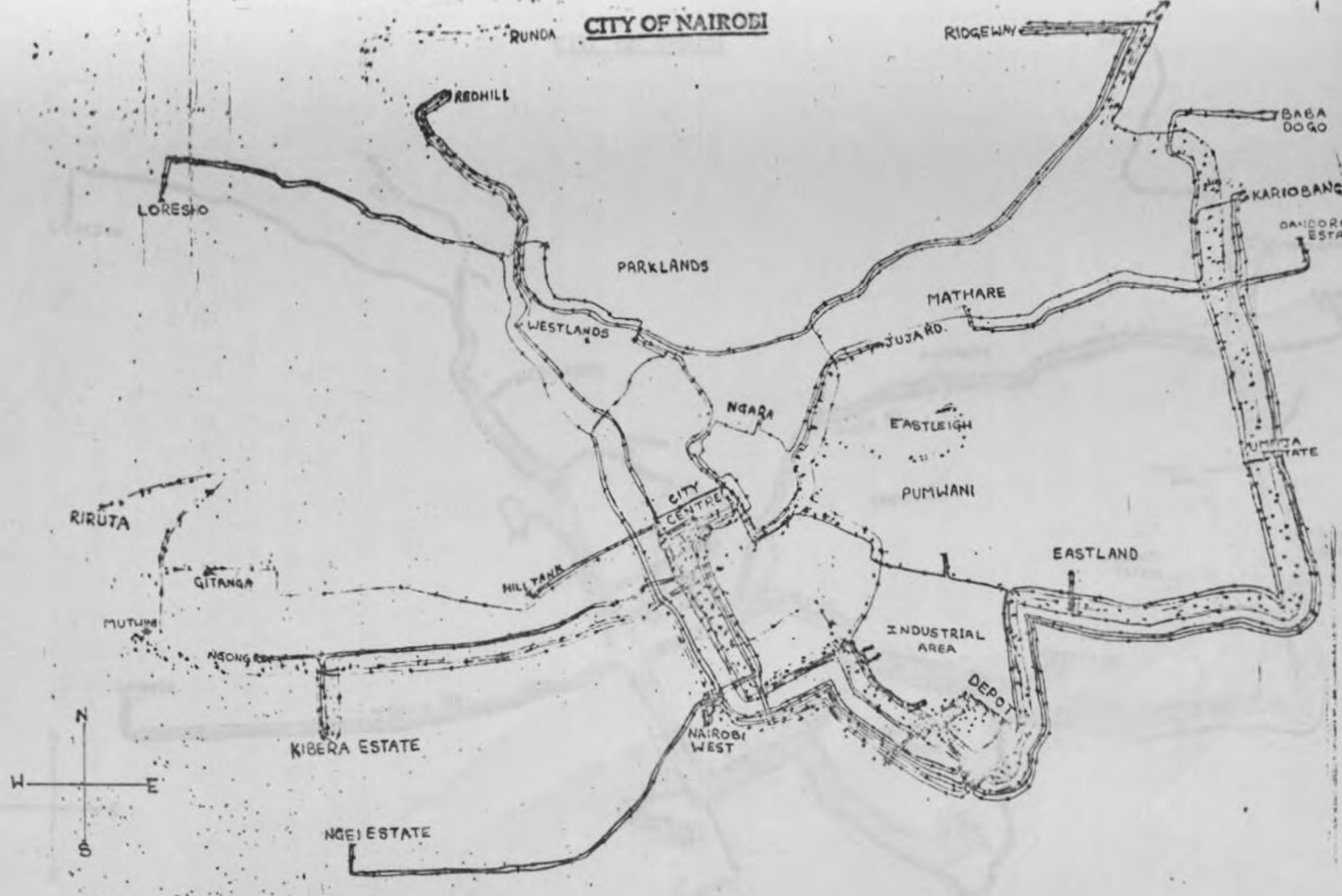
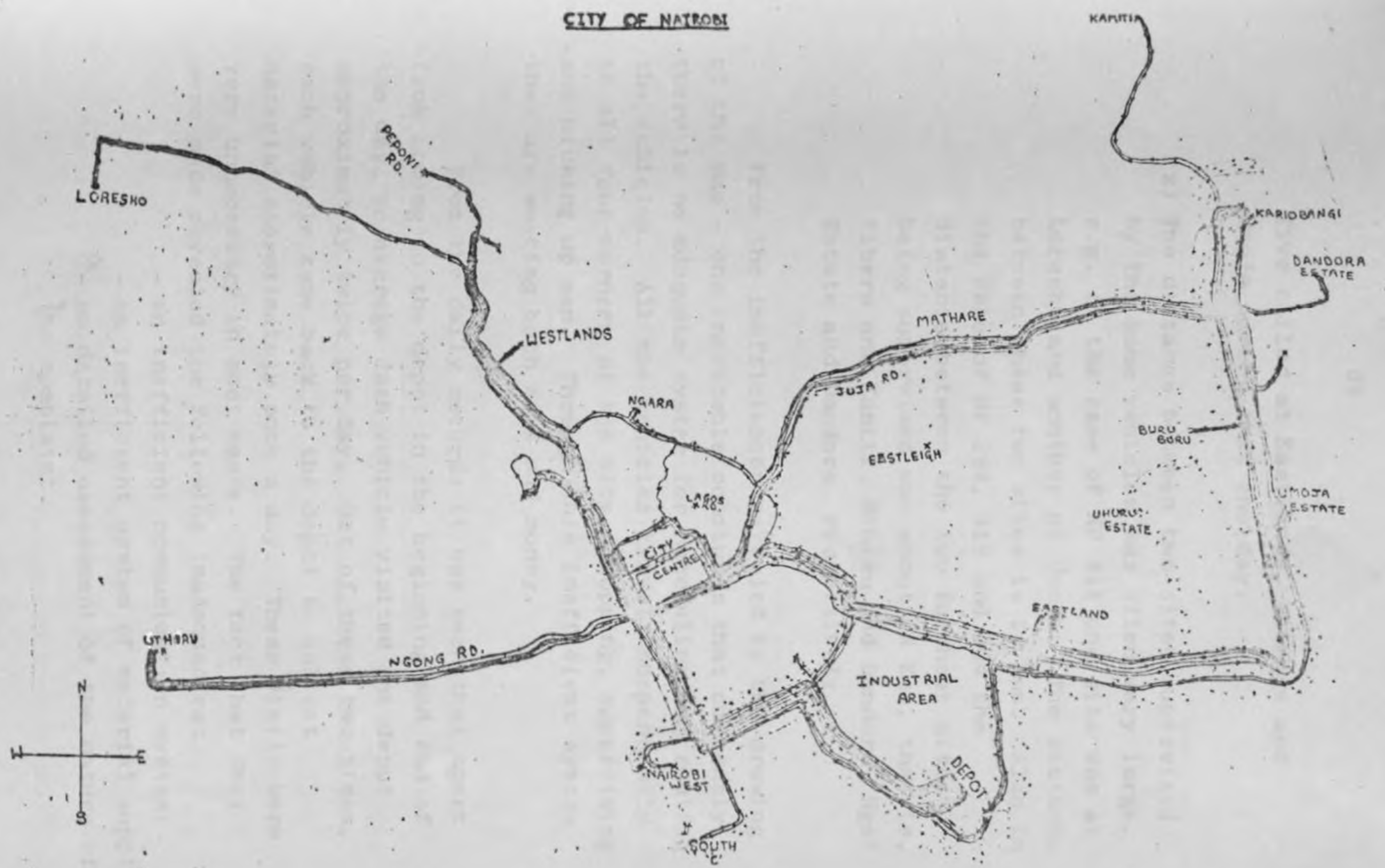


