TRANSPORTATION IN THE NAIROBI AREA: A GEOGRAPHICAL ANALYSIS

by

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

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This thesis has been submitted for examination with our approval as University supervisors:

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ABSTRACT

This study of transportation in the Nairobi Area investigated four major aspects of the road transport system. The areas examined comprised the analysis of the road network properties and the explanation of the processes and factors that have shaped them, public transportation and trip patterns, vehicle volumes and patterns of their movement and lastly the major problems of transportation in the area.

The major network properties analysed consisted of network density, connectivity and accessibility. These were examined in relation to geographical variables such as distance, population, land use, relief and drainage. Public transportation was studied in terms of the relative importance of the city buses, taxis and matatus in the movement of people. A further analysis on this line consisted in the examination of trip modes and purposes in terms of their relative distribution both in space and time. Furthermore,the relationships between traffic movements on the

nodal linkages and factors such as distance, network properties and land use were examined to establish a basis for the understanding of the principles underlying the geography of movements in the city. Lastly, the major road transport problems in the area were identified, their nature analysed and suggestions made for their solution. On the basis of these analyses it was, therefore, concluded that distance from the City Centre is the most important geographical variable determining the road network and movement patterns in Nairobi.

The major findings of this study can be summarised as:

i. Road network density zones form concentric rings round the City Centre,

ii. The trunk, primary and secondary roads of Nairobi are 45 per cent connected,

iii. Nodes on the road network system are spatially organised according to their levels of accessibility at fairly regular distances from the Central Area,

iv. Taxis are used mainly for recreational and social trip purposes,

v. Matatu Passenger Services are not only competitive, but also complementary and supplementary to the city bus services.

vi. Trip distribution by modes is predominantly on foot, but in terms of purpose, work, school and business trips are the most important.

vii. Over 50 per cent of the country's motor vehicle capacity are registered, used and are effectively owned in Nairobi.

viii. Motor vehicle movement patterns in the Central Area is predominantly to and from the west and north of the City Centre, and

ix. The major problems of transportation in the area were identified as accidents, mixed traffic and traffic congestion.

All these findings are of particular relevance to the understanding of the transport geography of Nairobi. This is particularly so in relation to the identification of the major spatial forms of the road network and their relationships with other aspects of the landscape including the phenomenon of traffic flow. Thus, the geographical significance of this study lies in the description, and explanation of the above phenomena as spatial aspects of the human organisation of the landscape of Nairobi.

PREFACE

Transportation geography is a subject with many component parts, each of which could be studied on its own right as a distinct field of investigation. This study was an attempt to integrate the various aspects of the discipline at a sub-national scale. The approach was adopted by the author to give a complete picture and understanding of the road transport sub-system of the area. The analyses, therefore, consisted of the examination of the network, motor vehicle volumes and flow patterns, public transport and trip modes and lastly, problems of transportation in the area. Such an approach made it possible to describe and explain circulation as the infrastructure of the geographic landscape of Nairobi. It is my sincere hope that the view points and methods presented in this thesis will stimulate further investigations into those aspects less or not exhaustively touched.

Before concluding these prefatory remarks, I should like to take this opportunity to acknowledge the generous helping hands I received from various

bodies and individuals, without which, this study would not have been accomplished. My first thanks must go to the Dean's Committee of the University of Nairobi for the research grant which made the completion of this work possible. Secondly my thanks go to Professor S.H. Ominde of the Department of Geography who stimulated me with the idea of undertaking this study.

In preparing the thesis I received a good deal of assistance. On this line my thanks first go to Professor R.B. Ogendo, whose sympathetic and systematic advice and help made the work assume its present shape. Secondly I must thank Dr. A. Ferguson for his detailed chapter to chapter advice and for enriching my statistical background knowledge in handling geographical data. To them, I owe a lot of academic debt. Among the people who nibbled at the original draft of the thesis, I must thank Professor R.S. Odingo for his useful suggestions, some of which, I incorporated. None of these people bears any responsibility for my errors and omissions.

I wish also to thank the following for their wonderful assistence in making data available for this study: John Swai of the City Council, A. Situma of the City Council, A. Agalo Ochieng of the Ministry of Works and last but not least the Traffic Manager of Kenya Bus Service Company Ltd. Lastly, my thanks go to Miss Jane Miduda for her cartographic work and to Miss Essey N. Senvumo for typing the thesis. To each and everyone of these people, my heart-felt thanks.

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INTRODUCTION

1. STATEMENT AND NATURE OF THE PROBLEM.

Nairobi is the main focus of transportation, and communication network systems of Kenya. Along with the rapid development of the City, there has emerged an intricate road network system for internal circulation and access to other parts of the country. The City has, therefore, become the core of Kenya's movement system. This study of transportation in Nairobi Area was directed towards examining and clarifying the spatial structure and pattern of the road transport network system and its traffic flow pattern. Four lines of investigation were chosen as follows:

(a) to analyse the structural properties of the network and to find out factors that have determined them;

(b) to examine the role and relative importance of modes of public transport within the city;

(c) to analyse the composition and usage of motor vehicles, and

(d) to identify problems of road transportation

A. THE OBJECTIVES AND SCOPE OF THE STUDY

In a geographical study of a transportation network system, such as this one, interest should be focused on the relative location of places and spatial structure formed by the network elements. The analysis of the network properties and the explanation of the processes that have created them are, therefore, the basic geographical problems that this study dealt with. Transportation network structure, that is, its layout, and the characteristics of the nodes and linkages show how connected and accessible places are to each other. But a knowledge of connectivity and accessibility as such is meaningless unless we know the magnitude of interaction that takes place via the nodal linkages. Such a knowledge is important because there is a close and direct relationship between network properties and the magnitude of movements generated over the entire network[1]. This relationship and its spatial dimensions and manifestations is examined in this study as a basis for the understanding of the underlying principle of transportation geography of Nairobi. Taking the existence of road transportation network of Nairobi as given, the question of how much traffic flows over the different routes

and their linking nodes is a crucial one in studying its road transport network. As the volume of traffic movements varies spatially and temporally over the different routes, this study made an attempt to determine the role played by the frictional effect of the intervening distance between places on the network; as a basis for the explanation of the variations. It was, therefore, decided to adopt this functional and systematic approach in relation to the study of the road network of Nairobi, to look for answers to the foregoing problems.

In addition to the above aspects that are examined, this study also made an attempt to identify the pattern of the spatial organisation of the area contingent upon the structure of road transport network. The study has, therefore, highlighted some of the social and economic aspects of the geography of Nairobi. Lastly, the study has identified some of the problems that have emerged as a result of the growth and expansion of the road transport facilities in this fact prawling metropolis of Kenya.

For the purpose of this study, the Nairobi Area includes the present provincial boundary as defined by the Regional Boundary Commission Report of 1963. Also considered as part of the area are some relevant neighbouring peri-urban locations such as Mwimuto, Gachie, Uthiru, Wangige and Kingeero, which have been included because of the close links they have with the city through the city bus services. Transportation in the Nairobi Area, as considered in this thesis, means road transportation. The two other transportation systems represented in the area, i.e. rail and air have not been considered as the two transport systems are in essence for external links. Transportation in the Nairobi National Park, though part of the internal road transport system, has also been excluded from the study as it does not fall within the general road transport system of the area and because it serves a different and special purpose. Because of the time limit and difficulties faced in obtaining relevant data and the large size of the research project, some aspects of road transportation in Nairobi were omitted. Movements of goods by road and of people by country buses, which were originally included in the study, have been omitted.

B. HYPOTHESES

This study was based on four major hypotheses that:

(i) The road network density varies with distance from the city centre;

(ii) The accessibility of a node on the road network system is determined by its distance from the Central Area;

(iii) The frequency of bus movements between the city centre and a node on a bus service route is a function of the accessibility of the node, and that

(iv) Traffic movement on the roads linking the City with the surrounding districts is a function of the distance from the City Centre.

2. DEFINITION OF PRINCIPAL TERMS

While most of the terms used in the thesis are clear day-to-day language and do not need further definition, for the general reader, certain technical terms need both operational as well as general definition to show what they mean within the context of this study. Only those terms whose meanings are not explained within the text are dealt with here. The rest are explained within the text or as foot notes.

Transportation or transport as used in this study means strictly the movement of people and goods as opposed to the movement or flow of information and ideas which is generally known as Communication. The two concepts of movement are not generally rigidly separable as they deal with all kinds of spatial interaction and can be summed up in the term circulation[2]. In this thesis the terms transportation and transport have been used interchangeably without assigning specific meaning to where one is used and not the other, as essentially they mean the same thing. The spatial structure of transportation network is the locational patterns formed by the nodes and the linking routes between them. A number of measures have been evolved

by Garrison and Kansky to identify the major structural properties of networks such as connectivity, centrality or accessibility, density etc. and are explained elsewhere in the thesis.

The total pattern of use of space by a given society is known as the spatial organisation of that region. In considering the role of road transport network of Nairobi in organising activities in the area, it was found, for example, that activities in Nairobi are mainly organized around certain nodes of varying significance. Such nodes included the Central Area, the Industrial Area and Nairobi Airport which are located at road intersections or at terminal points.

Graph theory is a branch of topology closely related to algebra and matrix theory. It is commonly used in the analysis of transportation networks. Topology is a branch of mathematics which studies the properties of geometric configuration, always transforming the structures by mapping[3]. One of the indices developed from graph theory for measuring the connectivity of a transportation network and which was used in this study is the gamma index. The index measures the number of observed connections

between nodes or points as compared to the maximum number of connections in that network. Connectivity of a transport network is the degree of direct link from one location to other locations on the same network. It is one of the most important structural properties of a network. The numerical range for the gamma index lies between 0 and 1. The relative degree of ease with which a location on a transportation network may be reached is its centrality or accessibility level. Graph theory again provides a means of measuring nodal accessibility of a transport network by representing the network in the form of a matrix. For example, it was found in this study that the Central Area, because of its central position on the road network is the most easily accessible node from other locations in the city. Traffic as used here means motor vehicles, pedal cycles or pedestrians either moving or static. It also includes the movement of people or goods by motor vehicles or pedal cycles.

Immediately after independence, there sprang up a number of small motor-vehicles used illegally as public passenger carriers in Nairobi.

As years went by, these vehicles assumed the name 'matatu' because of the attractively low thirty cents, flat rate fare, the passengers were charged per trip. Under the Presidential Decree of June, 1973, all motor vehicles of less than 3 tons tare weight were exempted from operating with Transport Licensing Board (T.L.B.) permits as passenger carriers. Hence from that date the matatu motor vehicles have been operating under the cover of this decree as public passenger carriers in Nairobi and elsewhere in Kenya.

3. LITERATURE REVIEW

Not much has been written on transportation in Nairobi 'per se', except as part of the general appraisal of development progress or as part of the general geography of the area. One of the most outstanding contributions to the understanding of the road transportation infrastructure of Nairobi is the recent work by Nairobi Urban Study Group[4].

The Nairobi Urban Study Group describes the City as the focus of a series of radial roads from all parts of the country. The radial roads are well connected by a system of ring roads in all parts, except the northern parts. The City buses are the most important means of public transport. But because of poor organisation of taxi services, unknown number of unlicensed taxis (matatus), which compete both with the city buses and the licensed taxis, are being operated. An important feature about trip making in the city is that the majority of people in Nairobi still travel on foot. The study points out that the major road transport problems of the City are peak hour traffic congestion and the inadequacy of parking spaces in the Central Area. It is the

recommendation of the study that the development of a comprehensive network of roads and public transport routes,and the creation of more parking spaces are the main solutions to the internal road transport problems of the City.

A geographical work which has outlined the historical evolution of roads in Nairobi is that edited by Morgan[5]. In relation to transport planning problems, Morgan sees the ridges and valleys of the Upper Nairobi as presenting difficulty of accessibility to the Central Area and hence are important factors influencing the pattern of road transport development in the area. Walmsley wrote that people living in Eastlands have transport problems during the morning and evening rush hours. He noted further that in the Western parts of Nairobi,bus routes are widely spaced as the routes connect residential areas with the city centre but not with one another. According to him a well developed pattern of interconnecting roads are to be found in the northern suburbs; but there is lack of direct bus route connection between Eastlands and the Industrial Area[6]. It is about twenty years since Walmsley's book was written and much of the information is certainly dated.

It was Soja who noted the dominant position of Nairobi City in the overall transportation network of Kenya[7]. Nairobi,he noted,has the greatest number of motor vehicles compared to any other urban centers of Kenya or East Africa and is a dominant node in the entire communication system of the country.

So much for the literature review on transportation in Nairobi,which is quite brief. In the case of transportation and the geography of transportation in general, the literature is massive and cannot be exhausted all in a brief review such as this. The literature which touches on aspects dealt with in the thesis comprises the following. It was Ullman who saw movement as an indicator of the degree of connection between areas on the earth's surface and a factor that underlies all patterns of interchange. This led him to postulate his 3-factor typology of spatial interaction: complementarity, intervening opportunity and transferability as bases for spatial interaction[8]. This idea is illustrated in Olsson's[9] and Haggett's[10] reviews of studies of movements in relation to distance.

It was Cooley who saw as early as 1894 that the character of transportation as a whole and in detail, at any particular time and throughout its history, is altogether determined by its interactions with physical, economic and social forces and conditions. To understand transportation means simply to analyse these interelationships[11].

The ideas about the nature of the relationship between transport and development have changed considerably over the years. Much of the literature on transportation economics and transportation geography of less developed countries reveal a wide spread belief in the importance of transport and the efficiency of its improvement in accelarating development process[12, 13]. Geographers, too, have long recognised the importance of transportation and its close relationship to economic development. In recent years they have evolved numerous methods of spatial analysis in this context. The use of graph theory as a method of transport network analysis introduced by Garrison[14] and developed and elaborated by Kansky[15] has assumed in this respect a wider significance in geography as a whole[16]. Some studies have

used graph theoretic analyses as the most precise means of analysing network connectivity and accessibility and other structural properties of networks. An attempt to relate transport network properties to development levels in statistical terms has also received wider practical applications[17, 18]. Other studies have applied the gravity model and its many variations to answer questions in cases involving intercity travel, commodity flows, identification of hinterlands and the general concept of accessibility[19].

In the field of urban transportation geography, it was the detailed study by Borchert of the road pattern in the twin-cities area of Minneapolis - St. Paul in the North Central United States which revealed the very strong association between population density and network density[20]. In a study undertaken in connection with the long term problems of traffic in towns, a very striking feature about the future growth of the motor-vehicle number in towns and the nature of urban traffic, have been highlighted[21]. Some of these factors constitute crucial problems faced by urban transport planners.

The literature on which the preparation of this thesis was based ranged from those that provided theoretical background to transportation studies in general to those that were of practical applicability to this case study and are cited in the relevant chapters of the thesis.

4. THE RELEVANCE OF TRANSPORTATION TO THE STUDY OF GEOGRAPHY

The study of transportation geography as an aspect of spatial interaction has occupied the attention of many geographers for many years and has been a lively aspect of the discipline[22]. It is a part of economic geography concerned with transportation development, location and movements of people and goods within the territorial - economic complexes of countries and regions. Its inter-relationship with the location of industry, agriculture, population distribution, cities and natural resources has been recognised by many geographers[23].

Some characteristics of the geography of transportation show that it is a relevant field of geography worthy of study. The pecular form in which the geographical environment can be used as natural routes for transportation or as a basis for the construction of artificial routes for transportation, shows that transportation routes have spatial expression. The predominantly linear distribution of means of transportation

distinguishes it fundamentally from the predominantly point location of industry or areal distribution of agriculture. Transportation plays the role of a material carrier of the territorial - economic productive capacity and makes geographical division of labour a profitable undertaking. All these characteristics of transportation account for its highly geographical character. Thus, transportation geography is part and parcel of the study of geography itself. Spatial analysis of distributions and interactions of phenomena is, therefore, fundamental to the study of the geography of transportation. For the geographer, the chief importance of transportation arises from its role as one of the principal factors affecting the location and distribution of economic and social activities and in its role in organising space. Geographers are, therefore, concerned with the changing spatial structure of transportation networks in relations to other aspects of the landscape and with factors affecting changing patterns of traffic flows.[24] Thus, the ultimate aim in geographical studies of transportation consists of the description and explanation of the phenomena of networks and flows through them as features of the earth's surface.

In a developing country, such as Kenya, there has been a widespread concern for transport in the context of the desire to promote rapid economic and social development. It is opportune that a study of transportation in the leading urban centre of the country, has been undertaken at a time when the public should be made to know the social and economic roles of the road transportation infrastructure.

5. BACKGROUND TO THE STUDY AREA

(a) HISTORICAL BACKGROUND

The initial "raison d'etre" for the growth of Nairobi was as a transportation centre on a railway station and later as an administrative centre. To the Uganda Railway constructors of 1899, the site of what is now Nairobi offered many advantages. It was mid-way between Mombasa and Kisumu and a suitable place for a stop before continuing railway construction over the difficult land a head. To the east and south-east of Nairobi lay the flat terrains of the Athi Plains. To the west and north-west were much steeper slopes and the Rift Valley presented great constructional problems. Nairobi was, therefore, the obvious site. Other advantages for the site selection were adequate water supply from the Nairobi River, ample level land for railway tracks and sidings, an elevated cooler ground to the west suitable for building houses and apparently deserted land offering freedom for land appropriation. Thus, the physical characteristics of the site and their relationship with the surrounding country combined to make Nairobi the choice.

The embryo settlement was named after Masai word, 'Enkare Nairobi' which means a "place of cold water". The rail head reached Nairobi in 1899 and thereafter the railway headquarters, then at Mombasa and the Provincial Government Administration at Machakos were transferred to the site. By 1900 a small Indian Bazaar had appeared and in the same year the Nairobi Municipal Regulations which defined the township area were published. The early growth of the town was characterised by a number of problems. Low standard of buildings, inadequate water supply, poor drainage and the outbreaks of plague in 1901-2 and 1904 all made the choice of the site of Nairobi questionable. However, by 1906 it was decided, despite all these setbacks, that the site had to stay. Definite land use zones had appeared, the pattern of which still underlies the present day Nairobi. It is important to note that by 1906 much of the road network in the Central Area as we know it today had been established.

In 1919 Nairobi became a Municipality with a Corporation and the municipal boundary was extended. Further boundary changes came in 1928. From 1928 to 1963 the boundary remained the same, except for a few additions and excisions. The new boundary

on which this study is based was defined in 1963 as a result of the Regional Boundaries Commission Report recommendations. In 1950 Nairobi became the first town in Kenya and indeed in East Africa to be granted the status of a City.[25] From its early growth the City's functions have developed and expanded so that today it has achieved an overwhelming dominance in the political, social and economic life of the people of Kenya and of the whole of East Africa. Nairobi, the national capital and primate city of Kenya, houses almost all the government and business functions of the country (Plate 1.1).

(b) GEOGRAPHICAL BACKGROUND

A closer examination of the location of Nairobi shows that the city is situated at the Southern end of the agricultural heartland and centre of Kenya[26]. The city lies 1° 19^{1}s of the Equator and 36° 59^{1} E of the Prime Meridian. In terms of physical distance, it is some 480 kilometres (300 miles) west of the Indian Ocean. The Nairobi area on which this study is based occupies an area of 690 square kilometres(268 square miles) and had a population of 509, 286 according to the 1969 census[27], which gives an average

Plate 1:1 The City Centre from the Air.

population density of 734 persons per square kilometre (1903 per square mile). Today, Nairobi's population is almost ¼ of a million people and it continues to increase. It is by far the smallest administrative province in Kenya in terms of size and second smallest in terms of population (Figure 1.1).

The Nairobi Area can be divided into two distinct and well defined physiographic regions. To the west and north is the hilly and broken country, generally known as the Kikuyu Plateau ((Figure 1.2). The land falls from an altitude of over 1905 metres (6250 feet) to 1676 metres (5500 feet) above sea-level, at the city centre. The plateau surface is covered with lava flow material generally called Nairobi trachyte. To the east and south of the city centre are the flat featureless Athi Plains, generally 1500 metres (5000 feet) above sea-level. The parent rocks are the successive layers of Nairobi and Kapiti phonolites both of which are volcanic in origin. These have weathered down to produce the heavy black cotton soils of the plains. Unsurfaced roads on these soils are very muddy and slippery in wet weather and even those with good foundations and tarmaced

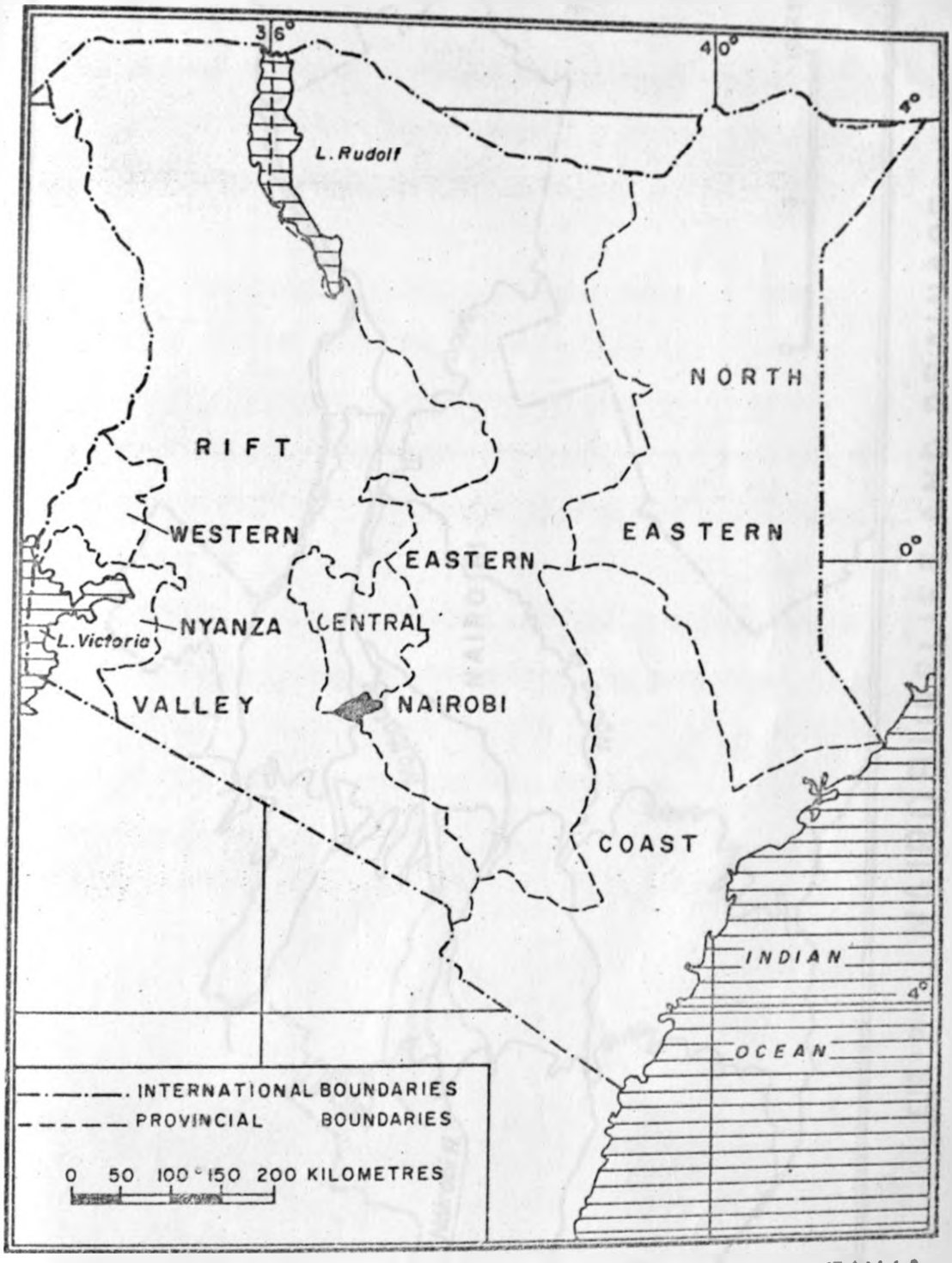

FIG. 1.1 LOCATION OF NAIROBI IN KENYA

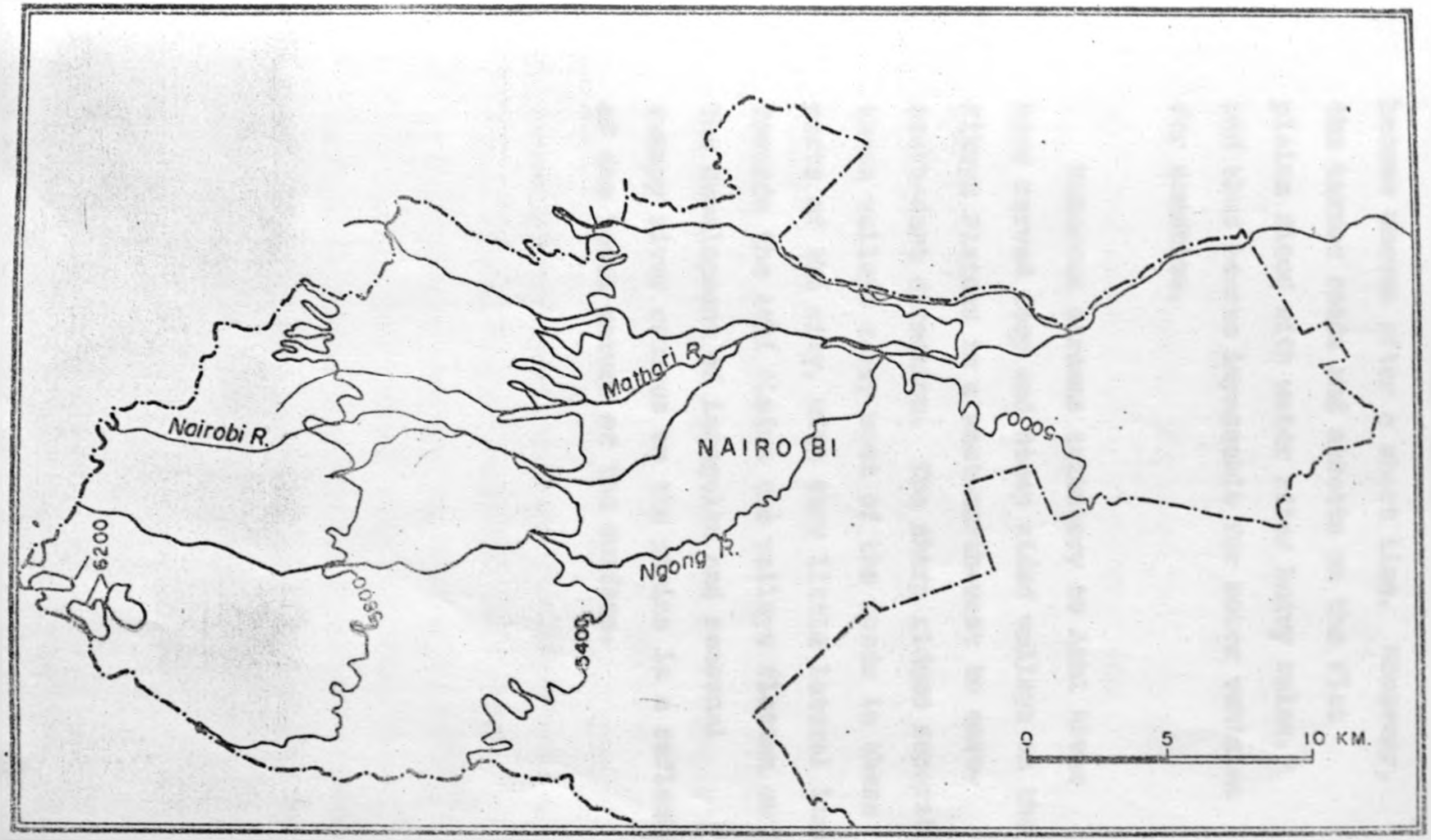

FIG. 1.2 NAIROBI: RELIEF AND DRAINAGE

become uneven after a short time. Moreover, the tarmac roads and streets on the flat plains flood with water after heavy rains, and thus become impassable for motor vehicles for sometime.

Numerous streams tributary to Athi River have carved deep and steep sided valleys on the Kikuyu Plateau in a west-north-west to east-south-east direction. The sharp ridges separating these valleys carry most of the roads in these parts of the city, with very little lateral links. Towards the Athi Plains the valleys flatten out. The development of irregular and seasonal swampy river courses on the plains is a reflection of the level nature of the surface.

