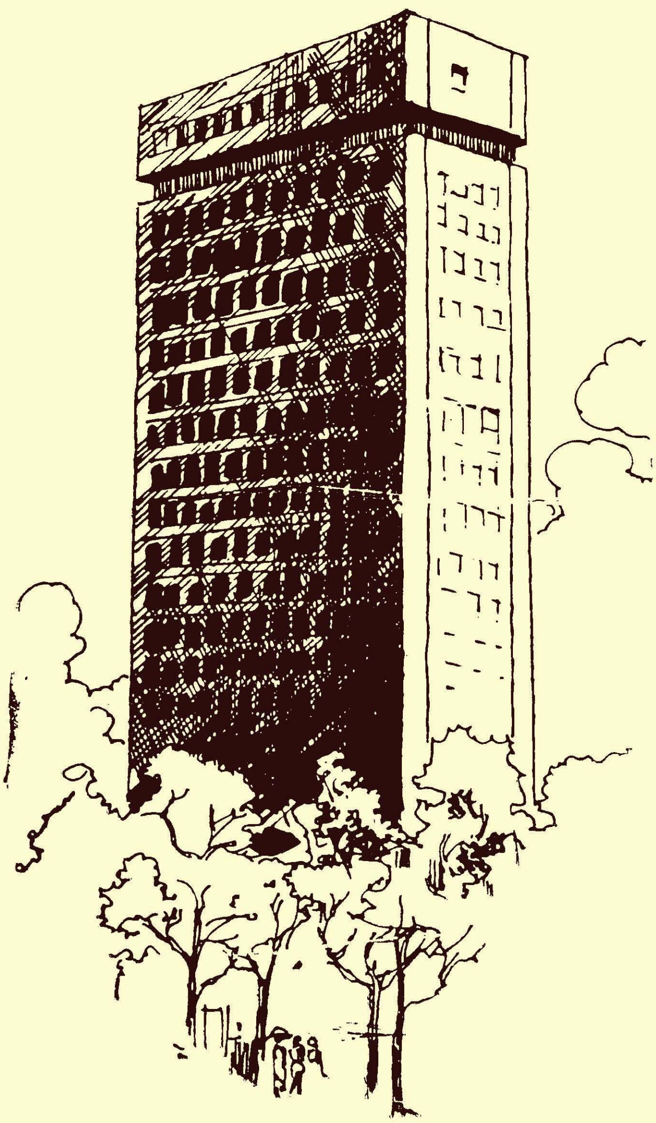
Essays on Bangalore

VOL. 3

Convenors

Vinod Vyasulu

Amulya Kumar N. Reddy



KSCST

ESSAYS ON BANGALORE

VOL. 3

Convenors

Vinod Vyasulu
Amulya Kumar N. Reddy

Karnataka State Council for Science and Technology
Indian Institute of Science, Bangalore - 560 012

First Impression – November 1985

Published by :
Karnataka State Council for
Science and Technology
Indian Institute of Science,
Bangalore-560 012

Cover Designed by :
MARCO, Bangalore

Printed at :
PRABHA PRINTERS & PUBLISHERS
150, Coconut Avenue Road
Malleswaram, BANGALORE-560 003

CONTENTS

PREFACE

Bangalore was the fastest growing city in India in the 1970's. But, before this fact become generally known, two scholars had set out to study the structure of this emerging metropolis. Prof. V.L.S. Prakasa Rao and V.K. Tewari undertook a meticulous study that yeilded a veritable gold mine of data. [1] This study has been the main inspiration for the essays that follow, which are grouped into four parts.

As an earlier review pointed out, there was a great deal more that could have been gleaned from the data provided by Professor Prakasa Rao and Tewari. This is well brought out in the study of slums in Bangalore by Dr. H. Ramachandran. Also, if the data was to be of immediate use to the Policy maker, there were several other aspects that needed examination. The essays that follow may not succeed in completing this task, but they have succeeded in taking a small step forward. Thus, the study of the late Dr. Ramachandra Rao has many suggestions that will help rid the city of the mosquito menace. The study of firewood and charcoal by Prof. Amulya Reddy and Mr. Sudhakar Reddy also pose sharply the choices that face policy makers. The study of Dr. Anna Mani on Bangalore's climate makes certain points about architectural styles that will need to be taken into accounts in any future master plan for the orderly growth of Bangalore. This is true of the points in many of the other essays.

There are also areas of non-clarity.

Dr. Ramachandra Rao would like a reduction in the number of tanks in Bangalore to control mosquitoes; Dr. D. K. Subramanian would like more tanks to harvest rain to augment the city's water supply. These are areas that require further study.

Policy makers have been concerned with the growth of Bangalore. In this context, one should be careful in drawing policy implications from these essays. While several authors suggest ways of improving quality of life in the city, and even suggest certain levels of investment, it does not follow that these investments must necessarily be made. A hundred crores spent on Bangalore has to be seen against a hundred crores spent on making life better in other cities in Karnataka. If Raichur, Mysore, Hubli, Mangalore and so on become more attractive, it may be the best way of slowing down the growth of Bangalore. An investment on cities should also be assessed against the alternative of improving the quality of life in villages. This is an exercise that these essays have not undertaken.

---

1. V. L. S. Prakasa Rao and V. K. Tewari, 'The Structure of an Indian Metropolis' : A study of Bangalore', Allied Publications, New Delhi, 1980.

It has also to be recognized that there are other factors that would influence urban growth in Karnataka. If, for instance, the railways were to construct broad-gauge lines from Mysore to Miraj, from Mangalore, Hassan, Shimoga to Raichur and Gulbarga, it would make a very basic difference to the entire pattern of economic development of Karnataka. A great deal of the more positive aspects of development in neighbouring Andhra Pradesh can be attributed to a good rail network.

In short, these essays show how much more needs to be done to develop a coherent set of policies for urban growth in Karnataka. If they result in stimulating further work, they will have served their purpose.

Vinod Vyasulu
Amulya Kumar N. Reddy

ACKNOWLEDGEMENTS

We thank the Karnataka State Council for Science and Technology for sponsoring the project on 'Bangalore as an Urban Ecosystem'. Apart from generous financial and excellent administrative support, the researchers were given complete freedom.

We would also like to thank the members of the Working Group constituted by the KSCST to guide the project, for encouragement and support in our work.

We were fortunate in having the support of several scholars whose papers appear in these volumes. The encouragement given by their institution—the Indian Institute of Science, the Institute for Social and Economic Change and the Indian Institute of Management, Bangalore and so on are gratefully acknowledged.

We thank the several young project assistants who worked hard and cheerfully. They are : Shri B. Sudhakar Reddy, Ms. Tara N. Srinivas, Shri S. Ramakrishna, Shri Ashok Kumar Kattimani, Ms. Fathima Nusrat Tehan, Dr. S.G. Sathyanarayana, Shri Sukumar Muralidharan, Shri K. Arun, Shri P. N. Swamy, Ms. V. S. Vathsala, and Ms. Shuba Abraham.

The participants in the two seminars held in June 1983 and May 1984 made many useful comments which the authors have taken into account in revising their papers.

Of course, errors and opinions are those of the authors, the organization is the responsibility of the Convenors, and the credit should go to the KSCST.

Vinod Vyasulu
Amulya Kumar N. Reddy
(Convenors)

TRANSPORTATION IN BANGALORE: I

M. S. V. RAO *

EXISTING TRANSPORT NETWORK

A. Road Network

In the sphere of Transport, Bangalore is endowed with a radial pattern of road and rail network. National Highway No. 4 (Bombay-Madras) and No. 7 (Varanasi-Cape Comorin) cut across the city in four different directions, while three major state highways, link Bangalore with other parts of the State. A couple of outer rural highways also provide access to and from the city. The roads particularly in the heart of the city are narrow and make movement of motorised vehicles extremely difficult. The arterial roads particularly the ones which link the residence with central areas and work centres are extremely inadequate. This inadequacy, apart from being of road space is also due to deficient traffic control measures especially at intersections.

The traffic volume surveys conducted by the Department of Town Planning, during 1977 indicate five fold increase in the traffic volume on all the roads, between 1964 and 1977. The growth in the volume of traffic during peak hours in 1964 and 1977 on 18 important roads is indicated in Table 2.

The design line of origin destination trips portray radial pattern of traffic movement to the Cetral Area from peripheral areas such as H.A.L., H.M.T., B.E.L., Bangalore University, Jayanagar and Rajajinagar.

The phenomenal increase in population, the outward sprawl of the city and high concentration of economic activities have contributed to a spurt in the number of motor vehicles. The average annual growth in the vehicle population during the last decade was 22.6 percent. During the same period the growth in population was about 7.6 percent clearly indicating disaproportionate growth of vehicle population and inadequacy of public transport. The number of vehicles per hundred population has increased from 2.5 in 1966 to 5.5 in 1976 and 6.8 in 1981.

It is however pertinent to point out that the increased intensity of traffic combined with the inherited radial pattern of roads, has resulted in acute traffic congestion in and around the two Central Business Districts of the city and the average travel speed in these areas has come down to about 6 to 10 kms per hour.

The number of accidents has increased from 613 in 1966 to an enormous figure of 2,516 in 1976 constituting an increase of 350 percent. The number of accidents has further increased to 3,523 in 1977 and to 4279 in 1981, a rise of 7 times the 1966 level.

* *Indian Institute of Management, Bangalore*

B. Bus Network

Bus Transport is the predominant mass transport in the city. Public sector and other industries also provide omni bus service for the workers to commute between residence and work place. The transport provided by Bangalore Transport Service in the year 1977 accounts for 80 percent of the total mass transport trips constituting 64 percent of the total trips. Although there have been periodic increase in fleet strength, route length and the number of routes offered by Bangalore Transport Service as evident from table 3, the level of service provided by the BTS is grossly inadequate to meet the demand. There was one vehicle for 902 passengers in 1958, 921 in 1968 and 1447 in 1978, showing a deteriorating situation in the fleet strength as compared to the escalating demand. The roads can only take about 750 to 780 schedules per day. The number of schedules being operated at present already has reached the saturation limit.

C. Rail Network

At present railway lines from five different directions terminate at Bangalore City Station except for the narrow gauge line. There are,

(1) Miraj line (M. G.) in the north-western direction ;

(2) Guntakal line (B. G.) towards north ;

(3) Salem line (M. G.) passing from North-west to south-east ;

(4) Madras line (B. G.) towards east ; and

(5) Mysore line (M. G.) towards the south-west.

1. The Bangalore-Miraj (M. G.) line

This line starts from the city station and runs parallel to the Bangalore-Salem line upto Yeshwantapur. Densely developed residential areas such as Srirampura, Malleswaram, Yeshwantapur and Rajajinagar residential areas are located along this line. Work centres like Rajajinagar Industrial Area, H.M.T., B.E.L. and other industries towards the north-west are also developed on either side of this. Tumkur, the nearest city to Bangalore (population in 1981 – 1,09,231) is located at a distance of 70 kms. along this line and in addition Malleswaram and Yeshwantapur Railway Station are also located on this line within the developed area of the city.

2. The Bangalore-Guntakal (B. G.) line

This line was until recently a metre gauge line and was converted to broad gauge and ran parallel to the Miraj line and deviated to Yelahanka from Yeshwantapur. The line starting from the city railway station now runs upto Krishnarajapuram along city Madras line and turns towards the north short of Krishnarajapuram and passes through Yelahanka. The line now serves cantonment and Kodegenahalli. The Wheel and Axle Plant of the Indian Railways at the Yelahanka Satellite Town is also located along this line. The conversion of this Bangalore–Guntakal metre gauge line into broad guage was completed in May 1983.

3. Bangalore-Salem (M. G.) line

The Salem line branches off from the earlier Bangalore-Guntakal M. G. line and runs towards the South–East passing through Agricultural University Campus and the residential areas of Devara Jeevanahalli and Maruthi Sevanagar. It crosses the Madras Broad guage line near NGEF. There are two railway stations on this line *i.e.*, Banaswadi and Belandur Road. The formation on this line has been designed to accommodate broad guage line.

4. Bangalore-Madras (B.G) Line

This line commences from the city station and running east cuts across the densely developed mid suburbs to the north of the Central Business District such as: Subhashnagar, Madhavanagar, Vasanthanagar, Benson Town, Cleve Land Town, Pottery Town and Cooks Town. Major industrial work centres such as: Indian Tobacco Company, N. G. E. F., H. A. L., I. T. I. and the Whitefield Industrial Complex are located along this track. The proposed international container terminal for Bangalore is also being located near Whitefield. Apart from the main city station the other stations located along this track are: Cantonment, Bangalore East, Byappanahalli, Krishnarajapuram sections has been completed. The work of doubling on Krishnarajapuram Whitefield section will be completed by the end of this year.

5. Bangalore-Mysore (M. G.) line

This line commences from the main city terminal and traverses towards the South-west passing through residential areas such as: Binnypet, Vidyaranyanagar and Padarayanapura. Important industrial work centres like BHEL, the Central Industrial Workshop and many other industries, as also the Bangalore University Campus, are located along this lime. In addition to the main city terminal two other stations i.e., Nayandahalli and Kengeri are located along this line. Kengeri is being developed as a satellite town. The work on conversion of Bangalore - Mysore metre gauge into broad gauge is in progress.

Growth in Rail Travel

Bangalore city is connected by railway to all important regions of India through a railway network converging at Bangalore City station.

A total of about 17,500 passengers had arrived and left Bangalore City Station during the year 1981-82, and the same for the period 1977-78 onwards in respect of both the Bangalore City and Bangalore Cantonment Station is presented in the Table 4.