Figure 13

ROUTES TRAVELLED BY VEHICLES



five called at Eastlands, Mathare and Umoja during that one day.

(x) The distance between two sites supervised by the same vehicles was often very large, e.g. in the case of NP 311 one site was at Loresho and another at Umoja. The distance between these two sites is 14 Kms. Also in the case of NP 294, 318 and 204 the distance between the two furthest sites being supervised was about 14 Kms, that is, Kibera and Kamiti, Uthiru and Dandora, Ngei Estate and Dandora, respectively.

From the inefficiences revealed by the drawing of the map - one inevitable concludes that currently there is no adequate system for scheduling and routing the vehicles. All the vehicles travel independently to all four corners of the city, dropping, supervising and picking up men. Through this inefficient system they are wasting both time and money.

From the daily records it was seen that apart from coming to the depot in the beginning and end of the day, on average each vehicle visited the depot approximately twice per day. Out of these two times, each vehicle came back to the depot to collect material approximately once a day. These visits were very unnecessary in most cases. The fact that they were made revealed the following inadequacies:

- an inefficient communication system;
- an inefficient system of material supply;
- no detailed assessment of the nature of the complaint.

As far as the redirection of vehicles in the field is concerned, the Control Room on average redirects only one vehicle per day via radio from its pre-assigned place of work.

6.2 LABOUR

Numerous facts about the use of labour were extracted from the data. The Meter Section is not taken into account here because of lack of information and difference in organization.

6.2.1 Attendance

The attendance according to the daily work allocation sheet and the roll-call register, over the three day period was as shown in Table 8.