(c) LAND USE PATTERN

Superimposed upon the above historical background and natural set up of the geography of Nairobi is the human land use of the area (Figure 1.3). The variations in the distribution of road and rail transportation network in Nairobi are closely associated with the pattern and types of land use of the Area. The City has a clearly differentiated Central Commercial and cultural core accommodating business offices and commercial facilities, Government and the offices of the civic authorities. In the south-east and close to the commercial core is the railway station complex which is a block to the development of road links between the Central Area and the Industrial Area. The major architectural land marks of the Central Area are Parliament Building, the Central Law Courts, the City Hall, Kenyatta Conference Centre and the Hotel Inter-Continental all of which form an impressive view within the city square (Plate 1.1). To the extreme north

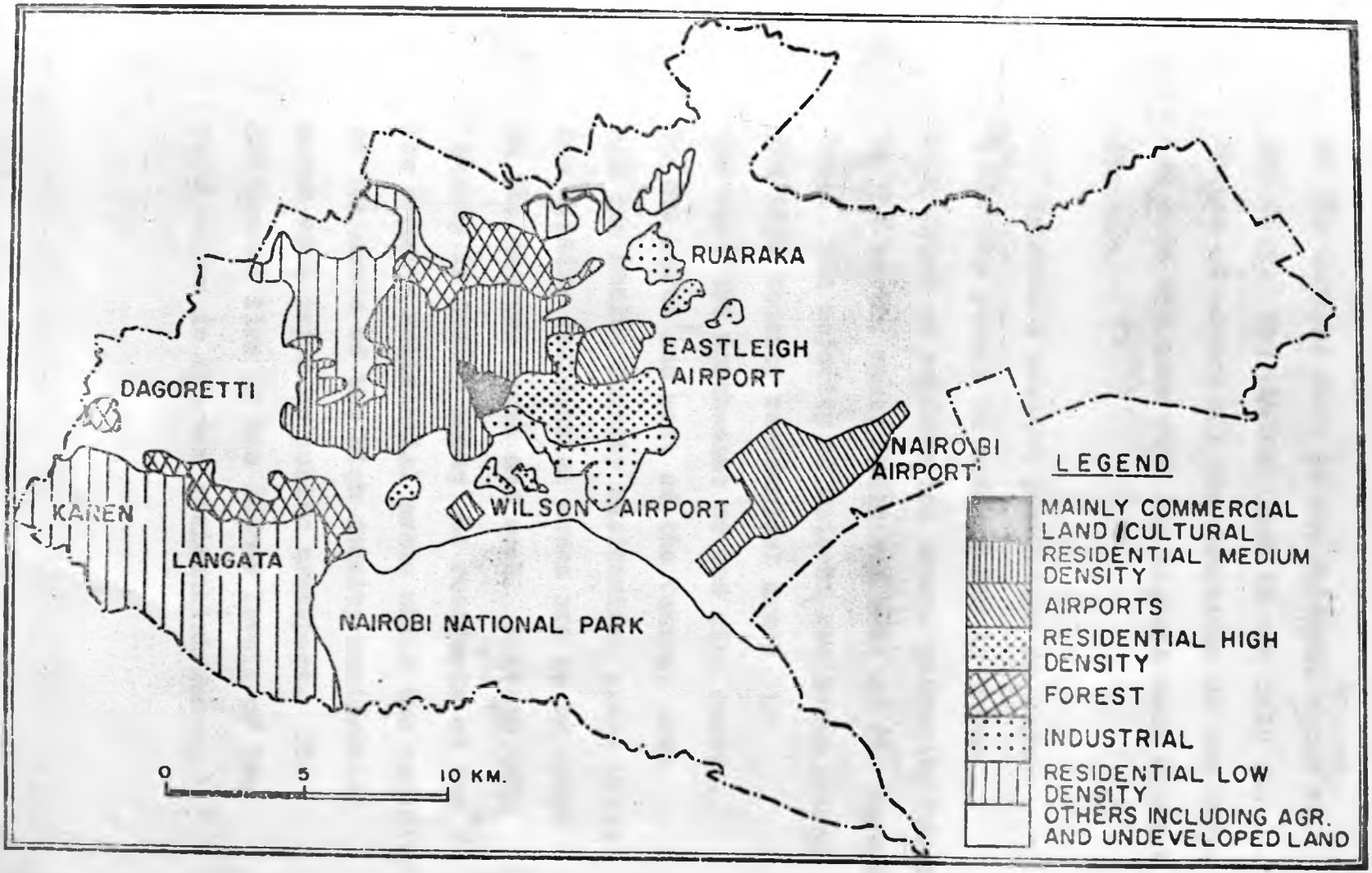

FIG.1.3 NAIROBI: LAND USE PATTERN

of the Central Core is the cultural focus of the city. The Central Area is not only the Centre of almost all the functions of the city, but also the area with the highest road network density.

Nairobi's present population of about ¾ million people is catered for in three main types of residential areas, primarily located to the north, west, south and east of the Central Area. The majority of Nairobi residents occupy the high density residential areas to the east and north-east of the city centre. To the north and west of the Central Area are the medium density residential areas while low density residential areas are to be found in the extreme north and west. Private trip making is common among the residents of the low density residential areas while the majority of residents of the high density residential areas make trips by public transport. The difference lies in the income levels of the populations in the two residential zones.

The expanding and varied industrial activities are normally accommodated in the level land extending from the railway property almost to Nairobi Airport. This is the area where the railway activities in Nairobi are concentrated. Other Industrial development areas have sprung up in the Ruaraka, Dandora and Kassarani areas north-east away from the Central Area.

The boundary extension of Nairobi in 1963 brought in large areas of farm land and forests in the east, west and north. In addition, Nairobi is lucky in having close to the Centre a large Game Park which is a Centre for attraction to both Kenyan residents and to tourists from abroad. A considerable area of land still remains under the Government and the City Council and this has made it possible for the development and expansion of the three airports of Embakasi, Wilson and Eastleigh.

Within this simple and very generalised geographic background of Nairobi has evolved a network of road transportation lines which have

transformed the city into a modern centre of local as well as of international repute. The details of the structure and patterns of these lines of link are dealt with in Chapter 3 of the thesis.

6. OUTLINE OF THE CHAPTERS

This study consists of seven chapters and appendices. Chapter One examines the nature of the problem in terms of its objectives and the scope of the study, hypotheses, definition of principal terms, literature review and the relevance of transportation to the study of geography. Also examined in this introductory chapter is the historical and a brief geographical background to the study area.

In Chapter Two the Methodology, which includes data collection techniques employed and methods of processing, analysing and presentation of the data collected are discussed. As a prelude to the methodology, some research difficulties experienced in the field and those that were of miscellaneous nature are pointed out and ways used to overcome some of them explained.

Chapter Three deals with the spatial structure and pattern of the road transport network. The structure and pattern of the network are described and analysed qualitatively and quantitatively.

Public transportation and trip patterns and characteristics are discussed in Chapter Four. The chapter discusses the roles of city buses, hired taxis and matatus as public carriers and their interrelationships evaluated. Chapter Five gives an analysis of the composition and usage of motor vehicles in the city. The chapter concludes by looking at some of the practical implications which are likely to come up as a result of the increasing number and usage of motor vehicles in the area.

Chapter Six of the thesis deals with problems of transportation in Nairobi including some suggestions for possible solutions. Summary and conclusions come in Chapter Seven. Major findings and recommendations for further improvement of the road transport facilities are outlined. The Chapter concludes by suggesting areas which need further research in future.

Lastly two appendices have been included to provide further details about aspects examined in the study. Contents of the appendices should be regarded as part of the work which went into the preparation of the thesis and therefore need to be referred to whenever necessary.

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CHAPTER 2

METHODOLOGY

1. MAJOR RESEARCH DIFFICULTIES

2. DATA COLLECTION INSTRUMENTS

   (a) Sources of Analytical Techniques used in Processing the Thesis Data.

   (b) Maps and Publications.

   (c) Surveys, Visits and Photographing.

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   (e) Sampling Designs.

3. DATA PROCESSING, ANALYSIS AND PRESENTATION

   (a) Data Processing:

      (i) Editing

      (ii) Tabulations

      (iii) Quantitative analyses

   (b) Map Designs and Graphic Representations.

METHODOLOGY

1. MAJOR RESEARCH DIFFICULTIES.

The initial plan of this study was to cover all aspects of transportation in the area. It was realised later that some of the aspects included in the proposal could not be covered, either because the data on such items was not available at the time of the survey or because limited funds and lack of other necessary research resources made the extension of the survey to include such aspects in the study impossible. The study of travel patterns and characteristics in the field was not possible because such a study needed a team of field surveyors and assistance from the police force to help in stopping vehicles and questioning passengers. An individual project such as this lacked such resources, so the author resorted to published work on those aspects of transportation in Nairobi,[1] with modifications to suit the requirements of the study. Movements of commercial goods by road was omitted from the study, because it was found in the field that firms which specialise in this form of transportation are so varied in sizes and organisation that it

proved difficult to locate them precisely in Nairobi. While some firms, such as Kenatco, are big and well organised, it was actually difficult to obtain data from them because of the confidential nature of some of the items they record.

A similar problem came up in the case of passenger movements by country buses. Some bus companies would only release data on the number of buses despatched from Nairobi to up country towns but not the actual number of passengers moved for any given period whatsoever. So this field of investigation was also given up. Information on the number of bicycles and hand carts licensed by the City Council each year was not also available.

Some business operations were very co-operative and gave useful answers to the questionnaire, but some would not give answers to certain questions for fear of giving information which they regarded as confidential to the firms or business concerned. The Secretary of the Matatu Owners Association had to stop my field assistants from further

questioning the matatu operators. If any information was needed on matatu operations the questions had to be directed to the association bosses, and not to individual matatu operators. Fortunately, the interference came after information was already in hand.

In the field of raw data collection, some data were found to be irrelevant to areas of inquiry and some data were still in classfied files and the authorities would not allow anyone to have access to them except with special permission from above. Where this was possible, the data had to be collected in the disorganised state of arrangements and later to be processed in the forms suitable for the needs of the study. This was indeed a very slow and tedius job.

The other difficulty was in connection with how much data was needed and how long was the span of the period for which the data was needed. Data for a one year period was possible to get, but anything upto five or more years would not be released. Some firms frankly expressed their fear of comparative

and trend analysis of such data if they were for longer periods. In the circumstances, the author had to resort to annual reports where these were available for data spanning over a number of years.

In Nairobi, one of the difficulties encountered by a research bent on collecting as much information as possible in any field of investigation is the over whelming a bundance of the material available in the form of reports pamphlets etc. But on closer scrutiny of the material, one finds that some of them lack clear definition. Some material is incomplete or simply the data are inaccurate and conflict when comparative analysis is made. It was, therefore, decided to extract only the most essential and the less essential had either to be trimmed down to manageable proportions or to be discarded altogether.

Nairobi is a complex city which requires researches covering the whole area such as this one, to be organised on a team basis. This being the nature of the research difficulties faced by the author, any errors of omission should be regarded as those that were beyond his resource capacity.

2. DATA COLLECTION INSTRUMENTS

(a) Sources of Analytical Techniques used in Processing Thesis Data.

Field work for this research started in May, 1975 and took a period of six months to accomplish. The early stages of the work were spent on intensive review of pertinent literature on transportation in Nairobi. The literature, thus, reviewed included reports on transportation planning, annual reports from bodies concerned with various aspects of the transportation industry in the area and above all, a general review of books and allied publications. Of tremendous assistence to the preparation of this thesis were books and publications on transportation geography in general. These provided the basis of much of the theoretical background to this study. Most of the theoretic techniques of transportation analysis used in this study came from these sources. These included graph theoretic techniques and other statistical techniques of analysis applicable to transport study. Such references are cited in the relevant chapters of the thesis.

(b) Maps and Publications

Maps of various types, published and unpublished were the major sources of much of the data collected on route networks and flow patterns. The National Atlas of Kenya; City of Nairobi: Map and Guide and topographical maps of Nairobi and the adjoining sheets, all published by the Survey of Kenya, provided the information required on transportation networks of Nairobi. Of considerable value were the road traffic census maps for the Central Area prepared by the Traffic Engineers Department of the City Council. Information on the City bus service movements was obtained from the Kenya Bus Service route map prepared by the Kenya Bus Service Company Limited. A base map of Nairobi on the scale of 1:50,000 was used for recording information on road transportation. Other techniques of collecting information or data from maps are explained in the relevant chapters of the thesis.

The rest of the data which went into the preparation of this work came from publications. This was particularly so in the case of data on motor vehicle registration, the main sources of which were the Economic and Statistical Reviews,

published by the East African Statistical Department and Statistical Abstracts published by the Central Bureau of Statistics of Kenya. Other data on road transportation came from unpublished sources, which included files, record books and pamphlets. These were obtained from the Registrar of motor vehicles. Data on travel patterns and characteristics in Nairobi was extracted with several modifications from "Nairobi: Metropolitan Growth Strategy", Volumes 1 and 2, published by the City Council of Nairobi. Data on matatu passenger trips came from a recent study undertaken by the City Council to determine the level of their operation as public carriers, entitled: "Pirate Taxis (Matatu) Operations in Nairobi".

(c) Surveys, Visits and Photographing

Extensive personal field surveys of the entire Nairobi Area were carried out by the author with a view to acquainting himself with the pattern of road network. These surveys were very important for the study of road transportation network because of the present changes in street and road names

that have taken place in Nairobi since the country attained independence. These on spot visits culminated in taking of photographs, holding discussion with transport authorities on their day-to-day operations. Much of the information on transportation problems was collected in this way.

(d) Questionnaire and Interviews.

These were directed to the following bodies and people:

(a) Ministry of Works, Roads Department;
(b) City Engineer's Department, Planning Section;
(c) Kenya Bus Service Company Limited;
(d) The Matatu Operators;
(e) Hired Taxi Operators, and
(f) The Kenya Police Traffic Division, Nairobi Area.

It was from these sources that most of the missing gaps in the information obtained from published and unpublished data sources were filled up.

The questionnaire and interviews administered are included in this thesis as part of the appendices.

In the case of questionnaire to matatu operators and hired taxis operators, the interviewers were asked to put a tick against the responses and write the registration number of the vehicles whose operators were interviewed. Other interviews were of the question and recorded type.

(e) Sampling Design.

A simple systematic sample of forty licensed taxis for hire was chosen from approximately 150 private hire taxis operating from twelve fixed ranks in Nairobi. The interviewer was instructed to interview every third taxi operator he came across at each of the twelve ranks. It was very difficult to determine precisely how many matatus are in operation in Nairobi. It was, therefore, decided arbitrarily to use the same sample size of 40 for matatus as well. Furthermore, the interviewing techniques as those for hired taxi operators were applied. Other techniques of Sampling used in this study are discussed and explained in Chapter 3 in the main body of the thesis.

3. DATA PROCESSING, ANALYSIS AND PRESENTATION

(a) Data Processing.

Two stages were involved in data processing, namely, editing and tabulation. It should be pointed out here that all the stages were done mechanically by the author in the light of too high expenses which should have been incurred if a computer was used. Though this was a laborious job hardly free from mistakes inherent in such analyses, it was the only alternative.

(i) Editing

Editing was applied to the statistical data collected from various sources as well as to the information from the questionnaires and interviews. In certain cases some of the statistical data were found to contain certain facts which did not lend themselves to analysis for this study. Under these circumstances the data had to be summarised for presentation in the main body of the thesis or simply some information which was not found to be relevant was discarded altogether. The information from questionnaire and interviews was similarly edited leaving only the information which was

found to be absolutely essential and complete. In cases where the information was in excess of what was needed, it was summarised and heavily truncated.

(ii) Tabulations

The raw data from the various sources named above were processed with a view to presenting them in forms suitable for the requirements of the type of interpretation the author had in mind. In this work, therefore, most of the statistical data were presented after processing in tabular form. The main technique used in the analysis of table data was the calculations of percentages. Such tables will be found in the text as they provided a basis for discriptive accounts and interpretations of the information found. Those that were of miscellaneous nature or that were used as part of the quantitative analyses are also included in the text.

(iii) Quantitative Analyses.

Some of the data collected for this study have been analysed by statistical methods, both descriptive and inferential. Two basic statistical analytical techniques were employed. They are the graphtheoretic analyses of network systems and the simple correlation and regression analyses. Graph theoretic analyses were applied to determine network connectivity and accessibility using certain indices for measuring network connectivity and using matrix table for accessibility[2]. The details of these analyses are discussed in Chapter 3. The details of the applications of correlation and regression analyses are discussed in Chapter 3, 4 and 5.

In cases involving the application of simple correlation and regression analyses the inferential statistics used was the F - test for the analysis of variance test of the hypothesis that $\rho = 0$[3]. In each case the level of significance was held at 0.01. Details of the results are also discussed in the relevant chapters.

A semi-quantitative analysis was carried out in preparing a map for road density zones (Chapter 3). A transparent tracing paper was superimposed on a road transportation network map (Figure 3.1). Grid cells each measuring 4 centimetres enclosing an area of 4 square kilometres were drawn on the map. To determine the road network density a system of counting the number of road junctions in each grid cell was employed. It has been found elsewhere that road junctions are highly correlated with total road length in any given unit area of measurement[4]. The number of road junctions were, therefore, used as a measure for the density of the road network in Nairobi. The number, thus, obtained was recorded at the centre of each of the grid cells covering the map of the whole of Nairobi Area. Isolines were drawn on the map at intervals of 20 road junctions. In this way a map showing road density zonesin Nairobi was constructed (Figure 3.3).

(b) Map Designs and Graphic Representations.

The thesis is illustrated with nineteen maps, both qualitative and quantitative in design. The maps were designed basically to illustrate some aspects of the geography of Nairobi and to illustrate patterns of the road network structure and the phenomenon of traffic flows.

Purely qualitative maps include, the location of Nairobi in Kenya (Figure 1.1), relief and drainage (Figure 1.2), land use pattern Figure 1.3), road network of Nairobi (Figure 3.1), road density zones (Figure 3.3), major streets of the Central Area(Figure 3.2) road network connectivity (Figure 3.5), road accessibility (Figure 3.6) and road accident spots (Figure 6.1). The remaining ten maps are either pure or semi-statistical. The purely quantitative or semi-quantitative maps vary from those that show volume of traffic movements measured in terms of proportional thickness of the lines to those that simply record the amount of traffic handled in a given period of time on individual route links. The other group of quantitative maps have proportional circles showing the relative sizes of nodes or places in terms of the amount of traffic

passing or using a particular point or node in a specified period.

Both the qualitative and quantitative maps are simple in design, but nevertheless show effectively the information they illustrate. Since transportation studies deal mainly with the mapping of linear distribution of phenomena, these maps were the best thought suitable for the illustrations. The only form of a graphical illustration used in the thesis are photographical plates. These are seven in number.

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CHAPTER 3

THE SPATIAL STRUCTURE AND PATTERN OF THE NAIROBI TRANSPORTATION NETWORK SYSTEM

THE SPATIAL STRUCTURE AND PATTERN OF THE NAIROBI TRANSPORTATION NETWORK SYSTEM

1. INTRODUCTION.

The Nairobi Area is well served with an adequate road network system for both internal circulation and for connection with other parts of the country. It is linked to the Western Kenya by the heavily used trunk road via Nakuru. To the Mount Kenya Region, Thika Road provides such a link, while Mombasa Road links it to the Coast Region. A further improvement in the City's external links is the new tarmac highway which has been constructed between Athi River and Namanga to provide access to southern parts of Kenya and to Arusha in Tansania. Plans are also under way to provide an all-weather road to link the city with Ethiopia through the drier northern region of Kenya. In addition to the external links provided by the trunk roads, the city also gains access to outside world through its airports and the railway lines. The trunk roads, though not essentially part of the general internal transportation system, are nevertheless important traffic generators in so far as they affect the traffic movement volume in the internal road transport system of Nairobi.

The trunk roads such as Waiyaki Way, Thika Road and Mombasa Road are important traffic generators to the internal road transport system. Much of the motor traffic which streams daily into and out of the city is carried via those major arterial highways. A measure of their importance in this connection can be illustrated by the fact that on average, each of them carries over 5,000 motor vehicles per day at the city boundary entry points (Figure 5.3). While some of this traffic could be considered through traffic, much of it forms part of the daily traffic on the road network system.

It is only in this connection that the trunk roads could be considered as part of the internal transport system of Nairobi, otherwise they are basically for external links. We turn now to a detailed study of the internal road network system of the area.

2. THE ROAD TRANSPORT NETWORK

In addition to the trunk roads considered above, a series of radial roads also converge at the city centre connecting Nairobi with the adjoining districts and the rest of Kenya. Between them a system of inner and outer ring roads provide lateral connections. The principal roads in this system comprise the Outer Ring Road, connecting Thika Road to Mombasa Road, the St. Austin's - Kingara Roads connecting Waiyaki Way to Ngong Road, and Langata Road linking Ngong Road to Magadi Road. It can be seen, therefore, that there is lack of ring road connection between the northern radial roads. This has been made difficult because of the existence of numerous steep-sided stream valleys separated by difficult ridges running parallel to the roads. Plans are, however, underway to construct additional ring roads to reinforce the existing ones[1]. Such new roads will include the Limuru-Rosslyn Road to run across the northern side of the city and will form part of the northern extension of the St. Austin's Road. The Trans-African Highway will join Kikuyu in the north-west to Mombasa Road in the south. The Eastern By-pass will connect

Mombasa Road near the Airport to Thika Road at Kassarani. Maps 1, and 2 in the appendices show these projected ring roads.

In addition to the radial and ring roads, a comprehensive network of interdigitating secondary and minor roads of greater complexity have also been developed. The pattern of this road network distribution is shown in Figure 3.1.

The gridiron layout structure is the dominant feature of the Central Area streets and roads (Figure 3.2). On the map are shown only the major streets with their names. For this study, the Central Area has been defined as that area bounded in the north by University Way, in the south by Haile Selassie Avenue-Race Course Road, in the west by Uhuru Highway and in the east by Kirinyaga Road. In between the streets and roads numerous smaller streets and lanes of minor internal circulatory importance provide access to shopping and other service centres in the Central Area.

Basing this study on the Ministry of Works road classification system, five categories of roads have been identified:

FIG. 3.1: ROAD AND RAIL ROUTE NETWORKS OF NAIROBI

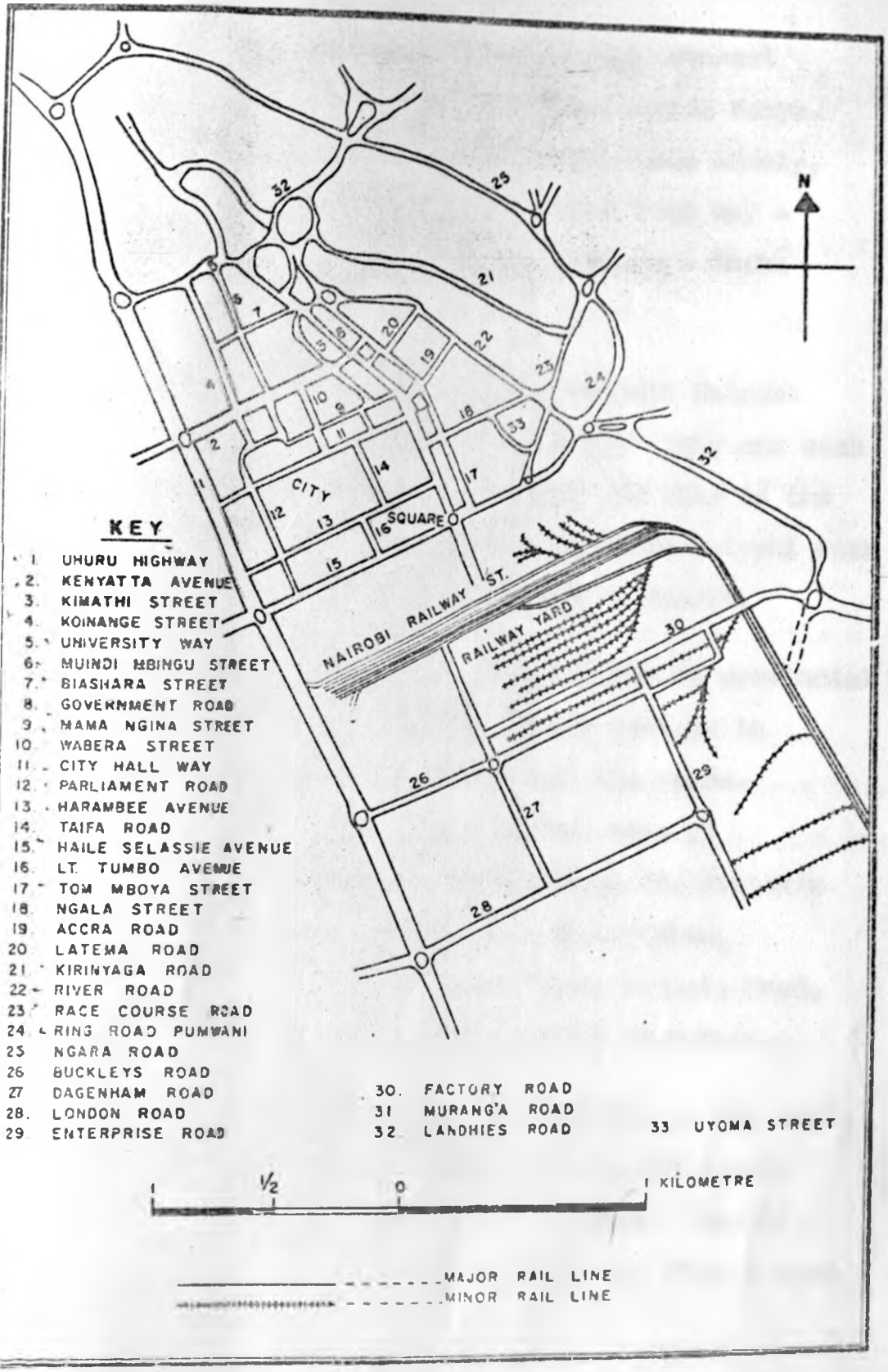

FIG. 3.2: THE CENTRAL AREA MAJOR STREETS

(a) International Trunk Roads connect Nairobi with countries outside Kenya. There are only two such roads namely, the Mombasa Road - Uhuru High Way - Waiyaki Way and the Muranga - Thika Road.

(b) National Trunk Roads connect Nairobi with an external country. Only one such road exists in Nairobi and this is the Airport Road which connects Nairobi with an external world, the "Airport".

(c) Primary Roads, link Nairobi to provincial or major administrative centres in Kenya and include the ring roads. They are nine in number namely: Kiambu Road, Limuru Road, St. Austin's Road, Naivasha Road, Ngong Road, Aerodrome - Magadi Road, Langata Road, Outer Ring Road and Koma Rock Road.

(d) Secondary Roads are feeders to the trunk and primary roads. Three roads fall within this category namely: Kamiti Road, Lower Kabete Road and Kikuyu Road.

(e) Minor Roads are also feeder roads but are basically for internal circulation and accessibility. The remaining roads including streets and lanes of the Central Area are categorised as minor roads.

An important feature of the distribution of the road network system of Nairobi is the strong north-west to south-east or west to east orientation of most of the roads, particularly those to the north and west of the Central Area. This can be explained by the strong influence exerted by the general alignments of valleys and ridges in the same direction on these parts of the city. Here most of the roads are found on the ridges, while valley bottoms have few and in some cases no roads at all. In the western and north-western parts routes connect the residential areas with the City Centre but not with one another. Such lack of lateral inter-connections between settlements can be noticed in the Kilelesahwa, Lavington and Spring Valley areas. So, relief appears to have a considerable influence on the pattern of road network development in the northern parts of the city.

Another interesting feature observable in the pattern of road development is the apparently limited route links between the Industrial Area

and Eastlands. Here the rail lines from the railway station to the Industrial Area are an obstruction to the development of such road links. The city buses serving the Industrial Area have to take the longer and more round about path via Haile Selassie Avenue - Uhuru Highway detour before they gain access into the area. A much more direct bus route should have connected the Industrial Area with the Eastlands via the Jogoo Road round about behind Landhies Muthurwa. The road would simply cross the rail lines by an overhead bridge. The construction of such a route had, however, commenced, but apparently little progress has been made towards its completion. The railway yard land block is another obstruction to the development of road link between the Central Area and the Industrial Area.

A qualitative analysis of map Figure 3.1 reveals that high density networks are concentrated in the Central Area, Ngara, Pangani and Westlands - Parklands areas. The medium density residential areas immediately to the west of the City Centre and the high density residential areas of Eastlands also have high road network densities. Medium road network densities occur in most of the medium density residential areas

and in the Industrial Area. Elsewhere the densities are relatively low. A comparision with the road density map, Figure 3.3 confirms this observation. From such qualitative observation and analysis one would be tempted to suggest that high road network densities have closer spatial associations with areas of high housing density and population concentrations, while low density networks are associated with low density residential areas and with difficulty relief.