It will be seen that the annual growth in passenger traffic at Bangalore City Station is about 7.4%. It is surprising that the passenger traffic is actually registering a fall in the case of Bangalore Cantonment from 1979 onwards. One of the possible reasons for this trend perhaps is that the Cantonment area and the eastern sector of the city have not appreciably developed compared to the western and southern sectors of the city. It is also observed that for the past 3 to 4 years there has been an accelerated development in the Rajajinagar area on the west and Jayanagar and Sarakki in the south. Though Bangalore city has not been provided with a suburban system, commuters from various urban centres around Bangalore 'commute in' and 'commute out' using the railway system. The trips are performed through the 'locals' to and from HAL, one local to and from Krishnarajapuram and two to Kengeri and back, in addition to other passenger trains in different directions. About 15,600 trips are made on the railway system which can be classified as suburban trips.

This works out to 0.87% of the total trips performed daily in the Bangalore metropolitan area. The contribution of the railway in meeting the commuter travel demand is, therefore, very minimal though its potential is great if regular sub-urban services with EMUs are introduced in regular schedules as in Bombay, Madras and Calcutta.

Growth of Air Travel

The Bangalore Airport situated about 11 kms. away from the centre to the east of the city was opened for passenger traffic in 1947. At present there are 13 flights each way per day, though these flights do not terminate or originate at Bangalore. These flights connect Delhi/Bombay/Madras/Coimbatore/Mangalore/Madurai/Cochin/Goa to Bangalore. On an average, about 990 passengers arrive and leave by flights. The growth of air travel in the year 1977-78 to 1981-82 is given in Table 5.

For the last 5 years, there has been an increase of about 50% in air traffic indicating an annual growth rate of about 12.7%. This rate is likely to be maintained and may even be accelerated when Bangalore is linked to the Jumbo map of India.

From what has been discussed it is evident that Bangalore City has grown considerably in a multi-dimensional fashion and current trends point to the fact that this growth is going to be sustained.

Comprehensive Development Plan

As per section 19 of the Town and Country Planning Act, a Comprehensive Development Plan in the prescribed manner is prepared by the Directorate of Town Planning in 1966. The Comprehensive Development Plan consists of a series of maps and documents indicating the manner in which the development and improvement of the entire local planning area of Bangalore City is to be carried out and regulated. The plan includes proposals for the following.

1. The comprehensive zoning of land use together with zoning regulations.

2. Complete street pattern indicating major and minor roads, national and state highways and traffic circulation pattern.

3. Areas reserved for parks, playgrounds, and other recreational uses, agriculture, public open spaces, public buildings, and institutions and for any other new civic developments.

4. Major road improvements.

5. Area for new housing.

6. New areas for future development and the stages by which the plan is to be carried out.

Details regarding acquisition of lands for the purpose of implementing the plan, financial responsibility connected with the proposed improvement and the manner in which these responsibilities are proposed to be met are also dealt in detail.

The Comprehensive Development Plan contemplates a population of 38 lakhs at the end of year 2001. The development in the Comprehensive Development Plan area is proposed to be taken up in three stages, the first stage being 1981 for a population of 22 lakhs, the second stage being 1991 for a population of 29 lakhs and the final stage by 2001 for a population of 38 lakhs. The plan proposes development within an area of 124 sq. miles. The remaining area of 69 sq. miles is designated as 'Rural Tract' in which spot development zoning has been proposed. Etxension to villages lying in the rural tract to the extent of half to one furlong radius from the Gramathana area proposed to accommodate the increase in population by the plan period i.e. 2001.

However, a revision of Comprehensive Development Plan has become a necessity with the unprecedented growth in population in Bangalore Metropolis which as per census of 1981 is 2.91 millions with a growth rate of 76.17% during the decade 1971–1981. Bangalore Development Authority ceased of the situation have taken up revision of Comprehensive Development Plan for a population of 7.00 million for 2001.

In evolving the structure plan attempts have been made to relate the spatial distribution of population and economic activities with the Transport System development. The following Policy approach are adopted for economic activities.

1. No large industry will come up in Bangalore and spare capacity of 20% of large industry will be utilised fully.

2. Activities to increase the workers participation like in Trade and Commerce will be encouraged.

3. Intensification of density in built area with emphasis on trade and commerce in the central areas.

A study Group constituted by Government of Karnataka in 1980 for suggesting improvements in the tranpsort system in Bangalore Metropolitan Area, in its report to the Government has suggested an integrated approach, for improving the transport system in Bangalore Metropolitan Area. The recommendations include increasing the supply of road transport by augmenting the fleet to meet the future travel demand and to achieve operational efficiency of the road transport by improving road network. The main emphasis is for construction of ring roads as recommended in the Development Plan to reduce the present accentuation on radial movements and for application of Traffic Management measures.

Methodology for the Study

Presented with a city structure of all major activities in the core area, industries in the periphery and low density residential development it is not conducive for efficient transport development. Need is to restructure the city properly inter-relating transport and land use.

The following methodology has been adopted for assessing travel projections for rail system development for Bangalore Metropolitan area.

Physical planners today use increasingly mathematical models. The mathematical models of land use planing seek to reflect combination of three characteristics of models. (1) Descriptive model–expressing a set of relationships at one point in time : (2) Predictive model – a set of descriptive relationships into the future by time factor and (3) Planning models - incorporating alternative future. Most of the mathematical models used in land use planning consider interface between transport and development.

The urban land use and transport interface modelling* is complicated by the fact that it is the result of direct and indirect interactions of many known and unknown variables. These decide the dynamics of a metropolitan system at the settlement level as well as at community and individual levels.

The cost and time parameters on the one hand, and the difficulties involved in making accurate future prediction with data environment in terms of reliability and availability on the other hand, have resulted in constant pressure on the model builders to evolve more simplified models requiring limited inputs.

Some of the variables of greater importance vital to a simplified model are population, employment, density and land use in respect of recreation, education, business and shopping, which determine the total traffic movement and volume in metropolis.

**Michel Batty "Urban Modelling", Cambridge University Press, 1976*

In the Indian metropolitan environment, emphasis had to be laid on the trips made by the public transport system. Such trips account for nearly two thirds of the total number of trips. 50% of trips by purpose are work and their return home component. Trips for educational purpose is becoming increasingly important and with return account for nearly 12% of the total trips. Emphasis, therefore has to be laid on work trips, educational trips and public transport system.

The traditional land use transport models regard traffic as both cause and function of land use and transportation system. The type and the intensity of land use along with capability of transportation system would determine the type and intensity of traffic generation. Keeping this in mind as a basic concept, the methodology evolved in developing the models has the following characteristics.

1) Simplicity in use.

2) Capable of repeated use and adaptable to any other urban area with minor modifications.

3) Data input requirements minimal and easily available from existing sources.

4) Able to predict the distribution of population for a given employment distribution under a chosen set of transport development policy options.

5) Able to forecast the total travel demand and the demand on public mass transit system for different years under different transport developments scenarios and able to predict trip movement by purpose.

The model thus developed consists of a series of sub-models which are sequentially as follows.

1. Population distribution sub-model.
2. Trip distribution sub-model for various purposes.
3. Model split sub-model.
4. Trip assignment sub-model for assignment of trips to rail net work for different transport development scenarios.

The model developed therefore is expected to provide an output on :

1. Population distribution.
2. Trip distribution by purpose considering the choice of residential location.
3. Trip distribution by mass transit system.
4. The link loadings on railway network.

In order to have the above outputs the sub-model should have the following inputs for Base Year and Horizon years.

1. Base year population by traffic zone and holding capacity of population by traffic zones and group zones.

2. Available residential area for development by traffic zones.

3. Workers' participation rate in total population.

4. Distribution of total employment by traffic zones.

5. Available commercial area for development by traffic zones.

6. Students places by traffic zones.

7. Per capita journey characteristics of base and horizon years of the study area by purpose.

8. Distribution of trips by trip length frequency and mean trip length for different purposes for the base year.

Department of Town Planning of Karnataka State Government and Bangalore Development Authority have a data base on variables such as population, residential and commercial area distribution, employment distribution and occupation. As stated in the earleir chapter the Town Planning Department have additional data for 1977 on the movement patterns of commuters and public mass transport system. The model developed takes these existing information available into consideration and puts it to maximum use.

The model is specifically developed for the Bangalore Metropolitan Area which covers about 193 sq. miles with a population of 2.91 million. For the purpose of model building, Bangalore Metropolitan Area is divided into 41 zones. The Bangalore Development Authority has divided the Metropolis into 18 planning districts for which they have worked out planning parameters and land use analysis for the horizon years 1991 and 2001. However, as the planning districts boundaries are not co-terminus with the traffic zones boundaries, the data of land use analysis and planning parameters are reanalyzed traffic zone wise and grouped into 15 group zone for purpose of input to the model.

Land use analysis and planning parameters for 1977 traffic zonewise are given in the annexures of the data supplement of this report.

Per Capita Trip

Per capita trips for 1977 for different purposes have been obtained from the household travel survey. For the study period, it has been assumed that the per capita trip is likely to change and will not remain constant. The comparison of 1966 and 1977 surveys has been utilised to obtain the natural growth factor for per capita trip. The growth in per capita trip is about 0.134 in 11 years period which is used for future projections, moderated for increase in participation rate of working force to total population for the horizon years 1991 and 2001.

Calibration of Gravity Model

The value of the parameter in the double constraint gravity model used for 'work', 'education' and 'other trips' has been determined by an interactive process till the mean trip distance obtained approximates with the trip distance obtained from the inter-zonal trip matrix and travel distance matrix of the field study. The values thus obtained are presumed to remain unchanged for the study period and used for developing inter–zonal trip matrices for the projected trips of the horizon years 1991 and 2001.

Travel Distance Matrix

Travel distance matrics giving minimum distance path between pairs of zones for the base and horizon years have been computed from the survey data for the Department of Town Planning, Karnataka State Government and MTP (R) Madras.

The model uses travel distance as one of the important determinants of travel behaviour. The variation in travel speed between road and rail has been taken into account by weighing the travel distance by rail by a ratio of travel speed by bus to travel speed by train. The travel distance matrices for all the 41 zones based on the above assumption are commuted for all the transport development policy options. These matrices have been used as an input in following sub-models.

1. Population distribution sub-model.
2. Work, Education and other trips distribution sub-model.
3. Model split sub–model.

Conceptional Frame and Validation of the Model

The theoretical frame work for the model indicating the variables in the model and their usage as inputs, inter-actions between the variables and output at different stages is shown schematically in figure 1. The validation of the sub-models developed are tested for agreement between the synthesised and field data for traffic zone wise and distribution of trips by trip length frequency and mean trip lengths for different purposes.

Population Distribution Sub–Model

The pupulation distribution sub-model answers some of the questions and finds a solution regarding the choice of a residential area by an individual which bears a relation to the location of work places–employment dirtribution by zones. It takes into consideration the accessibility index of the residence with the work place and vice–versa in conjuction with the availability of area for residential development in a zone.

Theoretically Transport–Land use model should first estimate the population distribution based on basic employment. The travel distance of basic work trip and the basic employment in a zone will decide the attraction of the population to a zone in particular. The population estimated, based on the basic employment, should be the basis for computing the service employment in a zone. The travel distance for service work trips will decide the additional population allocation in the zone. As the service population generates additional population, this process has to be repeated till the system achieves equillibrium status.

Travel distance for the basic work trips and service work trips has not been collected separately in the household travel survey conducted by the Department of Town Planning, Karnataka State Government. The travel distance for work trips obtained from the survey, therefore, was used to obtain approximations for the mean travel distance for basic and service work trips.

The travel distance for work trips obtained from survey data has been used and total employment in the zones considered in the model. These two factors together explain the population distribution reasonably well for the base year. This method has therefore been accepted and adopted in the sub-model.

Along with this, certain constraints in the population distribution were used in this model having regard to the development that has already taken place and likely to take place through intensification of density and priority for development in new area as stipulated by the planning agency, Bangalore Development Authority, population of group zones were held as stipulated as recommended by Bangalore Development Authority for fixing the holding capacity of population. However, the base year 1977 population for 1991 and 1991 for 2001 has been considered as the lower limit of population in the respective zones in the sub-model. For each of the horizon years the population content of each traffic zone has been worked out, holding the group zone population as stipulated above and adjusting density of traffic zones by altering the weights having regard to maximum and minimum limits of population as stipulated above.

The sub-model was operated to project the distribution of population for the base year 1977 with total employment for each zone and the travel distance for work trip provided as inputs in the model. The population of group zones for the year 1977 was held in the model for estimating the population distribution zone-wise. The output obtained from the sub-model on the population distribution is presented in Table 6. It can be seen from the table population obtained from the model and the population as worked by the planning agency for the base year 1977 matches very closely in most of the zones.

Trip Distribution Sub-model

The operation of this sub-model is explained in the flow chart.

The total trips are estimated for four different categories.

1. Work trips
2. Education trips
3. Other trips
4. Return home trips

The per capita trip rates for the above categories are obtained from the survey data of 1977. The per capita work trips obtained from the survey analysis are used to compute the work trips generated by the population allocated to zone. The work places used as an input while allocating the population in the earlier sub–model is used as an attracted trip and input in this sub–model for obtaining inter–zonal work trip matrix.

The second stage of the sub–model is to find out the 'Education' and other trip distributions based on the population allocated to different zones. The total number of education and other trips generated by the various zones were calculated by using the per capita education and other trips rate. To determine the attracted education trip for each zone, number of education places at high school and above level for 1977 are computated from the data obtained from Directorate of Education, Karnataka State Government and inter–zonal trip matrix for education prepared by Department of Town Planning, Government of Karnataka from 1977 Travel Survey Data. A norm for students of the above category making interzonal trips at 42 students per thousand population has been established. These trips distributed between zones have been obtained using a double constraint gravity model.