Table 8

Attendance Sheet

Section	1st Day		2nd Day		3rd Day	
	Artizan	Labour	Artizan	Labour	Artizan	Labour
Mains	16	49	16	49	16	51
Services	17	49	18	49	18	49

6.2.2 Labour Deployment

The workers are officially required to be on duty from 8.00 a.m. to 4.00 p.m., and with that piece of information together with the data extracted from the Vehicle Work Ticket and the Daily Work Allocation Forms, it was possible to compile the following table no. 9 on labour deployment.

From the table of labour deployment the following facts were extracted:

- The total non-productive hours in the three days = 1289 hours

  Average daily non-productive hours

  $$= \frac{1289}{3} = 429.66 = 430 \text{ hours}$$

Table 9

LABOUR DEPLOYMENT

August 14th - 16th 1979

1 Vehicle Number NP	2 Date (August 1979) (A.M)	3 Departure time from the depot	4 Average arrival time at place of work	5 Average Time spent before reaching place of work (column 4 minus 8 a.m Hrs.	Mins.)	6 Number of men in the vehicle	7 Man hours spent before arrival at place of work	8 Average Depart-ure time from place of work (p.m)	9 Travelling time from place of work (4 p.m minus column 8) Hrs.	Mins.	10 Number of men in the veh-icle	11 Man hours spent travelling from place of work	12 Total man hours spent off the job (column 7 + column 11)
MAINS 311	14	9.15	10.05	2	5	16	33 1/3	2.30	1	30	8	12	45 1/3
	15	9.00	10.10	2	10	12	26	2.55	1	5	8	8 2/3	34 2/3
	16	8.35	8.55		55	18	16½	2.30	1	30	18	27	43½
325	14	9.00	9.30	1	30	33	49½	2.50	1	10	25	29 1/6	78 2/3
	15	9.00	10.15	2	15	29	65¼	3.00	1		29	29	94¼
	16	9.00	10.30	2	30	37	92½	2.45	1	15	25	31¼	123¾
296	15	8.50	14.15	6	15	4	25	2.30	1	30	4	6	31
	16	8.50	9.45	1	45	8	14						14

Mains Contd......

1	2	3	4	5		6	7	8	9		10	11	12
294	15	9.00	9.30	1	30	8	12						12
	16	8.50	8.55		55	8	7 1/3	2.50	1	10	8	9 1/3	16 2/3
256	14	9.30	13.00	5		16	80	2.40	1	20	12	16	96
	15	9.05	9.20	1	20	16	21 1/3	2.45	1	15	12	15	36 1/3
…ER-	14	9.25	9.50	1	50	15	27½	2.40	1	20	7	9 1/3	36 5/6
…ICES	15	9.15	9.50	1	50	20	36 2/3	2.20	1	40	8	13 1/3	50
323	16	8.50	9.55	1	55	18	34½	2.20	1	40	18	30	64½
312	14	8.35	10.20	2	20	28	65 1/3	3.00	1		28	28	93 1/3
	15	9.10	11.20	3	20	14	46 2/3	3.15		45	14	10½	57 1/6
	16	9.05	10.15	2	15	11	24¾	2.10	1	50	11	20 1/6	44 1/12
309	14	9.25	11.10	3	10	23	72 5/6	2.45	1	15	23	28¾	101 7/12
	15	9.50	11.45	3	45	18	67½	3.00	1		7	7	74½
	16	9.10	10.55	1	55	24	46	2.15	1	45	12	21	67
293	15	9.15	10.00	2		11	22	1.15	1	45	11	19⅓	41⅓
	16	9.30	9.40	1	40	10	16 2/3	2.30	1	30	10	15	31 2/3
Total						397	903 1/6					385¾	1288 11/1

(ii) Equivalent number of non-productive men

$= \frac{430}{8} = \underline{\underline{54}}$ non-productive man-days per working day.

(iii) Total average labour force = 115 men

therefore 47% $\left(\frac{54}{115} \times 100 = 47\%\right)$ of the labour force is normally non-productive.

6.2.3 Cost of Non-Productive Hours

On average one artizan works with three labourers. Therefore out of the 54 non productive man-days per day one would expect 13(25% of 54) of those to be due to artizans and 41(75% of 54) due to labourers. The cost of this non-productive labour force is:

Average monthly pay: Artizan - K.Shs. 894.50

Labourer- K.Shs. 503.85

∴ Monthly pay for non productive men:

Artizan: 894.50 x 13 = 11,628.50

Labourer: 503.85 x 41 = 20,657.85

Annual non-productive labour cost is K.Shs.387,436.20

6.2.4 Summary of Utilization of Normal Hours

The following Table showing the utilization of an average day was constructed from the detailed table on labour deployment (see section 6.2.2 above).