The road network density map (Figure 3.3) shows that Nairobi can be divided into three broad road density zones, within which lie intermediate zones, namely, high, medium and low density. A striking feature about the zones is the concentric cells they form round the Central Area, an area which has the highest road network density. This concentric cell pattern is a reflection of the sequence of Nairobi's growth in the process of its development over the years. The line dividing the medium road density zone from the low density zone shows that road network development within the 'Old City' boundary took place before the 1963 boundary extension came into being. In fact the line traces fairly accurately the old city

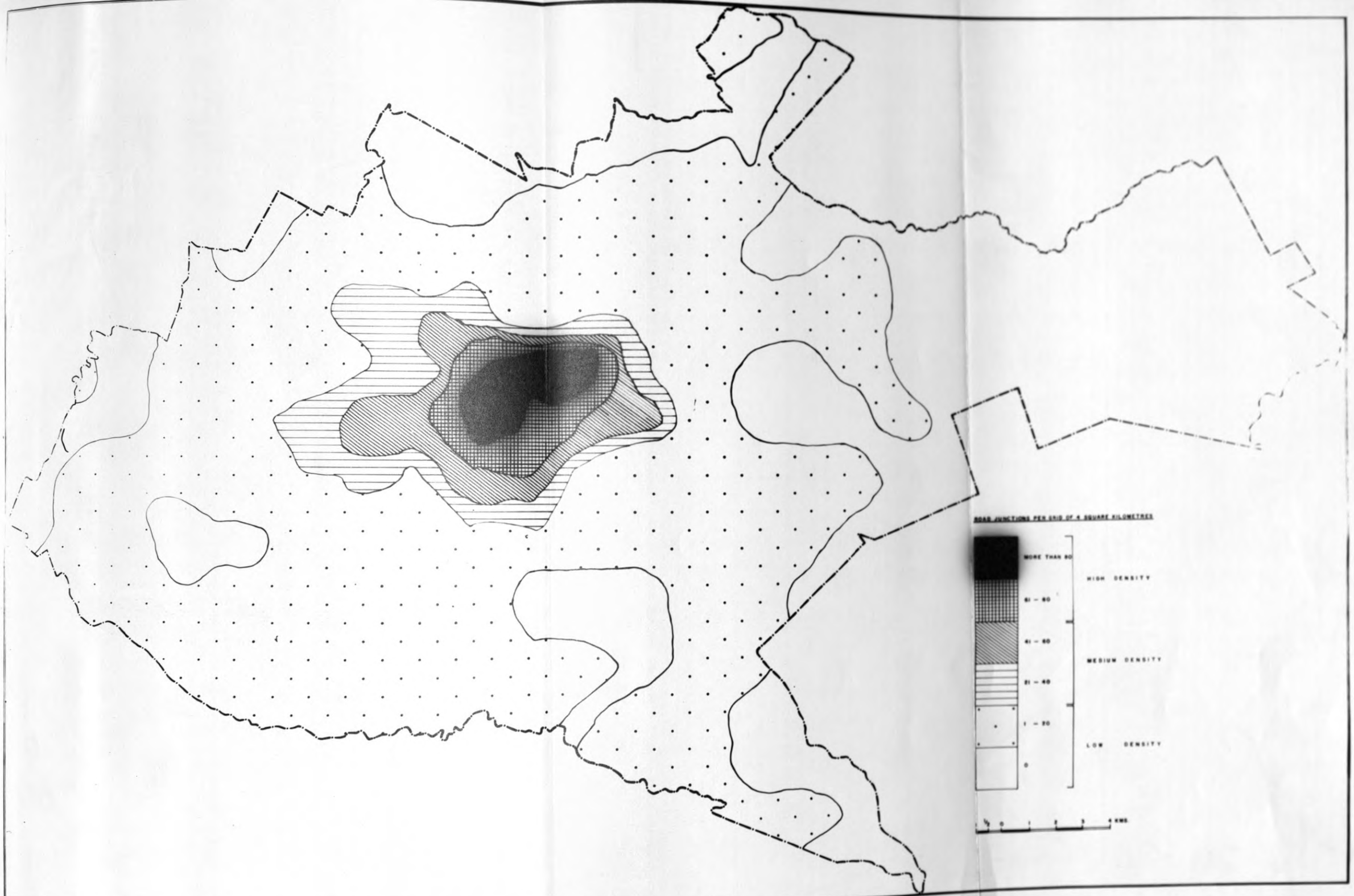

FIG. 3.3: NAIROBI: ROAD DENSITY MAP

boundary before the 1963 extension and defines a Central zone of high road density similar to it. The medium to high road density network contours show steeper gradients to the north, south and east of the Central Area, and gentler gradients to the west of it. This is a reflection again of the association of the low density networks with the hills, valleys and the comparatively low housing densities found to the west of the city centre. The steeper gradients are a reflection of the association of the high density networks with the high and medium housing densities to the north, south and east of it as was observed early. The medium and high network densities are represented in that small portion of the land area surrounding and including the Central Area, while the greater proportion of the land area of Nairobi is characterised by low density road networks. In fact as the distance from the Central Area increases, road network densities decrease so fast that they become very low in the peripheries. It could, therefore, be hypothesised that the distribution of road network density is a function of the distance from the City Centre. The low densities are particularly well marked on the northern, western and eastern peripheries.

This is particularly so because much of the land areas in these locations still remains under private ownership and forest reserves.

From these observations it could be concluded that road network density distribution is both a function of the distance from the Central Area and partly a function of land use distribution.

3. FACTORS AFFECTING ROAD NETWORK PATTERNS

In the preceding section, factors such as relief and drainage, land use, population and distance from the City Centre were suggested as being in part associated with distribution of roads in Nairobi. Such an observation by the author was based purely on subjective judgement arrived at as a result of cartographical analysis. How much each of the factors is responsible for the pattern of roads in the area is difficult to assess in the absence of supporting data. An attempt to analyse the contributions of each of the factors or their combined contribution in explaining the variation in road network pattern proved difficult because some of the variables could not be measured quantitatively by the author. This was particularly so in the case of relief, drainage and land use. With the population distribution the data could not be fitted into clearly defined areal units. A similar problem was also faced with the distribution of land use. In the circumstances, therefore, it was decided to analyse the degree to which distance from the City Centre is related to road network density.

This was done in the form of a basic regression model, and an attempt was later made to assess the relationship with the other variables by cartographic techniques.

The data for roads and distance was readily available from a road map of Nairobi prepared by the author (Figure 3.1) and from a topographical map of Nairobi published by the Survey of Kenya on the scale of 1:50,000. The road map was divided into four sectors by two co-ordinate lines intersecting at the City Centre, in the location of City Hall. The purpose of doing so was to give equal chance to sampling from all sides of the City Centre. A random sample of ten grid cells each enclosing an area of 4 square kilometres was selected from each of the four sectors making a total sample of forty grid cells. This represented a sample fraction of 1/5. For each of the grid cells, the number of roads was counted. For this analysis, all the main, secondary and minor roads including the Central Area streets and lanes were counted as roads, but roads in the Nairobi National Park were not counted as these serve a different and special function. A straight line distance in kilometres was measured from the City Centre to

the centre of each of the grid cells. On the basis of a preliminary graphic analysis, it was decided to transform the number of roads to natural logarithms. The purpose of the transformation was to ensure linearity in the regression analysis.

The first analysis consisted in the computation of the regression co-efficient, with the log of the number of roads as dependent variable and the distance from the City Centre as independent variable (Table 3.1). Thus a regression equation of Log Y = 1.79 - 11x was produced. Moreover, the relationship was a substantially high one as measured by the computed value of a correlation co-efficient of r = - 0.89. As expected, the regression and correlation co-efficients indicated that the relationship between the log of the number of roads and distance from the City Centre is an inverse one, showing that as distance from the City Centre increases there is a corresponding decrease in the provision of the number of roads. In terms of road network density, it therefore means that there is a higher density of road networks nearer the City Centre and a lower density as distance from the City Centre

TABLE 3.1 THE RELATIONSHIP BETWEEN NUMBER OF ROADS AND DISTANCE FROM THE CITY CENTRE

OBSERVATION	DISTANCE (KM)	LOG NO. OF ROADS	OBSERVATION	DISTANCE (KM)	LOG NO. OF ROADS
1	5.5	1.46	21	1.8	1.69
2	6.1	1.00	22	2.9	1.41
3	12.5	0.47	23	4.8	1.32
4	11.7	0.47	24	5.7	1.36
5	13.7	.00	25	6.1	.77
6	9.8	.47	26	7.2	.90
7	7.6	.77	27	9.9	.47
8	3.5	1.74	28	8.6	.90
9	4.1	1.30	29	10.8	.84
10	2.8	1.71	30	10.8	.00
11	8.6	.60	31	13.6	.47
12	6.5	.69	32	15.0	.30
13	2.2	1.49	33	12.9	.00
14	2.9	1.60	34	10.3	.47
15	9.6	.95	35	12.1	.69
16	7.0	1.11	36	8.4	.77
17	9.7	.60	37	4.0	1.66
18	13.5	.77	38	6.7	.90
19	16.8	.47	39	8.5	.77
20	14.4	.30	40	10.4	.69

$r = -0.89$

The relationship significant at 0.01 level.

increases towards the peripheries. These statistical analyses, therefore, confirm the intuitive judgement arrived at earlier from the cartographical analysis that the distribution of road network is a function of the distance from the City Centre. Subjecting this relationship to test for significance, it was found that the relationship was statistically highly significant at 0.01 level. Thus, from the basic regression equation or model, it is possible to determine precisely the number of roads that could be expected at any given distance from the City Centre subject to errors of estimate or the variation in the distribution of other factors that were not taken into consideration in the road-distance equation.

Let us look at the significance of this relationship in perspective. The variations in the road network density can be understood in a slightly greater depth when we examine the geography of land use and its values in a city. The most desirable locational property of a Central Area or site in an urban area is its centrality or maximum accessibility, particularly in respect to commercial land use.

This is because transport routes converge at the Centre, and much of its use that pays is directly related to centrality[2]. The less central a location, the greater are the transport expenses incurred and the lower the net returns. Rent bids thus decline with the distance from the City Centre. The resulting spatial structure of land use is therefore one that is zoned according to relative accessibility, and the intensity of its use diminishes with distance from the City Centre[3]. Since land use is intense at the City Centre, one would expect high road density to be nearer the centre and low density at the peripheries. This should therefore mean that as land use intensity decreases with increasing distance from the City Centre, road network density should also drop with due allowance for the influence exerted by other factors. A further factor which could be considered relevant to the existence of high road network density at the City Centre is the concentration of movement of people. The manner in which population densities in general decline with distance from the central business district suggests that there should be a corresponding decline in the road network density as the two variables are closely related.[4,5] Finally,

it could be said that the more central parts of a city have higher road network densities and the periperal locations lower densities because earlier developments were concentrated in the City Centre.

The regression model shows that distance from the City Centre is a very strong determinant of the provision of road network facilities in Nairobi as the variable alone accounts for about 80 percent of the variation in road network distribution. We have to look elsewhere for other factors responsible for the remaining 20 per cent variation in the distribution of road network. One major difficulty with our regression equation is that it suggests a simple relationship, whereas we know intuitively that the distance factor is working as a part of complex factors, some of which we have examined above. The application of a multiple regression equation would allow the combination of other factors, but for the reasons given earlier, this was not possible at least for this particular study.

This relatively simple regression analysis was then tied to cartographical analysis in an attempt to uncover further possible factors that seem to be particularly relevant to road network distribution. The analysis consisted in the construction of a map of residuals (Figure 3.4) from the regression equation. The residual map was superimposed upon the topographical map of Nairobi. A comparison of the maps suggested that negative residuals have a tendency to occur in areas with ridges, and stream valleys. The negative residuals are particularly observable in a belt running from the north-west to south-west to the north of the city centre and to the east of it. A closer examination of the locations of these residuals reveals that they are associated with the ridges, valleys and streams of upper Nairobi and stream valleys of the eastern parts. Such areas with fewer roads than expected from the distance equation are found in the neighbourhoods of Kitisuru, Lower Kabete and to the east of Dandora and Kariobangi. Within the same belt, but to the extreme north, two rather isolated residuals seem to be associated

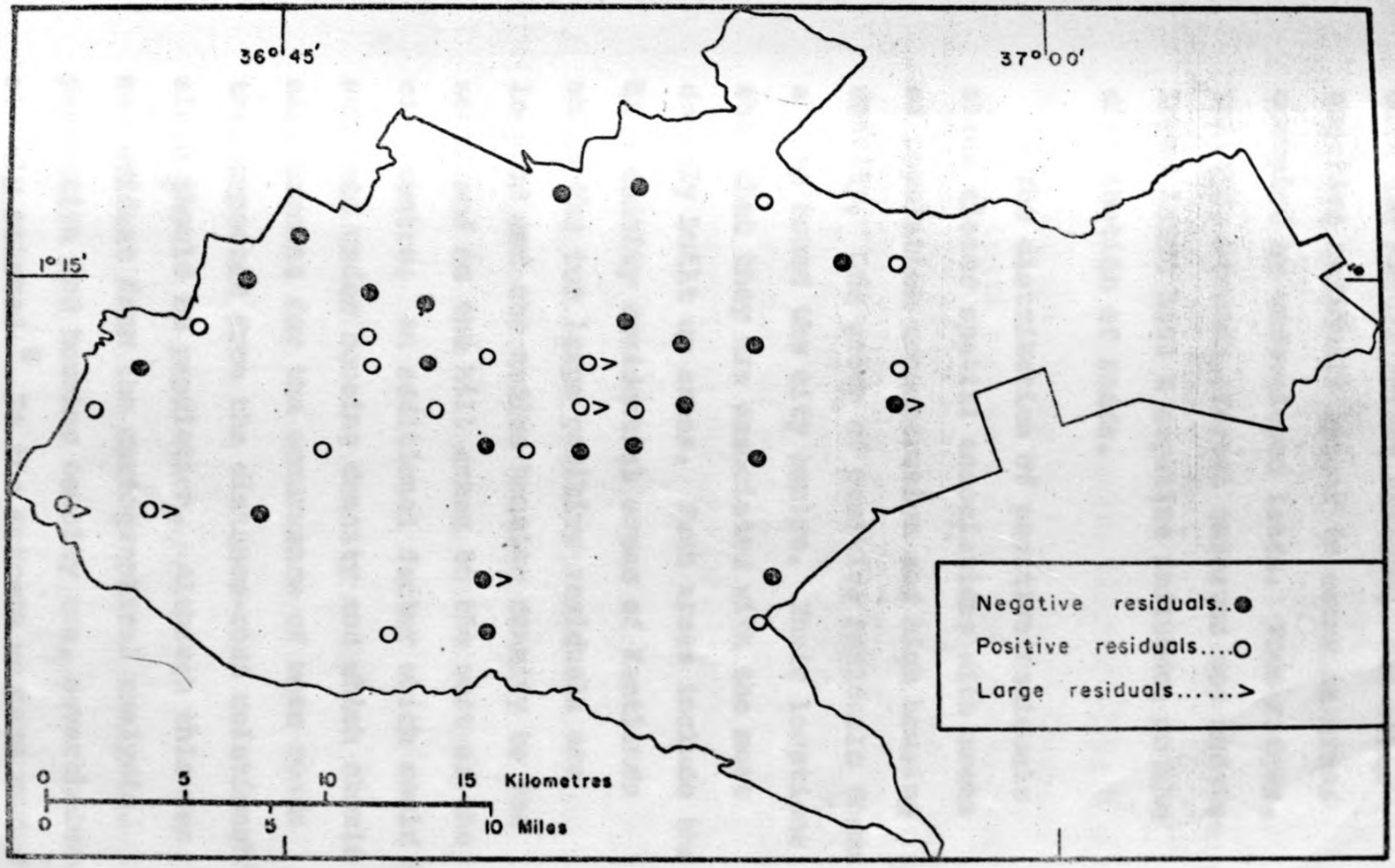

FIG 3.4: RESIDUAL MAP OF THE RELATIONSHIP: BETWEEN NUMBER OF ROADS AND DISTANCE FROM THE CITY CENTRE

with the Karura Forest Reserve. The other negative residuals appear to occur in areas occupied by undeveloped lands. Thus ridges, valleys, streams, forest reserves and undeveloped lands have a negative influence on the distribution of roads.

The distribution of positive residuals shows closer spatial associations with areas of population concentration and high housing density. One group of positive residuals forms a ring round the city centre. Their locations show that they are associated with the most densely built up areas. Such areas include the high density residential areas of Eastlands where the two large positive residuals are located and the medium housing density to the south and on the hill areas to the west of the city centre. An additional factor which could be subsumed under housing density and which should also account for the occurrence of more roads than expected from the distance-road relationship alone should be population. Although this was not evident from the cartographical analysis, population and housing density are, nevertheless, closely related.[6] To the extreme western corner

of the map is located a group of positive residuals, two of which are substantially larger ones. They seem to be located on the low density residential areas of Karen and Langata and on the commercial dairy farms found in these areas. There should, therefore, be a greater demand for more roads to link the residential housing units here on the one hand and to link the various dairy farms on the other hand, than distance from the city centre could explain. Thus, three factors seem to be positively related to the provision of road network namely, housing density, population and commercial agriculture.

In conclusion, while distance from the city centre explains the highest proportion of the variation in the distribution of roads in Nairobi, it would seem plausible to suggest on the basis of the cartographical analysis, thus, attempted that the factors identified from the residual map are also responsible for the observed variations in the road network distribution. The relative contribution of each of the factors is difficult to ascertain from such purely qualitative analysis. The identification of these additional factors should form a possible avenue of future

investigation into factors relevant to road transport network development in Nairobi or in other urban areas of Kenya. This may be accomplished by field investigation, by the development of more useful transport parametres and by the application of more regorous methods of analysis and model verification.

4. STRUCTURAL ANALYSIS OF THE PROPERTIES OF THE ROAD NETWORK.

So far the road transport network has been described and analysed cartographically and quantitatively to identify its density elements. The analyses, though, served a useful purpose in their own right, were not accurate enough to reveal the major internal characteristics of the road transport network, such as its connectivity and nodal accessibility[7]. The use of more refined measures to identify these structural properties should give a much better picture of the real internal characteristics of the network. In recent years, a set of summarising measures of network characteristics has been developed in order to provide a basis for comparison and evaluation of transport networks[8]. These efforts have drawn heavily on the concepts of graph theory to describe the topological structure of networks[9].

(a) NETWORK CONNECTIVITY

We are able to study the characteristic properties of networks only by oversimplifying their reality. In order to apply graph theory to the analysis of transport networks, it is necessary to idealise the network into the form of a graph. This requires that some information

about the network be deliberately discarded[10]. In doing so, we are treating only the topological[11] properties of a transportation network system and not the whole range of properties that are identifiable with any given network.

Transport networks can be represented by a series of vertices (nodes) and a set of edges (linkages) together with relationship of incidence that associates each edge with two vertices.[12] Measures of spatial properties of networks are structural and deal with the geometric patterns of networks. Two types of measures have been used in describing and analysing the spatial structure of the road transport network in this study. These are measures describing the degree of network connectivity and accessibility of individual nodes to the whole network.

In transportation studies of networks, the concept of connectivity is meaningful when a given network is either compared with other networks or its growth is viewed through time. It has been found that greater connectivity of transportation networks is associated with advanced levels of economic development of countries and the reverse is the case.[13] Moreover, as the expansion

of transportation linkages between nodes is directly related to increased demand for transportation facilities to move goods and people, the degree of connectivity of transportation network is indicative of the complexity of the spatial order that it imposes on the region it serves[14]. It should also be expected that the largest nodes in terms of population should both attract and generate the largest traffic flows, and because they are large they should also have the highest degree of connectivity within the network system. Furthermore, the largest flows should be partially related to connectivity itself for the higher the local degree the greater the amount of traffic that can be carried[15].

(b) THE CONNECTIVITY OF THE ROAD TRANSPORT NETWORK IN NAIROBI

In this analysis and description of the connectivity of the road network of Nairobi, not all the roads in the area were used. To do so would have been a cumbersome and tedious task. So, it was decided to use only the trunk, primary and secondary roadsfor the analysis. Nodes were identified as road intersection points where three or more routes meet, while nodes other than

intersection points were identified as important terminals on the above categories of roads, such as airports, industrial or commercial locations. Also treated as nodes are boundary points, for in essence, there are nodes at or immediately beyond the boundaries.

The road network was, therefore, abstracted as a graph with a set of 65 vertices and 85 edges (Figure 3.5). Using the cyclomatic number, which is the measure of the number of circuits in the transportation network or the number of links in the network excess to the number required to tie the vertices together in a minimal way[16], it was found that the network is made up of 21 circuits, showing that the road network is connected, but not completely connected. To evaluate the degree of connectivity of the network in terms of percentage connectivity, the gamma index, evolved by Kansky[17] was applied. The gamma index for a planar graph[18], such as this one, is expressed as:

$$\text{Gamma} = \frac{e}{3(V-2)}$$

e = the number of edges in a network

v = the number of vertices in a network.

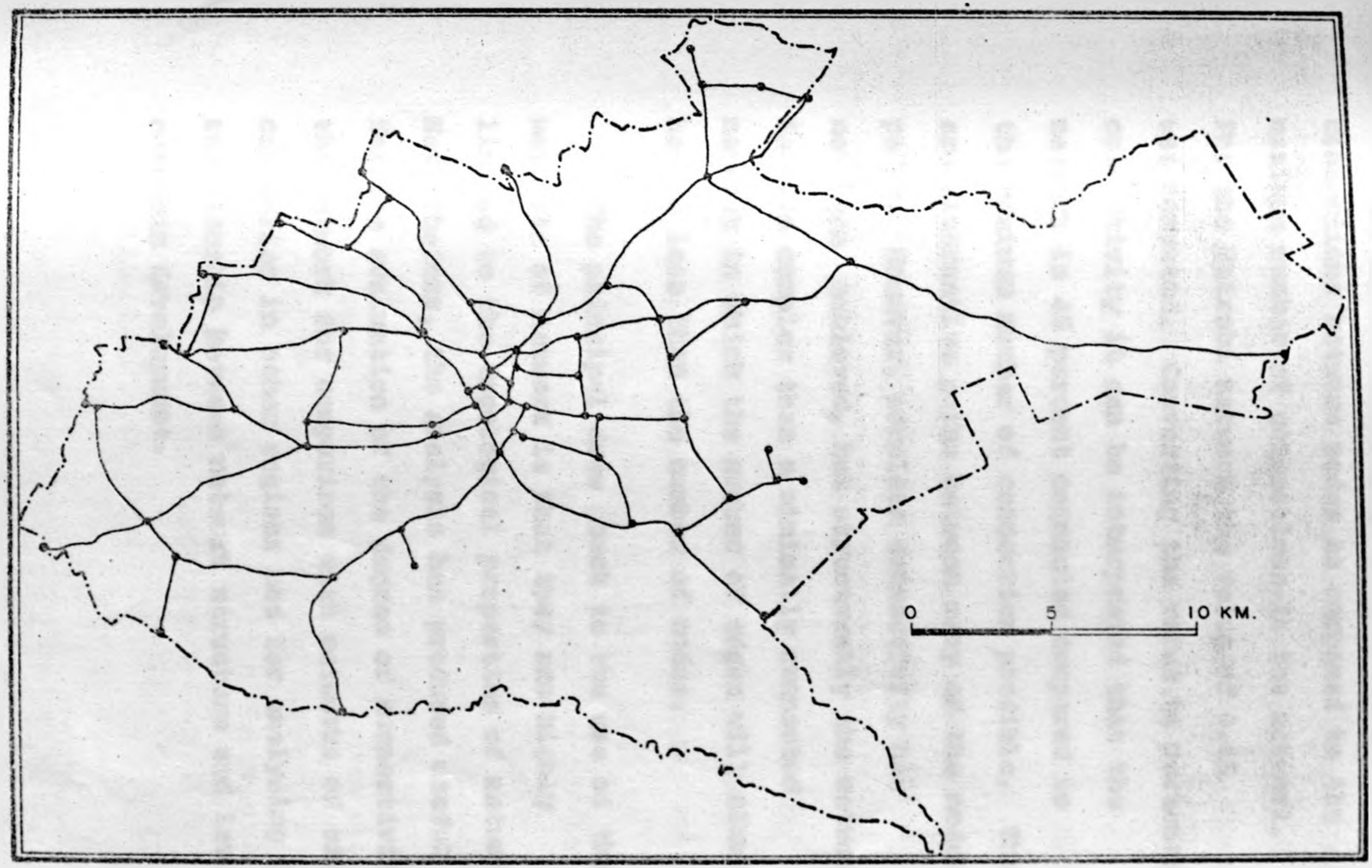

FIG. 3.5: NAIROBI: ROAD NETWORK CONNECTIVITY

The index measures the number of observed connections between nodes as compared to the maximum number of connections in the network. For the Nairobi network the value of 0.45 was computed. Converting the value to percentage connectivity it can be interpreted that the network is 45 percent connected compared to the maximum number of connection possible. There are alternative paths between many of the nodal pairs. However, complete connectivity has not been achieved, but structurally the network is more complex than a minimally connected network in which the number of edges will always be one less than the number of nodes.

The principal draw back to the use of these measures of network is that they are highly limited to the topological properties of networks. Nevertheless, the analysis has produced useful measures for the evaluation of the degree of connectivity of the network for comparison with networks of similar categories in other regions and for analysing the relationship between network structure and levels of economic development.

(c) NODAL ACCESSIBILITY

A given place has one important characteristic, and that is, its quality of location with respect to its arrays of economic and social activities. The quality of the location of a place is a dominant factor in determinig the intensity of its land use. It can be expressed in distance terms or as a relative quality which accrues to a place by virtue of its relationship to transportation network operating at some specific period of time[19]. The most accessible places on a transportation network are in most cases the intersection points or some of the most heavily used highways. Measures of accessibility levels could, therefore, provide a useful guide to transport planners in helping provide traffic management facilities to improve and promote smooth and efficient traffic flow through nodes. A knowledge of accessibility levels of nodes is also an important pointer towards improvement and expansion of the existing highway capacity in the form of dual carriage way system. The measures are therefore of considerable practical importance to transportation studies.

When examining a transportation network for evidence of the spatial organisation of an area, we are not limited to the aggregate characteristics such as the degree of connectivity of the network. The emphasis is sometimes placed on the nodes themselves to reveal their relative locations within the network. They could be examined in terms of their functions and accessibility to the rest of the network to identify spatial dominance and competition among them. Graph theory again provides a convenient means of measuring and identifying the accessibility levels of nodes on a transportation network.

A network can be abstracted as a graph and then represented in the form of a matrix. A refined measure which takes into account the indirect connections through intermediate nodes between pairs of nodes was used in this analysis. Instead of entering in the matrix cells the presence or absence of linkages between nodal pairs, actual distance in terms of kilometres were recorded in the cell entries (Table 3.2). Column or row totals provided on index of the accessibility level of a node on the network. Lower values indicate higher levels of accessibility, while higher values show lower levels of accessibility.

For this study, twenty four nodes were selected on the road network on the basis of place names. The place names are not actually located at the nodal points, but suggest that the node is the focus of most of the activities around. It will be noted also that the road network is highly abstracted to a set of straight lines. A further simplification of the network is reflected by the inclusion of only those roads on which the nodes are located and is highly graphical (Figure 3.6). The graph has been represented in the form of a 24 by 24 matrix (Table 3.2). The column totals provide an index of the accessibility level of each of the twenty four nodes on the network. As a result of this, the centres or nodes have been ranked to show their accessibility levels (Table 3.3).