To determine the attracted 'other trips' which include the component of business, recreation and social trips for each zone, a regression equation is fitted for 1977 data as follows:

$$Y = 3749 + 399\ x$$

Where Y is the total other trips and x is the commercial land use in acres. The correlation co-efficient was found to be 0.6586.

The ratio of trips involving commercial component and other than commercial component (recreation and social) works out to 7:3.

The third stage of the sub–model is to calculate the return home trips.

From the survey, it is found that the return home trips constitute 87 percent of work, education and other trips and in the model it is assumed that it will hold good for each zonal pair also.

The mean travel distance for 1977 by purpose as estimated in model as obtained from the survey analysis is presented in Table 7. The model estimate and survey findings being the same, validate the sub–model.

It can thus be concluded that the model has given a good fit not only on the population distribution but also on the mean travel distance.

Model Split Sub–Model

Final total trip distribution matrix between the zones in Bangalore Metropolitan area computed in the earlier sub–model, is used in this sub-model as an input. The aim here is to find out the percentage share of trips by public mass transit system. The traffic zones in the Bangalore Metropolitan area are grouped into two categories: (1) Core and (2) Non-core. Core zones include the traffic zones in the central area which have high accessibility by the public transport system. The other zones are included in the non–core. The classification of traffic zones is kept flexible for different scenarios. The traffic zones in the influence corridor of rail networks are grouped in the 'core' category with the rail network development of different scenarios.

The model split for trip length frequences for core and non–core established from survey data 1977 are given in the Table 8.

For each pair of zones, the travel distance range was noted. Using the model split corresponding to this travel distance range from the survey analysis classified under grouping of zone in 'core' or 'non–core', the total trips were divided into trips by public transport and interzonal public transit matrix obtained.

Trip Assingment Sub–Model

The operation of this sub-model includes in sequential steps the following.

1. Working out rail trip distribution matrix between pair of zones within the influence are of rail corridor according to a pre-determined percentage share of rail trips to the total public transit trips, the percentage share of rail trips to total public Transit Trips of zones with 1.5 kilometers on either side of rail network being 100 percent. However, for pairs of zones with one zone within 1.5 kilometers of rail network and other zone beyond 1.5 kilometer but travel time by rail shorter than by road, the percentage share of rail trips is 50 percent of the total Public Transit Trips.

2. Assign the rail trips to rail links between pairs of zone according to a defined path of rail links between origin and destination stations.

Population Distribution and Travel Demand Projections

In the absence of correct growth rate over the period 1971-81 for the Bangalore Metropolitan Area, different methods have been adopted by Government and non-Governmental agencies to project the future population for the metropolitan area. Population projection has been worked out by Bangalore Development Authority for the years 1991 and 2001 adopting the prescribed methods as follows.

	Population in 1991 in lakhs	Population in 2001 in lakhs
1. Arithmetical progression	45.22	70.28
2. Incremental increment	40.76	56.13

3. Geometric progression	65.78	115.00
4. Arithmetical increment	41.72	54.31

The State Government has taken a policy decision to curb the growth of industries in Bangalore and to provide incentives for encouraging development of industries in other areas of the State. The industries department is providing incentives by provision of developed industrial sites, concession in taxes and rates etc., in new growth centres.

In the light of the Government policy to curb the growth of Bangalore by encouraging development in other centres, and in view of the problems faced by Bangalore in providing adequate infrastructural facilities, Bangalore Development Authority for the revision of comprehensive development plan have assumed a lesser growth rate for Bangalore Metropolis for the horizon years 1991 and 2001 as compared to the increase observed between 1971 and 1981. In the light of above, the population projections recommended for the Bangalore Metropolis for the horizon years 1991 and 2001 are 45 lakhs and 70 lakhs respectively.

Population Densities

Population densities proposed for 1991 and 2001 take into consideration the building bye-laws finalised by the Bangalore City Corporation where the emphasis is to decongest central area and to encourage development in the areas outside excluding intensively developed areas and slums.

The densities proposed upto 1991 are based on the consideration to provide higher densities along the proposed suburban railway influence area. The densities proposed for 1991 are from 100 to 200 persons per acre on the western side and 100 persons per acre on the other side. The densities proposed outside the suburban railway alignment is mostly 100 persons per acre. Densities recommended for the year 2001 lay stress on the gradual increase in the density upto 300 persons per acre in the areas within the suburban railway influence area. These areas include the extensions which have been formed and are under development. Density upto 300 persons per acre is proposed in the developed areas on the western and northern part along the railway influence corridor. Beyond the suburban rail corridor density of upto 100 persons per acre is proposed.

Land use Proposals - 1991

The requirement of land for development upto the year 1991 is worked out based on the population projection upto 1991 and the density proposed. The population of Bangalore is expected to be 45 lakhs by the year 1991. The developed area required will be about 119 sq. miles. Table 9 gives the land use analysis for the year 1991.

Land use Proposals - 2001

The requirement of land upto 2001 is worked out on the basis of projected population of 70 lakhs. The total developed area proposed upto 2001 is 160.18 sq. miles. Table 10 shows the land use analysis for the year 2001.

Employment

According to 1981 census, the working force constitute 37.55% of the country's total population while the workers among the urban population constituted 31.47% showing that the participation of the population in the work activities of the country is more in the rural areas compared to urban areas.

The percentage of working force to the population in Bangalore City was almost the same during 1961-71 and 1971–81. According to 1981 census, 29.83% of the population were workers, compared to 29.52% in the previous decade. The workers' participation requires to be increased by creating employment in sectors like administration, ancilliary and service industries.

It is learnt from Bangalore Development Authority as reported from the Industries and Commerce Department that heavy and medium industries in Bangalore Metropolis are utilising capacities upto 80%. 20% spare capacity is available for utilisation in future.

The policy approach of Bangalore Development Authority for projecting the working force and reserving areas for industries in the development plan of Bangalore Metropolis is as follows.

1. No large industries will be set up in Bangalore. Only the spare capacity of 20 percent will be allowed to be utilised by them.

2. Only medium scale and household industries will be set up in Bangalore. Ancilliary units required for 20 percent spare capacity to be utilised by the existing large industries, will be allowed to be set up.

Population Distribution

The growth in population is envisaged mainly in the fringe zones, large areas of which are outside corporation limits. The population in the fringe zones is envisaged to increase from 10 lakhs in 1981 to 22 lakhs in 1991 and 43 lakhs in 2001, as against in the rest of zones the growth is from 19 lakhs in 1977 to 27 lakhs in 2001.

Per Capita Trips

As stated in the earlier chapter it has been assumed that the per capita trips per day will not remain constant and will change due to change in the socio–economic conditions of the people. The per capita trips for the horizon years 1991 and 2001 based on past trends and moderated for the participation rates are shown in Table 12.

Projected Trips

The projected trips per day purpose wise for the horizon years 1991 and 2001 as obtained from the trip generation and distribution models are shown in Table 13.

Model Split

The Public Transit Trips for different scenarios for the horizon years 1991 and 2001 are obtained from the model split. Model is given in table No. 14.

As already stated the model notes the travel distance range between each pair of horizons and using the model split corresponding to the travel distance apportions the total trips to trips by public transport system to develop the intermatrices for different scenarios of the horizon years 1991 and 2001 are given in the annexures of the report. With the improvement in the accessibility to rail network there is a gradual increase in model split from 64 percent in 1977 to 68.9 percent in 1991 and 75.8 percent in 2001.

The approach paper prepared by the Planning Commission with regard to the role of mass transportation in the metropolitan cities in India recommends a policy of fostering public transport in these cities through conscientious of judicious monitoring of model choice aimed at achieving a model split of 80%. However, considering the base year model split of 64% the magnitude of transport inputs and the structure of the city, the achievement of 80% model split can be achieved only in stages and that it will only be after 2001 that it will be possible to achieve this model split.

The total public transit trips estimated per day for the horizon years 1991 and 2001 for Bangalore Metropolitan area are 26.0 lakhs and 51.00 lakhs respectively, which gives the annual per capita public transit trips as 201 and 256 respectively. Obviously it is difficult to compare the annual per capita mass transit trips for various metropolitan cities as their land use and socio-economic structure, heuristic characteristics of the population and the level of transport inputs vary considerably. However, the trend of increase in the annual per capita public transit trips compare favourably with other metropolitan cities.

Conclusions and Recommendations

1. Bangalore Metropolitan Area with a population of above 29.13 lakhs in 1981 is the 5th largest metropolis in the country. The metropolitan area had the highest growth rate of 7½% per annum in the decade 1971–81 in comparison to other metropolitan cities in India. This rapid growth of population was a sequel to the growth of large industries during the last three decades and if sustained, will aggravate the already strained infrastructural facilities which may defy any solution by conventional means.

2. We agree with the policy decision of the Karnataka State Government to restrict the growth of lage industries in Bangalore metropolitan area and to provide incentives for development of industries in other areas of the State. If implemented, this will slow down the growth rate of population in Bangalore metropolitan area to an acceptable level comparable to other metropolitan cities for which comprehensive development plans are being prepared.

3. Having the above State Government policy in view, B. D. A. has projected the population for Bangalore metropolitan area to 4.5 million for 1991 and 7 million for 2001.

4. The study of the present city structure with its heavy concentration of all major activities in the core area, industries in the periphery and low density residential development shows that it is not conducive for efficient transport development.

5. The transport network which had marginal development during the last three decades has proved inadequate to cater to the level demand. There is inefficient utilization of the transport system which originates from strong radial movement to the core area.

6. The paramount need of the moment is to bring about a change in the pattern of movement from the radial to the orbital to reduce congestion in the core areas. In this connection, we agree with the recommendations of the report of the study group constituted by Government of Karnataka for suggesting improvements in the Transport system in Bangalore metropolitan area. The study report has given high priority for implementation of ring roads and intense application of Traffic Management measures. This will go a long way in gradual improvement of the transportation system in the metropolis and help in the integration of the proposed rail network and the road trasport for the future.

7. With inadequate role of public transport facility operated by BTS, there has been an enormous increase in private modes which has resulted in gradual deterioration of traffic situation on roads, attended with enarmous increase in accidents. The study group report has brought out the limitations in the operation of BTS and has concluded that future travel demand in the Bangalore metropolitan area can only be adequately met with the additional provision of rail facility.

8. We agree with the following approach of Bangalore Development Authority restructuring the metropolis in connection with the revision of the comprehensive development plan.

(a) Emphasis to decongest the cental area and encourage development on a polynodal concept to the areas outside the central area.

(b) Intensification of densities in the developed area with high density development along the suburban railway influence area.

9. This study has shown that the restructured metropolis thus recommended inter-relates the proposed transport system and land use very effectively.

10. Per capita trip is observed to change over a period of time due to changes in socio-economic conditions of the people. The per capita trip which was 0.5 in 1966 increased to 0.63 in 1977 and is anticipated to increase to 0.84 in 1991 and 0.97 in 2001.

11. Daily total trips forecast for Bangalore Metropolis for 1991 and 2001 are 38 lakhs and 67 lakhs respectively. Daily travel demand for public transit are 26 lakhs and 51 lakhs respectively for the two horizon years. With the addition of rail net work to transportation system of the metropolis, the model split i.e., percentage of the total trips by public transit system increases gradually from 64 percent in 1977 to 76 percent in 2001.

12. With the gradual increase in the length of urban rail network, the sub-model split i.e, the percentage of total public transit trips by rail increases from 13 percent to 48 percent.

13. The rail network proposed for different scenarios of 1991 and 2001 is a need based programme. The scenarios 3 and 4 which have the same rail length give the assessment of rail trip loading for 1991 and 2001. It clearly shows that non-implementation of R.T.S. between Rajajinagar and Jayanagar by 1991 will have considerable impact on the sub-model split which will fall from 40 percent to 30 percent and thereby place heavy demand on road-based bus system.

14. The transport system that emerges for the horizon year 2001 requires a well integrated and a co-ordinated road-based and rail-based public transit facility. The feeder trips (i.e. bus trips) account for nearly 16 percent of the total station load for the horizon year 2001. The operational efficiency of the rail net work to a great extent will depend on the operational efficiency of the road based system. It is therefore, imperative that optimisation of road-based bus facility should be given the same priority and implemented simultaneously to achieve a well co-ordinated and balanced development of the transport system in consonance with the planning objectives.

15. There is a strong interdependence of the circular and radial routes in the proposed rail network. It is therefore, necessary that to achieve full benefits from optimisation of existing rail corridors, simultaneous development of high capacity R.T.S. facility between Rajajinagar and Jayanagar and necessary action for reservation land for the circular railway for its operation between 1991 and 2001 be initiated.

16. Bangalore City Station emerges as a major dispersal point as well as an interchange point between various rail routes. In addition to this it will also be loaded with considerable amount of intercity interchange traffic. It is estimated

that the total volume of both intra city and inter city will be of tune of more than one million trips daily by 2001. This will need considerable additional land and careful planning not only for station expansion but also for dispersal facilities in the station area. In the light of very heavy volume of inter–change trips forecast at Bangalore City Station for 2001, we recommend for modification in the rail track at Bangalore City terminal for ensuring through inter–route movements between Kengeri and H.M.T., Kengeri and Whitefield and H.M.T. and Whitefield. This can reduce transfer trips and Bangalore City Station by nearly 50 percent.

17. Circular rail network emerges as a strong corridor with 13 lakhs of trips by 2001. The proposed alignment for circular rail network and the outer ring road are in close proximito. We recommend that the two alignments be merged and developed as a multi model corridor in a phased manner as traffic along the corridor builds up.

Phase 1 : Bus system operating in a mixed flow condition (estimated capacity 1.2 to 1.3 lakh trips/day).

Phase 2 : Bus system operation on an exclusive track (estimated capacity 2.2 to 2.5 lakh trips/day).