The table shows that the workers are actually working for only 4 hours and 15 minutes out of an official day of 8 hours. Thus 47% of their time is non-productive, spent at the depot and travelling to and from their place of work. Noting that we were not able to collect data on transfer time from one job to another and idle time while waiting for materials, non-productive

Table 10

Utilization of an Average Day

	Total Hours	Average Time Spent in Depot in the Morning		Average Travel Time to Job		Average Time on Job		Average Travel Time From Job	
SECTION	Hrs.	Hrs.	Min.	Hrs.	Min	Hrs.	Min	Hrs.	Min.
MAINS	8	1	00	1	21	4	22	1	17
SERVICES	8	1	14	1	13	4	08	1	25
AVERAGE	8	1	07	1	17	4	15	1	21

time is in fact higher than the 3 hours and 45 minutes shown on the table.

From the Daily Work Record and Daily Allocation, it is calculated on average that the number of man hours taken per job by an artizan plus his labour per day were as shown in Table 11.

Table 11

Man Hours Per Job

Section	Average No. of Jobs done per Artizan	Average No. of Men on Job		Total Men	Average No. of Man Hours taken on Job
		Artizan	Labour		
Mains	0.625	1	3	4	51.2 hours/ Job
Services	1.0	1	3	4	32 Hours/Job

6.2.5 Overtime

Amount of overtime worked daily and on average is shown by these tables 12 and 13.

Table 12

Overtime (On a Daily Basis)

Sect-ion	Artizan O.T. Hours				To-tal	Labour O.T. Hours				To-tal	Overall Total Overtime
	1st Day	2nd Day	3rd Day	4th Day		1st Day	2nd Day	3rd Day	4th Day		
Mains	13	12	9	15	49	20	30	30	30	110	159
Serv-ices	11	8	27	15	61	45	24	40	45	154	215
Total					110					264	374

Table 13

Overtime (On an Average Basis)

Section	Artizan	Labour	Average Total Overtime
	Average O.T. per day	Average O.T. per day	
MAINS	12.25 Hours	27.5	39.75
SERVICES	15.25 Hours	38.5	53.75
TOTAL	27.5	66.0	93.5

The average annual cost of overtime can be computed as follows:

Overtime pay rates: Artizan - Shs. 5.61 per hour

Labour - Shs. 3.15 per hour

Average overtime hours per day:

Artizan - 27.5 hours

Labour - 66 hours

assuming that there are 26 working days per month, then:

Artizan overtime hours per month = 27.5x26 = 715 hours

Labourers overtime hours per month = 66 x 26 = 1,716 hours

Cost of overtime:

Artizan -	715 x 5.61 =	Shs. 4,011.15
Labour -	1,716 x 3.15 =	Shs. 5,405.40
Total O.T. pay per month		Shs. 9,416.55

Total annual cost of overtime = Shs. 112,998.60

6.2.6 Time Taken to Satisfy a Consumer Complaint

On doing an analysis of the complaints over two weeks, that is from the 4th of August to the 17th August, from the Daily Complaint Book of the Control Room, it was found that the total number of complaints that came in during that period were 298 of which the number of complaints dealt with were 146. That is, 49% of the complaints were dealt with within that period.

The response time on average for each section is:

Mains - 1.29 days
Services - 3.50 days
Meters - 4.32 days

On average the time taken to satisfy a consumer is approximately 3.1 days.

This figure has been cross-checked by analysing the number of complaints dealt with in a month and the days taken to act on them. This analysis was done for the period from 20th July 1979 to 20th August 1979. The total complaints satisfied within this period were 248 and the number of days taken to satisfy these complaints were 761. So the average time taken to satisfy a complaint was again 3.1 days

6.3 MATERIAL

Data was extracted from the Stores Issue Voucher and the special form described in Section 5.6.2 (iii), to show the type and amount of material used each day. This detailed account can be seen from the Appendix G.

6.4 SUMMARY

The overall summary of all the important quantitative facts analyzed from the data are:

(i) Annual cost of fuel = Shs. 315,859.00

(ii) Average annual distance travelled per vehicle = 47,000 Kms.

(iii) Breakdown of the utilization of an eight hour working day:

- Average time spent at the depot in the morning = 1 hour and 07 min.
- Average travel time to job = 1 hour and 17 min.
- Average time spent on job = 4 hrs. and 15 min.
- Average travel time from job = 1 hr. 21 min.

(iv) Average daily non-productive hours = 430 hours.