In the rank order, the Central Area is the most accessible node in the entire network followed by Ngara, Parklands, Pangani, Muthaiga Westlands, Nairobi South, Eastleigh, Eastlands and the Industrial Area in that order. Places with medium accessibility levels include, Kariobangi, Ruaraka, Dandora, Dagoretti Corner, Upper Kabete and Riruta. As would be expected, Nairobi Airport, Kamiti, Kahawa, Dagoretti Market and other nodes

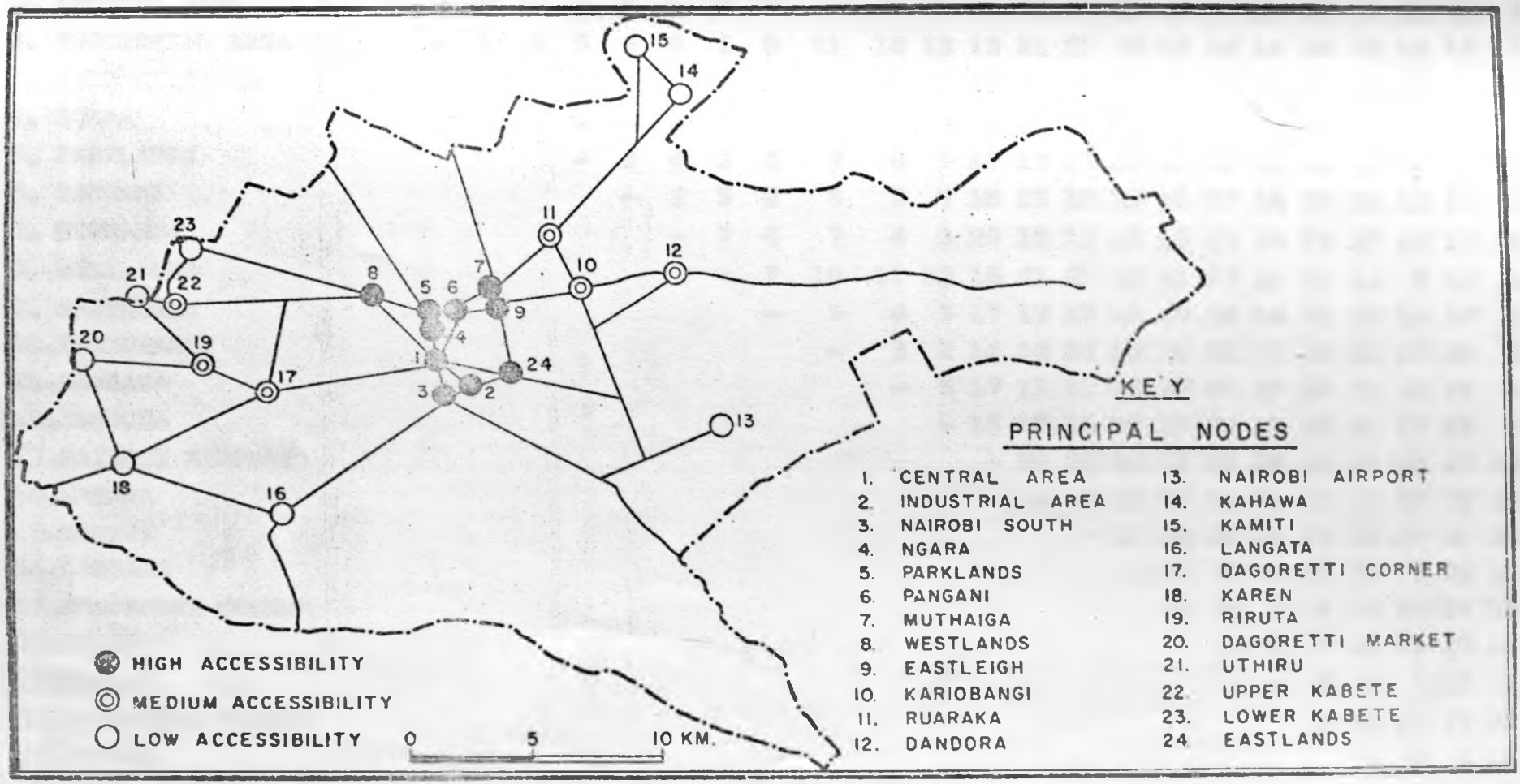

FIG. 3.6 NODAL ACCESSIBILITY ON THE ROAD NETWORK OF NAIROBI

TABLE 3.2 ACCESSIBILITY MATRIX FOR 24 NODES ON ROAD NETWORK, 1975 ACCESSIBILITY VALUES

NODE	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
1. CENTRAL AREA	-	3	3	1	2	3	5	3	5	8	8	10	15	18	18	10	8	14	11	17	13	11	12	3
2. INDUSTRIAL AREA		-	1	4	5	6	8	6	8	11	14	13	13	21	21	8	11	14	14	20	16	14	15	3
3. NAIROBI SOUTH			-	4	6	6	8	6	8	10	11	11	12	21	21	7	11	13	14	20	16	14	15	4
4. NGARA				-	1	2	4	4	4	7	8	9	16	17	17	11	9	15	12	18	15	11	14	4
5. PARKLANDS					-	2	4	3	4	7	8	9	17	17	17	12	10	16	13	19	14	10	13	5
6. PANGANI						-	2	5	2	5	5	7	18	15	15	13	11	17	14	20	16	12	15	8
7. MUTHAIGA							-	7	4	7	4	9	20	13	13	15	13	19	16	22	18	14	17	10
8. WESTLANDS								-	7	10	11	12	16	21	21	13	11	17	14	20	11	9	10	6
9. EASTLEIGH									-	3	6	5	17	17	17	15	13	19	16	22	18	14	17	3
10. KARIOBANGI										-	3	2	14	14	14	18	16	22	19	25	21	17	20	6
11. KUARAKA											-	5	17	11	11	19	17	23	20	26	22	18	21	9
12. DANDORA												-	15	16	16	20	18	24	21	27	23	19	22	7
13. NAIROBI AIRPORT													-	28	28	19	23	25	26	32	28	26	27	10
14. KAHAWA														-	4	30	28	34	31	37	33	29	32	24
15. KAMITI															-	30	28	34	31	37	33	29	32	24
16. LANGATA																-	12	6	15	21	20	2	26	11
17. DAGORETTI CORNER																	-	6	3	9	8	10	14	11
18. KAREN																		-	9	7	14	16	20	17
19. RIRUTA																			-	6	5	7	11	14
20. DAGORETTI MARKET																				-	11	13	17	20
21. UTHIRU																					-	2	6	16
22. UPPER KABETE																						-	4	15
23. LOWER KABETE																							-	15
24. EASTLANDS																								-

TABLE 3.3 THE RANK OF NODES ON THE ROAD NETWORK ACCORDING TO ACCESSIBILITY IN TERMS OF TOTAL DISTANCE BETWEEN NODAL PAIRS

RANK	PLACE	ACCESSIBILITY INDEX
1	Central Area	201
2	Ngara	207
3	Parklands	214
4	Pangani	218
5	Muthaiga	232
6	Westlands	233
7	Nairobi South	242
8	Eastleigh	244
9	Eastlands	244
10	Industrial Area	249
11	Kariobangi	279
12	Ruaraka	291
13	Dagoretti Corner	300
14	Dandora	320
15	Upper Kabete	334
16	Riruta	342
17	Langata	373
18	Uthiru	379
19	Lower Kabete	395
20	Karen	401
21	Dagoretti Market	466
22	Nairobi Airport	472
23	Kahawa	511
24	Kamiti	511

on the peripheries rank low in the list with low levels of accessibility. The pattern of the distribution of these levels of accessibility is very striking. Nodes with high levels of accessibility are organised spatially around the Central Area within an area of an average radius of three to five kilometres from the Central Area. The are extends from Nairobi South in the South, through Eastlands in the east, Eastleigh and Muthaiga in the north-east and terminates at Westlands in the north. They form four distinct triangular clusters round the Central Area to the south, north-east and north of it. Nodes with medium levels of accessibility are in general organised about five to ten kilometres west and east of the City Centre, while nodes with low levels of accessibility are on the peripheries and are in general about fifteen or more kilometres distant from the Central Area.

The foregoing analysis of nodal accessibility levels does suggest that they are a function of the distance from the Central Area, which is the most highly accessible node on the road network system. An attempt to justify the significance of this observed relationship in

quantitative terms consisted in the calculation of the correlation between the accessibility indices of the twenty four nodes and their road distance from the Central Area (Table 3.4). The associated number[20] for each of the twenty four nodes was calculated and correlated with their respective distance from the City Centre. A positive correlation coefficient of r = 0.89 was produced. The high positive correlation shows that as distance from the Central Area increases nodes (with higher values of associated number) become less and less accessible. The correlation was a highly significant one at 0.01 level of test. This confirmed that the observed order and regularity in the distribution of nodal accessibility levels in terms of their varying with distance from the Central Area is a reality that can be tested against available facts. The finding is the result of an attempt to generalise on one of the properties of network structure, accessibility, and to represent that generalisation in a testable form. It should, therefore, open up a richer ground for further investigations into the effect of distance from the most Central location on a transportation network on the distribution of accessibility levels of other locations on the same transport network

TABLE 3.4 THE RELATIONSHIP BETWEEN MODAL ACCESSIBILITY AND DISTANCE FROM THE CITY CENTRE

NODE	DISTANCE (KM) FROM C.A.	ASSOCIATED NUMBER
Central Area	0	5
Ngara	1	6
Parklands	2	6
Pangani	3	5
Muthaiga	5	6
Westlands	3	6
Nairobi South	3	6
Eastleigh	5	6
Eastlands	3	5
Industrial Area	3	6
Kariobangi	8	7
Ruaraka	8	7
Dagoretti Corner	8	6
Dandora	10	8
Upper Kabete	11	8
Riruta	11	7
Langata	10	7
Uthiru	13	9
Lower Kabete	12	7
Karen	14	7
Dagoretti Market	17	8
Nairobi Airport	15	8
Kahawa	18	9
Kamiti	18	9

r = 0.89

The relationship significant at 0.01 level.

either in an urban setting or in a non-urban regional framework.

The other observable feature of the distribution of nodes is the pattern of their spatial organisation in relation to the distribution of land use. There seems to be a close spatial relationship between the nodal accessibility levels and the degree or intensity of land use. The most accessible nodes are found within areas which are most intensively used. The nine highly accessible nodes shown in Figure 3.6 are located within the commercial and cultural area, the high and medium density residential areas and within the Industrial Area of Nairobi (Figure 1.3). In terms of building density, commercial and industrial activities, these are the most intensively used land areas. In contrast, the low density residential areas,such as Karen, Langata and Kabete are the least accessible on the road transport network. Other nodes with medium to low levels of accessibility such as Nairobi Airport, Dagoretti Market, Riruta, Kariobangi, Dandora, Kahawa and Kamiti are in general located towards or on the peripheries. These locations are characterised by less

intensively used lands mostly devoted to forestry, agriculture and other land uses including undeveloped lands. It should seem, therefore, that the intensity of land use is determined in part by the ease with which a location can be reached, that is, its accessibility. The degree of such a relationship could be measured in quantitative terms by relating accessibility indices of the nodes to land rent values at the locations in which the nodes are found. Such analysis was not possible for this study because of lack of relevant data on land rent values at the nodal locations.

5. SUMMARY

Nairobi Area is well served with an adequate road network system for internal transport links. For external links the city is dependent on its trunk roads which are also important traffic generators in the internal road transport system. A system of ring roads provides links between the several radial roads that converge at the City Centre, except in the northern parts of the city where ring road development has not been made possible by the existence of difficult ridges separating the radial roads. In addition to the ring roads, a comprehensive network of secondary and minor roads connect different parts of Nairobi in vary degrees of density. To the north and north-west of the city relief has a considerable influence on the pattern of road distribution. To the south of the City Centre the development of road links between the Industrial Area and the Central Area on the one hand and between Eastlands and the Industrial Area on the other hand has been obstructed by the rail line and the rail way yard landblock. A qualitative examination of the distribution of road network in Nairobi suggests that factors such as distance from the City Centre, land use,

population, relief and drainage are important determinant of road network distribution. A very striking feature about the distribution of road density zones in Nairobi is the concentric cell formation of the zones round the City Centre. This is partly a reflection of the sequence of development which has taken place over the years and partly a reflection of the influence distance from the City Centre has in determining road distribution. The pattern seems to fit fairly closely Burgess's theory of urban land use pattern.

A statistical analysis employing the simple regression model found out that distance from the City Centre accounts for about 80 per cent of the variation in road network distribution. A further cartographical analysis involving the use of a residual map identified other possible factos as land use, population, relief, drainage, forest reserves and undeveloped lands to be particularly relevant to the distribution of roads in Nairobi.

To understand fully the real internal characteristics of networks such as connectivity and accessibility it was necessary to employ

the concepts of graph theory to describe the topological structure of the network. By abstracting the trunk, primary and secondary roads of Nairobi as a graph with a set of 65 vertices and 85 edges it was possible to calculate the degree of connectivity of the network. Using the cyclomatic number as a measure of circuitry, it was found that the network consists of 21 circuits, indicating that the network is more than minimally connected. The application of the gamma index to the same network revealed that it is 45 percent connected, compared to the maximum number of connections possible. One draw-back in the use of these measures is that they are highly limited to the topological properties of the network. But the measures are useful for evaluating the degree of connectivity of a network for comparison with others and for evaluating or analysing the relationship between network structure and levels of economic development.

In using graph theory to describe and analyse the spatial organisation of an area, we are not limited to the aggregate characteristics such as the degree of connectivity. The component

node-linkage relationships of the network may be the basis for determining the accessibility of the nodes to each other. To determine nodal accessibility in the Nairobi's road network, the network was abstracted as a graph and then represented in the form of a 24 by 24 matrix. Using the actual distance in the cell entries it was possible by finding column or row totals to rank the twenty four nodes according to their accessibility on the road network. It was found that nodes with high levels of accessibility are spatially organised about 3 - 5 kilometres from the City Centre, while medium and low level accessibility nodes are respectively organised about 5 - 10 and more than 15 kilometres from the City Centre. An attempt to analyse the statistical distribution of the accessibility levels proved that the relationship between distance from the City Centre and accessibility indices is statistically significant. Finally, one observable feature of the distribution of nodal accessibility is the striking pattern of their spatial organisation in relation to the distribution of land use. No attempt was, however, made to determine the degree of relationship, because of lack of data on land use values.

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11. By topological we mean that locations or nodes are taken in terms of their position on the geometrical net, not by their actual locations.

12. The term vertices and edges will be used in this thesis to refer to abstract networks, whereas the terms nodes and linkages will refer to a real world network before it is abstracted.

13. Yeates, M.H. - 1968 - An Introduction to Quantative Analysis in Economic Geography, New York, McGraw Hill Book Co. pp. 117.

14. Taaffe, E.J. and Gauthier, H.L. - 1973 - ibid pp. 102.

15. Yeates, M.H. - 1968 - ibid, pp. 117.

16. The equation for the cyclomatic number is written: Cyclomatic number = e - v + p, where e is the number of edges, v the number of vertices and p the number of non-connected sub-graph.

17. Kansky, J.K. - 1963 - ibid.

18. A planar graph is one in which no edges intersect except at vertices. A planar graph is typical of the networks of surface modes of transport, i.e. rail and road.

19. Wingo, L. 1961 - Transportation and Urban Land. Resources for the Future, Inc., pp. 26.

20. The associated number expresses the maximum number of edges in the shortest path between a vertex and the most remote of the other vertices. It is thus a measure of the centrality of a vertex.

CHAPTER 4

MOVEMENT OF PEOPLE

1. PUBLIC TRANSPORTATION
   - (a) THE KENYA BUS SERVICES
   - (b) TAXIS AND MATATUS
     - i. Taxis
     - ii. Matatus
2. TRAVEL PATTERNS AND CHARACTERISTICS
   - (a) MODAL SPLIT
     - i. Trip Modes
     - ii. Trip Purposes
     - iii. Movement Distribution Pattern
3. SUMMARY

REFERENCES.

MOVEMENT OF PEOPLE

1. PUBLIC TRANSPORTATION

The principal element of today's traffic on the streets of Nairobi is the private car. But these are only for the services of the wealthier minority of the city's population. It is the services provided by the Kenya Bus Services (Nairobi), hired taxis and the matatus that are important to the majority of Nairobi residents who do not own or have the use of private cars. In a recent study carried out by the Nairobi Urban Study Group to investigate into the major characteristics of the daily trip distribution by modes of travel, it was found that about 38 per cent of the population use private cars, the rest of the population (58 per cent) make their choice between walking and using public transport, a choice which is dictated fundamentally by the financial circumstances of the individual[1]. The relative importance of the City buses, hired taxis and matatus in the aggregate share as public transport carriers in the city's internal transport system is difficult to assess as no such a comparative study has been carried out. This chapter examines the role of the Kenya Bus Services, hired taxis

and matatus, as they are the most important public transport carriers within the city boundary. In a later section of the chapter trip modes, patterns and their characteristics are also examined.

(a) THE KENYA BUS SERVICES

Public transportation travel within Nairobi has been provided officially by the Kenya Bus Services Company Limited, but in the recent past, the matatu passenger services have also been recognised by the public as means of public transportation, supplementing the city bus services. The company, which is a joint undertaking of United Transport Overseas Limited and the City Council of Nairobi, began operating bus services in Nairobi in 1934 with only a fleet of 13 buses. Today the company owns about 290 buses. The early buses, some of which were of the double-decker type, were slower and carried a maximum of only fifty passengers. In contrast, the modern buses are faster and can carry as many as a hundred passengers or more. So, it can be seen that over the last forty years there has been a considerable increase both in the number of buses used and in their

passenger carrying capacity. The need to provide a cheaper mode of public transport for the rapidly expanding population of the city, coupled with favourable conditions created by the City Council as a share holder in the company have made possible such a steady growth and expansion in the city bus services over the last four decades.

A fleet of the city buses can be seen (Plate 4.1) at the main bus station in the City Centre behind Tusker House. On a normal week-day, the city buses cater for about 250,000 passengers, with the heaviest passenger services provided in the morning and evening peak periods, when public transport demands are highest for essential trips such as work, school and business trips. On the basis of a monthly circle, peak services occur at the middle and end of the month when most of the workers have the money to spare for trip making. During the off-peak periods, and on other days of the month, business is slightly slack but not below capacity. Normally, about 270 buses are dispatched daily during the morning peak, but the number falls down to only 120 buses during the off-peak periods, the rest coming back

Plate 4.1 A fleet of City buses stationed behind Tusker House

to service during the evening peak. This is not a strange phenomenon in an urban commuter system where temporal fluctuations in the aggregate demand for public transport services in most of the service routes are inevitable. In addition to the spatio-temporal fluctuations in the demand for the city bus services, the company now faces a severe competition from matatu vehicles, and this may well have reduced to some considerable extent the number of their potential passengers. The magnitude of the seriousness of the competition in monetary terms is not possible to assess because of lack of such data, but the existence of a competition has been acknowledged by the city bus authority. Another factor which has affected slightly the number of passengers patronising the city bus services is the current increases in bus fares occassioned by rising fuel prices and other operating costs. But such a drop in the number of passengers has been negligibly small, and in any case, it is not the result of people shifting their travel habits to cheaper modes of transport, rather the drop is the result of people shifting to walking shorter distances. Moreover, the lowest fare of 50 cents and the highest which has not exceeded 2/50 on the longest cross-city routes are

comparatively lower than those charged by other public passenger services in the city. It is unlikely that such increases in the city bus fares will have a very serious effect on the number of passengers they carry as fares have also gone up in other modes of public transport in the city.

One problem encountered by the Kenya Bus Services has been pointed our earlier, and that is, temporal fluctuations in the aggregate public demand for the services. The other problem which is related to this is that of backhauling or empty running. These are inevitable in any system of passenger or goods traffic. The other problem is the slow rates at which buses move within and around the city centre caused by traffic congestion during peak periods. One solution to this movement rate problem could be the provision of exclusive busways or lanes to enable buses to travel at faster rates, thereby doing more trips than they do under conditions of mixed traffic. In this way much of the commuters' wasted time during the rush hours could be saved. The other possibility which could be of benefit not only to the city bus users but also to other road users in and around the city centre could be the introduction

of a system of staggering working hours, at least in the City Centre. This should have the effect of spreading the peaks over much longer periods, thus keeping most of the buses in service throughout much of the day.

In Nairobi, as elsewhere in the country, people work on average for eight hours a day, beginning at 8.00 a.m. and ending at 4.00 p.m. It is about these hours that peaking and traffic congestion is at its worst at the City Centre. Without effecting drastic changes in the length of working hours per day, work hours could be staggered in three consecutive stages in such a way that different categories of workers begin work at 7, 8, and 9 a.m. and end at 3, 4 and 5 p.m. respectively, thus spreading the morning and evening peaks into three lighter peaks. In all the cases, the workers would still be doing an eight-hour-day job. There are, however, problems of social nature inherent in steggering working hours. But the practicability of such a system could only be realised if a consensus of opinion is sought between the government, the City Council and the employers on the one hand and between employers and employees or their representatives

on the other hand. Other solutions to the peaking and congestion problem such as the construction of by-pass roads and the decentralisation of working places from the City Centre are being adopted[2]. May be a combination of these measures could be a move in the right direction towards the solution of peaking and congestion problem which is becoming increasingly serious as the number of motor vehicles and people continues to increase.

During the day time, the city buses operate from the main bus station behind Tusker House on over 51 bus routes serving more than forty bus terminals within and beyond the city boundary (Figures 4.1 and 4.2). On the map (Figure 4.1) are shown the service routes, their terminals and the frequency of bus movements. The terminal stages are represented by proportional circles indicating their relative importance as passenger traffic generators. Some routes and terminals have higher bus frequencies than are actually shown, particularly during peak periods, while others have lower frequencies during the off-peak periods. The map, therefore, only gives

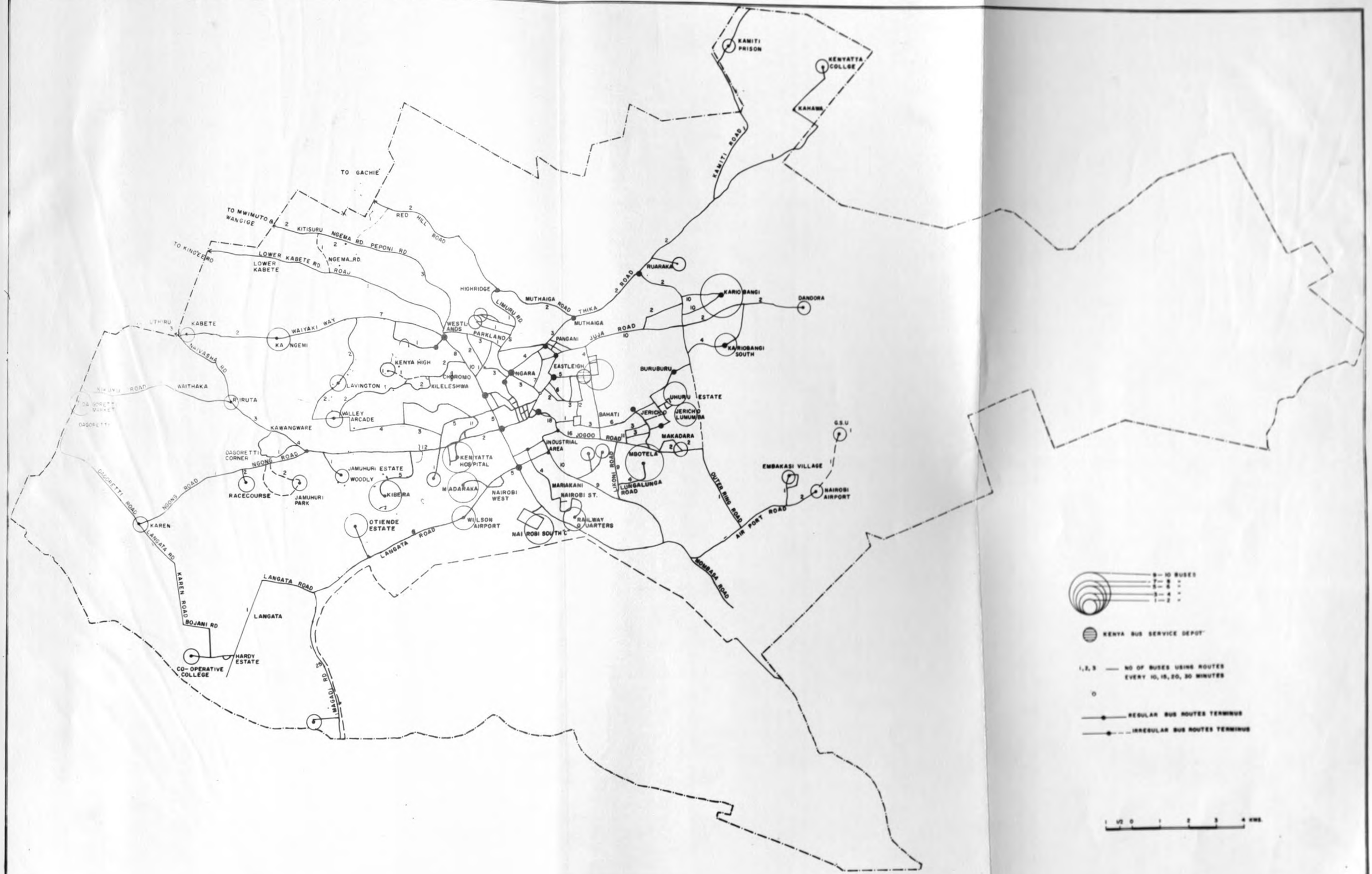

FIG. 4.1 : THE KENYA BUS SERVICE ROUTES AND THE INTENSITY OF THEIR USE

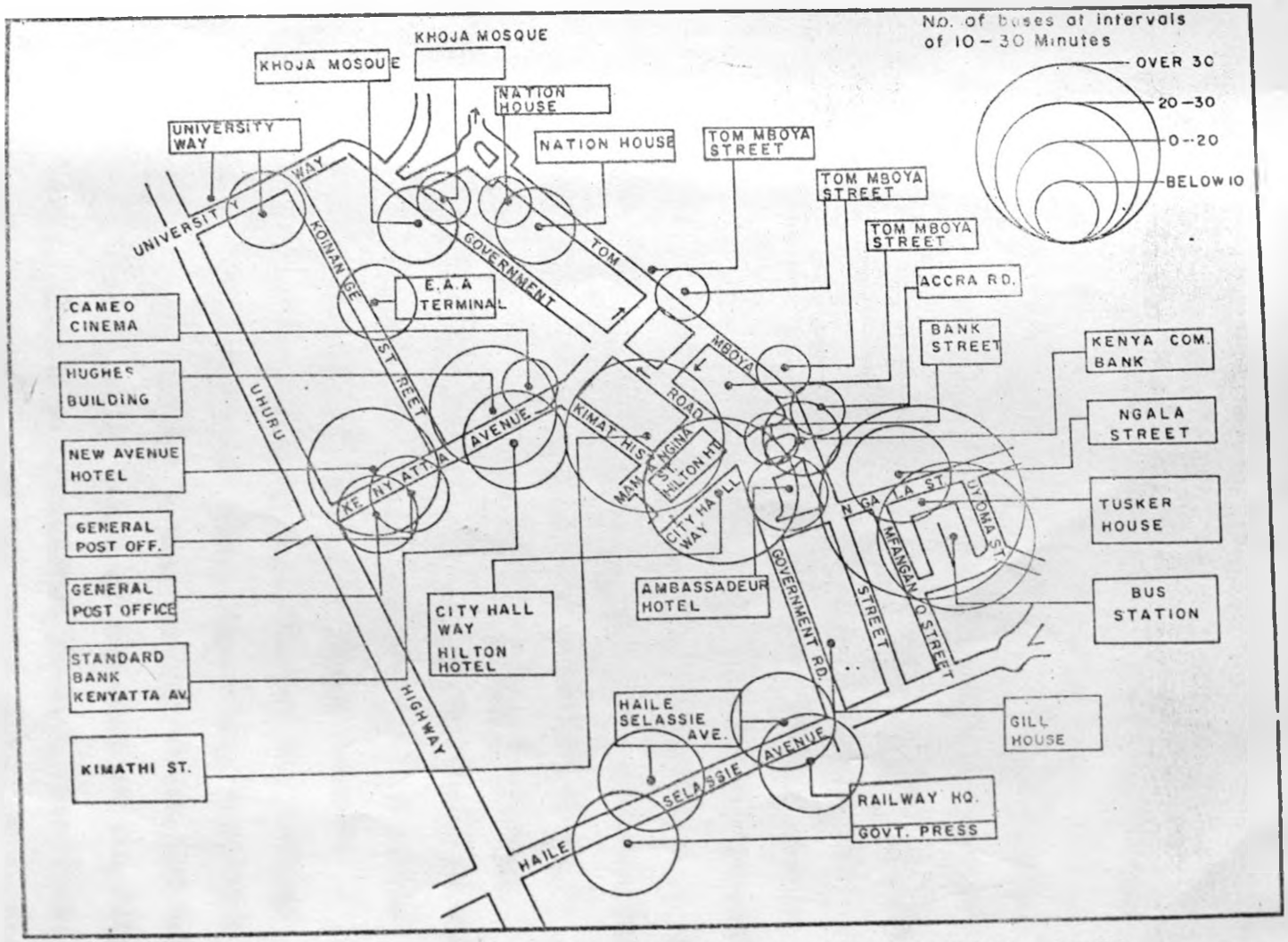

FIG. 4.2: THE CITY PASSENGER BUS SERVICE IN THE CENTRAL AREA

a simple and generalised picture of the level of bus services provided. Moreover, some routes such as those to Jamhuri Park and to Race Course are used irregularly, and only on special days when there are functions at the terminals.

In many respects, the bus service network is analogous to the route network examined in the previous chapter. This is in respect to the properties of network density, distance and accessibility. In the service network, higher densities occur in the areas immediately around the City Centre. The density falls gradually in all directions in a manner similar to the route network in such a way that in the peripheral locations the bus routes become so scattered and far between that in some places there is only one route and in others none at all. Specific locations with particularly higher network densities within this belt include the Central Area, the Industrial Area, Eastlands, Westlands - Parklands - Pangani areas, Nairobi South and West areas and the hill areas to the West of the City Centre. The service network density, therefore, varies spatially with the distribution of centres of employment and commercial activities such as Central Area and the Industrial Area. In addition,

there is a variation with the distribution of housing density. The relatively high population concentration in the Central Area, Industrial Area and in the high and medium housing density areas means that there are higher demands for the city bus services, hence the existence of higher service network densities within these specific locations. Where housing density is low or where the land is predominantly under forest, agriculture, undeveloped or less intensively used, the bus service routes are fewer or non-existent. This is clearly marked in the Muthaiga, Karen-Langata, Riruta-Waithaka, Kabete-Kitisuru and in the open ranching land areas to the east of Dandora. On the basis of this cartographical analysis it can be concluded that the pattern of the bus service network is determined by distribution of land use and by distance from the Central Area. These two factors were also found to be similarly related to the route network distribution. The marked similarities between the service and route networks should not be surprising, as essentially the service network is a subsystem of the route network system, hence their identity in most of the respects should be expected.

A closer examination of the distribution of bus terminals shows that they are concentrated in a belt running in a south-west to north-east direction from Otiende Estate in the south-west to Kariobangi in the north-east. Within this belt are located some terminals with the highest bus frequencies such as Kariobangi, the Industrial Area and the City Centre, while bus terminals to the north and west of the City Centre are widely spaced and have comparatively lower bus frequencies. This difference in the distribution of bus terminals can be explained by the difference in the distribution of income among the population resident to the north and east of City Centre. The relatively higher level of private car ownership among the households living in the northern and western parts of the city as compared to that of households living in the south and east of the city means that the majority of the people in the south and east depend mainly on public transportation, hence the higher concentration of bus terminals in these locations.