Phase 3 : Rail-based public transit system replacing the bus system on the exclusive track when the traffic goes over the above mentioned level.

"There are distinct advantages in planning for bus rapid transit as the first stage development within major transportation corridor, even when ultimate conversion to a rail system is contemplated, as the introduction of bus rapid transit will do much to define and maintain the market for rapid transit and will warn the transportation planner, well in advance, of the time when rail transit may be needed*."

18. Building a suburban and rapid transit net work for Bangalore metropolis is a capital intensive endeavour. In the face of tight monetary position, finding the required resources would be a major problem and cannot be entirely left to any single agency - either central or state. The rail network for the metropolis being a project for the benefit of city dwellers, the State Government and the local authorities will have to play a major role in the implementation and operation of the system.

19. Experience all over the world proves that urban transportation will be required to be subsidised for construction and operation. Even in USA, where people are strongly profit motivated, urban transport by rail requires as much as 58 per cent of subsidy, while road transport requires about 26 per cent. It is therefore, imperative that the cost of construction and operation is required to be met as followed in many western countries, by the Centre, State and Local authorities.

**Ref.* "The Potential for Bus Rapid Transit" Wilbursmith and Associates, February, 1970.*

The state government and the local authorities can raise additional resources by making railway construction cost as a charge on land and land use particularly along the corridor which will be benefitted by the rail network. Working group set up by the Railway Reforms Committee for "Metropolitan Transport" feel that "Land required for any purpose by the development authorities will require money to be spent for land development, roads, drainage, water supply, sewerage, electricity supply etc., there is no reason why ultimate buyers of land should not pay Rs. 4 to 15 per square yard more for transport facilities just as they have to pay for utility and services.*

20. The unsatisfactory aspect of Bangalore Metropolitan area transportation is the absence of single co-ordinated transport authority for planning and administration of transport policies. Many key transportation functions are the responsibility of many agencies like traffic police, municipal corporation, P.W.D., Bangalore Development Authority and K.S.R.T.C. Traffic and transportation system is made up of separate and well defined segments such as road, railways, road transport and traffic management. These facilities builts on a piece meal basis over a period of time have been largely developed to serve only a part of the total transportation needs and have hardly any relationship to the function of other parts. There is also absence of co–ordination between the various modes.

21. In our view what is really necessary in the Bangalore metropolitan area is the need for developing an effective total transportation system. This is possible if there ia a co-ordinating agency in the form of a single transportation authority capable of planning, implementing and administrating an efficient transport system. In this connection, it may be appropriate to set up a single transport authority as a part of the regional development authority which is being constituted for Bangalore metropolis. This authority should be in the overall charge of all modes of transport operation as city services, including metropolitan rapid rail transport system and matters connected with them like determination of fare structure, subsidies, traffic management measures, traffic signals and operation of parking.

22. In other metropolitan cities like Calcutta, Bombay, Delhi and Madras, the technoeconomic feasibility study for provision of intraurban rail facility and studies for integrated road and road transport programmes have been initiated as a follow up action of total transportation system studies. However, for Bangalore metropolis this has not been followed.

In our view, the Comprehensive Traffic and Transportation Studies needs to be given priority. It would than be possible to develop a 'System approach' to urban transportation problems so that total transportation plan and overall system it provides makes the network much more productive than the sum of it in separate parts.

**Report of the Working Group on Metropolitan Transport, Railway Reforms Committee. Ministry of Railway, Government of India 1982*

23. It is the experience of many cities in Western countries and also in Calcutta, that the implementation of intra-urban rail network in the absence of proper development plans, and land use control generally result in large scale speculation and high rise developments. We feel that Area Development Plans for areas within a radius of 1 km of all stations of the rail network proposed, be prepared and implementation monitored under a special committee constituted for the purpose with railway representation on similar lines as has been followed by Calcutta Metropolitan Development Authority for Calcutta.

24. The Bangalore City Station and its environs with intra and inter-city bus terminals have emerged as a large transport terminal centre. We recommend that an integrated urban design scheme be prepared for the area to the west of city station, city station area, BTS and KSRTC terminals. The emphasis in the exercise has not only to be on aesthetically acceptable scheme but also to provide for easy circulation of different modes of traffic with segregation of intra-city and inter-city movements.

TABLE-1

Bangalore - Population Growth - Increase in the Number of Vehicles - Number of Accounts

Sl. No.	Particulars	Year					
		1966	1971	1976	1977	1978	1981
1.	Population (in lakhs)	14.00	16.54	20.00	21.00	22.00	29.14
2.	Vehicles on road in numbers	35279	67980	107576	115535	140120	196968
3.	Accidents in numbers	643	1634	2516	3523	4185	4279

Source : Department of Town Planning, Bangalore

TABLE–2

Growth in Volume of Traffic During Peak Hours 1964–1977

Sl. No.	Name of the road	Peak hour volume of traffic 1964	1977	Percentage increase
1.	Jayachamarajendra Road (near Unity Building)	4180	6070	45.2
2.	Sampige Road (near Sampige Theatre)	1255	5188	313.4
3.	Vidhana Veedhi Road (near Multistoreyed building)	758	5025	562.9
4.	Residency Road (near Janardhana Tower)	308	4234	1274.7
5.	Residency Office Road (opposite St. Martha's Hospital)	910	4386	382.0
6.	Platform Road (near City Road Station)	520	4023	673.6
7.	Lokamanya Tilak Road (opposite Shanthala Silk House)	505	3786	649.7
8.	Mysore Road (near Krishnarajendra Road)	950	3754	395.2
9.	Race Course Road (opposite Race Course)	1505	3739	148.4
10.	Seshadri Road (near Ananda Rao Circle)	2060	3664	77.9
11.	West Tank Bund Road (near Thotadappa Choultry)	1199	3613	201.3
12.	Kempegowda Road (near Janatha Bazaar)	2108	3570	69.4
13.	Rajajinagar Ist Main Road (near Sujatha Theatre)	290	3488	1102.8
14.	Narasimharaja Road (opposite Naaz Theatre)	2020	3391	67.9
15.	Central Street (opposite Shivajinagar Bus Stand)	450	3204	612.0
16.	Guttahalli Road (between link Road and Govinda Rao Street)	1080	3109	187.9
17.	Nrupathunga Road	950	3145	231.1
18.	Diagonal Road (near Sajjan Rao Circle)	1520	3093	103.5

Source : Department of Town Planning, Bangalore

TABLE–3

Bangalore–Growth of Bangalore Transport Service

Year	Passengers carried in lakhs	Fleet Strength	Vehicles on the road	No. of routes	Route length in Kms	Number of Schedules
As on 31-10-56	0.91	131	113	57	402	105
1956—57	1.01	148	110	59	454	105
1957—58	1.01	156	116	64	695	120
1958—59	1.25	178	126	76	999	136
1959—60	1.52	254	160	164	1,564	192
1960—61	1.93	250	205	196	1,783	198
1961—62	2.04	256	209	247	2,293	205
1962—63	2.08	266	220	258	2,338	221
1963—64	2.17	284	232	355	2,553	226
1964—65	2.31	291	243	377	2,777	237
1965—66	2.47	314	253	379	2,846	248
1966—67	2.73	366	291	410	3,313	291
1967—68	2.76	356	297	413	3,430	294
1968—69	2.80	350	304	419	3,553	304
1969—70	3.26	396	317	424	3,577	315
1970—71	3.12	455	325	437	3,745	317
1971—72	3.18	408	331	432	3,465	325
1972—73	3.51	379	333	438	3,540	328
1973—74	4.77	413	365	440	3,581	347
1974—75	4.88	435	370	445	3,660	376
1975—76	5.30	503	430	465	3,902	424
1976—77	6.79	648	514	503	4,620	490
1977—78	7.09	602	506	508	4,716	498
1978—79	7.25	655	520	510	4,739	534
1979—80	7.33	702	547	NA	NA	556
1980—81	NA	NA	NA	NA	NA	715

NA: Not available

Source: Karnaka State Road Transport Corporation

TABLE–4

Growth in Rail Travel

Year	Bangalore City	Bangalore Cantt.
1977—78	13,549	2,885
1978—79	16,154	2,905
1979—80	16,637	2,395
1980—81	15,270	2,372
1981—82	17,549	2,390

TABLE–5

Growth in Air Travel

Year	Passengers
1977—78	2,39,513
1978—79	2,80,079
1979—80	2,54,716
1980—81	2,77,960
1981—82	3,61,292
Growth per year	12.71 %

Source : Indian Air Lines

TABLE–6

Population Distribution 1977 Traffic Zone Wise Computed and From Model

Traffic Zone	Population computed	Population from model
1	2	3
1.	52606	54000
2.	25144	25275
3.	66213	66082
4.	141478	144540
5.	61200	61380
6.	27222	27560
7.	36650	35588
8.	32776	33170
9.	162189	154361
10.	66902	68145
11.	94515	95535
12.	41070	33890
13.	97626	100510
14.	21026	17854
15.	38800	40145
16.	110426	109994
17.	85539	89750
18.	65854	68120
19.	40475	31079
20.	58556	59625
21.	19795	20300
22.	99460	101700
23.	17580	14026
24.	81388	62700
25.	88664	92960
26.	21561	21561
27.	25271	25271
28.	26545	26545
29.	73614	78360
30.	17648	22975
31.	29647	29607
32.	25432	21950
33.	13469	11624
34.	15307	15500
35.	38003	37810
36.	46436	47500
37.	7252	7350
38.	69909	68752
39.	2918	3160
40.	1577	1335
41.	2655	2695

TABLE–7

Mean Trip Length – 1977 for Different Purposes by Field Survey and Model

Purpose	Mean trip length (km)	
	Field survey	Model
Work	7.2476	7.2476
Education	4.8526	4.8526
Others	5.3792	5.3792

Source : Consultants

TABLE–

Model Split by Trip Length Frequency

Trip length (km)	Model split (%)	
	Core	Non–Core
0—1	38.00	41.00
1—2	55.00	47.00
2—3	56.00	48.00
3—4	61.00	55.00
4—5	67.00	61.00
5—6	71.00	64.00
6—7	72.00	67.00
7—8	74.00	69.00
8—9	76.00	73.00
9—10	87.00	76.00

Source : Consultants

TABLE–9

Land use Analysis — 1991

Sl. No.	Particulars	Area in Hectares	Area in Acres	Percentage
1.	Residential	10593.70	26166.44	34.36
2.	Commercial	1075.50	2656.49	3.49
3.	Industrial	33126.14	7721.57	10.14
4.	Public and Semi–public	2837.51	7008.65	9.20
5.	Parks, playgrounds and open spaces	3110.20	7682.19	10.09
6.	Transportation	6405.71	15822.10	20.77
7.	Unclassified	2400.50	5929.24	7.78
8.	Water sheet and agriculture	1285.10	3174.20	4.17
	Total	30834.36	76160.88	100.00

Source : Bangalore Development Authority

TABLE–10

Land use Analysis — 2001

Sl. No.	Particulars	Area in Hectares	Area in Acres	Percentage
1.	Residential	15586.72	38499.19	37.55
2.	Commercial	1734.89	4285.17	4.18
3.	Industrial	4121.03	10178.94	9.93
4.	Public & Semi–public	3757.51	9281.04	9.05
5.	Park, playground and open spaces	4107.95	10146.63	9.90
6.	Transport and communication	8527.97	21064.08	20.55
7.	Unclassified	2400.50	5929.23	5.78
8.	Water sheet	1285.10	3135.64	3.06
	Total	41521.67	102519.92	100.00

Source : Bangalore Development Authority

TABLE–11

Growth of Population in Fringe and Non–Fringe Zones

(in lakhs)

	Fringe	Non–Fringe	Total
Group Zones	3, 4, 5, 6, 7, 8, 12, 13,	1, 2, 9, 10, 11, 14, 15,	
Population 1981	10.0	19.1	29.1
Population 1991	22.4	22.6	45.0
Population 2001	43.1	26.9	70.0

Source : 1. Bangalore Development Authority
2. Consultants

TABLE–12

Percapita Trips Purposewise – 1991 and 2001

Purpose	Per Capita Trips			
	1991		2001	
	Post trend	Adjusted for participation rate	Part trend	Adjusted for participation rate
Work	0.212520	0.235290	0.263220	0.280202
Education	0.056467	0.056467	0.063170	0.063170
Others	0.1547740	0.154740	0.163108	0.173108
Return	0.375760	0.395952	0.442951	0.458010
Total	0.799487	0.842449	0.942449	0.974490

Source : Consultants

TABLE–13

Projected trips per day purposewise 1991 and 2001

Purpose	1991 Scenario 1,2,3	2001 Scenario 4,5,6
Work	1058788	19224095
Education	254218	434015
Others	697577	1193585
Return	1782969	3149615
Total	3793552	6701310

Source : Consultants

TABLE–14

Model Split Scenariowise 1991 and 2001

Scenario	Year	Trips (in lakhs) Total	Trips (in lakhs) Public Transit	Model Split
1	1991	37.9	25.8	68.1%
2	1991	37.9	25.8	68.1%
3	1991	37.9	26.1	68.9%
4	2001	67.0	46.2	68.9%
5	2001	67.0	50.3	75.0%
6	2001	67.0	50.8	75.8%

Source : Consultants

TRANSPORTATION IN BANGALORE–II

N. MURALI MOHAN*

1.0 Research on urban traffic management focusses on systematic control of operation of cars, trucks and high occupancy vehicles over an existing transport infrastucture so as to achieve a comprehensive set of mobility, energy, environmental and efficiency objectives.