(v) Average labour force normally non-productive = 47%

(vi) Annual non-productive labour cost = Shs. 387,436.00

(vii) Number of man-hours to complete a job -

A Mains Job - 51 hours/Job

A Service Job - 32 hours/Job

(viii) Average total overtime worked daily = 93.5 hours.

(ix) Total annual cost of overtime = 112,999.00

(x) Average time taken to satisfy a consumer complaint = 3.1 days.

CHAPTER 7

RECOMMENDATIONS FOR IMPROVEMENT AND SUGGESTIONS FOR FURTHER RESEARCH

7.1 RECOMMENDATIONS

In this chapter we make a number of suggestions for improving the efficiency of the Operations and Maintenance Section of the Kampala Road Depot. The recommendations are based on the analysis given in the preceding chapters.

7.1.1 Reorganization of the Section

At present all activities of the Operations and Maintenance Section are divided into Mains, Services and Meters. This division brings about confusion and inefficiencies; for example,

(i) Sometimes it becomes very difficult to assess a complaint and decide whether it should be dealt with by the Mains Section or the Services Section. This in turn leads to confusion between the two sections and delay.

(ii) At times one part of a complaint can come under the Mains Section and the other part under the Services Section; this complicates the situation.

(iii) A separate Mains and Services Section leads to wastage, e.g. if there is a Mains job and a Services job to be attended to situated next to each other, the same men will not deal with both the jobs. Instead the Services men will deal with the Services job only and the Mains men with the Mains complaint. Therefore there will be two teams of men, two vehicles, and two supervisors or foremen in the same area.

It can be seen from the study that the Mains and Services jobs are fundamentally the same and are very interlinked. It is therefore proposed that the Services and Mains Sections should be merged together to form one large section dealing with all types of repair works. The repair jobs done by the Meter Section should also be handled by this one section. This new section will therefore have complete responsibility for all repair works in the city.

However, apart from the repair jobs the rest of the Meter Section should remain separate to deal with the new connections, disconnections and reconnections of meters.

7.1.2 <u>Subdivision of the City</u>

It is further proposed that the whole City should be subdivided into small operational areas. This idea of subdividing the city into small areas arose from the findings of the study, which revealed that at present vehicles often travel all over the city unnecessarily. This results in the needless waste of labour hours, vehicle hours and petrol.

When dividing the City into small areas a number of factors should be taken into consideration:

(i) The boundaries of each area should be flexible from day to day because workload in each area will fluctuate.

(ii) The areas should be divided on the basis of workload and area.

(iii) The number of areas should correspond to the number of vehicles available at the time.

At least one vehicle and one foreman should be assigned to each area on a permanent basis. Each team (one vehicle, one foreman, his labour force and artizans) should deal with all the daily and emergency complaints in its area.

This will help to reduce the travelling time to a great extent and will improve the supervision of each job. Also the Control Room, knowing the whereabouts of each vehicle will easily be able to contact the right vehicle and men in case of an emergency in a nearby area. Furthermore a great deal of confusion will be eliminated because everyone will know where to go everyday. Lastly the subdivision of the city will help in allocation of the jobs according to areas, and this in turn will increase the overall output.

7.1.3 Supplies Vehicle

A separate supplies vehicle should be allocated to the Stores. This vehicle should be administered by a stores attendant and a driver.

The supplies vehicle will be fully equipped with all the frequently used material and the material specially required by each foreman via the radio.

With this supplies vehicle operating the foremen will have more time to supervise jobs. For instead of all the vehicles and foremen going back to the depot to collect material now only one vehicle will be doing the job which will result in efficiency and savings.

7.1.4 Store Timings

The times when the stores can issue material and petrol should be changed to suit the requirements of field operations. Currently the materials are issued from 10.00 a.m. to 12.30 p.m. and then from 2.00 p.m. to 3.30 p.m., and fuel is issued from 9.30 a.m. to 10.30 a.m. and then from 3.00 p.m. to 3.45 p.m. These timings are one of the major causes of non-productive hours.

The store should be open throughout the official working hours i.e. from 8.00 a.m. to 4.30 p.m. so that the foremen can issue the material required before they leave the depot for work and whenever they want later on. Petrol should be issued from 8.00 a.m. to 9.00 a.m. and then from 2.00 p.m. to 6.00 p.m. so that most vehicles do not have to come back to the depot early from work to fill up for the previous day it should fill up early in the morning and leave the depot on time.

7.1.5 Material Withdrawal

Foremen should be relieved of the demanding task of withdrawing material during the day so that they can concentrate on their main duty of supervision.

Most of the material required for that day should be issued and taken with the foreman in the morning, when he leaves the depot. But in case of any further requirements the foreman should radio in to the Control Room and tell the attendant exactly what he requires. A special team of men under the control of both the senior man in the Control Room and Stores should be created for drawing and loading the material on the vehicle for delivery.