The other notable feature in the distribution of bus service routes is the apparent absence of route terminals in the northern peripheral locations

and the absence of a bus service on Kiambu Road (not shown on the map). Bus terminals on Lower Kabete, Peponi, and Red Hill Roads are located outside the city boundary at Kingeero, Wangige and Gachie respectively. The extension of the city bus services to Kiambu District has been made possible by the existence of high demand from the large number of people who commute daily to the city from these peripheral locations. In addition, there are fewer competing modes of public transport operating between these centres and Nairobi along the same routes and this apparently has made it economically viable for the city buses to operate beyond the city boundary. This is in contrast to Kiambu Road where the operation of a large number of country buses and matatus precludes the extension of city bus services. An additional factor which could be considered relevant is that, Kiambu Road traverses a forested area with relatively few people living along much of its length, hence the route is not important as passenger generator.

A further cartographical analysis of the bus service routes suggests that the frequency of bus movements on several routes is related to the concept of nodal accessibility examined in the

previous chapter. Nodes which are highly accessible are in the majority of cases located on the service routes with higher frequencies of bus movements (Figures 3.6 and 4.1), while the less accessible nodes are to be found on sections of the service routes with lower bus frequencies. On the basis of this observed relationship, it was hypothesised that the frequency of bus movement between the City Centre and nodes on the service network is determined by the accessibility levels of the nodes. To test the significance of this relationship in statistical terms, the number of buses (frequency) operating between the city centre and each of the twenty three nodes was correlated with measures of their accessibility (Table 4.1). A statistically siginficant correlation coefficient of -0.79 was produced. As would be expected more accessible nodes from the City Centre have more frequent bus services than the less accessible nodes found at peripheral locations. In the previous chapter we found that the accessibility of nodes on the route network depends on the distance from the City Centre. Since accessibility of a place depends on the magnitude of movement cost involved in getting from one place to another, which in

turn depends on the distance moved[3] there should therefore be a relationship between accessibility and the frequency of bus movement on the service network.

Figure 4.2 shows the pattern of bus movements in the City Centre and the frequency of their stopping at the various bus stages. Table 4.2 gives a summary of the frequency of these movements. The dominance of Kenyatta Avenue, Ngala Street and Government Road in handling the largest number of bus movement (over 10%) can be assessed from the table. The map shows that the movement pattern is predominantly from west to east, a pattern which is similar to the direction of movement outside the City Centre considered earlier (Figure 4.1).

Bus movements are focussed on the City Centre and practically all the movements to and from the various parts of the city originate and end or pass through the centre. Because of this, there are some streets which are subjected to handling more bus movements out of proportion to their sizes. Ngala Street is a case in point. All the buses moving to and from

TABLE 4.1 THE RELATIONSHIP BETWEEN ACCESSIBILITY INDICES AND THE FREQUENCY OF BUS MOVEMENTS

NODE	INDEX OF ACCESSIBILITY	BUS FREQUENCY (10-30 MIN.) INTERVAL
Ngara	207	10
Parklands	214	5
Pangani	218	11
Muthaiga	232	5
Westlands	233	8
Nairobi South	242	11
Eastlands	244	10
Eastleigh	244	10
Industrial Area	249	10
Kariobangi	279	10
Ruaraka	291	2
Dagoretti Corner	300	6
Dandora	320	2
Upper Kabete	334	3
Riruta	343	3
Langata	373	1
Uthiru	379	3
Lower Kabete	395	1
Karen	401	1
Dagoretti Market	466	2
Nairobi Airport	472	2
Kahawa	511	1
Kamiti	511	1

$r = -0.79$ The relationship significant at 0.01 level. Larger figures show that the nodes are less accessible.

Eastlands and the bus station, just a few yards away from it, pass through the street. It is a 2 by 2 lane street with two very close and opposite bus stops. Within an interval of ten to thirty minutes the street handles well over fifty buses. Given the high frequency of bus movements here and a mixture of pedestrian, motor and other traffic movements, there is a clear evidence that the street handles more than its traffic capacity (Plate 4.2) and the condition becomes even worse and more confused during rush hour periods. Some of the bus traffic could be diverted to by-pass it if it has to continue to serve both public transport vehicles as well as others. Some of the buses travelling to and from Eastlands could be diverted so that they pass through Government Road - Haile Selassie Avenue roundabout.

Basing our judgement on the distribution of bus stages in the City Centre, on the frequency of bus movements and on the daily experiences of conditions of traffic congestion, particularly during peak periods, it would be advisable to suggest that in future some of the bus stages will have to be located on the peripheries to give room for the free movement of pedestrian and other motor traffic. Alternatively, the problem of mixed traffic could be alleviated by the creation of a

Plate 4.2: The busiest bus stage on Ngala Street

TABLE 4.2 KENYA BUS MOVEMENT FREQUENCY IN THE CENTRE OF THE CITY AT INTERVALS OF 10 - 30 MINUTES AT STAGES

STREET NAME	INBOUND MOVEMENT	OUTBOUND MOVEMENT	TOTAL MOVEMENT	PERCENTAGE TOTAL MOV.
1. Kenyatta Avenue	27	18	45	19.07
2. Ngala Street	13	32	45	19.07
3. Government Road	12	21	33	13.98
4. Tom Mboya Street	10	14	24	10.17
5. Haile Selassie Avenue	13	11	24	10.17
6. City Hall Way	-	24	24	10.17
7. Kimathi Street	21	-	21	8.9
8. University Way	7	7	14	5.91
9. Koinange Street	6	-	6	2.56
	109	127	236	100.00

Source: Kenya Bus Service Company Ltd. - 1973 - The City Bus Service Route Map.

system of rapid public transport routes through the City Centre, which should be exclusively for the use of the city buses. The adoption of both or either of the measures would considerably improve conditions of traffic flow in the City Centre. Such a move would be hailed by many motorists and pedestrians, as traffic congestions are likely to be worse in future because of the continuing increase in the number of motor vehicles and their usage in the Centre of the City.

(b) TAXIS AND MATATUS

(i) Taxis

There are two types of taxis' operating in Nairobi namely, the yellow band (Plate 4.3) and "pirate" taxis. Both types of taxis are operated by either owner-drivers or by drivers employed by some business men or employees working in Nairobi. The yellow band taxis are officially licensed for hire purposes by the City Council of Nairobi, but the pirate taxis are known to operate illegally, hence the name "pirate". There are 150 licensed taxis in Nairobi, based at the official taxi ranks provided at big hotels or at any of the several taxi ranks found at shopping centres or city markets. The pirate taxis on the other hand have no fixed operating bases, but in most cases they operate from country bus stations, the railway station, petrol stations or from bars and night club premises. The two types of taxis in general cater for the general public, but some of the licensed taxis specialise in transporting visitors, especially tourists and may go well beyond the city boundary.

Plate 4.3: The yellow-band taxis at the City Market taxi rank.

The taxis normally operate during the day time, but in some cases they go into the late night hours taking people to night clubs, hotels, bars or to places of residence. In the day time, they take people to recreational sites such as the National Museum, Nairobi National Park, Bomas of Kenya or to Nairobi Airport. With the average seat occupancy of 2 persons per trip, it is estimated that the licensed taxis carry approximately 2000 passengers per day[4]. The busiest periods on any normal working day are the morning and evening peak hours. In addition to the busy morning and evening periods, they have exceptionally heavy passenger traffic throughout the day on week ends and month ends.

One significant observation can be made on the basis of this study, and that is, hired taxis are generally used for recreational trip purposes. For essential trips, such as work and school trips, the services provided by city buses and matatus are the most important. Taxis provide some measure of personal privacy and door to door services, which other forms of public transport do not offer. In this way, they are a special type of public transportation which does not present competition problems to either the city buses or matatus.

(ii) Matatus

The operation of 'matatu' passenger services in Nairobi and elsewhere in the country is no longer questioned. There is, however, very little knowledge of the scale of their operation within the context of public transport as a whole because of lack of proper organisation and data on the level of their operation. In Nairobi, matatu passenger services started in the early nineteen sixties. After independence, restrictions on the movements of people to towns within Kenya were lifted, with the resultant increase in the population of Nairobi, particularly those in the lower income bracket. This increase in the population created a considerable increase in the demand for public transport of a cheaper type. The existing public transport services could not offer cheaper services[5]. So, the required cheaper, but substandard service was offered by matatus, which are various types of mini-buses and combies (Plate 4.4).

There are two types of matatus, the hired and non-hired matatus. The hired matatus are similar to pirate taxis considered above but these can also ply for passengers on certain chosen routes.

Plate 4.4: Matatus are various types of mini-buses and pick-ups.

The non-hired matatus normally operate on the same routes used by the city buses plying for passengers at rates of fares similar to those charged by the city buses. In this way, they pose a serious threat to the operation of the city buses. In the past their operation in the city as public carriers was illegal, but with the Presidential Decree of June 1973 they are now regarded as legal modes of public transport not only within Nairobi, but throughout Kenya.

Matatu passenger services lack proper management and organisation, as the vehicles are individually owned. It is, therefore, difficult to determine precisely the actual number of matatus operating in Nairobi. Two organisations already registered, Kenya Matatu Organization and Nairobi Matatu Association are trying to rationalise their services but these efforts have not succeeded much. The existence of these two organisations shows that there are two distinct matatu services based in Nairobi. One group of matatus operates between Nairobi and other urban centres of Kenya and the other group operates only in Nairobi. It is the latter group of matatus that is examined in this thesis.

The matatu vehicles are generally defective and unroadworthy, but this is an over generalisation as recently some of the more successful operators have obtained new vehicles. Some of the vehicles do not hold insurance policies, and so operate without road licences. Some of the problems faced by matatu operators include, lack of stopping stages, which makes the vehicles a stumbling block to other traffic, and regular traffic police check-ups for mechanical defects and road licences. In addition, it appears that the vehicles are responsible for a number of road accidents in the city and the rates at which the vehicles break down seems to be relatively high. Lack of observation of traffic regulations is common with most of the matatu drivers. Illegal parking, over-speeding and over-loading coupled with frequent accidents make the movements of these vehicles a threat to the smooth flow of traffic in the city.

Since matatu vehicles have no fixed stopping stages, they use the official city bus stops as their passenger reservoirs or they simply drop or pick passengers any where. Within the City Centre they usually operate from petrol

stations, the railway station or from market places, but these bases are by no means fixed. Outside the City Centre, the city bus terminals are also matatu terminals. This means that matatu vehicles compete very seriously with the city buses. There is a particularly heavy competition for passengers on Thika Road, Jogoo Road and on Juja Road (Figure 4.3 and Table 4.3). It should,however, be noted that matatu services are sometimes complementary to the city bus services, especially when they operate beyond the city bus terminals on routes such as Thika Road, Ngong Road, Kikuyu Road and Magadi Road.

There are three types of matatu according to their trip making habits (Table 4.3). One group makes only two trips per day, during the morning and evening peaks. The second group operates at mid-day in addition to morning and evening peak. The third group operates for a whole day, making more than 15 trips in total. The first and third group are the most important as they perform the highest number of trips. Taking 15 as the average number of passengers carried by each vehicle, with 1618.5 as the total number of trips performed by all the matatus surveyed,it can be estimated that they carry an average

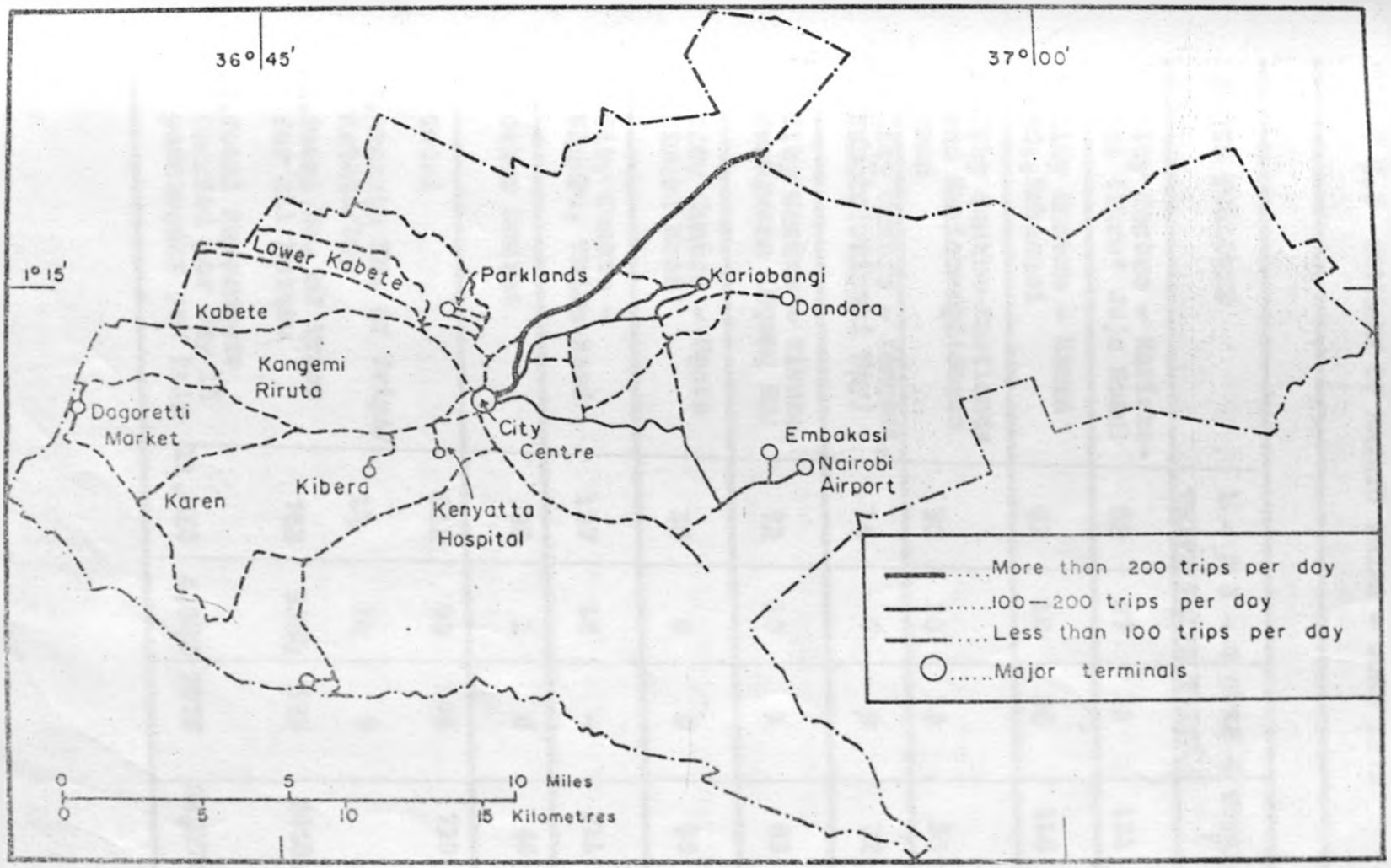

FIG. 4·3: ROUTES ON WHICH MATATUS COMPETE WITH THE CITY BUSES

TABLE 4.3 SUMMARY OF MATATU TRIPS - JUNE 1975

ROUTE FOLLOWED	1 - 2 TRIPS	3 - 4 TRIPS	OVER 4 TRIPS	TOTAL
1. City Centre - Kariobangi (Thro' Juja Road)	62	27	32	121
2. City Centre - Hamza Rd., Embakasi	62	18	36	116
3. City Centre-Eastlands and Kariobangi(Jogoo Road	30	10	13	53
4. City Centre - Kangemi, Kabete(Waiyaki Way)	16	7	9	32
5. City Centre - Riruta, Kwangware (Ngong Rd)	72	10	1	83
6. City Centre - Ngara (Limuru Road)	38	6	6	50
7. City Centre - Kiambu, Thika Road	197	14	-	211
8. Other Routes	35	1	8	44
9. Total	512	93	105	710
10. Average No. of Trips/ Matatu/Day	1½	3½	5	
11. Total No. of Trips for all Matatu	768	325½	525	1618.5
12. Total Passengers Carried per Day 15 passengers per trip	11,520	4,882	7875	24,277

of about 24,277 passengers daily. This is a high number and demonstrates that matatus play a substantial role in the daily movements of people in Nairobi. Some of the matatu vehicles move very fast and since they do not have time schedule like the city buses, are very popular and convenient for passengers who do not have time to wait for the scheduled arrivals of the city buses. More trips are made at month ends and it has been found that regular customers can in some cases obtain door-to-door services as well as credit facilities for a month's regular travel payable at the end of the month. One advantage which the matatus have over the city buses is that they have facilities for carrying passengers and their luggage, a service which is not provided for by the Kenya buses. From the foregoing examination of the role of matatus as means of public transport in Nairobi, there is no doubt that the general public has accepted matatus as additional or alternative means of public transport, but not as cheaper means of transport.

-. TRAVEL PATTERNS AND CHARACTERISTICS

(a) MODAL SPLIT.

Data on trips in Nairobi is readily available from surveys carried out in 1970/71 by Nairobi Urban Study Group[6]. It is from this source that the analysis of trip patterns and characteristics has been based in this section. They are discussed in terms of trip modes, purpose, length and distribution.

(i) Trip Modes

A trip, defined as the one way travel from one place (origin) to another (destination) for a particular purpose either by a person or vehicle[7], is a very complex and repetitive phenomenon in a large urban area such as Nairobi. In Nairobi, person trips by all modes of travel amount to 630,000 trips on a typical week day. The most striking feature of the daily trip distribution by all modes in Nairobi is the predominance of journeys on foot overall other modes of travel (Table 4.4).

TABLE 4.4: TOTAL DAILY TRIP DISTRIBUTION BY MODE - ALL PURPOSE

TRIP MODE	PERCENTAGE DISTRIBUTION
Walk	44.0
Cycle	2.6
Private Transport (Cars)•	38.0
Public Transport (Buses)	14.0
Others	1.4
Total	100.0

Source: City Council of Nairobi: Nairobi Urban Study Group - 1973 Metropolitan Growth Strategy, Vol. 2.

• Matatus were normally reported as car trips owing to their then illegal nature. While 38% of trips are made by private transport, only 14% are generated by public transport and the majority of trips are made on foot 44%. Bicycles and motor-cycles are of little significance as they account for only a small proportion. (2.6%). It should, therefore, appear that in Nairobi a substantial number of people own or have the use of cars, the rest of the population make their choice between walking and public transport, a choice which is dictated by the financial position of the individual.

(ii) Trip Purposes

Table 4.5 shows that work trips, school trips, personal and firm business trips which are essential purpose trips account for 83% of the total daily trips. The low level of trip making for non-essential purposes with less time constraints such as social and shopping could be explained by the generally low income of the majority of the population.

TABLE 4.5: TRIP DISTRIBUTION BY PURPOSE - ALL MODES

PURPOSE	PERCENTAGE DISTRIBUTION
Work	37.0
School	27.0
Personal and Firm Business	18.5
Social	7.0
Shopping	6.5
Others	4.0
Total	100.0

Source: City Council of Nairobi: Urban Study Group - 1973 .

Table 4.6 shows modal shares for different trip purposes. Work trips and business trips are similar in distribution, 35% of the trips being made on foot, 45% by private transport and 15% made by public transport. School trips are a special case with 62% being made on foot. The use of pedal cycle is surprisingly very low for all purposes, especially for school trips (0.5%). This is to be expected in Nairobi because of the generally heavy motor traffic during peak periods which are also school trip periods. The rates at which accidents occur at these periods are generally high, and this may place a check on the use of pedal cycles by school children. The 25% of school trips made as passengers in cars suggest that a substantial number of school children are taken to school in their parents' cars. For shopping trips, 48% are made on foot, 41% by private transport and 8% by buses. There is an indication that the use of private transport increases as the importance of trip purpose decreases. This can be confirmed by the distribution of modes for social and others purposes.

TABLE 4.6: TRIP DISTRIBUTION BY MODE FOR DIFFERENT TRIP PURPOSES

TRIP MODE	WORK	SCHOOL	SHOPPING	BUSIN.	SOCIAL	OTHERS
Foot	35	62	48	35	28	18
Cycle	5	0.5	2	5	2	1
Private	44	25	41	45	60	53
Public	15	11	8	14	9	27
Others	1	1.5	1	1	1	1
Total	100	100	100	100	100	100

Source: City Council of Nairobi:
Urban Study Group - 1973.

In terms of trip length frequency distribution for the three major modes, cars, buses and foot, the vast majority of trips fall within the range of 0.-8 kilometres[8]. For walk trips the distance ranges are below 3 kilometres and the number of trips fall rapidly with increasing distance. On the other hand public transport has a lower distribution in the shorter distance ranges. The frequency is greatest between 3 and 5 kilometres, but then falls sharply as distance increases. This would seem to suggest that people without cars tend to walk shorter distances but then transfer to public transport as distance increases. Trip by cars also show attenuating effect of distance, but generally trips by cars cover much longer distances.

Trip distribution by time of the day shows that there are three major peaks, morning, mid-day and evening peaks (Table 4.7). The three peaks account for about 63% of the total daily trips by all modes. The morning peak is the most concentrated as trips are mainly concentrated at 8 o'clock as compared to the distribution of trips during mid-day and evening peaks which are spread over much longer periods. The amount

TABLE 4.7: TRIP DISTRIBUTION BY TIME OF DAY - ALL TRIPS.

TIME OF DAY	PERCENTAGE DISTRIBUTION
6 - 7	2.7
7 - 8	2.7
8 - 9	17.5
9 - 10	6.25
10 - 11	3.0
11 - 12	2.5
12 - 1	11.25
1 - 2	11.25
2 - 3	3.5
3 - 4	5.0
4 - 5	13.25
5 - 6	9.5
6 - 7	5.0
7 - 8	3.0
8 - 9	1.7
9 -10	1.0
10 -11	0.75
Total	100.0

Source: City Council of Nairobi: Nairobi Urban Study Group - 1973.

of movements outside the three peaks is comparatively very low, which is consistent with the generally low level of trip making for non-essential purposes. The pronounced peakings are, therefore, attributable to work, school and business trips and this is particularly so during the morning peak.

(iii) Movement Distribution Patterns.

Walk trips are concentrated between the City Centre, the Industrial Area and Eastlands. Private transport movements predominate to the west and north of the City Centre, while bus movements are similar to walk trips in distribution except for a heavier concentration between the Central Area and the south-west[9]. The heavier concentration of bus trips to the south-west of the City Centre can be explained by the existence of high density residential estates such as Otiende, Madaraka, Nairobi West and South C., where the proportion of private car ownership is relatively lower among the households. To the east are the low income residential areas and to the west and north live the high income households with a higher proportion of private car ownership. The variation in the distribution of these movements can, therefore, be explained by the variation in income of the population to the west and east of the City Centre.

3. SUMMARY

The most important modes of public transportation in the internal transport system of Nairobi for people who do not own private cars are, the city buses, hired taxis and matatus. Comparatively, the city buses are the most important as they carry the largest number of passengers per trip and the largest number in terms of daily total. While the operation of city buses faces a number of problems, the most threatening of these is competition with matatus.

In many respects the bus service route network is similar to the route network considered in the previous chapter. This is particularly so with respect to factors determining its density, nodal accessibility and with respect to the influence exerted by distance from the City Centre which influences the magnitude of bus movements on several routes. Moreover, it was found in this study that there is a statistically significant relationship between the frequency of bus movement between the City Centre and nodes on the service routes and their nodal accessibility. One notable feature about the movement of buses, both outside

and within the City Centre is the predominance of west to east movements over movements to other directions, a pattern which is governed principally by the difference in income levels of the population resident in the city.

Two types of hired taxis can be identified in Nairobi,that is,the yellow band taxis and pirate taxis. Both taxis cater for the general public but it is the yellow band taxis which are officially licenced for hire purposes. In addition, a number of firms based in Nairobi also own cars and coaches for public hire purposes. In general the hired vehicles are used mainly for recreational trips.

Matatus have been accepted in Nairobi as means of public transport in addition to the city buses. The vehicles are generally known for being defective and driven by reckless drivers who do not observe traffic regulations. Because of this, many accidents occurring in the city seem to be committed by these vehicles. Matatus charge the same fares as the city buses,

use the same routes, stopping stages and even the same terminals. In this way, it is evidently clear that they compete seriously with the city buses.

One of the major features of trips in Nairobi is the predominance of journeys on foot over all other modes of travel. As a whole, the essential trips such as work, school and business trips are the most important as they account for the highest proportion of trips made daily in Nairobi. In terms of modal shares for different trip purposes, more use is made of private transport for the less essential trips. For the major modes of travel such as cars, buses and foot the vast majority of trips fall within the range of 0-8 kilometres. Finally for all trip modes, most of the travels are concentrated during the morning, mid-day and evening peaks, and they are concentrated in space in the Central Area, Industrial Area and Eastlands for walk trips, to the north and west of the City Centre for cars and in the Central Area, Industrial Area, Eastlands and south-west of the City Centre for buses.

In conclusion, it can be said that matatus carry such a substantial number of people daily in Nairobi, that they are now accepted as legitimate

public transport carriers, though the services offered are sometimes dangerous and substandard. Given the present annual growth rate of population in Nairobi of 9.7 per cent, it can be seen that by 1980's the city's population will hit the one million mark[10]. It is, therefore, doubtful whether the present number of city buses will cope with the number of passengers. In the light of this expectation of the increase of population of the city, matatu passenger services will play a significant role in public transportation system of Nairobi. While it is true that matatus are in competition with the city buses, it is also true that their services are both complementary and supplementary to the city bus services. What remains to be done by the City Council of Nairobi in collaboration with the Kenya Government is to design a properly formulated policy for the operation of matatus in Nairobi, and indeed in other parts of the country, if their role as public carriers has to be ascertained. This can be achieved by providing matatus with terminal stations in the City Centre similar to that for country buses. It is in this way that the number of matatus operating in the city could be known as each matatu would be required to pay some nominal fee for terminal use.

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CHAPTER 5

MOTOR VEHICLE VOLUMES AND MOVEMENT PATTERNS

1. INTRODUCTION

2. MOTOR VEHICLE VOLUME

3. MOTOR VEHICLE MOVEMENT PATTERNS

   (a) TYPE AND QUALITY OF THE EXISTING ROAD TRAFFIC CENSUS COUNTS

   (b) TRAFFIC FLOWS INTO AND OUT OF THE CENTRAL AREA: MORNING AND EVENING PEAK PERIODS

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MOTOR VEHICLE VOLUMES AND MOVEMENT PATTERNS

1. INTRODUCTION

The question of how much a city such as Nairobi can cope with the increasing number of motor vehicles without serious deterioration of the environment is fundamental to the understanding of the type of problems that are likely to be created. Three basic questions become very important in the assessment of the problems of urban traffic, and these are: How many vehicles are there? What is the composition of the vehicles? And at what rate does the number increase? The first part of this chapter makes an attempt to answer the foregoing questions in the case of motor vehicle capacity in Nairobi.

Motor vehicles move in connection with activities in which people are engaged. In Nairobi, such activities are so varied in space that in any given day a motor vehicle can move in connection with a number of them. This is particularly so because increased traffic flow is a reflection of development and the spatial aspects of flow in an urban area should

represent fairly accurately the spatial pattern of development[1]. This aspect of traffic flow is examined in the second part of the chapter.

2. MOTOR VEHICLE VOLUME

The question of location of motor vehicle capacity can be answered conceptually by considering location of ownership location of use and location of registration[2]. It is the last locational concept which is easily identifiable in the case of Nairobi because of the plate number registration system. Unfortunately it is also the least valuable information as the location of registration may bear little relation to the place of use and of effective ownership. In Kenya, more systematic recording of motor vehicle statistics for urban areas was introduced only in 1973. The data from the Central Bureau of Statistics has formed the basis for this analysis. Because the data relate to a period of two years only, it is not, however, helpful as a basis for forecast.

Table 5.1 illustrates the dominance of Nairobi in the registration of motor vehicles. A part from Nairobi, there are other ten urban centres in Kenya that register motor vehicles. In both years

TABLE 5.1 MOTOR VEHICLE DISTRIBUTION IN NAIROBI BY REGISTRATIONS, COMPARED TO THAT IN KENYA, 1973 - 1974

BODY TYPE	NAIROBI		KENYA		NBI % OF	NBI % OF	NBI %	KENYA %
	1973	1974	1973	1974	1973	1974	INCREASE 1974	DECREASE 1974
Saloon Cars	44970	49024	70660	78312	64	63	9.0	10.8
Station Wagons	5704	6914	10457	12623	55	55	21.2	20.7
Utilities and Pick Ups	18495	19698	35828	40004	52	49	6.5	11.6
LLorries	9851	10360	17943	19635	55	53	4.2	9.4
Buses	1055	1144	2532	2870	46	40	8.4	13.3
Mini-Buses	632	845	991	1326	64	64	32.1	33.8
Special Purpose	282	355	426	533	66	67	22.3	25.1
Roll. Grd. and Cranes	805	1023	957	1200	84	85	27.0	24.3
Wheeled Tractors	2555	2643	7710	8822	33	30	3.4	14.4
Crawler-Tractors	216	229	268	282	80	81	6.0	5.2
Motor-Cycles	3974	4302	8966	10332	44	42	8.2	15.2
Three Wheelers	86	95	126	147	52	71	10.4	18.2
Trailers	5028	5255	7359	8000	96	66	4.5	8.7
TOTAL	93653	101887	164222	184086	57	55	8.8	12.0

over 50 per cent of almost all types of motor vehicles in the country had Nairobi registration numbers, except buses, wheeled tractors and motor-cycles. Obviously, one would expect a greater need for the use of buses and wheeled tractors in other parts of the country than in Nairobi. The high percentage of the number of trailers (96%) registered in Nairobi in 1973 is more startling. This would seem to show that most of the firms operating trailer services in the country are based in Nairobi, a fact which is a reflection of the dominance of Nairobi in the commercial business life of the Country. In terms of growth rates, Nairobi had an increase of 8.8 per cent in the number of motor vehicles in 1974 over 1973 as compared to Kenya's growth rate of 12 per cent in the same year.