This paper presents a micro-level study of two specific aspects of road transport in Bangalore city, *viz.*, the intersection controls and the accidents. Efforts have been made by different research groups earlier towards developing a long range plan for transport services in Bangalore city. But in the short range planning, efficient use of existing infrastructure plays an important role. It has long been recognised that intersections are the most critical elements of a transportation system. Although this is well known and some efforts have been made to alleviate operation problems at intersection, they are still the locations where most accidents occur, where the greatest delays occur, where most fuel is wasted, where congestion is the greatest and where the adjacent land use tends to be in greatest conflict with the roadway. An effort has been made in this paper to throw light on some of these aspects in Bangalore city.

1.1. With increasing public concern for the conservation of energy resources and the environmental impact of various transportation system configurations, much greater emphasis is being placed on making efficient use of existing transportation resources and providing for the movement of vehicles and people in an efficient manner. Urban transportation planning process shall include the development of a plan consisting of both short range system management aspects and the long range perspectives also. The short range needs of an urbanised area may be identified as efficient traffic engineering and public transportation, regulatory pricing, effective and other improvements to the existing transportation system, not including new transportation facilities or major changes in existing facilities. The long range element has to provide for the long term transportation needs of the urbanised area by identifying new transportation policies and facilities, or changes in existing facilities (by locations and/or modes) to be implemented. The combined plan must be consistent with the area's comprehensive long range land-use plan, urban development objectives and its overall social, economic, environment system perfomance and energy conservative goals and objectives.

1.2 In case of Bangalore City, detailed studies are already available in the form of the report of the Study Group constituted by the Government of Karnataka

Karnataka State Council for Science and Technology, Indian Institute of Science, Bangalore-560 012

for suggesting improvements in the transport system in Bangalore Metropolitan area and Origin–Destination survey of passenger traffic in Bangalore–a study for Karnataka State Road Transport Corporation conducted by the Institute of Marketing Management, Bangalore both during 1981–83. In addition, under the project titled 'System Studies on the Bangalore Transport Service Operations', the KSCST sponsored performance studies on BTS during 1978–81. This study developed a triangular O – D matrix for each schedule derived from the way bill data. An interconnection matrix for the city services was constructed, which at a glance, provides, on an average basis the inherent philosophy of BTS operations. The first two reports mentioned concentrated on the long range planning for Bangalore City Transport. A good effort has been made in these reports to go into various aspects of traffic conjestion problems in depth, and also the nature and magnitude of financing required for the suggested solutions. The approach of this study group was a combination of two approaches, viz., expanding transport supply by improving roads, rail roads, sub–ways, parking facilities, terminal and inter-change points and other physical transport facilities, and increasing transport supply by innovations in hardware and software technology.

2.0 Intersection controls in urban areas

Greater emphasis needs to be given to the development and maintenace of optimal trafic flow at all urban intersections and not just those with the highest traffic volume since the traffic is visualised as a 'flow' and hence any disturbance at one point of the flow may respond with a reaction at another point of the flow. The importance of the effective intersection controls can be realised through the range of the deterimental impacts that may be arising due to their ineffective operation–accidents, delay, fuel consumption, congestion and land use. The opportunities for relieving one or more of these detrimental characteristics significantly are considerable but are often inadequately accepted by those responsible for traffic transport. In fact, one finds operations authorities permitting continuing degradation of the quality of service at intersections by the use of improper or inadequate traffic controls. The eventual result is more accidents, more delay, more fuel eonsumption, more congestion and more conflicts with roadside development.

2.1 The KSCST has sponsored two projects under Student Projects Programme in Rashtreeya Vidyalaya College of Engineering, Bangalore in consecutive years 1980-81 and 1981-82 for the study of fuel consumption at intersection control in Bangalore City. The data collected under these projects has been used to develop some of the indicators of the performance of intersection control in Bangalore City as explained later in this paper.

2.2 Intersection Control in Bangalore City

The traffic studies were conducted at the following ten intersection points in Bangalore City.

1. Malleswaram Circle
2. Basaveshwara Circle
3. Oriental Building Circle
4. Minerva Circle
5. Bharath Circle
6. Town Hall Circle
7. Corporation Circle
8. City Market Circle
9. Briand Square Circle
10. State Bank of Mysore Circle

All these points of intersection are from the central part of Bangalore City and hence may be able to represent the traffic pattern in the central business area of Bangalore.

The road patterns at these points of intersections are shown in Appendix I. The terminology used for the purpose of further analysis is explained in the following paragraphs.

2.3 To illustrate with an example, at a 4 - road junction, the number of possible traffic transactions are 12 (i.e. three transactions from each road to the remaining three) excluding the four transactions of pedestrian traffic across each road. Because of regulations of traffic control (such as one-way traffic), the actual transactions to be met by the intersection may be less. These actual transactions are distributed into number of phases depending on volume of traffic on each road for the purpose of intersection control. The total time taken to complete all these transactions is termed as cycle time. Otherwise, cycle time may be defined as the time interval from the start of green interval on any one lane to the reappearance of the green signal in the same lane. The duration of green interval is the service time for that lane since that is the time available to service the traffic in that lane. The rest of the time in the cycle is the waiting time from that lane. Idle time is the time period during the green interval when no traffic exists. It is the objective of any traffic management system to minimise the idle time along with waiting time over all the lanes.

3.0 The traffic flow observations made at these intersections has been divided into 5 categories, viz., (i) heavy vehicles (buses, lorries, trucks), (ii) cars, (iii) autorikshaws, (iv) scooters and motor cycles and (v) mopeds. Table 1 shows the cycle times and average number of vehicles per cycle and Table 2 gives the vehicular distribution of the traffic at each of these centres during a day in June 1982.

3.1 Traffic intensities

Perhaps, a more convenient indicator for comparative analysis would be the traffic intensities in terms of vehicles transacted per minute or vehicle transacted per cycle at each of these centres. These indicators are given in Table 3. The corresponding values of these indicators for the year 1980-81 (measured on a day during December 1980) are also presented in Table 3. From Table 1 it can be seen that in case of Basaveshwara Circle and City Market Circle only about 40% of the possible transactions are allowed or the traffic has been more constrained at these intersections. Thus need for such a control can be seen from the high traffic intensities at these circles – 114 and 128 vehicles per minute respectively.

3.1.1 In case of Corporation Circle and State Bank of Mysore Circle, the traffic intensities are very high and perhaps, a more constrained intersection control at these points is needed. Congestion is found primarily in the highly developed areas of the city and often results from inadequate out-grade intersection capacity. The efficient movement of traffic at these intersections is almost totatlly a function of traffic signals and traffic control techniques. Maximum of sophistication in traffic-responsive control techniques should be used where crpacity is a problem, (as in case of Corporation Circle) if such use is economically feasible and if the community can properly operate and maintain such techniques.

3.2 Diurnal variation in traffic at the intersections

It is a general observation that traffic volume changes through the day showing two peaks in the morning and evening. In order to get the diurnal variation pattern in the traffic, the timings for the observations were selected as morning (9 a.m. to 11 a.m.), afternoon (12.00 noon to 3.00 p.m.) and evening (4.00 to 7.00 p.m.). The diurnal variation in the traffic during these three periods of a day are given in Table 4 with corresponding figures from 1981 also.

The percentage increase in corresponding period during 1981–82 are shown in Table 5. The Corporation Circle and the City Market place are showing very high percentage of increase during this period. Land use pattren in the hinterlands of these two points of the intersection may be able to explain this growth.

Only in case Minerva Circle and Bharat Circle, which are separated by only about 0.5 kilometres, negative growth of traffic was found during this period. Such a phenomenon can be easily explained by the changes in the infrastructure or regulations in traffic control in the hinterland. Construction of a new by-pass road or over bridge or introduction of one way traffic in one of the lanes approaching or interconnected can cause this negative growth. Because of lack of required data on these points of intersection, the causal factors for the negative growth in the volume of traffic in the period observed have not been identified specifically.

3.2.1 The trend in the distribution of trips based on purpose of visits will also have its effect on the traffic at the points of intersection. The general opinion regarding the peaks in the morning and evening times is based on the presumption that the work trips are predominently concentrated during these hours. In order to have a broad view of this aspect, the trip distribution by the purpose of visit in Bangalore City for years 1975 and 1982 is presented in Table 6.

It can be observed from this table, the percentage share of work trips has come down by more than 15%. In other words, the growth in traffic observed in Bangalore city is not uniformly distributed over various causal factors. The passenger trips for entertainment and recreation have increased nearly by a magnitude of 10.

The changes in the distribution of passenger trips over the purpose of visits indicates that non-work trips are growing faster than the work trips. By nature, the non-work trips may be spanning over the whole day. In the urban areas, specifically in Bangalore, the trips for entertainment generally converge in two peaks viz., 10.00 a.m. to 3 p.m. and 5.30 p.m. to 7.00 p.m.

3.3 Land use considerations

Since the intersection is the location where the volume of traffic on a street is highest, it has become the desirable location for all types of commercial activities. Such activities use the street not for transportation but to sell their products, and public authorities and many transportation specialists continue to allow, for the reason of accessibility, continued heavy development at the intersections. The result is the development of an adverse and crippling environment at these intersections.

The intersection is the location where the demands placed on the motorists are usually the most severe. It inherently presents him with conflicts, it requires that he be quickly informed of the controls and that he properly and smoothly selects the proper path to continue his trip. It requires careful analysis to assure that the needed information is optimally provided within the physical constraints of the intersection and its approaches and within the driver's capabilities to assimilate it. Proper design of the adjacent roadside would minimise other influencing activities.

3.4 Perhaps, at this juncture, a profile of trip generation and attraction in Bangalore City might help to make some observation on the land use pattern in Bangalore City. Based on the O–D survey conducted by IMM, the list of top 10 corporation divisions in both trip generation and attraction is given in tables 7 through 10 for the BTS and for all the modes of conveyance separately.

Existing traffic pattern is largely influenced by the present land use pattern and the infrastructure provided. This point is borne out from the table 10. Shivajinagar, Subhashnagar and K. R. Market are topping the list of BTS trip attracting divisions. This is because of the fact that the BTS has large bus terminus stations developed in these divisions and hence the bus services are better than that are for other divisions. Moreover, most of these divisions which are the major centres of trip attraction or generation are mainly from the central part of Bangalore City. Thus the selection of centres for the study of intersection control has rationale in that they represent the most traffic dense part of Bangalore City.

3.5 The traffic pattern in Bangalore City is area based. This fact is brought out by a series of correlation tests conducted between population, area, traffic generated and traffic attracted of each division taking two parameters at a time. The correlation coefficients for traffic generation and attraction with population are 0.2621 and 0.255 respectively where as the same with respect to area of the divisions are 0.4387 and 0.4368 respectively. This shows that trip making is more strongly related to area rather than with population in Bangalore City. The matrix of correlation co-efficients between 10 chosen parameters is given in Table 11.

The parameters chosen for each division with their coded numbers are as following :

1. Population
2. Area in sq. km.
3. Traffic (number of trips) generated by all modes
4. Traffic (number of trips) attracted by all modes
5. Socio-economic status index
6. Population density (person per square kilometer)
7. Traffic generated per sq. km.
8. Traffic attracted per sq. km.
9. Traffic generated per 1000 population
10. Traffic attracted per 1000 population

The socio-economic status index values have been adopted as evolved in the work conducted by Prof. V. L. S. Prakasa Rao and Dr. V. K. Tiwari (The structure of Indian Metropolis – a study of Bangalore).

3.6 Fuel consumption due to waiting time at the inter-sections :

It is obvious that much of the delay encountered by motorists on the roads and streets occurs at intersections. Stops required because of approaching vehicles which have the right of way, or because of the requirements imposed by traffic control at the intersections consume much time of every person on virtually every trip made. These delays not only cost an amount of useful time, but more significant is the fuel consumption during this delay period. Two factors important in fuel consumption – vehicle speed and changes in speed – are directly affected by traffic operations and are those over which much control can be exercised by the traffic authorities.

In order to have an estimate of fuel consumption during the waiting time at intersection, the RVCE project team made observations on the waiting times on each lane during each phase at ten selected centres of intersection. Fuel comsumption by various vehicles are estimated as follows :

Heavy vehicle	39 cc/min
Car	15 cc/min
Autorikshaw	8 cc/min
Scooters	4 cc/min
Moped	3.5 cc/min

Under these rates of consumption, the total fuel consumption during the waiting time and its monetary value (on 1982 costs, diesel Rs. 3.18/litre and petrol Rs. 6.43/litre) was estimated. The working timings of traffic signals are between 8.00 a.m. and 9.00 p.m. i.e. 11 hours of operation. The loss of fuel is given in table 12. The total loss per day at only these ten selected circles is Rs. 39,206.37 or approximately 6100 litres of petrol. If these losses are scaled upto the whole of Bangalore City (the number of intersection points where automatic signalling is installed in Bangalore is 21 where the total number of regulated intersection points is about 40), the losses should be, on an extremely conservative estimate, atleast twice of this value i.e. 12200 litres/day of petrol. Hence in Bangalore City, annually 4453 kilo litres of petrol is being consumed during the waiting time at intersection points on the basis of motor vehicle population existing in 1982. At this juncture, it is appropriate to have a glance at the growth of motor vehicles in Bangalore City in comparison with growth of vehicles in the state as a whole.

3.7 Growth of motor vehicles

The details of motor vehicles under different classifications (two wheelers, three wheelers, cars, jeeps, buses, taxies, trucks, tractors, trailors an others) in Bangalore City during 1967-1982 are furnished in Table 13. Annual growth rates of vehicles in Bangalore City are much higher during the period 1960-65 compared to the later periods. This is, perhaps, due to the sudden spurt of industrial activity that took place during that period in Bangalore City. The comparative figures of annual growth rates of different motor vehicle during the periods 1960-65, 1965-70, 1970-75, 1975-80 and 1980-82 are given in Table 14. The details of motor vehicles in Karnataka State during 1956-83 are given in Appendix II.