7.1.6 <u>The Control Room</u>

For the recommendations I made to be successful on a long term basis it is necessary to maintain a good control over all the activities going on. The Control Room is set up for this purpose.

I suggest that the present Control Room should be moved to a larger room to accomodate the following recommended changes and additions.

(i) A senior person, who is conversant with repair works should be on duty in the Control Room directing repairs for the whole city. He should receive the calls (complaints), analyse the nature of each call by asking various related questions, classify them, and then allocate the work according to areas. He should then direct the foremen to the outstanding jobs according to their priority, and inform them of the material that will probably be required for each job.

(ii) The senior person in the Control Room should have assistants to help him run the Control Room efficiently and to maintain up-to-date records.

(iii) Wall charts, preferably one for each area, should be maintained in the Control Room, on which the work going on in each area, the work pending in each area and the location of the vehicles and foremen can be displayed visually. These various activities could be shown on the charts by differently coloured pins or magnets.

(iv) A separate map of the whole city should display the whereabouts of the supplies vehicle and the water tankers.

(v) The senior man in the Control Room should also be responsible for deciding overtime details e.g. which jobs require overtime, which vehicle(s) should be on overtime, who is to do overtime and for how long.

(vi) If a foreman in the field requires any additional meterial he should radio into the Control Room before a certain fixed time in the morning and in the afternoon, specifying his requirements. The Control Room staff will then prepare a stores issue voucher and arrange for this material to be issued from the stores and loaded onto the supplies vehicle for delivery.

7.1.7 Labour

Apart from the various changes that will come about in the labourers' daily routine as a result of the above recommendations, I recommend the following changes directly related to manpower.

(i) At present the men are picked up in the morning from their areas of residence and brought to the depot, where the foreman takes attendance, allocates work etc. Then later they are taken to the sites. - I recommend that the men should be picked up at the same time as they are at present but instead of bringing them to the depot they are taken straight to their places of work. This should save a lot of man hours and unnecessary travelling.

(ii) The foreman should take attendance on the site and any absenteesm should be reported to the Control Room over the radio, so that they can account for it and necessary action can be taken.

(iii) In the evening after work the men should be picked up at around 3.45 p.m. and taken straight home, instead of reporting to the depot first.

(iv) To economize on transport, different teams working in adjacent areas should be transported home in one vehicle and other vehicles should then go straight to the depot, instead of all the vehicles going all over the city to drop men home.

All the recommendations given above in one way or another are geared towards scheduling and controlling of the vehicles, labour force and material. The activities of men and material are so interlinked and dependent on the vehicles that they have to be scheduled alongside the vehicle scheduling.

The vehicles are allocated and their movements are scheduled from the beginning to the end of the day.

7.2 EXPECTED IMPROVEMENTS

From the above recommendations various improvements are likely to be seen. Some of these improvements are quantifiable and others are not. The quantifiable improvements are:

Under the Present System	Improvement Made Under the New System
(i) Milage Now a vehicle on average travels 150kms/day or 46,965 kms/year	Assumptions: each vehicle will daily be picking up the men, dropping them at the site, supervising them 4 times, and then dropping them home in the evening. Based on these assumptions we have calculated that each vehicle will travel on average 75kms/day or 33,400 kms per year. This is a 50% decrease.

CONT.

(ii) Cost of Petrol The cost of fuel for running these 11 vehicles now is K.Shs. 315,860/= per year	The cost of fuel of running these vehicles will decrease by half, that is, cost of fuel will be approximately K. Shs. 157,930/= per year.
(iii) Productive Labour At present the average number of productive labour are 4.15 hours per per day.	Under the new system it is assumed that the men will on average be dropped at their places of work by 8.30 a.m. and picked up in the evening at 3.45 p.m. so that productive time then will be 7.15 hours; that is, an increase of 3.00 hours. This is a 70.6% increase in productive time.
(iv) Satisfying Complaints From the Control Room records, etc. it is calculated that the men on average are able to satisfy 49% of the complaints over a period of time.	If under the present system when productive labour hours are 4.15 they satisfy 49% of the complaints, with the new suggested improvements of 7.15 productive labour hours the men will be able to satisfy 84% of the complaints in the same period of time
(v) Job Completion Time At present 3.1 days on average	We calculate that with the improvements under the new

CONT.

elapse between receipt of a call and completion of the work. This was calculated from the the Control Room records	system e.g. 7.15 hours productive hours instead of 4.15 hours, the average job completion time will be reduced to approximately 1.8 days

All the above recommendations put forward have been accepted and approved by the Chief Assistant Engineer, the General Manager and 11 Section Heads. They all agreed, that the implementation of these recommendations would improve the efficiency considerably and decided to draw out the implementation plan.