The dominance of Nairobi in having the largest registered number of motor vehicles in the country can be explained by the relatively large number of motor vehicle dealers based in the city. This is a reflection of the existence of a rich population with high effective demand for motor vehicles. But as was observed earlier, location of registration does not always bear relation to the location of use and of effective

ownership. This contention does not seem to be true in the case of Nairobi. For example, in 1973, the distribution of motor vehicles in Kenya according to location of use shows that over 56 per cent of all motor vehicles found in the country in that year were in fact being used in Nairobi[3]. This figure does tally well with the figures for location of registration (Table 5.1). The capacity of Nairobi to accommodate this large number of motor vehicles without serious deterioration of the environment is, therefore, a problem which should be examined critically, but in its right perspective. We turn now to the examination of the volume, movement patterns of motor vehicles and their implications to the existing road transport facilities in Nairobi.

3. MOTOR VEHICLE MOVEMENT PATTERNS

A measure of the importance of road transportation system of Nairobi is the steady rise in the number of motor vehicles in the post independence period. Today, Nairobi alone has a total of motor vehicle population of over 100,000, excluding the number of vehicles which flock in daily from the country side, a number which may be considerably higher at month ends. It is the flow of this motor vehicle traffic on the roads and streets of Nairobi which formed the source of data for this chapter's traffic flow pattern analyses.

(a) TYPE AND QUALITY OF THE EXISTING ROAD TRAFFIC CENSUS COUNTS

Remarks about traffic density and flows of road traffic depend upon the completeness and quality of the traffic counts that are taken. Such counts are important foundation for any rational planning of the road transport sector. Before proceeding to the discussion of traffic densities and volumes it appears, therefore, desirable to provide a short description of the methods that are used for collecting traffic data

for Nairobi roads and to give an evaluation of their quality.

A traffic census is taken during the peak hours only, in the Central Area of the city between 7.30 and 8.45 a.m., 12.30 and 2.00 p.m. and between 4.30 and 5.45 p.m. by the City Council enumerators. The counts are taken at street junctions once per year for each street junction census point by means of hand tallies. The closeness or density of the census points vary according to the spacing of street junctions and are very close and dense in the Central Area. The peak hour census counts are used specifically for determining the necessary street or junction capacity for the provision of traffic signals, creation of roundabouts or for the extension of street widths. In addition to the census counts taken in the Central Area, traffic counts are also conducted on the trunk, primary, secondary and minor roads linking the city with the surrounding districts. The counts are taken for five consecutive days from Monday to Friday by the Ministry of Works enumerators using hand tallies. For each day, counting starts from 7.00 a.m. to 7.00 p.m. and the vehicles are classified according to body types.

For the five days' counts, the average daily traffic is calculated for each of the census points. This is done once per year for each census point. The purpose for the Ministry of Works counts is to determine the road traffic capacity for planning road design alignment and as an economic indicator of the development of the surrounding districts. Both the City Council census counts and the Ministry of Works counts were used for this study.

There are, however, some disadvantages involved in the use of these traffic census data. The data for roads in Nairobi has been taken only since 1970. Prior to 1970 counts, the only census data collected was in 1969 and this was for the use by the Nairobi Urban Study Group. So, there is insufficient data to project trends on the basis of past years. Furthermore, the data gives no indication of the effect of seasonality in traffic flows. Despite these drawbacks, the available data have, however, provided a useful source of information for the analysis and evaluation of the road traffic flow patterns in 1974.

(b) TRAFFIC FLOWS INTO AND OUT OF THE CENTRAL AREA: MORNING AND EVENING PEAK PERIODS

Heavy traffic movements within and around the Central Area generally start about 7.30 and continue upto 8.30 a.m. with the heaviest concentration occurring about 8.00 a.m. when most of the government and business offices open or about to open. Figure 5.1 shows the pattern of motor traffic movements into and out of the Central Area during the morning peak. On the map are recorded the average hourly flow of motor vehicles between road intersections. Table 5.2 summarises the traffic flow volume as recorded on roads and streets linking the Central Area with the various parts of the city.

The summary table shows that the morning peak hour flow is dominated by movements to and from the north, west and south of the Central Area, from the southern end of Uhuru Highway in the south, through Kenyatta Avenue in the west to Muranga Road in the north. The dominance of these roads in accounting for over 70 per cent of the total number of motor vehicles entering and leaving the

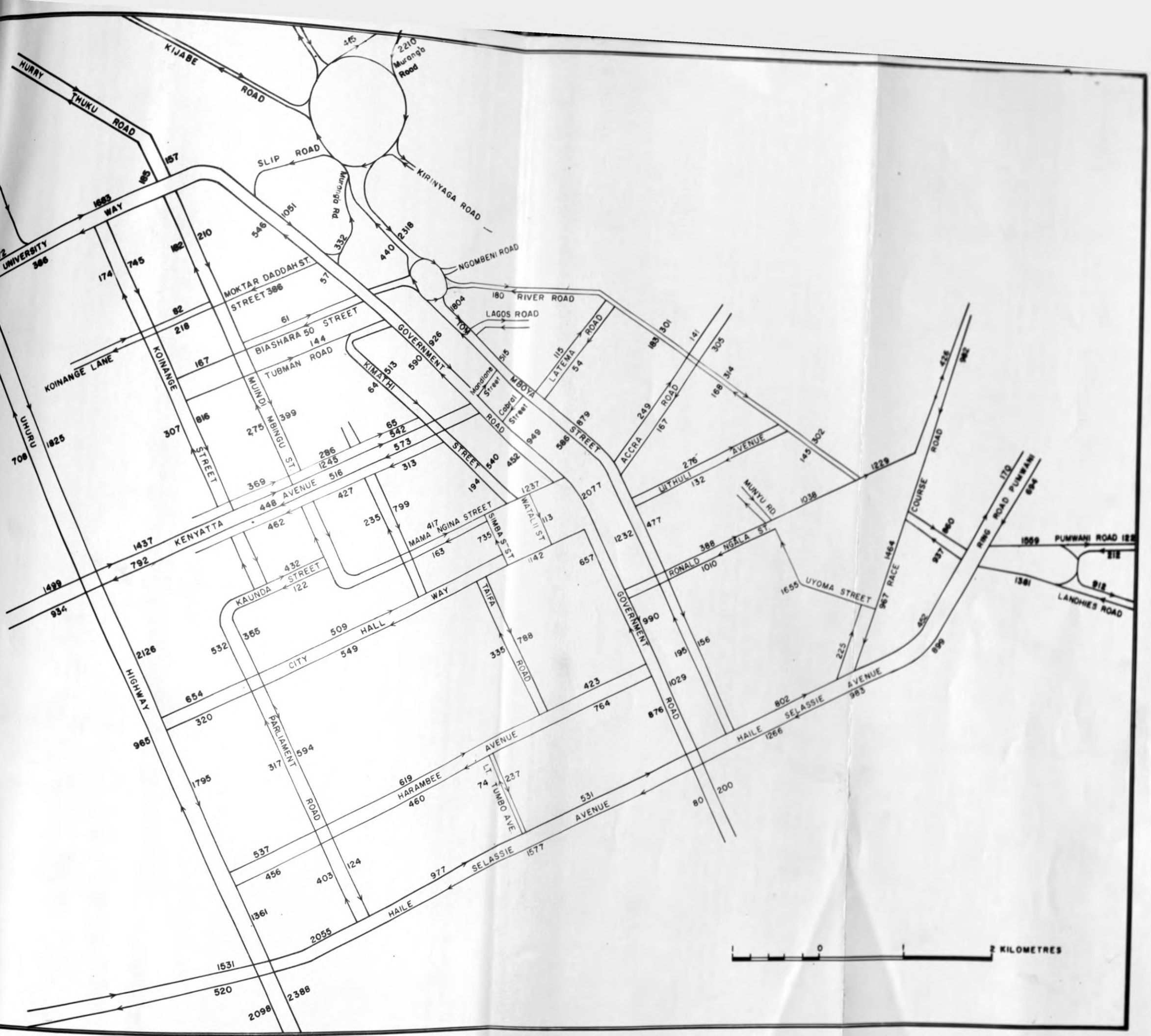

FIG. 5.1: PATTERN OF ROAD TRAFFIC MOVEMENTS IN THE CENTRAL AREA: MORNING PEAK (V.P.H)

TABLE 5.2 TRAFFIC FLOWS INTO AND OUT OF THE CENTRAL AREA: MORNING PEAK HOUR (V. P. H.) - 1974

STREET OR ROAD	INBOUND	OUTBOUND	TOTAL	PERCENT
Uhuru Highway North End	2650	921	3571	16.4
Uhuru Highway South End	2098	2388	4486	20.6
Kenyatta Avenue	1499	934	2433	11.1
Haile Selassie Aven.	1531	520	2051	9.4
University Way	1043	279	1322	6.0
Harry Thuku Road	157	257	414	1.9
Muranga Road	2318	440	2758	12.6
Race Course Road	982	428	1410	6.6
Ring Road Pumwani	694	170	864	4.1
Landhies-Pumwani Roads	1422	1034	2456	11.3
TOTAL	14394	7371	21765	100.0

City Centre during the morning peak can be explained by the existence of proportionately higher levels of car ownership among the population resident in the northern and western parts of the city as compared to those resident in the eastern parts[4]. Another important factor is the location of government and other employment offices on the hills to the west of the Central Area. These employment centres attract a considerable volume of traffic during the morning peak. Furthermore, the northern and western parts have larger and more numerous road links with the City Centre than are found to the east, where only Pumwani - Landhies and Race Course Roads provide such links. A combination of these factors seems to be particularly relevant to the explanation of the dominance of the northern and western routes during the morning traffic flows. To the east, only Landhies - Pumwani Roads have a comparable traffic volume. But even the roads have a combined traffic flow much lighter than those handled by most of the roads in this belt.

In the morning, all the roads linking the Central Area with the various parts of the city have total traffic flows of over 2,000

vehicles per hour, except University Way, Harry Thuku Road, Race Course and Ring Road Pumwani. University Way is part of a diversionary road, Race Course Road has some of its traffic diverted to Pumwani Ring Road, while Harry Thuku Road is insignificant and smaller. As would be expected, the outbound flows are in almost all the roads lower than inbound flows, except for the outbound traffic flow on the southern end of Uhuru Highway. The total for inbound flows which is twice as large as that for outbound flow, demonstrates that the Central Area, being the most important centre of employment and business concentration is the focus of traffic movement in the city.

The dominance of southern end of Uhuru Highway in carryig the heaviest outbound traffic and in accounting for the highest total traffic flow (20.6%) during the morning peak can be explained by the location of the Industrial Area to the south as the second most important centre of employment and business concentration. It is, therefore, an important traffic attractor during the morning peak hour flow. Furthermore, the southern end of Uhuru Highway handles virtually all the traffic moving to and from Nairobi Airport plus through traffic travelling via

the Uhuru Highway by-pass. In addition, the highway also handles all the motor traffic from the residential locations such as Langata, Karen, Nairobi South and Otiende areas with relatively high levels of car ownership. The dominance of Landhies - Pumwani Road to the east during the morning can be attributed to their being the only major arterial links between the Central Area and motor traffic from the heavily populated locations of Eastlands, in addition to Landhies Road being the main through road into the Industrial Area for traffic from north-east of the city. It is, however, difficult to isolate through traffic from traffic which has business in the Central Area on the basis of this data alone. But from the evidence provided on the map, it is possible to say that traffic moving on Uhuru Highway and on Ring Road Pumwani have some elements of through traffic as the highways are, in essence, by-pass routes.

The evening peak hour traffic flows are illustrated in Figure 5.2 which has the same information as the morning peak, and traffic flow

volume for the same streets and roads has been summarised in Table 5.3 A similar pattern of traffic movements to that for the morning peak still runs through the evening peak. The same roads, that is, Uhuru Highway northern end, Uhuru Highway southern end, Kenyatta Avenue, University Way, Harry Thuku Road and Muranga Road now account for slightly over 80 per cent of the total peak flow. In contrast to the morning peak, Muranga Road now has the heaviest traffic flow accounting for 21.8 per cent of the total flow, and its dominance in the outbound traffic flow is striking. This can be explained by the fact that the road is the most important arterial outlet from the City Centre for the traffic bound for the outlying urban centres such as Limuru, Kiambu, Ruiru and Thika, in addition to that bound for the northern residential areas such as Ngara, Pangani, Parklands and Muthaiga. Its dominance is, in part, the result of the continued flow and accumulation of traffic into the Central Area from the above outlying urban centres well after the morning peak trafficcounts are over. This traffic, plus that bound for the northern residential areas, where car ownership is high among the residents,

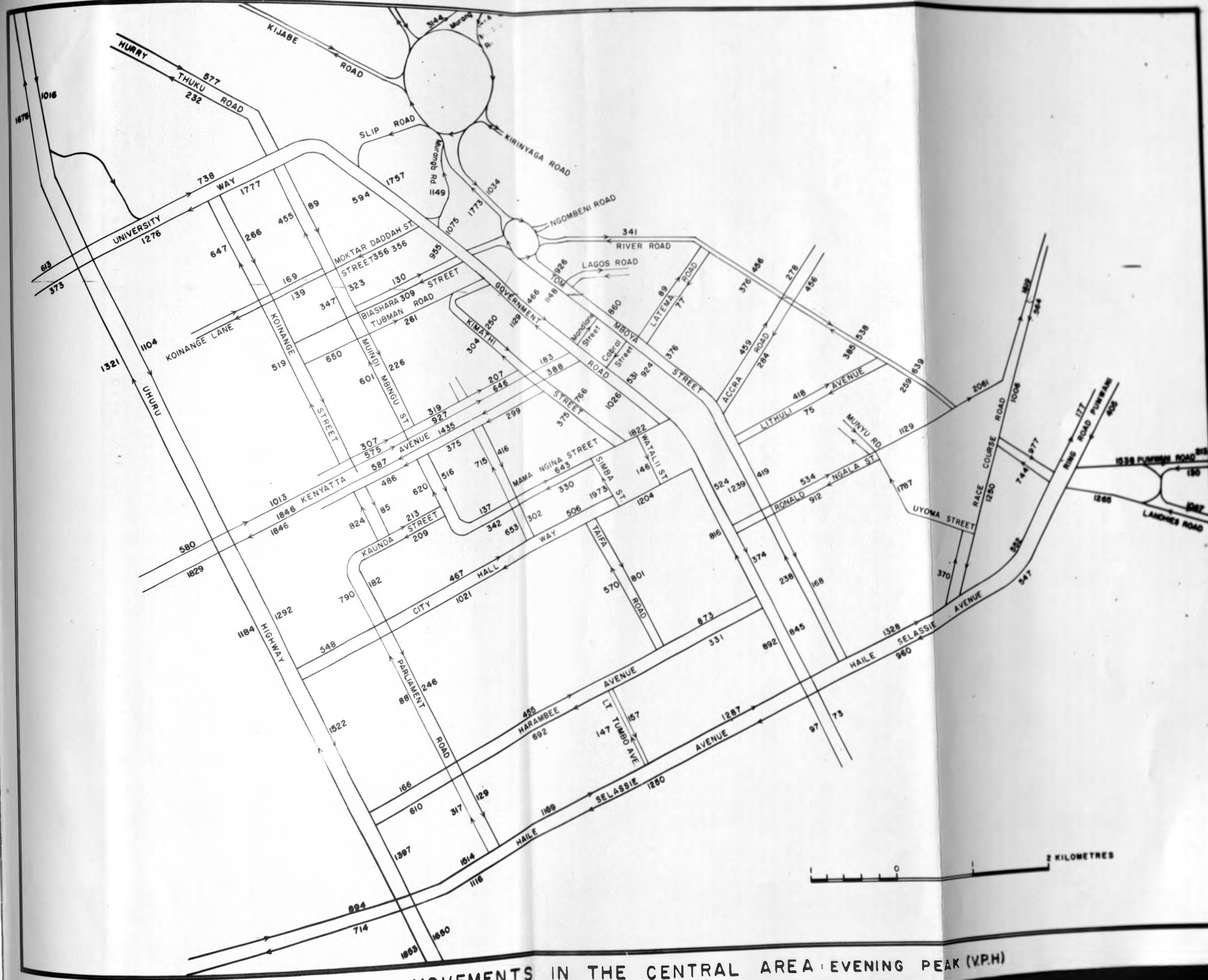

FIG. 5.2: PATTERN OF ROAD TRAFFIC MOVEMENTS IN THE CENTRAL AREA : EVENING PEAK (V.P.H)

TABLE 5.3 TRAFFIC FLOWS INTO AND OUT OF THE CENTRAL AREA: EVENING PEAK HOUR (V. P. H.) - 1974

STREET OR ROAD	INBOUND	OUTBOUND	TOTAL	PERCENT
Uhuru Highway North-end	1016	1676	2692	12.4
Uhuru Highway South end	1853	1650	3503	15.8
Kenyatta Avenue	580	1829	2409	10.8
Haile Selassie Av.	894	714	1608	7.2
University Way	613	373	986	4.6
Harry Thuku Road	577	232	809	3.8
Muranga Road	1744	3114	4858	21.8
Race Course Road	564	1619	2183	9.8
Ring Road Pumwani	405	177	582	2.6
Landhies-Pumwani Roads	1309	1300	2609	11.2
TOTAL	9555	12684	22239	100.0

accounts for the considerably higher volume of outbound traffic in the evening compared to outbound traffic in the morning. The light outbound traffic of only 440 vehicles on the road in the morning peak compared to the inbound traffic of 2318 vehicles is a reflection of the non-existence of major employment and business centres to the north of the City Centre. This is in contrast to the nearly equal traffic flows either way on Uhuru Highway, south end. These factors, therefore, seem relevant explanations for the discrepancy between the morning and evening peak traffic flows on Muranga Road.

Traffic movement on the streets serving the Central Area are summarised in Table 5.4. The average traffic flow per hour for each of the streets was obtained by adding all the traffic flows between street intercestion then dividing by the number of observations. The results obtained, thus, formed the mean vehicle flow per hour

for each street. This system of averaging the flows apparently has inherent drawbacks in that streets with multiple lanes and intersections such as Kenyatta Avenue have their mean traffic flows under represented. From the table, it can be seen that eleven streets have mean traffic flows of over 1,000 vehicles per hour during the morning peak as compared to fourteen streets with mean flows of over 1,000 vehicles per hour during the evening peak. The streets with more than 1,000 vehicles per hour are spatially concentrated on the eastern approaches to the Central Area. It would seem, therefore, that there is a considerably high concentration of traffic movements during the two peak periods on the eastern parts of the Central Area. Since some of these streets are one-way streets and some have no traffic lighting signals, conditions of congestion must be out of proportion on the eastern parts of the Central Area.

An examination of the two tables shows that the morning peak traffic flow is predominantly inbound, while the evening peak flow is predominantly outbound. This demonstrates as was examined earlier that the Central Area is the main focus of traffic movements

during the morning peak because of the concentration of employment places and business establishment here. The predominance of outbound traffic flows during the evening peak seems consistent with the diurnal cycle of traffic movement in urban areas when work and business times are over in the City Centre and traffic is homeward bound.

A comparison of the total flows for the two peak periods shows that the evening peak is more important as it carries the heaviest traffic movements, both on the approach roads to the Central Area and on the streets within the City Centre (Tables 5.3 and 5.4). The variation in traffic flows during the two periods could be understood much more clearly if we relate it to trip distribution by time for different trip purposes. Pronounced peaking has been observed in connection with essential trips such as work, school and business trips which account for 65 per cent of total trips in Nairobi[5]. Trips which have less time constraints on individuals, such as shopping and social trips are less concentrated during the morning peak, while all the trips are well represented during the evening peak. The importance of the evening

TABLE 5.4: TRAFFIC FLOW IN THE CENTRAL AREA: MEAN VEHICLE FLOW PER HOUR 1974.

STREED/ROAD	MORNING PEAK	EVENING PEAK
1. Uhuru Highway	1401	1303
2. Haile Selassie Avenue	1060	1146
3. Lt.Tumbo Avenue	156	152
4. Harambee Avenue	543	521
5. Parliament Road	388	342
6. Taifa Road	562	686
7. City Hall Way	1691	1976
8. Kaunda Street	277	211
9. Kenyatta Avenue	488	640
10. Simba Street	735	1973
11. Watali Street	113	82
12. Wabera Street	464	523
13. Mama Ngina Street	990	1488
14. Ronald Ngala Street.	1833	2318
15. Uyoma Street	1656	1787
16. Race Course Road	2046	1419
17. Landies Road	2432	2358
18. Pumwani Road	1726	1710
19. Government Road	2366	2644
20. Luthuli Avenue	204	247
21. Latema Road	85	83
22. Accra Road	208	372
23. Tubman Road	144	261
24. Biashara Street	56	219
25. Morktar Dada Street	386	356
26. Koinange Street	511	521
27. Koinange Lane	150	154
28. Muindi Mbingu Street	247	492
29. Kimathi Street	328	424
30. Tom Mboya Street	1459	1685
31. River Road	228	417
32. University Way	1179	1064
33. Muranga Road	332	1149
TOTAL	26,444	30,723

peak is also emphasised by the continued flow and accumulation of traffic in the Central Area for the rest of the day after the morning peak. These temporal variations in traffic movements explain why the evening peak is more important in terms of the total number of traffic movements.

(c) TRAFFIC MOVEMENTS ON THE ROAD LINKING THE CITY WITH THE SURROUNDING DISTRICTS

Figure 5.3 shows the average daily traffic on the roads linking the city with the rest of the country both at the boundary entry points and within the city. At the boundary entry points, the international trunk roads such as Mombasa Road, Waiyaki Way, and Thika Road handle over 20,000 motor vehicles per day compared to over 17,000 motor vehicles handled by the primary and secondary roads such as Kamiti, Kiambu, Limuru, Lower Kabete, Kikuyu, Ngong, Magadi and Koma Rock Roads. So, in total, the roads together handle approximately 40,000 motor vehicles which stream into and out of the city daily. This number of motor vehicles is essentially part of the daily traffic of the internal road transport system of the city. Apparently there is some element of through traffic on by-pass routes such as Waiyaki Way - Uhuru High Way - Mombasa Road and on Outer Ring Road. The heavier traffic flows of 16,329 and 78,344 on the lower sections of Mombasa Road and on Uhuru Highway respectively are a reflection of the importance of the Industrial Area and the Central Area as both traffic generators and attractors

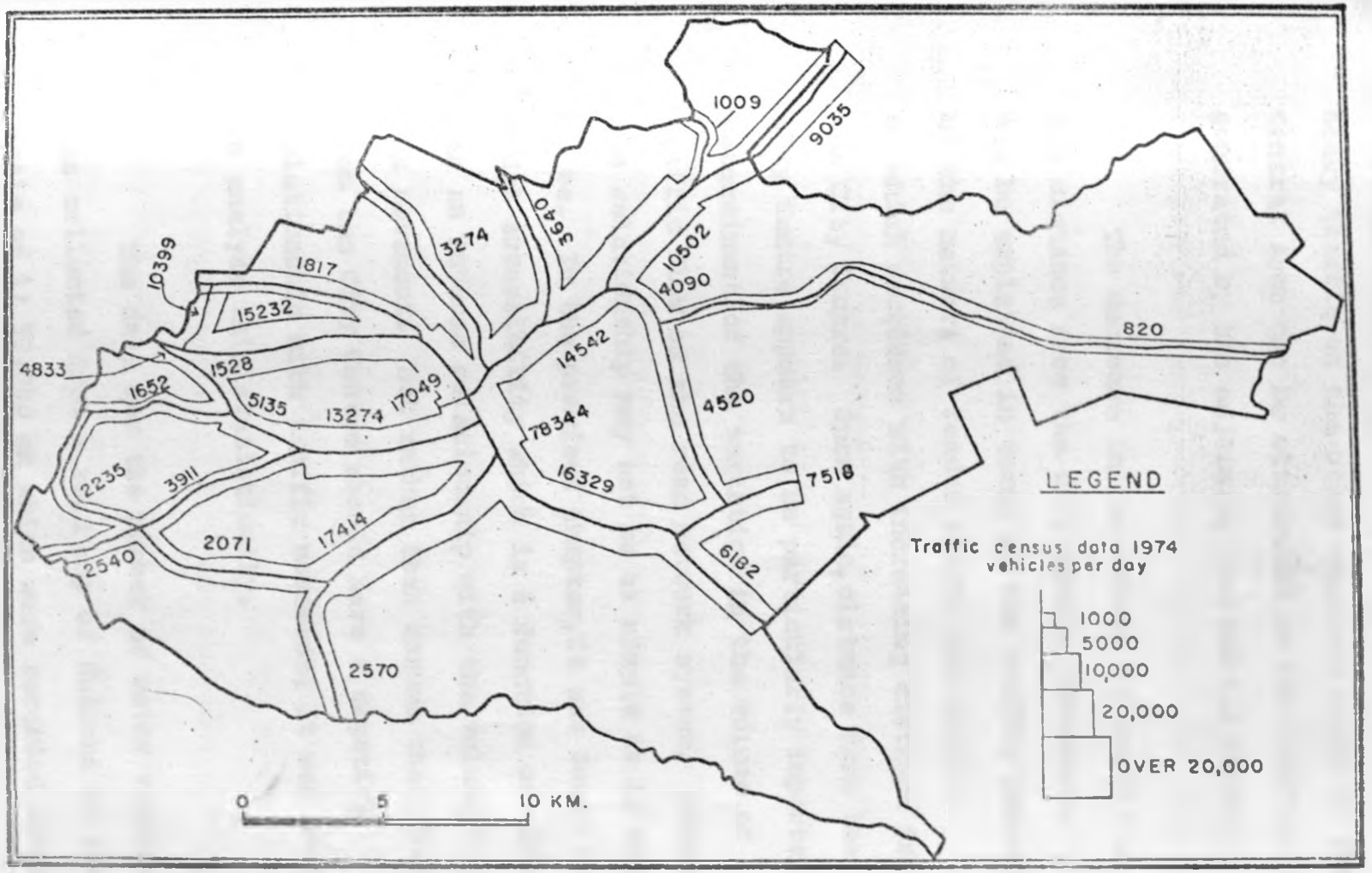

FIG.5.3: TRAFFIC FLOW ON THE TRUNK AND PRIMARY ROADS

in the internal road transport system. The heavy traffic on the other approach roads to the Central Area can be attributed to the traffic generated by the adjoining residential units.

The decrease in the volume of traffic as the distance from the City Centre increases can be explained in terms of the traffic generated by the network of feeder roads, the density of which decreases with increasing distance from the City Centre. Once again, distance from the City Centre appears to be particularly important determinant of the variation in the volume of traffic flow on the road network system. However, the relationship may not be as simple as it seems to be. In the previous chapter, it was found that nodal accessibility which is a function of distance has an inverse relationship with the volume of bus movement. But rather than assume that distance from the City Centre should have a negative relationship with traffic movement, it was decided to analyse this statistically.

The data for the number of motor vehicles was collected from a road map of Nairobi on the scale of 1: 50,000 on which were recorded traffic

census figures for forty traffic census points. From each of the forty census points a straight line distance in Kilometres was measured to the City Centre. For the distance measurement the City Centre was assumed to be the junction of Kenyatta Avenue with Uhuru Highway. To ensure linearity in the regression analysis, the set of data on motor vehicles was transformed to natural logarithms . The analyses produced a regression equation of Log Y = 4.26 - 0.07x and a correlation coefficient of r = -0.60 (Table 5.5). The regression and correlation coefficients, thus produced, show that distance from the City Centre and the volume of traffic flow are inversely related and such a relationship was statistically significant at 0.01 level.

From the regression model, only 36 per cent of the variation in traffic movements can be explained by distance from the City Centre. To uncover other relevant factors accounting for the remaining 64 per cent of the variation, the simple regression equation was then tied to cartographical analysis of the pattern of residuals (Fig. 5.4). The distribution of residuals

TABLE 5.5: THE RELATIONSHIP BETWEEN TRAFFIC FLOW AND DISTANCE FROM THE CITY CENTRE.

CENSUS POINT	DISTANCE (KM)	LOG OF NO. OF VEHICLES	CENSUS POINT	DISTANCE (KM)	LOG OF NO. OF VEHICLES
1	8.0	3.77	21	10.9	4.00
2	8.3	3.77	22	9.9	3.30
3	7.8	4.00	23	9.8	3.47
4	1.5	4.36	24	10.0	3.30
5	1.2	4.89	25	3.8	3.30
6	1.4	4.47	26	4.3	3.60
7	0.3	4.25	27	7.2	4.04
8	0.2	4.87	28	7.1	3.69
9	8.5	3.47	29	7.2	3.47
10	8.4	3.30	30	11.0	3.00
11	6.5	3.90	31	7.5	3.00
12	6.8	3.30	32	9.9	3.00
13	6.8	3.84	33	16.0	3.95
14	12.7	3.30	34	7.1	3.69
15	13.1	3.47	35	11.5	3.84
16	13.1	3.30	36	8.9	3.60
17	11.2	3.30	37	9.3	3.90
18	14.4	3.00	38	9.2	3.77
19	11.4	3.77	39	12.7	3.77
20	11.2	3.69	40	9.5	3.30

$r = -0.60$

Relationship significant at 0.01 level.