The rate of growth of motor vehicles in Bangalore City during 1980-82 is 20.33 or about 10% annually. At this rate of growth, and without any significant changes in the transport supply in terms of additional roads or more effective traffic control, the fuel losses during waiting at intersection point would be phenomenal of the order of 1.2 million gallons of petrol and at 1984 prices, the monetary loss per year would be Rs. 4 crores.

3.8 Accidents

Perhaps, road accidents are one of the major indicators of traffic congestion. The details of road accidents in Bangalore city 1971-82 are given in table 15. It is quite heartening to note that total number of road accidents are showing a declining trend, of late. But the persons killed in these accidents is not following this trend. For the purpose of comparative analysis the details of accidents in Bangalore district and Karnataka State are given in tables 16 and 17 respectively. The percantage share of area and population of Bangalore city in Bangalore district and Karnataka State are 2.17 and 59.2 and 0.09 and 7.8 respectively. Whereas the corresponding values for road accidents for 1981-82 are 86 and 35 respectively and in case of persons killed 68.5 and 16.6 respectively. These figures indicate the unenviable position of Bangalore city with respect to road accidents within its locality. Occupying 0.09 percent area and 7.8% of population of the state, the city shares 35 percent of road accidents and 16.6 percent of persons killed in road accidents in the state. At the same time, it is significant to note that city shares a larger part of non-fatal accidents rather than fatal accidents or otherwise the city contributes more towards non-fatal accidents.

Road accidents have been identified mainly due to bad condition of roads, mechanical defects of the vehicles and human errors. However, a very significant percentage of the accidents are due to human errors. The human errors leading to road accidents are mainly fault of driver and fault of pedestrians. From table 18, it is observable that in Karnataka State the fault of driver contributes to more than 80 percent of the road accidents. This point brings to light the fact more effective training and education is needed to the driver. And more efficient traffic management is an immediate necessity to reduce these accidents.

3.8.1 Road accidents in Bangalore city during 1982

Bangalore City area has been distributed into 6 traffi zones for the purpose of functional facility. The zonewise break-up of fatal and non-fatal accidents during year 1982 are shown in Table 19. Malleswaram and Ulsoor areas seem to the major accident prone areas. It is interesting to note that the intersection control analysis has not shown Malleswaram Circle as that congested as compared to other major points of intersection.

The breack-up of accidents with respect to occurrence daywise in a week and hourwise in a day are showing an expected pattern. Day-wise breakup is almost a uniform distribution. The hour-wise break-up is uniform over all the periods excepting the period 1500–1800 where all the three–death, injury and collission–accidents are showing a maximum.

Of the 344 persons killed in 331 fatal cases, 152 were pedestrians, 64 two wheeled riders, 60 cyclists, 22 passengers, 19 pillion riders, 18 occupants and 10 motor vehicle drivers. Of those 3325 injured, 447 passengers, 297 drivers, 199 pillion riders, 176 occupants and 19 others. In both the categories, majority of the victims were pedestrians followed by two wheeled riders and cyclists.

During the year, 1982, lorries were responsible for maximum number of deaths (123) and the BTS buses stood second (51), followed by autorikshaws (32), motor cars (21), private buses (20), motor cycles (18), scooter (17), KSRTC buses (15), factory buses (7), jeeps (4), mopeds (3) and military vehicles (1). The details regarding accident causing vehicles are given in Table 23.

4.0. Conclusions and Recommendations

4.1 The study shows that the trip generation and attraction in Bangalore city are more strongly correlated to the area of the zone than to the population of corresponding zone. Considering, the high rates of growth of population in Bangalore city, this may not hold good in future. However, for future planning-short range or long range, this point has to be given due consideration.

4.2.0 Fundamental to minimising detrimental intersection impacts is the use at every intersection of the proper type of traffic control.

4.2.1 At high volume arterial intersection traffic signalisation is a better option. Proper selection, operation, maintenance and management of the controls at such locations are critical to obtaining optimal benefits from the system.

4.2.2 However, where signals installed, they can easily cause unnecessary speed changes, stops, delays and wasted fuel. Hence at intersections of local low–volume roads where visibility distance is adequate for crossing vehicles to see each others while approaching at a safe speed of about 30 kmph, no controls other than the normal right-of-way rule may be preferred, and it certainly eliminates much of stopping or speed changing when no cross vehicles are not approaching.

4.3 Out of the range of modern traffic control techniques such as sophisticated signal controllers, interconnected signal system, continuous traffic survillance, rapid incident removal and those of traffic detective devices, in case of Bangalore City a traffic-responsive intersection control system may be attempted. Considering the large amount of fuel consumption during waiting time at intersection (estimated Rs. 82 lakhs worth of fuel per year) in Bangalore city, investment for better traffic management should not be treated as a limitation.

4.4 As the analysis showed, the main corridor through Yeshwantpur Circle, Malleswaram Circle, Basaveswara Circle, Corporation Circle, Townhall Circle, Bharath Circle and Minerva Circle is the major artery of road transport in Bangalore City. It is suggested that in this artery, a traffic responsive control system (using traffic detection devices) may be used in conjunction with properly adjusted traffic signal systems at those circles which are directly connected to this artery.

4.5 An important consideration in any traffic management system is the land use pattern and the changes thereon. At the present rate of growth of population in Bangalore city and the changes taking place in the land use on its periphery, any design for traffic management system based on the existing transport supply and demand may prove non–optimal in a near future. Hence, it is suggested that as mentioned in 4.4, traffic responsive intersection control system may be tried in central part of Bangalore City, where, more or less, the land use pattern has attained some stability imposed by space constraint.

4.6 The analysis on road accidents shows pedestrians are the major victims in both fatal and non-fatal accidents. Though the areas lies on the driver of motor vehicle and other factors also, the pedestrians should be instructed to conduct themselves more responsibly on the streets. In this connection, the traffic police department may think of showing the films on traffic/safety in schools and also on Doordarshan.

4.7 In both the cases of fatal and non–fatal accidents, lorries were the major cause of road accidents in Bangalore city during 1982. And in the cause of accidents, it is observed that fault of the driver is the major human error causing about 80 percent of the road accidents. In view of these facts more stringent action should be taken on overspeeding drivers. At those points of interesection, where lorries and trucks join coming from low traffic–density areas, traffic vigilancc should be reinforced.

Integrated Approach to Planning

4.8 This particular point now being raised is not confined to traffic management alone but refers to urban planning as a whole. The author, while working on this paper, found it difficult to correlate various socio–economic indicators for a common (geograghical) planning unit. The traffic zones are six as shown in table 19. The corporation zones are 83. The Postal and Telegraph department has its own zonation of the city by the postal index number. The Directorate of Industries maintains data on various industrial units in the city based on postal index numbers. The Bangalore Water Supply and Sewerage Board has its own zones for its regular operation and maintaining data on water tap points and water consumption in the city. Similarly, there may be many more geographical distributions of the city by various departments. For a researcher working on urban planning, all the socio–economic, demographic, industrial and etc. indicators should be available on a common geographical zone, which is not the case presently in case of Bangalore City.

Author of this paper discussed this point with his co–researchers during the course of this project and presently suggests that a common and uniform geographical unit should be evolved for the purpose of integrated planning by all the departments of the government.

References

1. Report of the study group constituted by the Government of Karnataka for suggesting improvements in the transport system in Bangalore Metropolitan Area, 1982

2. 'Origin – destination survey of passenger traffic in Bangalore' – a study for Karnataka State Road Transport Corporation conducted by the Institute of Marketing Management, Bangalore, 1982.

3. Technical reports submitted by Karnataka State Council for Science and Technology, Bangalore on "System Studies on the Bangalore Transport Source Operation"

i. Performance studies on the existing route network and operations – August 1976.

ii. Rajajinagar operation – August 1976

iii. Traffic management between focal nodes – October 1976

iv. Jayanagar and Basavanagudi operations – January 1977

v. An approach to planning of an integrated transport system for Bangalore Feb. 1977.

vi. Data document – March 1977

4. 'Determination of fuel losses during vehicle idling at traffic junction' – project reports (1980-81 and 1981-82) of Rashtreeya Vidyalaya College of Engineering, Bangalore, sponsored by Karnataka State Council for Science and Technology

5. Proceedings of the Eleventh Sir M. Visvesvaraya memorial Technical Seminar on "Transport and Communication" – October 27–28, 1977

6. Review of work done by Bangalore City traffic police during the year 1982 released by the Deputy Commissioner of Police, Traffic, Bangalore

7. "Transportation System" – a paper presented by Sri B. S. D. Baliga at Eigth All India Engineers Day on "Energy Planning for Karnataka" on 15 September 1975

8. Statistics of road accidents during the year 1981–82 in Karnataka State prepared by the Public Works Department, Government of Karnataka

9. "Economic analysis of rural road projects" – World Bank Staff working paper No. 24 – August 1976

10. "A rational approach to trip generation" – Brown R. J., from the compilation of paper on "Traffic, Transportation and Urban Planning" – 1981

11. "An entrophy maximising distribution model and its application to land use model" – Kondo. K., Sasaki, Tsuna, from the compilation of paper on "Traffic, Transportation and Urban Planning" - 1981

12. Measurement of travel demand and mobility" – Zahari Yacova from the compliation of paper on "Traffic, Transportation and Urban Planning"

13. "The Structure of Indian Metropolis - a study of Bangalore" – by Prof. V. L. S. Prakasa Rao and Prof. V. K. Tewari–1979

TABLE–1

Traffic at selected centres in Bangalore City 1982

Sl. No.	Point of Intersection	Cycle time (sec)	No. of lanes	No. of transactions	No. of phases	Average No. of vehicles per cycle
1	Malleswaram Circle	110	4	8	4	122
2	Basaveshwara Circle	108	6	12	4	206
3	Oriental Building Circle	84	4	9	3	149
4	Minerva Circle	130	5	14	4	135
5	Bharath Circle	105	4	10	4	88
6	Town Hall Circle	90	3	6	3	143
7	Corporation Circle	65	4	9	3	193
8	City market Circle	80	6	13	3	171
9	Briand Square Circle	84	4	8	3	130
10	State Bank of Mysore Circle	118	7	23	4	223

TABLE–2

Vehicular Distribution of the Traffic Flow at selected points of intersection in Bangalore City-1982

Sl. No.	Point of Intersection	Heavy vehicles	Cars	Autos	Scooters	Mopeds	Total
1	Malleswaram Circle	12.66	12.33	40.00	46.66	10.33	122.00
2	Basaveshwara Circle	13.00	47.66	64.66	66.33	14.66	206.00
3	Oriental Building Circle	6.00	34.33	39.33	56.66	13.00	149.32
4	Minerva Circle	16.66	21.00	59.66	25.33	12.00	134.65
5	Bharat Circle	15.66	14.00	32.66	29.66	0.00	87.98
6	Town Hall Circle	15.33	19.66	54.33	40.00	13.33	142.65
7	Corporation Circle	21.33	34.00	58.00	55.66	23.66	192.65
8	City Market Circle	17.00	18.66	72.66	40.66	21.66	170.64
9	Briand Square Circle	21.32	17.00	56.00	26.33	9.66	130.32
10	State Bank of Mysore Circle	32.33	8.33	71.00	70.33	41.33	223.32

TABLE–3

Comparative traffic intensities for 1981 and 1982

	Point of intersection	Vehicles/cycle		Vehicles/minute	
		1981	1982	1981	1982
1	Malleswaram Circle	107	122	58	66
2	Basaveshwara Circle	150	206	83	114
3	Orient Building Circle	134	149	96	106
4	Minerva Circle	158	135	70	69
5	Bharath Circle	133	88	66	50
6	Town Hall Cirle	117	143	91	95
7	Corporation Circle	140	193	109	178
8	City Market Circle	119	171	90	128
9	Briand Square Circle	91	130	49	92
10	State Bank of Mysore Circle	232	223	112	113

TABLE–4

Diurnal Variation of Traffic in Bangalore City

	Intersections	Average No. of vehicles per cycle						Average over a day	
		1981			1982				
		Mor.	A.N.	Eve	Mor.	A.N.	Eve	1981	1982
	1	2	3	4	5	6	7	8	9
1	Malleswaram Circle	106	101	114	112	113	141	107	122
2	Basaveshwara Circle	162	166	123	199	203	217	150	206
3	Oriental Building Circle	134	128	138	132	147	169	133	149
4	Minerva Circle	159	125	187	124	125	155	157	135
5	Bharath Circle	152	108	116	92	66	106	125	88
6	Town Hall Circle	116	118	117	168	139	121	117	143
7	Corporation Circle	110	130	160	213	121	245	133	193
8	City Market Circle	114	114	133	163	165	174	120	167
9	Briand Square Circle	106	91	117	123	105	163	105	130
10	State Bank of Mysore Circle	236	236	223	345	248	301	232	298

TABLE–5

Percentage increase in the Diurnal Distribution of Traffic during 1981-82

Sl. No.	Intersection	% increase in average traffic per cycle between 1981-82			Total
		Morning	A. Noon	Evening	
1	Malleswaram Circle	5.6	11.9	23.7	14.0
2	Basaveshwara Circle	22.8	22.3	76.4	35.9
3	Oriental Building Circle	– 1.5	14.8	22.5	12.0
4	Minerva Circle	–22.0	0.0	–17.1	–14.0
5	Bharath Circle	–39.5	–40.7	–8.6	–32.8
6	Townhall Circle	53.4	17.8	3.4	22.2
7	Corporation Circle	93.6	–6.9	53.1	45.1
8	City Market	43.0	44.7	30.8	39.1
9	Briand Square Circle	16.0	15.4	39.3	23.8
10	State Bank of Mysore Circle	46.2	5.1	34.9	28.4