7.3 SUGGESTIONS FOR FURTHER RESEARCH

This research could be extended in a number of ways.

7.3.1 Stores

An inventory control study of the stores could be a very important topic for research. The system that they follow at present is faulty and leads to a great deal of waste and inefficiency. The material is ordered in bulk and on a tender basis. At present on one hand they are always running short of very essential and important material items, and on the other hand there is material in Store that has not been used for years and may not be used for years to come.

The storing of the material is done in such a way that a great deal of expensive material is just stored in the open, where it is exposed to the heat, cold and rain, which therefore leads to rapid deterioration.

7.3.2 The Meter Section

The Meter Section operates as a separate unit. A detailed study of the Meter Section could be done to see what improvements could be made there.

7.3.3 Depot Location

Research could be done to see whether additional depots would improve the overall efficiency of the Section. Such a study would recommend locations for additional depots.

7.3.4 Others

Apart from the number of possible research areas given above, various small studies can be done to make improvements e.g. study of the repair of vehicles.

The study that we have presented here is very important. Even in industrial countries, consultants see their work concentrating on improving the internal efficiencies of companies, as we have tried to do here in the Operations and Maintenance Section. With the present increasing interest rates particular attention is being paid to inventory control and the reduction of material waste in any way.

BIBLIOGRAPHY

1. Boedecker, E., "The Original Manuscript of the Early History of Nairobi Township", Kabete 1936.

2. Makibia, Irene W., "Decision Making in the City Council of Nairobi", Dessertation, 1974, University of Nairobi.

3. Mwenja, N.S. and Craig-Mcfeely K.F., "Report No.1 Population". Nairobi City Council.

4. Smart, James, "Nairobi, A Jubilee History, 1900 - 1950," Nairobi City Council, Printed and Published by East African Standard Ltd., Nairobi, 1950.

5. Municipal Council of Nairobi, "Nairobi Municipality (General) By-Laws", 1948.

6. Municipal Council of Nairobi, "Abstracts of Accounts", for the year ended 31st December, 1943.

7. City Council of Nairobi, "Abstracts of Accounts", for the year ended 31st December 1955.

8. City Council of Nairobi, " Summarized Accounts", for the year ended 31st December 1965.

9. City Council of Nairobi, "Summarized Accounts and Balance Sheets for the year 1972".

10. City Council of Nairobi, "Careers".

11. City Council of Nairobi, "Annual Report 1957".

12. City Council of Nairobi, "Chania-Sasumua - Kiburu Water Supply Scheme 1969".

13. City Council of Nairobi, "Annual Report of the General Manager, Water and Sewerage Department for the year 1970."

14. City Council of Nairobi, "A Report on the Present and Future per Capita Water Consumption," City Hall Nairobi, 1968.

15. City Council of Nairobi, "Nairobi Water Supply."

16. Nairobi City Council, Urban Department, "Urbanization Report on the Development required to Cover the Period 1971 -1976," City Engineer.

17. City Council of Nairobi, Sewerage and Ground Water Survey, Organization, Management, Finance and Legislation, Special studies prepared for WHO acting as executing agency for UNDP Part 1, 30 Marth 1973, Sweco, Stockholm - Nairobi.

A P P E N D I X

'A'

CITY COUNCIL OF NAIROBI

WATER AND SEWERAGE DEPARTMENT - KAMPALA ROAD DEPOT

DAILY WORK ALLOCATION

DATE	NAME	TYPE OF WORK AND PLACE	TRANSPORT
		FOREMEN	
		CHIEF INSPECTOR	

'B'

VEHICLE FLEET NO.........

SECTION ALLOCATED.......

NAIROBI CITY COUNCIL

WATER & SEWERAGE VEHICLE WORK TICKET

TICKET NO...........................

DATE	DRIVER'S NAME, SIGNATURE & NUMBER.	FULL DETAILS OF ROUTE.	MATERIALS OR GOODS CARRIED (Purpose of Journey).	SPEEDOMETER READING		TIME		NAME & SIGNATURE OF OFFICER I/C
				START	FINISH	ARRIVAL AT PLACE OF WORK.	DEPARTURE FROM PLACE OF WORK.	