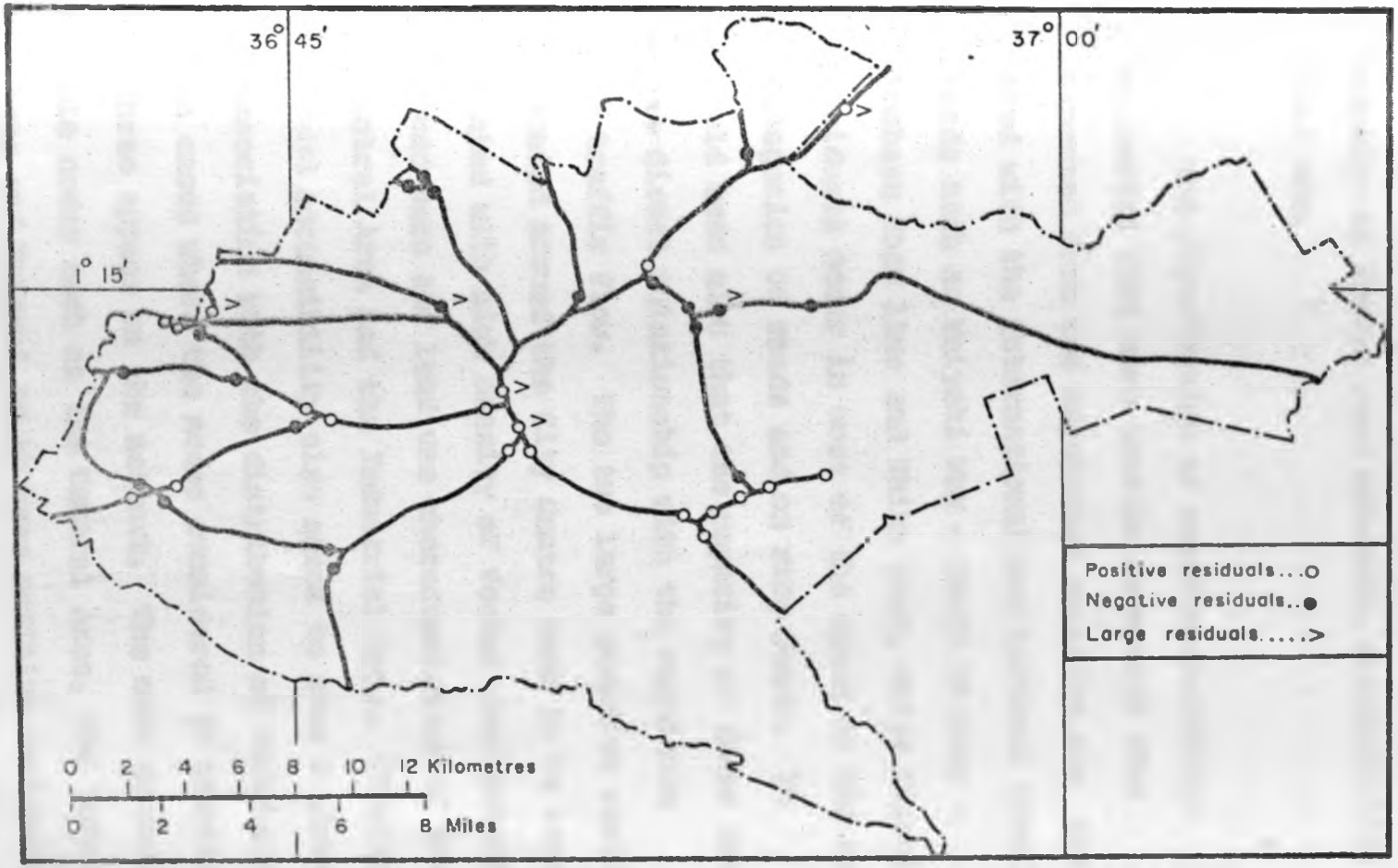

FIG. 5.4: RESIDUAL MAP OF THE RELATIONSHIP BETWEEN TRAFFIC MOVEMENTS AND DISTANCE FROM THE CITY CENTRE

suggested that traffic movements are also associated with the classes and capacity of roads, the density of feeder road networks, accessibility and land use.

The distribution of positive residuals suggested that more traffic movements than expected from the regression equation are associated with the international and national trunk roads such as Waiyaki Way - Uhuru Highway - Mombasa Road line and Thika Road, while negative residuals occur in most of the cases on the lower categories of roads and on ring roads. It would seem also that the capacity of these roads has direct relationship with the magnitude of traffic flow. The two large positive residuals located around the City Centre seem to be associated with high density of feeder road network found here and land use characteristics of the Central Area and the Industrial Area. Finally, nodal accessibility also seems to show a close association with the distribution of residuals in cases where the nodes considered in chapter three appear on the network. The more accessible nodes such as the Central Area, the Industrial Area and Nairobi South have positive residuals

while the less accessible ones such as Dagoretti Market, Karen,Langata and Riruta have negative residuals. But these associations on the other hand seem to be explanable much more in terms of categories of roads on which the nodes are found than on the accessibility levels of the nodes alone. In conclusion, therefore, two properties of network structure, density and accessibility appear to be related to the variation of traffic flow in addition to categories and capacity of roads and land use.

4. THE IMPLICATIONS OF MOTOR VEHICLE VOLUMES AND MOVEMENT PATTERNS

Some concluding observations with practical implications for the present and future traffic management in Nairobi can be highlighted in connection with the volume of motor vehicles and their movement patterns. Parking spaces are already scarce in the centre of the city. To alleviate this problem will require the provision of additional parking spaces in a place where vacant sites are rapidly being taken over for new developments. There is, therefore, an immediate need for the City Council or the Government to formulate a comprehensive programme for the decentralisation of work places and certain categories of land use. This will mean the provision of additional parking spaces in the new locations. Maybe, where new developments take up vacant sites, the policy should be to include parking spaces as part of the building or development plans. With the increased volume of traffic, some of the existing narrow streets and small intersections will require enlargement and additional traffic management signals will

have to be installed if efficient traffic movement within the Central Area has to be maintained. Coupled with the increased traffic volume is the inherent high cost of road maintenance. Lastly the formulation of a comprehensive plan for the creation of by-pass routes immediately around the Central Area will go along way towards solving much of the congestion problems that are experienced during the peak periods.

Vehicle movements on the roads linking the city with the rest of the country also show some practical implications for the future planning and improvement of their traffic capacity. Only Thika Road is a complete dual carriage way structure from the city boundary to the City Centre. The particularly heavy traffic of over 10,000 motor vehicles per day handled by Waiyaki Way, Ngong Road, Aerodrome Road and Mombasa Road shows that the roads require dual carriage way structure or multiple lanes if they have to handle the present and future traffic efficiently. The highways are approaching or have reached the limits of their daily traffic capacity, particularly on those sections where they carry single lane traffic either way. It is true that once a route has reached a capacity traffic density, the maintenance of capacity speed is critical[6].

Experience along these roads, supported by the traffic flow data suggests that traffic movements on these roads have fallen below capacity speed. The major features of parking and congestion problems are discussed in greater details in the next chapter.

5. SUMMARY

Road transport networks are provided to facilitate motor vehicle movements. The larger the number of vehicles using the network, the more complex the network. The variation of traffic flow on individual links of the network should, therefore, represent fairly accurately the spatial pattern of development and activities. These relationships between network form and traffic flows seem to be particularly relevant in the case of Nairobi.

More systematic recording of motor vehicle statistics in Kenya for urban areas was introduced only in 1973. In 1973 and 1974 over 50 per cent of all motor vehicles operating in the country had Nairobi registration number. An important feature of this distribution is that 50 per cent of almost all types of motor vehicles were registered in Nairobi. This analysis of location by registration of motor vehicles does seem to bear a close relation to the volume of motor vehicles actually used and owned in the city.

For this study, the analysis of motor vehicle movement patterns was based on the traffic census counts collected by the City Council of Nairobi and the Ministry of Works for the year 1974. While the data have some major drawbacks, admittedly they provide a useful source of information for the understanding of traffic movement patterns in the city. The data for the morning peak flow in the Central Area shows that movement patterns is predominantly to and from the west and north of the City Centre, with Uhuru Highway southern end carrying the heaviest traffic. This belt alone accounts for over 70 per cent of all the traffic entering and leaving the Central Area. The same pattern is repeated during the evening peak flow, with Muranga Road carrying the heaviest traffic. The dominance of traffic flows to and from the west and north can be explained by three major factors: the existence of higher levels of car ownership among the population resident on these parts, the existence of larger and more road links with the Central Area and lastly by the location of work places on the hills to the west of the City Centre. Within the Central Area, eleven streets have traffic flows of over 1,000 vehicles

per hour during the morning peak compared to fourteen with over 1,000 during the evening peak. Most of these streets are spatially concentrated on the eastern approaches to the Central Area.

Traffic movements on the roads linking the city with the adjoining districts show that the international trunk roads handle the highest number of motor vehicles at the boundary entry points. One geographical variable which was found to be statistically significant in explaining the variation of traffic flows on these roads is distance from the City Centre. In addition to this variable, two properties of network structure: density and accessibility also seem to be related to the variation of traffic flow. Other factors include categories of roads and the distribution of land use.

The volume of motor vehicles and their movement patterns in Nairobi pose some problems for the planning of the road transport infrastructure. These include the construction of new roads and the expansion of the existing ones, easing of the current traffic congestion and attention to the present high demand for parking spaces and high costs of road maintenance.

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CHAPTER 6

PROBLEMS OF TRANSPORTATION IN NAIROBI

1. ACCIDENTS

2. MIXED TRAFFIC AND TRAFFIC CONGESTION

3. SUMMARY

REFERENCES

PROBLEMS OF TRANSPORTATION IN NAIROBI

In the previous chapter, it was observed that the rising number of motor vehicles in Nairobi coupled with their increased usage have direct and indirect bearing for the short as well as for the long term planning programmes for the road transport network facilities in the area. In this chapter, a more detailed analysis of the most apparent road transport problems is presented under two major headings: (1) accidents, and (2) mixed traffic and traffic congestion.

1. ACCIDENTS

According to traffic police, the major causes of accidents in Nairobi as well as in other parts of the country are attributable to carelessness on the part of pedestrians and drivers, and faulty vehicles. But if all road users exercised unremitting care, all the time, many accidents would be avoided, except those caused by unpredictable mechanical defects.

Table 6.1 shows road accident figures for Nairobi for the years 1971 - 1974. As can be seen in the table, there is some evidence that the total number of injury accidents has been

increasing but only at decreasing rates from 1971 - 1973. In 1972, there was an increase of 150 injury accidents over the year 1971, but in 1973, there was an increase of only 20 accidents. Since the figures for 1974 are incomplete, it is not possible to say with certainty that the general trend has been that of a decreasing increase.

TABLE 6.1 ROAD ACCIDENTS 1971 - 1974*

TYPE OF INJURY SUSTAINED	1971	1972	1974	1974	Total
Fatal	233	252	282	279	1046
Serious	626	670	764	602	2662
Slight	1647	1734	1630	1528	6539
TOTAL	2506	2656	2676	2409	10,247

Source: Nairobi Area, Traffic Police Division.

*Figures for 1974 were for the period upto September.

This is in contrast to the increasing rates of motor vehicle volumes in the city(Table 5.1). While the general trend or picture for the two years is that there was a decrease in the total number of injury accidents, the picture is far from clear for the different types of accidents sustained. Moreover, the table does not show figures for non-injury accidents which involve motor vehicles damages only. These appear to be just as high as those for injury accidents. For example, in 1974, there was a total of 2409 injury accidents as compared to 2334 non-injury accidents that were reported and dealt with. Incidentally, some of the non-injury accident cases are solved by the involved parties a nd never reach the police. If the number of non-injury accidents cases that do not reach the police were to be considered, the figures would be considerably much higher.

The decrease in the total number of injury accidents dealt with in the period under consideration has been attributed to the massive programme of lectures given to schools and institutions in Nairobi and throughout Kenya by the officials of the Kenya Traffic Police Section since 1969.

By giving lectures to school children, it is hoped that by the time this group of the public own cars they will be better and careful road users. Moreover, it is claimed that in the past before these lectures were given to schools, accidents involving school children occurred much more often than they do now. Other measures that are thought to have had influence on the decrease in the number of injury accidents include the use of mass media for public instruction, routine checks on motor vehicles for defective parts, frequent traffic and radar checks for over speeding where speed limit specifications are indicated, court prosecutions and the establishment of traffic liaison committees in the provinces. On the basis of the evidence provided by the data, it would seem that these measures have had some effect in reducing the rate of motor vehicle accident occurrences in Nairobi.

The major accident spots involving most of the fatal cases in Nairobi show a very striking spatial pattern (Figure 6.1). It is of interest to note that the Central Area where most of the pedestrian and motor traffic movements are

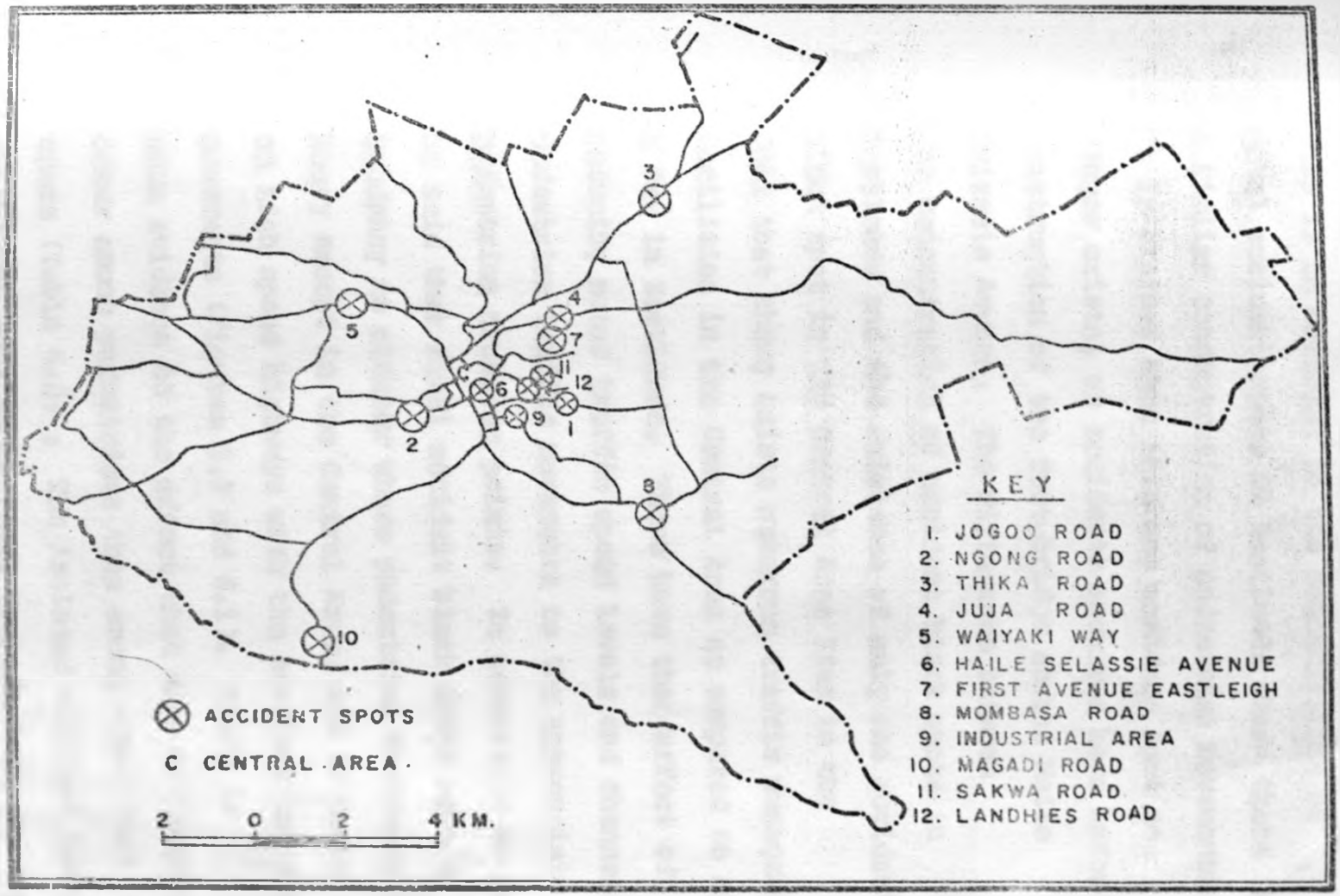

FIG 6.1: MAJOR ACCIDENT SPOTS IN NAIROBI

concentrated has only one fatal accident spot. This is in contrast to the concentration of fatal accident spots in Eastlands where there is a similar concentration of pedestrian movements. It is claimed that this one accident spot no longer exists, as accidents occurred here before the construction of the foot-bridge across Haile Selassie Avenue. The difference between the concentration of accident black spots in Eastlands and the existence of only one accident black spot in the Central Area lies in the fact that there exists numerous traffic management facilities in the Central Area as compared to only a few in Eastlands. These have the effect of reducing motor traffic speed levels and channelling pedestrian traffic movements to the appropriate pedestrian crossing points. In general, it could be said that fatal accident black spots have a tendency to cluster where pedestrian movements are heavy except in the Central Area, and to occur on high speed highways with the heaviest traffic movements (Figures 5.3 and 6.1). There is some evidence to the effect that more accidents occur among pedestrians than among other road users (Table 6.2). The isolated accident spots on Waiyaki Way, Thika Road, Mombasa Road and on

Magadi Road would, therefore, seem to involve mainly motorists and motor vehicle passengers as the locations are far from areas with high concentrations of pedestrian movement. One conclusion which could be drawn on the basis of these observations, subject to empirical investigations, is that there is a close spatial association between accident black spots and areas of pedestrian movement concentration.

TABLE 6.2 BREAK DOWN OF PEOPLE INJURED ON NAIROBI ROADS, 1972 - 1975•

PERSONS INVOLVED	FATAL	SERIOUS	SLIGHT	TOTAL
Motorists	10	36	79	125
Pedal Cyclists	13	54	117	184
Passengers	10	85	128	223
Pedestrians	25	100	226	351
TOTAL	58	275	550	883

Source: Nairobi Area, Traffic Police Division

• This break-down apparently omitted some figures on injury accident cases.

The seriousness of accident problems encountered in Nairobi can, thus, be assessed on the basis of loss of life and bodily injuries sustained. During the four-year period under consideration, over 10,000 people suffered various types of body injury, including death and some were probably permanently maimed. Of these unfortunate members of the public over 1000 lost their lives. It could be said roughly that about 250 people lose their lives on the roads of Nairobi every year. Apart from loss of life and bodily injuries sustained, the losses should also be gauged in terms of the number of lesser accidents involving damage to vehicles and personal property,all of which set in process unplanned financial expenses.

2. MIXED TRAFFIC AND TRAFFIC CONGESTION

Mixed traffic is one of the most common features of road traffic in Nairobi. There is, however, a system of route specification for country buses and certain categories of heavy commercial vehicles. Most of these vehicles do not leave or enter Nairobi through the City Centre streets. Country buses moving to and from the western districts follow Haile Selassie Avenue, while those to and from the northern and eastern districts follow the eastern by-pass routes. But the City buses, cars, smaller commercial vehicles and certain categories of heavy commercial vehicles which provide wholesale stores, petrol filling stations and offices with essential supplies are sometimes mixed up with pedestrians, cyclists, and push-carts on some of the Central Area streets. This kind of mixed traffic movement sometimes makes traffic flow very inefficient and unsafe (Plate 6.1). More efficient and safe traffic movement could be attained or maintained in the Central Area if a policy for separate and exclusive routes for different categories of traffic were formulated.

Plate 6.1: The problem of mixed traffic in the City Centre.

Another solution could be to discourage the location of certain wholesale establishments, small scale workshops and manufacturing activities, and petrol filling stations from the City Centre. This would be desirable because these forms of urban land use not only attract labour into the City Centre, but also generate and attract a considerable volume of heavy commercial traffic.

In Nairobi, there is a need for organised pedestrian movements, particularly along the roads leading into the Central Area from Eastlands. A large number of pedestrians, cyclists and push-carts is a common feature of traffic on the approach roads such as Landhies and Pumwani Roads. The mixture of slow moving traffic and faster traffic results in not only less efficient, but even less safe traffic management for all categories of traffic than if they were subjected to a greater degree of separation and control. The same problem applies to the uncontrolled crossing of pedestrian traffic which sometimes occurs along the whole length of many of the roads or streets on the eastern parts of the City Centre. There is a tendency for some pedestrians to ignore light

signals and other pedestrian movement facilities. Such haphazard pedestrian movements within and outside the City Centre are sometimes an obstacle to the free flow of motor traffic. It is the expressed fear of the City Traffic Department that even if the most elaborate pedestrian movement facilities were provided, some pedestrians would not make maximum use of them. Such a fear may be justified on the grounds of cost-benefit consideration, but considering the inevitable increase in the volume of motor and pedestrian traffic in the City Centre, it is the free flow of traffic and pedestrian safety which should be taken into consideration.

One of the biggest road traffic problems in Nairobi is the inadequacy of parking spaces in the Central Area. Coupled with peak hour traffic congestion, there is a parking problem which is increasing rapidly as the Central Area employment opportunities increase and the vacant sites once used for parking are being developed (Plate 6.2). Furthermore, with the rapid increase in the number of motor vehicles at the rate of 8.8 per cent per year (Table 5.1), the inadequacy of parking spaces is a problem which is likely to stay, at least in the City Centre.

Plate 6.2: Parking problem in the unofficial parking sites.

In 1971, there were only 15,000 spaces used for parking in the Central Area as compared to an estimated demand of 21,200 spaces (Table 6.3)[1], and the condition doesn't seem to have improved since. Of the on-street parking spaces, about 40% are used for long term parking. Parking meter zones are being expanded, but as yet only 2,440 spaces are controlled by meter. This means that there is an inadequate organisation for meter parking. There is, therefore, a need for the increase in the number of on-street parking spaces controlled by meter. Moreover, it has been observed that some people use the meter controlled parking spaces for long term parking with impunity. This would seem to mean that meter control parking conditions are not strict enough.

Considering the present position of parking demand which is only 73 per cent satisfied, severe measures should be instituted to curb demand for parking spaces in the Central Area. Such measures should include higher charges for parking in both the meter controlled and off-street car parks, the regulation for parking for shorter durations in shopping areas and stricter enforcement of meter parking regulations. Other solutions

TABLE 6.3 EXISTING PARKING SPACES IN C.A.

TYPE OF PARKING	NO. OF SPACES	%	DEMAND	BALANCE
On-Street	6510	42		
Private Dev.Spaces	3875	25	21200	5700
Off-Street Public Parks	2480	16		
Un-Official Parking Sites	2635	17		
Total	15,500	100	21200	5700

Source: City Council of Nairobi: Urban Study Group - 1973.

could be the restriction of Central Area employment to parkings space availability and the creation of additional off-city centre parks. The present Government policy of building new office complexes on the hills to the west of the Central Area will go a long way towards solving some of the parking and congestion problems experienced in the City Centre today. This has had the effect of diverting motor traffic movements from the Central Area and creating additional parking spaces off the Central Area. Similar moves should be encouraged for other potential employment sectors. In addition, some new parking spaces could be created off-city centre on the open spaces to the west of Uhuru Highway and along the banks of Nairobi River to the east of Muranga Road roundabout. These locations are within walking distances from the City Centre, and should, therefore, not create transport problems.

To maintain the present parking spaces at more or less the same level, there should be a policy that whenever an official parking site is taken over by a new development, such a development should include parking spaces as part of the building plan. The provision of parking spaces

in the basement or in the form of multi-storey buildings are such possibilities.

The other problem experienced on Nairobi streets and roads is traffic jam. This is a major feature of traffic movement during peak periods, and the condition sometimes becomes worse when there is a road accident. There are a number of road lengths, especially at the approaches to certain intersections where there are high levels of traffic jam caused by lack of traffic management facilities. Such road sections include approaches to Government/Haile Selassie Avenue roundabout, Tom Mboya/Ngala street intersection, Ngala street/River Road junction, Accra Road/River Road junction, Latema Road/River Road junction and Haile Selassie Avenue/Pumwani - Landhies Roads Roundabout. All these streets are found on the eastern parts of the Central Area. While street intersections in the City Centre and those on the western approaches to it have efficient traffic flows because of the presence of traffic lighting systems for both vehicle and pedestrian traffic,

such facilities are badly lacking on the above street intersections. Since most of these streets carry the heaviest traffic (over 1000 vehicles per hour) during morning and evening peak hour flows, they need immediate attention to ease conditions of traffic congestion and jam experienced along them.

There are other roads such as Tom Mboya Street, Muindi Mbingu Street, Koinange Street and others where congestion conditions are created during peak hours simply because motorists lack guidance. This is particularly so because of the haphazard manner in which some motorists stop and wait, thus obstructing the free flow of traffic. A system of Clearway, No Stopping or No Waiting should be applied on the sides of the streets with the heavier traffic during the peak periods. Similar conditions should also be applied on One-way and narrow streets. Although some of these regulations exist on some of the narrow streets, traffic congestion still exists. Stricter enforcement of these regulations needs to be put into effect than it seems to be at the moment.

Finally, it would seem that the most threatening of all metropolitan problems is air pollution.[2]

In urban areas, from 50 - 90 per cent of all air pollution is caused by vehicle traffic[3,4]. It is, however, not known as yet to what extent this claim is true in the case of Nairobi. If it is true that vehicle traffic is the leading polluter of air in the urban environment, then this should be a serious matter which should attract the immediate attention of urban planners and public health officials of Nairobi. Whatever the relevance of this assertion, we people in Nairobi must accept the fact that, primary pollution, such as derelict motor vehicle bodies littering the open spaces on either side of Ring Road Pumwani and along the Nairobi River bank, is evident enough to justify the seriousness of this form of pollution. There is, however, the need for research in the case of air pollution by motor vehicle exhaust fumes to find out the degree of the seriousness of the problem, if the above claim has to be ascertained in Nairobi. But the most annoying of all the motor vehicle movement results is the nuisance of noises produced by sports cars, motor cycles, defective exhaust pipes and loose motor vehicle bodies.

The solutions to most of these problems should rest with the City Council, the Government and the assistence of the public in general.

It is, however, demonstratable that the geographer has a role to play in the analysis of the spatial nature of the problems, so that in subsequent planning programmes lack of foresight should not create further problems. The author has the impression that the City Council of Nairobi is working towards the solution to some of the problems identified above. It is, therefore, hoped that the suggestions put forward in this study will serve as a basis for reflection and future reference.

3. SUMMARY

The rising number of motor vehicles in Nairobi couples with their increased usage pose some intractable problems which should be carefully analysed for the formulation of short and long term policy programmes for the road traffic in the City. The major serious road traffic problems identified in this study as expected are: accidents, mixed traffic and traffic congestion.

While there is some evidence that road accident cases are decreasing at an increasing rate, the picture still looks grim with over 10,000 people having lost their lives or suffered various forms of body injury between 1971 and 1974. Unspecified number of people are also feared to have suffered losses of personal property as a result of road accidents in the same period. It should also be noted that all these accidents set other processes in train involving a lot of financial expenses. One of the most striking features of road accidents in Nairobi is the spatial pattern of fatal accident spots. The City Centre seems to be a safer site as far as the distribution of fatal accidents is concerned

with only one accident spot. The distribution of fatal accident spots shows that there seems to be a high spatial association between these black spots and areas of pedestrian movement concentration, except the City Centre.

Mixed traffic and traffic congestion are specifically pronounced in the Central Area. There is a need here to subject all categories of traffic to a greater degree of separation and control. The biggest problem of traffic congestion is that of inadequate parking spaces. At the moment, only 73 per cent of parking demand is satisfied. Worse still, even the available parking spaces are not properly utilised because of the laxed conditions for parking. This applies particularly to the meter controlled parking spaces. The move should be to discourage parking in the Central Area as much as possible by all the means available to the City Council or to the Government, including stricter and severer parking conditions.

Traffic jams are a prominent feature of traffic movement during peak periods or when some accident occurs. The phenomenon is much more

marked on the eastern parts of the Central Area than on the northern and western parts. Attention should be paid to certain road intersections on the eastern parts and if possible these sections should be provided with traffic lights or other traffic control facilities, where they do not exist.

It is the hope of the author that the identification and the analysis of the nature of these problems and some of the suggestions for solution made here will serve as a basis for reflection and future reference.

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CHAPTER 7

CONCLUSIONS

1. MAJOR FINDINGS AND CONTRIBUTIONS MADE BY THE STUDY

   (a) Contributions to work in the General Field of Transportation Geography.

   (b) Contributions to work in Transportation Geography of Nairobi.

2. RECOMMENDATIONS

3. SUGGESTED FUTURE RESEARCH AREAS

REFERENCES.