TABLE–6

Passenger Trips as per purpose of journey in Bangalore City

Sl. No.	Purpose of visit	Percentage share of the purpose of the visit	
		1975	1982
1	Work	79.73	62.30
2	Shopping	6.31	8.50
3	Entertainment and recreation	0.49	4.40
4	Education	3.73	3.30
5	Health	1.16	—
6	Visiting	—	9.80
7	Others	8.58	11.70
		100.00	100.00

TABLE–7

Major Centres of Trip Generation by all Modes in Bangalore City – 1982

Rank	Corporation Division	Trips generated	Percentage to total number of trips generated
1.	Rajajinagar	92,800	5.4
2.	K. R. Market	84,400	4.9
3.	Subhashnagar	78,100	4.5
4.	Shivajinagar	77,600	4.5
5.	Jayanagar	60,100	3.5
6.	Gandhinagar	54,400	3.2
7.	Yeshwantpur	52,100	3.0
8.	Townhall	45,200	2.6
9.	Highgrounds	42,300	2.4
10.	B. D. A.	37,300	2.1

TABLE–8

Major Centres of Trip Attraction by all Modes in Bangalore City – 1982

Rank	Corporation Division	Trips attracted	Percentage to total number of trips attracted
1.	Rajajinagar	90700	5.3
2.	K. R. Market	84600	4.9
3.	Shivajinagar	78400	4.6
4.	Subhashnagar	75500	4.4
5.	Jayanagar	61300	3.6
6.	Gandhinagar	56700	3.3
7.	Yeshwantpur	51700	3.0
8.	Town Hall	45000	2.6
9.	High grounds	43100	2.5
10.	Binnypet	37100	2.1

TABLE–9

Major Centres of BTS Trip Generation in Bangalore City–1982

Rank	Corporation Division	Trips attracted	Percentage to total number of trips generated
1.	Subhashnagar	73400	8.8
2.	Shivajinagar	71500	8.6
3.	K. R. Market	69600	8.4
4.	Gandhinagar	42600	5.1
5.	Rajajinagar	38300	4.6
6.	Jayanagar	31700	3.8
7.	Yeshwanthpur	26600	3.2
8.	High grounds	22400	2.7
9.	Binnypet	21200	2.5
10.	Town Hall	20100	2.4

TABLE–10

Major Centres BTS Trip Attraction in Bangalore City – 1982

Rank	Corporation Division	Trips attracted in a year	Percentage to total number of trips
1.	Shivajinagar	61900	7.5
2.	Subhashnagar	60500	7.3
3.	K. R. Market	56100	6.7
4.	Gandhinagar	40200	4.8
5.	Rajajinagar	39700	4.8
6.	Jayanagar	31800	3.8
7.	Yeshwantpur	26400	3.2
8.	High grounds	24000	2.9
9.	Town hall	22400	2.7
10.	Binnypet	20000	2.4

TABLE–11

Matrix of Correlation Coefficients

	1	2	3	4	5	6	7	8	9	10
1	1.0000									
2	0.5331	1.0000								
3	0.2621	0.4387	1.0000							
4	0.2550	0.4368	0.9993	1.0000						
5	–0.0363	0.2115	0.0798	0.0807	1.0000					
6	0.3454	–0.2761	–0.1120	–0.1140	–0.1404	1.0000				
7	–0.1767	–0.2536	0.5940	0.5881	–0.1339	0.1747	1.0000			
8	–0.1741	–0.2504	0.5896	0.5831	–0.1346	0.1748	0.9997	1.0000		
9	–0.2849	0.1553	0.7054	0.7171	0.1356	–0.0758	0.5576	0.5496	1.0000	
10	–0.2850	0.1535	0.71	0.7212	0.1353	–0.0741	0.5704	0.5627	0.9997	1.0000

TABLE–12

Fuel Losses at Intersection Point due to delay in Terms of Monetary Value

Sl. No.	Circle of Intersection	Losses/Day in Rupees
1.	Malleswaram Circle	2965.93
2.	Basaveshwara Circle	5121.82
3.	Oriental Building Circle	3584.24
4.	Minerva Circle	3545.41
5.	Bharath Circle	2533.99
6.	Town Hall Circle	2954.38
7.	Corporation Circle	1052.10
8.	City Market Circle	3959.89
9.	Briand Square Circle	3047.33
10.	State Bank of Mysore Circle	7441.28

TABLE–13

Details of Motor Vehicles in Bangalore City During 1967–1982

Year	Two wheelers	Three wheelers Auto	Three wheelers goods	Cars	Jeeps	Buses	Taxies	Trucks	Trac-tors	Trai-lors	Others	Total	% increase over previous yr.
1967–68	11068	1341		8774		1709	537		2932		850	27211	—
68–69	22646	2280		10076		1824	587		3163		1081	41657	53.08
69–70	27566	2930		11679		2015	639		3510		1227	49566	18.98
70–71	32931	4007		13171		2208	698		4047		1461	58523	18.07
71–72	39648	5059		14482		2369	759		4474		1678	68469	16.99
72–73	47027	5538		16336		2473	822		4737		1881	78814	15.10
73–74	—	6597		17857		2617	864		5065		2051	—	—
74–75	54185	7597		19792		2903	1002		5639		2270	93388	—
75–76	—	7832		21194		3131	1008		6140		2538	—	—
76–77	62199	8699	498	21670	2048	3487	1045	6081	1419	1121	578	108845	—
77–78	78974	10132	546	27810	2986	3685	964	6516	1454	1164	641	134872	23.91
78–79	87753	10608	662	29302	3179	4000	999	6920	1531	1236	781	146971	8.89
79–80	97110	10726	648	30145	3396	4301	1034	7575	1897	1680	505	159017	8.19
80–81	111750	10044	664	31738	3554	4671	1120	8236	1929	1734	549	175989	10.67
81–82	125600	10355	704	32429	3570	5090	1171	8545	1781	1637	475	191357	8.73

TABLE–14

Growth Pattern of Motor Vehicles in Bangalore City

	% increase during				
	1960–65	1965–70	1970–75	1975–80	1980–82
Private vehicles Cars/Jeeps	57.77	29.90	50.26	58.25	7.32
Two Wheelers	31.48	101.22	64.54	66.87	29.33
Public Transport					
Buses	848.41	–26.55	31.47	37.36	18.34
Taxies	188.36	–0.26	43.55	2.57	13.24
Autos	310.37	104.39	89.59	45.22	–2.76
Goods	54.88	–6.77	55.57	81.62	7.27
TOTAL	150.17	45.88	59.57	57.26	20.33

TABLE–15

Details of Road Accidents in Bangalore City During 1971–1982

Year	Total No. of road accidents	Persons killed	Persons injured	Accidents due to			% increase of road accidents over previous year
				Bad condition of roads	Mechanical defects of the vehicles	Human errors	
1	2	3	4	5	6	7	8
1971–72	1634	181	1543	—	—	1634	—
1972–73	1741	166	1415	—	—	1741	6.54
1973–74	2074	176	1722	—	3	2071	19.12
1974–75	1721	189	1685	2	20	1699	(–17.02)
1975–76	2052	204	1790	1	22	2029	19.23
1976–77	2895	201	2616	—	2	2893	41.08
1977–78	3682	256	2976	1	15	3666	27.18
1978–79	4381	280	4108	—	8	4373	18.98
1979–80	4332	314	3221	3	43	4286	(–1.1)
1980–81	4311	323	3614	7	10	4294	(–)
1981–82	4221	357	3350	175	73	3973	(-2.08)

TABLE–16

Details of Road Accidents in Bangalore District During 1971–1982

Year	Total No. of road accidents	Persons killed	Persons injured	Accidents due to			% of accidents due to human errors
				Bad condition of roads	Mechanical defects of the vehicles	Human errors	
1	2	3	4	5	6	7	8
1971–72	1938	270	1895	—	30	1908	98.45
1972–73	2076	239	1834	—	48	2028	97.68
1973–74	2406	277	2230	—	19	2387	99.21
1974–75	2082	292	2245	8	52	2028	97.40
1975–76	2415	305	2226	7	45	2363	97.84
1976–77	3254	291	3040	12	22	3220	98.95
1977–78	4181	380	3659	15	76	4090	97.82
1978–79	4870	403	4752	8	61	4801	98.58
1979–80	4857	465	4020	15	71	4771	98.22
1980–81	4830	494	4390	27	51	4752	98.38
1981–82	4910	521	4175	189	116	4605	93.78

TABLE–17

Details of Road Accidents in Karnataka State During 1981–82

1	2	3	4	5	6	7	% of accidents due to human error previous year
71–72	5784	1164	6222	203	547	5034	87.03
72–73	6518	1288	6804	182	580	5756	88.03
73–74	6741	1275	6885	246	936	5559	82.46
74–75	6297	1331	6894	225	827	5245	83.39
75–76	6952	1455	7186	47	366	6539	94.06
76–77	8258	1456	8813	181	391	7686	93.03
77–78	10196	1636	10104	65	304	9827	96.38
78–79	11600	1812	11554	227	661	10712	92.34
79–80	11679	1832	11321	96	682	10901	93.33
80–81	11311	2064	11918	113	501	10697	94.57
81–82	11864	2149	12064	285	333	11246	94.79

TABLE–18

Details of Road Accidents due to Human Error in Karnataka State during 1974–82

Year	Total No. of road accidents due to human error	Fault of drivers	Fault of Pedestrains	Other errors
		(with respective % in brackets)		
1974–75	5245	4816 (91.9)	203 (3.8)	226 (4.3)
1975–76	6539	5845 (89.4)	284 (4.3)	411 (6.3)
1976–77	7686	6660 (86.7)	162 (2.1)	864 (11.2)
1977–78	9827	7893 (80.4)	551 (5.6)	1383 (14.0)
1978–79	10712	8563 (80.0)	623 (5.8)	1526 (14.2)
1979–80	10901	8559 (78.6)	1628 (14.9)	714 (6.5)
1980–81	10697	8442 (79.0)	784 (7.3)	1471 (13.7)
1981–82	11246	9342 (83.1)	801 (7.1)	1103 (9.8)

TABLE–19

Zone wise break up of Fatal and Non-Fatal Accidents for 1982

Sl. No.	Zone	Fatal accidents	Non–fatal accidents				Total No. of acci-dents
			Serious injury	Slight injury	Collision	Total	
1	Malleswaram	74	23	508	236	767	841
2	Seshadripuram	57	35	468	260	763	820
3	Ulsoor	74	53	498	263	814	888
4	Ulsoor Gate	54	41	399	201	641	695
5	Chickpet	30	25	226	129	380	410
6	Central	42	57	251	114	422	464
	TOTAL	331	234	2350	1203	3787	4148

TABLE–20

Age groups of persons involved in road accidents in Bangalore city during 1982

Sl. No.	Age Grop	Killed		Injured	
		Male	Famale	Male	Female
1	Below 6 years	14	11	102	54
2	Below 6–18 years	44	8	406	117
3	Below 19–30 years	84	6	1253	114
4	Below 31–50 years	102	8	878	112
5	Above 51 years	51	17	232	57
	TOTAL	295	50	2871	454

TABLE–21

Hour-wise Break up of Accidents

Sl. No.	Hours	Death	Injured	Collision	Total
1	0000 — 0600	17	97	82	196
2	0600 — 0900	53	254	141	448
3	0900 — 1200	50	491	215	756
4	1200 — 1500	55	498	224	777
5	1500 — 1800	65	545	261	871
6	1800 — 2100	50	403	161	614
7	2100 — 2400	41	296	119	456
	TOTAL	331	2584	1203	4118

TABLE–22

Break-up of Accidents Occurrence Day-Wise

Sl. No.	Day	Death	Injuries	Collision	Total
1	Sunday	43	344	131	518
2	Monday	60	399	191	650
3	Tuesday	46	368	167	581
4	Wednesday	48	394	200	642
5	Thursday	43	339	173	555
6	Friday	45	370	169	584
7	Saturday	46	370	172	588
	TOTAL	331	2584	1203	4118

TABLE–23

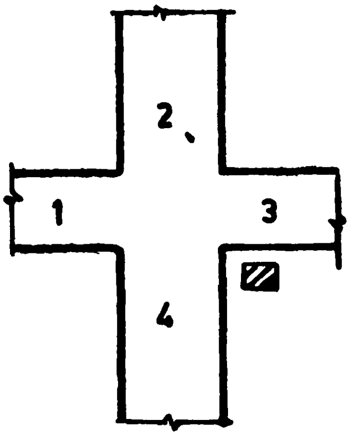
Vehicle Factor in Road Accidents in Bangalore City During 1982

Sl. No.	Type of vehicle		Killed		Injured		Collision		Total	
			Primary	Secondary	Primary	Secondary	Primary	Secondary	Primary	Secondary
1	BTS Buses	....	51	—	264	118	139	39	454	157
2	KSRTC Buses	....	15	—	37	60	29	9	81	69
3	Factory Buses	....	6	1	40	9	32	6	78	16
4	Private Buses	....	18	2	53	55	40	22	111	79
5	Lorries	....	116	7	347	179	349	134	812	320
6	Motor Cars	....	18	3	376	73	208	45	602	121
7	Autorickshaws	....	32	—	410	81	114	46	556	127
8	Motor cycle	....	18	—	330	29	58	40	406	69
9	Scooters	....	17	—	366	43	51	35	434	78
10	Mopeds	....	3	—	56	6	9	2	68	8
11	Tempos	....	11	—	84	22	36	12	131	34
12	Jeeps	....	4	—	52	13	19	7	75	20
13	Vans	....	12	—	71	30	45	15	128	45
14	Military Vehicles	....	1	—	17	12	12	1	30	13
15	Unknown Vehicles	....	9	1	20	1	43	11	72	13
16	Tractors	....	—	—	16	9	6	—	22	9
17	Taxies	....	—	—	11	1	4	—	15	1
18	Cycles	....	—	—	26	—	6	20	32	20
19	Jatakas	....	—	—	3	—	1	—	4	—
20	DB and SB Carts	....	—	—	3	—	2	—	5	—
21	Others	....	—	—	2	—	—	—	2	—
	TOTAL	....	331	14	2584	741	1203	444	4118	1199