'C'

MATERIAL ISSUED

NAIROBI CITY COUNCIL

WATER AND SEWERAGE DEPARTMENT

Date:____________

TIME MATERIAL ISSUED	VOUCHER NUMBER	VEHICLE NO. AND FOREMAN'S NAME

'D'

PETROL ISSUED

NAIROBI CITY COUNCIL

WATER AND SEWERAGE DEPARTMENT

Date:____________

TIME MATERIAL ISSUED	PETROL IN LITRES	DIESEL IN LITRES	OIL IN LITRES	VEHICLE NUMBER READING	SPEEDO-METER

'E'

VEHICLE RE-DIRECTION FORM

NAIROBI CITY COUNCIL

WATER AND SEWERAGE DEPARTMENT

Date:____________

VEHICLE NUMBER	TIME	JOB BEING DONE AT PRESENT	LOCATION SENT TO	JOB TO BE DONE

'F'

DAILY WORK RECORD

NAIROBI CITY COUNCIL

WATER AND SEWERAGE DEPARTMENT

DATE	WATERWORKS OR QUERRY SHEET NUMBER	LOCATION	TYPE OF JOB	COMPLETED OR NOT

'G'

MATERIAL

Type of Material	Unit	Quantity 13/8	14/8	15/8	16/8
1½" Pipe	Metre	150		246	
1½" Sockets	No.	10			
1½" Union	No.	4	1	1	
½" Pipe	Metre	60	60		48
½" Stop Cock	No.	20	2	3	115
½" Bend	No.	12	6		31
1½" Junior Coupling	No.	3		2	5
1½" x ½" Tee	No.	1	1		1
½" Ferrule	No.	1			1
½" Meter	No.	168			2
¾" Pipe	Metre	18		6	42
½" Union	No.	6			
¾" Union	No.	2		1	
¾" Tee	No.	1			
¾" x ½" Bush	No.	2		1	2
¾" Nipple	No.	3		4	3
¾" Bend	No.	2		6	12
½" Nipple	No.	9		3	118
2" Junior Coupling	No.	12			4
3" G.I. Pipes	Metre	18		30	
3" Flanges	No.	2			
3" x 2" Reducers	No.	1			
2" Gate Valve	No.	1			
2" Nipples	No.	6			
2" Bend	No.	4		4	
2" Meter	No.	1			
2" x 1½" Bush	No.	1			
2" Union	No.	4			
3"x 2" Bush	No.	1			

Type of Material	Unit	13/8	14/8	15/8	16/8
2" G.I. Pipe	Metre	312			
4" x 2" Reducers	Metre	2			
6" Flanged Adaptor	Metre	2			
1" Pipe	Metre	120		192	. 6
1" Socket	No.	6			
1" Bend	No.	6		12	4
¾" Meter	No.	6		1	2
4" Pipe	Metre	6		6	
4" x 3" tee	No.	1			
10" Pipe Wrench	No.	1	3	3	1
14" Pipe Wrench	No.	1	2	1	1
18" Pipe Wrench	No.	1	5	2	1
2" x 1" tee	No.	3			
½" Elbows	No.	5	2		30
1" x ½" Bush	No.	3			
1" Junior Coupling	No.	5			
24" Pipe Wrench	No.	1			
¾" Stop Cock	No.	1		2	3
1" Meter	No.	3		2	
1" x ½" Tee	No.			3	
½" Plug	No.			3	6
1½" Bend	No.			2	4
1½" x 1" Tee	No.			1	
1" Stop Cock	No.			2	
¾" Ferrule	No.			5	1
¾" x 1" Bush	No.			1	1
1" Nipple	No.			4	7
Fire Hydrant Boxes 6"	No.			6	
Sluice Valve Boxes	No.			6	
Fire Hydrant Boxes 9"	No.			-	
Fire Hydrant Covers	No.			11	

Type of Material	Unit	13/8	14/8	15/8	16/8
8" x 6" Reducers	No.			2	
6" Pipe (G.I.)	Metre			60	
6" Pipe (UPVC)	Metre			102	
8" Pipe	Metre			102	
6" V.J. Couplings	No.			11	
3" Fire Hydrant Head	No.			1	
4 x 3" Fire Hydrant Tee	No.			1	
4" Mechanical Joint	No.			2	2
1" Ferrule	No.			1	
½" Meter Lining	No.				2
1" Valve Sockets	No.				10
1" P.V.C. Coupling	No.				10
1½" Valve Sockets	No.				4
1½" P.V.C. Coupling	No.				4
1½" Nipple	No.				5
3" x 1½" Bush	No.				1
1½" Gate Valve	No.				1
1½" Meter	No.				1
Alumina Sulphate	Bags				60
¾" x ½" Tee	No.				6
1" Elbow	No.				4
½" Sockets	No.				25
½" Tee	No.				10
Soda Ash	Bags				120
1" Union	No.				2
3" Mechanical Joint	No.				1
1" Plugs	No.				4
⅜" Plugs	No.				4
3" Saddle Piece	No.				2
4" Saddle Piece	No.				2