CONCLUSIONS

The analysis of the road network properties and the explanations of the process and factors that have created them are the basic geographical problems that were examined in this study. The major properties of the network, thus, analysed consisted of network density, connectivity and accessibility and their relationship with geographical variables, such as distance, population, land use, relief and drainage. Furthermore, the relationships between traffic movements on the nodal linkages and factors such as distance, network properties, and land use were examined to establish a basis for the understanding of the underlying principles of transportation geography of Nairobi. The salient features of the study have been summarised under the relevant chapters and therefore will not be repeated here. The chapter is, therefore, devoted mainly to the major concluding remarks based on the findings from the various analyses made.

1. MAJOR FINDINGS AND CONTRIBUTIONS MADE BY THE STUDY

Several aspects of this study should, however, be considered in total as findings and contributions made to the work in the field of transportation geography in general and to the understanding of transportation geography of Nairobi. While the author claims no originality in the methods of analysis employed in the manipulation of the statistical data that were collected, the results produced, their interpretations, and conclusions arrived at, should be regarded as distinct findings and contributions of this study. The author, nevertheless, acknowledge the contributions of other scholars in the field of transportation geography whose techniques of analysing transportation networks and flow patterns were indispensable in the study. Among the scholars whose methodologies and ideas were widely used are: Taaffe et al.[1], Taaffe and Ganthier[2], Garrison[3], Kansky[4] and Hay[5]. Others whose works were of considerable aid in the preparation of this thesis are listed in the relevant parts of the work.

(a) Contributions to Work in the General Field of Transportation Geography.

Major findings of this study which should be considered contributions to the knowledge and understanding of transportation geography in general can be listed as:

i. a significant inverse relationship was established between the pattern of road network and distance from the City Centre (Table 3.1),

ii. the road density zones of Nairobi form concentric rings round the City Centre (Figure 3.3),

iii. accessibility of the nodes on the road network system was found to be significantly related to the distance from the City Centre (Table 3.4)

iv. the frequency of bus movements between the City Centre and the nodes on bus service route network is significantly related to the accessibility levels of the nodes (Table 4.1), and

v. traffic movements on the roads linking the city with the surrounding districts show a significant relationship with distance from the City Centre.

From these findings it can be seen that an important feature of the road network system and traffic movement patterns is their variations with distance from the City Centre. This feature of the road transport network and its flow patterns should not be surprising in view of the fact that urban development processes, including the development of transportation infrastructure, is concentrated both in space and time, at least initially, in the Central Business District. There is therefore, a tendency for human activities and movements to agglomerate at the City Centre to take advantage of scale economies. Such locational decisions and concentration of activities are made in general so as to minimise the frictional effect of distance. In a sense, the idea of movement minimisation is closely related to accessibility, especially when the former is measured by the costs involved in overcoming distance[6]. Road network density and traffic movements are, therefore, concentrated at and around the City Centre and decrease with distance from it because the centre has developed through time as the major focus of routes and consequently it is the most easily reached part of the entire Nairobi Area.

Another contribution is the author's use of the number of road intersections as a method for constructing road density map of Nairobi. While this technique has been used in other studies[7], the most important result of the exercise is the emergence of concentric zones round the City Centre. This illustrates that in urban areas road network development or provisional intensity decreases as distance from the Central Business District increases.

Other contributions should be considered technical rather than methodological. This is especially in relation to the presentation of most of the maps which have appeared in this work for the first time. Finally, it would seem that a major contribution to the field of transportation consists of the materials collected in the field and from other sources and which went into the preparation of the thesis. These include statistical tables and photographic plates. The statistical tables presented in the work could form a useful source of information for further research and a basis for reference on the several aspects of road transportation dealt with.

These information sources, therefore, contribute substantially to work in transportation geography in general.

(b) Contributions to Work in Transportation Geography of Nairobi.

As a result of the analyses and interpretation of the data on transportation that were assembled, the following features of road transportation in addition to the ones examined above came out as major findings relevant to the knowledge and understanding of the geography and general aspects of transportation in Nairobi.

i. The variation in the distribution of road network appears to be related to variables such as relief, drainage, population distribution and land use distribution.

ii. The trunk, primary and secondary roads of Nairobi are 45 per cent connected compared to the maximum number of connections possible, hence the network is more than minimally connected (Fig. 3.5).

iii. Nodes with high, medium and low levels of accessibility are spatially organized about 3 - 5, 5 -10 and 15 or more kilometeres respectively from the Central Area (Fig. 3.6).

iv. That there seems to be a close spatial relationship between nodal accessibility levels and the degree or intensity of land use.

v. The movements of city buses both outside and within the City Centre are predominantly west to east, a pattern which is governed basically by the differential distribution of income levels of the population resident in the city.

vi. Taxis are used mainly for recreational and social trip purposes.

vii. Matatu passenger services are not only competitive,but also complementary and supplementary to the city bus services (Figure 4.3).

viii. Trip distribution by modes is predominantly on foot, but in terms of trip purposes, work, school and business trips are the most important (Tables 4.4, 4.5).

ix. Spatially, there is a concentration of walk trips in the City Centre, Industrial Area and in Eastlands; a similar pattern being displayed for bus trips, while private transport movements predominate to the west and north of the City Centre.

x. Upto 1974, Nairobi had a total registration of 101,887 motor vehicles, a number which does not differ significantly from that which is used and effectively owned in the city. This figure represents over 50 per cent of all the motor vehicles registered in Kenya. (Table 5.1).

xi. Motor vehicle movement patterns in the Central Area during the morning and evening peaks is predominantly to and from the west and north of the City Centre. (Tables 5.2, 5.3).

xii. In addition to the relationship with distance from the City Centre, traffic movements on the roads linking the city with the surrounding districts also seem to be a function of network density, accessibility, classes and capacity of roads, and land use.

xiii. The major road transport problems of Nairobi were identified as accidents, mixed traffic and traffic congestion, including shortage of parking spaces in the Central Area.

The above listed findings are in total contributions to knowledge and understanding of road transportation system of the area. The work also made an attempt to show by name and number, the classification of roads in Nairobi into five categories. For the first time, the City of Nairobi has been divided into road density regions which show a close semblance to the city boundary evolution over the years. A further contribution to the understanding of the geography of spatial organisation of the city is the ranking and grouping of the leading nodes on the road network system according to their levels of accessibility. All these findings must be regarded as substantial contributions to work in transportation geography of Nairobi.

2. RECOMMENDATIONS

One of the fields of investigation that this study undertook was to identify some of the problems which have grown or grow concomitantly with the development and expansion of road transportation facilities in Nairobi. It was not, however, the major task of the study to present recommendations for possible solution to the problems, rather the aim was simply to expose them. But the results and findings of a study, such as this, would not serve a useful purpose if the attention of those responsible for the planning and improvements of the conditions of road transport infrastructure is not drawn to aspects which need immediate and particular attention. The author is aware that some of the problems examined here and the recommendations presented for solution are being tackled by the relevant city authority in collaboration with the Government. The following are the most outstanding recommendations the study presents on the basis of its findings:

(a) There are very limited route connections between the Industrial Area and Eastlands. This can be illustrated by the fact that the city bus serving the Industrial Area from Eastlands take the longer and more roundabout path via Haile Selassie Avenue - Uhuru Highway detour before gaining access into the area. A direct bus route should link Eastlands with the Industrial Area via Jogoo Road roundabout behind Landhies Muthurwa. The completion of the construction of the over-head bridge across the rail lines would make the Industrial Area more accessible from Eastlands by city buses.

(b) There are generally little lateral interconnections between settlements on the ridges in the north-west and north of the City Centre. The existing routes provide links only between the settlements and the City Centre. A programme for ring or lateral road development on these parts of the city should facilitate such links.

(c) The City Centre already suffers enough traffic congestion even outside peak periods. This has been made worse by the fact that virtually all the city buses use the City Centre as through traffic. To alleviate some of the

congestion problems in the Central Area, some bus routes need to be diverted to by-pass the City Centre, alternatively buses should pick passengers on the peripheries. The other solution could be the creation of exclusive busways or lanes through the City Centre. A system of staggering of working hours in the City Centre could also be a move in the right direction towards solving the problem of traffic congestion during peak periods. The problem of rush hour characteristic of a single peak would thus be solved by two or more light peaks.

(d) The general public in Nairobi have accepted Matatu public passenger services, not as cheaper modes of travel, but as additional to the city bus services. Now that the government has formally legalised their operation, a proper policy for the organisation and operation of their services should be formulated. It should be made mandatory that all matatu operators have the vehicles in perfectly roadworthy conditions, hold insurance policies and valid road licences.

The provision of terminal stations within the City Centre will make it possible to ascertain the actual number of matatus in operation within the city and outside it as each vehicle will be required to pay some nominal fee for terminal use.

(e) The present traffic volume of over 10,000 vehicles per day on Waiyaki Way, Mombasa Road, Ngong Road and Aerodrome Road suggests that the highways are approaching or have reached the limits of their daily traffic capacity on those sections where they carry single - lane traffic either way. These roads, therefore, need dual carriage way structure throughout their length or multiple lanes if efficient and smooth traffic flows have to be maintained along them in the future.

(f) To reduce the problem of mixed traffic in the Central Area and on certain approach roads to the City Centre, such as Landhies - Pumwani Roads, there is an immediate need to provide pedestrian and cyclists movement facilities. Wholesale shops, small scale workshops and manufacturing activities, and petrol filling stations occupy a considerable

portion of land area in the Central Area. Locations of some of these land uses at the centre in future will need to be discouraged as these forms of urban land use not only attract labour into the City Centre, but also generate and attract a considerable volume of heavy commertial traffic which is also a feature of mixed traffic in the City Centre.

(g) To reduce some of the congestion problems on the eastern streets of the Central Area traffic lighting signal facilities need to be installed at the following intersections: Government Road/Haile Selassie Avenue roundabout, Tom Mboya Street/Ngala Street intersection, Ngala Street/River Road Junction, Accra Road/River Road Junction, Latema Road/River Road Junction and at Haile Selassie Avenue/Pumwani-Landhies Roads roundabout.

(h) Some solutions to the Central Area parking problems may be gained by implementing the following measures:

i. Employment level in the Central Area should be restricted. The present Government policy of office development on the hills to the west of the Central Area is a move in the right direction. Similar moves should be encouraged.

ii. Meter and other parking conditions should be made severe. These should include stricter enforcement of the regulations, higher charges for parking in both the meter controlled and off-street public car parks, and parking for shorter durations in shopping areas.

iii. Whenever unofficial parking sites are taken over by new developments, such developments should include parking spaces as part of their building plans. The provision of parking spaces in the basements is one such possibility.

(i) A system of clearway, No stopping or No waiting should be applied on the sides of streets with heavier traffic during peak periods to lessen the problem of traffic congestion and jam.

SUGGESTED FUTURE RESEARCH AREAS

Transportation study in a city such as Nairobi is a complex subject which points to several sidelines for future investigation. Some of these sidelines, however, were examined, though briefly to facilitate the presentation of a comprehensive picture of the feature of the road transportation studied. Other areas were not at all touched because of time or scope of the work. The following areas need further treatment if a fuller understanding of transportation geography of the area has to be of maximum value:

(a) An investigation into the historical evolution of the road network of Nairobi, with particular emphasis on the impact of the changes in the structure and pattern over the years.

(b) The influence of road network pattern, including nodal accessibility on land use pattern.

(c) A comparative study of the importance of road and rail public transportation in the movement of people to and from Nairobi.

(d) The role of tourist operator firms in the movement of tourist in and around Nairobi.

(e) A detailed study of the degree of competition between matatus and city buses as public transport carriers in the city.

(f) A study of the role of road transportation in the movement of goods within the city and to and from Nairobi.

(g) An investigation into the level of environment pollution in Nairobi attributable to the motor vehicle traffic, and

(h) A study of the role of rail and air transportation in the internal transport system of Nairobi.

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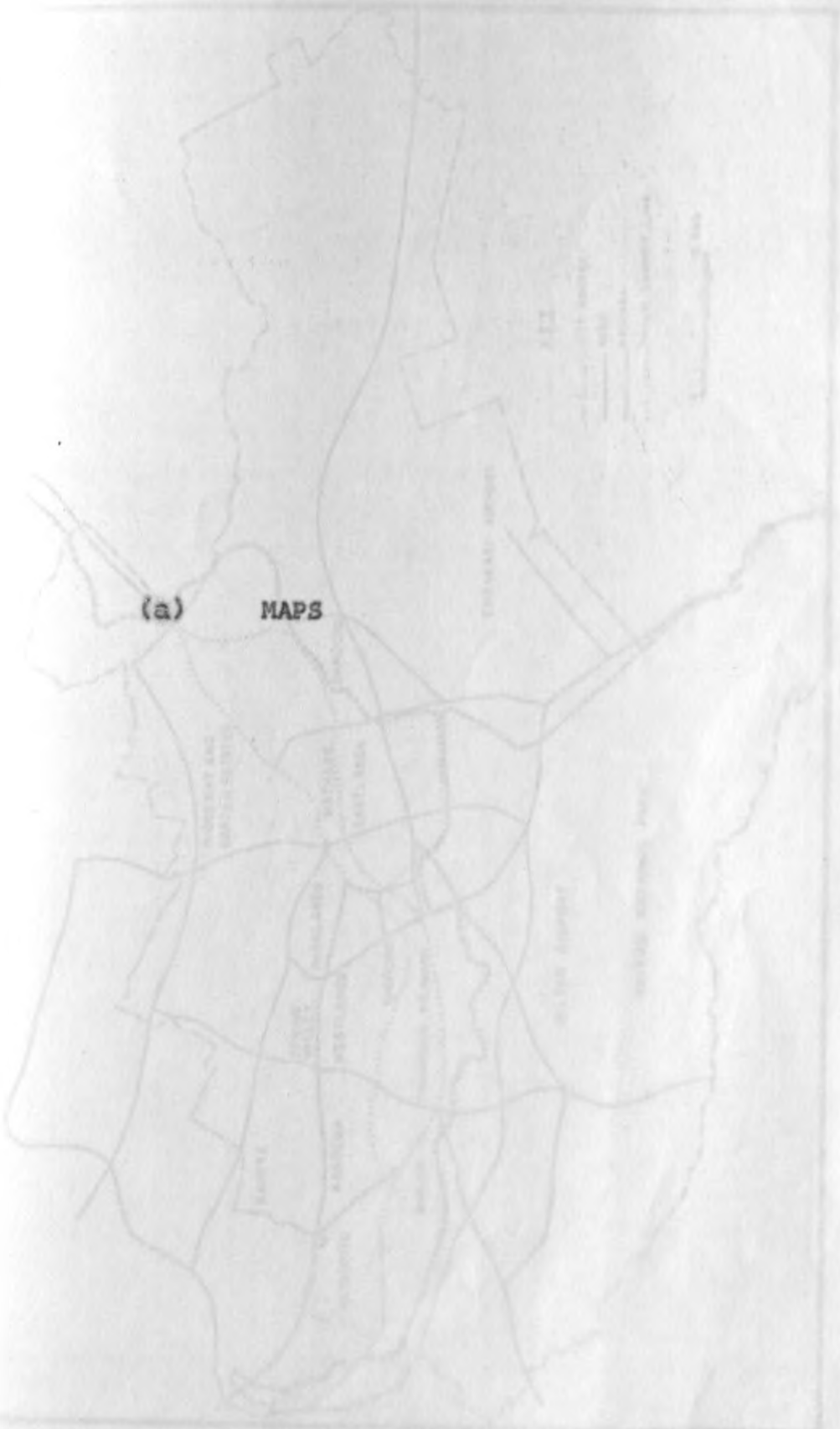
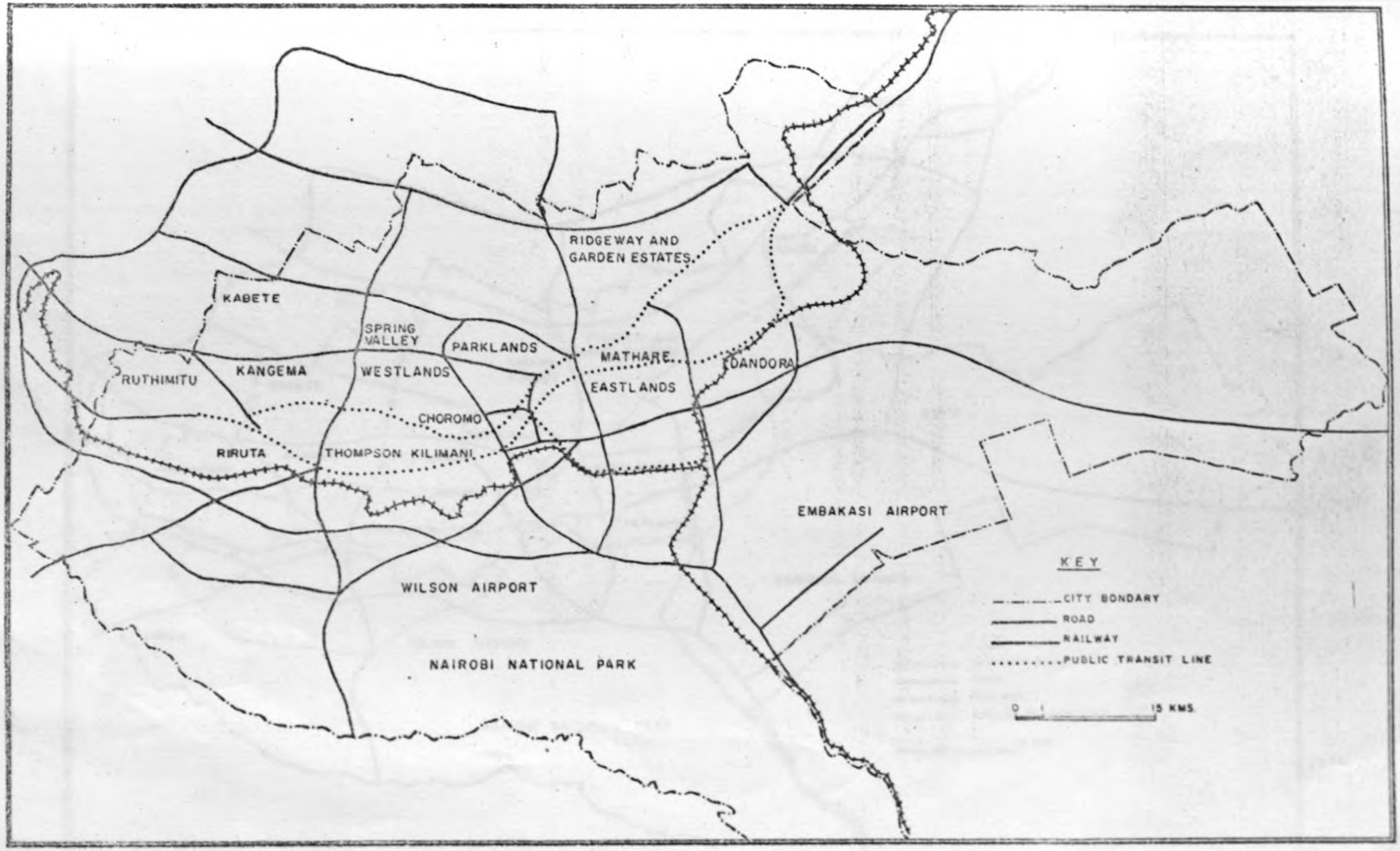
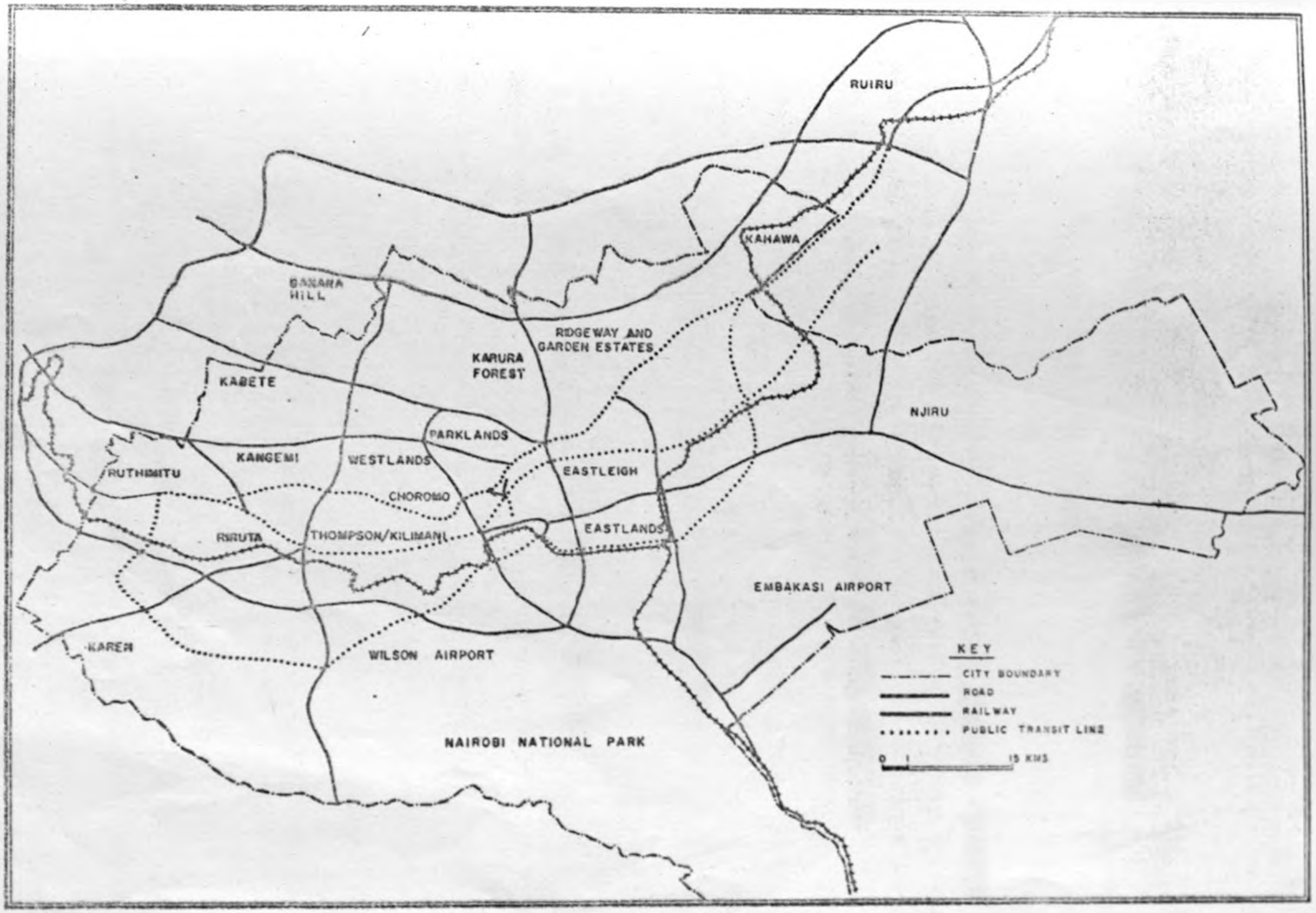
9. APPENDICES

(a) MAPS





NO.1 RECOMMENDED STRATEGY 1985



NO 2 PREFERRED STRATEGY 2000

QUESTIONNAIRE AND INTERVIEWS

1. THE PLANNING OF ROAD TRANSPORT NETWORK AND RELATED PROBLEMS.

2. QUESTIONNAIRE FOR ROAD TRAFFIC CENSUS COUNTS

3. QUESTIONNAIRE FOR THE KENYA BUS SERVICE COMPANY LIMITED

4. QUESTIONNAIRE FOR TAXI OPERATORS

5. QUESTIONNAIRE FOR MATATU OPERATORS

TRANSPORTATION IN THE NAIROBI AREA

1. THE PLANNING OF ROAD TRANSPORT NETWORK AND RELATED PROBLEMS.

(a) What are the major economic, social and physical factors which are considered when planning for road construction in Nairobi?

(b) Are all parts of Nairobi sufficiently served by road network? If not; which places? What plans are underway to supply them with sufficient network?

(c) Are parking facilities within the Central Area adequate for the present number of vehicles? If not what measures are being taken to improve the situation?

(d) In a city such as Nairobi traffic congestion, is one of the leading problems. What are some of the measures taken to put the situation under control?

(e) How effective are road signs in Nairobi in controlling traffic Movement?

_____

_____

_____

(f) During rainy days, flooding is sometimes a feature on some of the streets and roads in Nairobi?
What are the causes of this phenomenon?
What measures have been taken to solve the problem?

_____

_____

_____

(g) Is there a system of separate routes for different traffic types? If not, don't you think there is a need for such a system for traffic movement?

_____

_____

_____

(h) What system of road classification do you use?

_____

_____

_____

(i) Apart from the above road transportation problems discussed so far, what are the most intricate urban transport planning problems you experience in Nairobi?
What are the short and long term solutions to them?

_____

_____

_____

2. ROAD TRAFFIC CENSUS COUNTS QUESTIONNAIRE

(a) Who conducts the counts?

(b) How far back have the data been collected?

(c) At what points on the road network are the counts made?

(d) How dense are the census points?

(e) At what times or periods of the day are the counts made? And how often is the data collected?

(f) What type of traffic flows are recorded? Are vehicles counted according to class type?

(g) What techniques of counting do you use?

_____

_____

_____

(h) What use do you make of these traffic counts data?

_____

_____

_____

(i) How do you store the data? By flow line maps? Graphically? or by tabulation?

_____

_____

_____

(j) What are the problems encountered during the processing of data?

_____

_____

_____

3. QUESTIONNAIRE FOR THE KENYA BUS SERVICE COMPANY LIMITED

(a) Who owns the Kenya Bus Services Company Ltd.?

_____

_____

_____

(b) When did the Kenya Bus Service Company start operating in Nairobi?

_____

_____

_____

(c) What were the main reasons for starting the service in Nairobi?

(d) How many buses were in operation when the city bus service started? How many are in operation now?

(e) Is there a difference between the buses used then and those that are in use now? What is the difference?

(f) What has been the average annual rate of increase in the number of buses used in the city since 1960?

(g) How many routes in all are served by the city bus service? What factors determined the choice of routes?

(h) What is the maximum distance served from the city centre to the periphery? What determines this maximum distance?

(i) Are there specific routes used by the city bus service as opposed to those used by other passenger traffic? If so why?

(j) How adequate are your services to the general public?

(k) The matatu passenger transport services are important to some residents within the city? Do you think these services are competitive, complementary or supplementary to your services?

(l) The current high price of oil has been marched by high bus fares. What effect has this had on your services to the public?

(m) What are the lowest and highest fares charged by your company? Do these compare well with the fares charged by other passenger services within the city?

(n) What are the main problems encountered by your bus company in providing services to the public in Nairobi?

_____

_____

_____

(o) What are the solutions to these problems?

_____

_____

_____

4. QUESTIONNAIRE FOR TAXI OPERATORS

1. NAME OF VEHICLE OWNER_____

2. VEHICLE REGISTRATION NUMBER_____

3. DATE OF INTERVIEW_____

(a) Who owns this taxi? myself; some business-man; some paid employee.

(b) For how long has this taxi been in service? Less than five years; more than five years; more than ten years.

(c) Are you licenced for this hire service? Yes, No; who issues the licence?

(d) Where in Nairobi are you normally based for hire service?

(e) Which people come for your hire services? Mostly visitors to Nairobi; mostly residents within Nairobi; we cater for both groups of people.

(f) Is your car fitted with a meter charge? No, Yes.

(g) How much do you charge your passengers per Kilometre?

(h) What is the maximum distance travelled by your car from this taxi rank?

(i) Where in Nairobi do you take most of your passengers? to hotels and bars; to residential areas; to recreational sites.

(j) What periods of the day are you busiest? morning hours; mid-day; evening hours.

(k) What period of the month are you busiest? month end; mid-month; all through the month.

(l) When in the day do you begin and end your taxi service?

(m) Do you as well operate night service? To which places do you particularly take people?

5. QUESTIONNAIRE FOR MATATU OPERATORS

1. NAME OF VEHICLE OWNER:_____

2. VEHICLE REGISTRATION NUMBER:_____

3. DATE OF INTERVIEW:_____

(a) When did you start 'matatu' passenger service in Nairobi?

(b) Who owns this motor-vehicle? myself; some businessman; some employee working in Nairobi.

(c) Are you licensed to carry passengers? Yes; No.

(d) Where in Nairobi do you catch most of your passengers?

(e) Which are your terminal stations from the city centre?

_____

_____

(f) Do you charge the same fares per stage as the Kenya Bus Service?

(g) Where do most of your passengers travel to? To the city centre, to residential quarters within the city; from the city to the suburbs.

(h) How far from the city centre do you carry passengers?

(i) During what period of the day do you transport most of the passengers? morning rush hours; lunch hours; evening hours; throughout the day.

(j) In any given month; when do you have the busiest service? end of month; mid-month; busy throughout the month.

(k) Do you compete with the Kenya Bus Service for passengers? Yes; No.

(l) Why do you think some passengers prefer your service to the Kenya Bus Services? low fares; go much faster than Kenya Bus Service; use routes Kenya Bus Service buses do not use.

(m) Roughly how many trips do you make per day? and how many passengers do you carry on each trip?

(n) At what time of the day do you begin transporting people? and when do you end?

(o) What are some of the problems you experience in operating 'matatu' service?