Appendix -I

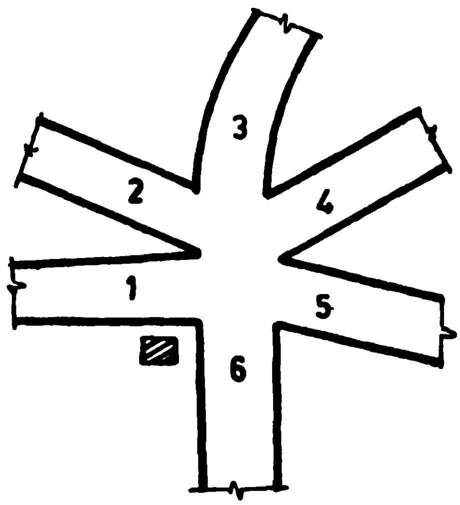
ROADPATTERN AT SELECTED POINTS OF INTERSECTION IN BANGALORE CITY

(1) Malleswaram circle



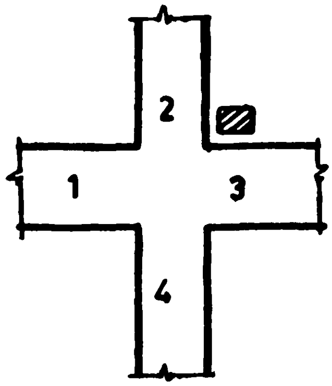
1-3 Sampige road
2-4 5 th cross
▨ Hotel Poornima

(2) Basaveshwara circle



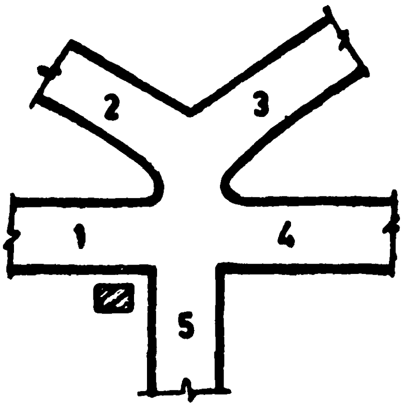
1-5 Palace road
2 Miller road
3 Rajbhavan road
4 Residency park road
6 Race course road
▨ Hotel Chalukya

(3) Oriental building circle



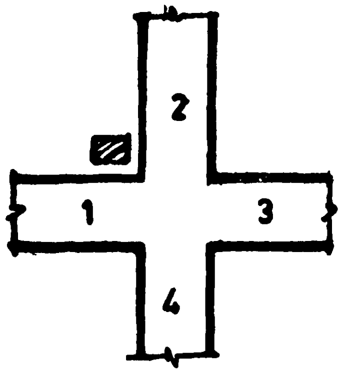
1 BRV Road
2-4 M.G Road
3 Saint marks road
▨ Oriental buildings

(4) Minerva circle



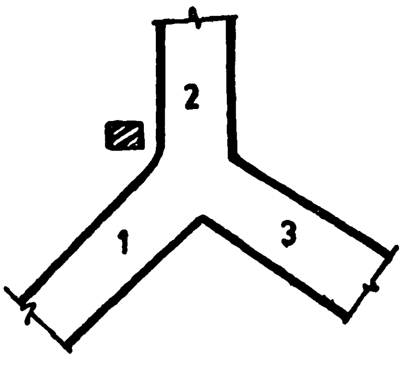
1 Lalbagh road
2 R.V Road
3 Diagonal road
4 To city market
5 J.C Road
Minerva theater

(5) Bharat circle



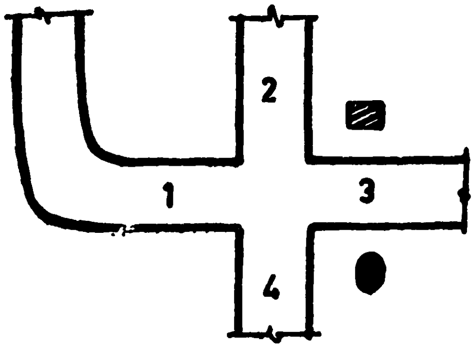
1-3 J.C Road
2 H. Siddhaiah road
4 Armugan mudaliyar road
Bharat talkies

(6) Town hall circle



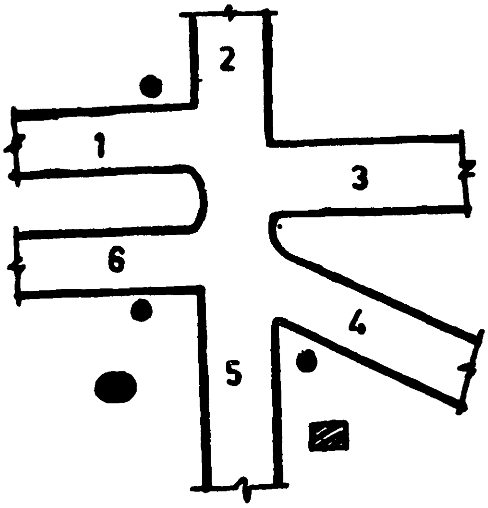
1 Narasimharaja road
2 J.C Road (Corporation)
3 J.C Road (Ravindra kalakshetra)
Town hall

(7) Corporation circle



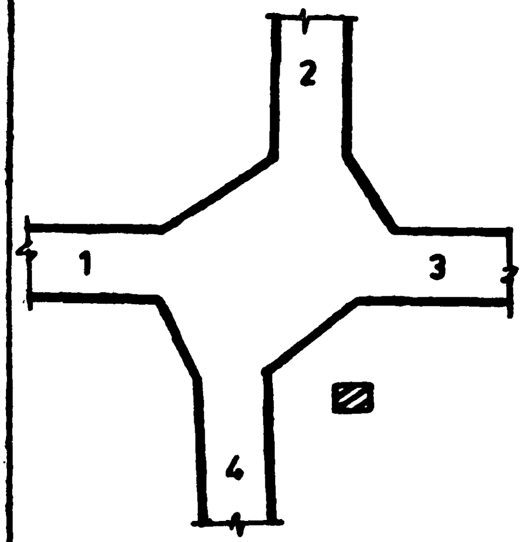
1 Toward Police corner
2-4 J.C Road
3 Mission road
Corporation office
Unity buildings

(8) Citymarket circle



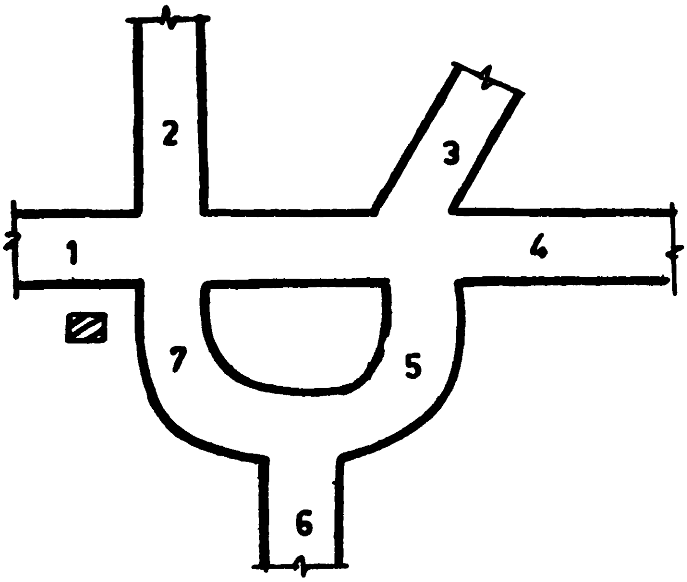
1 K.R Market frontage road
2 Avenue road
3 Narasimharaja road
4 Towards Parimala theatre
5 Vanivilas road
6 Mysore road (Opp. Victoria Hospital)
Dental college
Apsara theatre
Subway for pedestrains

(9) Briand square circle



1-3 Mysore road
2 Bhashyam road
4 Sultan road
Chruch

(10) Statebank of Mysore circle



1 Kempegowda road
2 Palace road
3 Post office road
4 District office road
5-6-7 Avenue road
Statebank of Mysore

APPENDIX–II

Details of Motor Vehicles in Karnataka State during 1956–83

Year	Motor cycles	Motor Cars	Jeeps	Motor Cars	Auto-rick-shaws	Omni buses	Stage carri-ages	Con-tract carri-ages	Goods vehicles	Trac-tors	Trailers	Others	Total all vehicles	% of increase over previous years
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
56–57	3106	10835	....	611	....	....	2843	....	7487	....	....	1094	25976	....
57–58	4255	13264	....	484	326	216	3977	....	9063	....	....	1474	33059	27.26
58–59	4636	13405	....	513	....	....	4082	....	9207	711	....	1047	33601	1.63
59–60	4403	14211	1289	765	447	....	3886	....	9902	....	....	1631	36534	8.72
60–61	5621	13946	....	724	591	208	4248	....	10656	....	....	3238	39232	7.38
61–62	7534	14184	1866	808	749	286	5044	....	11921	910	607	2211	46162	17.66
62–63	10466	17866	2284	939	1015	382	5670	72	13652	....	....	3506	55852	20.99
63–64	12143	19286	2431	916	1261	510	5619	108	14592	....	....	4415	61281	9.72
64–65	14882	20611	2844	1074	1625	545	4435	187	14591	....	....	3896	64690	5.56
65–66	18980	21602	3374	1158	2018	842	6323	110	15179	....	....	6152	75738	17.07
66–67	20898	22227	3746	1155	2172	....	6850	....	17052	....	....	5476	79576	5 06
67–68	24170	22023	1145	1093	3296	659	4899	403	15271	2304	1478	1352	81113	1.93
68–69	27086	25516	4486	1334	4052	0000	7030	0000	17673	0000	0000	6498	93675	15.48
69–70	36450	26453	4946	1467	5224	0943	5525	589	16977	3806	2541	1921	106842	14.06
70–71	45463	28470	5272	1617	6479	1027	5543	652	18214	4789	3410	2323	123259	15.37
71–72	54524	30826	5450	1905	7174	1081	5985	693	18156	5623	4222	2500	138139	12.07
72–73	65242	33117	6380	2105	8593	1217	6088	766	18544	6442	4838	2836	156168	13.05

73–74	77830	36707	6957	2479	10124	1344	6443	933	19924	7387	5736	3161	179025	14.64
74–75	92148	38588	7210	2541	11265	1389	6948	1040	21139	8370	6703	3500	200841	12.19
75–76	106859	40582	7603	2521	12255	1559	7279	1098	23529	8787	7353	5286	224711	11.89
76–77	123223	42538	8151	2568	13415	1704	7539	1037	23835	7520	7014	9513	248057	10.39
77–78	153337	51525	10389	2535	15857	2004	8138	1076	27087	9482	8348	8985	298763	20.44
78–79	176574	58094	11248	2681	17600	2253	9018	1022	29657	14996	14661	4072	341876	14.43
79–80	195467	59493	10838	2672	18767	2505	9439	997	32040	16028	16328	3199	367773	7.57
80–81	223389	61900	10993	2791	19116	2830	9791	....	31010	15971	16589	5863	400293	8.84
81–82	261605	64467	11565	3198	20716	3183	11632	540	33425	18771	18588	5924	453614	13.32
82–83	289893	66739	12132	3727	22811	3549	12065	543	35835	20143	20257	6695	494389	8.99
% of increase from 71–72 to 81–82	379.80	109 13	112.20	67.37	188.76	194.45	94.35	22.08	84.10	233.83	340.27	136.96	228.38	
% of increase from 76–76 to 81–82	112.30	51.55	41.88	24.53	54.42	86.80	54.29	47.93	40.23	149.61	165.01	37.73	82.86	

THE ENERGY SECTOR OF THE METROPOLIS OF BANGALORE

AMULYA KUMAR N. REDDY * and B. SUDHAKAR REDDY*

PART–I FIREWOOD **

Introduction

The importance of non-commercial energy in general, and firewood in particular, in the national energy system has been realized only over the last decade. India has been a pioneer in this area – for example, as long back as 1974 the Report of the Fuel Policy Committee (of the Planning Commission) begins with the sentence : "The most important fact about the energy situation in India is that nearly half of the total energy consumed in the country comes from non-commercial sources.[1]" Despite this, the details of, say firewood consumption, are far less understood than electricity consumption for example. Fortunately, during the past few years, a number of rural energy studies,[2] including ASTRA's,[3] have thrown light on the pattern of non-commercial energy usage in *rural* areas. But, no comparable studies exist for urban populations. There is, however, a notable exception – this is the valuable "Analysis of 1977-78 National Sample Survey on Household Energy Consumption (32nd round) - Karnataka" of the Perspective Planning Division of Karnataka's Planning Department (published in July 1981).[4]

Firewood consumption invariably produces negative environmental impacts because it is often associated with deforestation. At first, it was assumed that the cause of deforestation lies in the villagers' dependence on firewood as a cooking fuel. However, several studies, including ASTRA's,[3] have shown that, in several rural areas, this is not the case. The point is that villagers rely predominantly on twigs, roots and thin branches, gathered mainly by women and children. It has therefore been suggested that, apart from rural brick-burning which requires logs from felled trees, deforestation must be attributed mainly to urban consumption of firewood. But, this suggestion needs substantiation from studies of firewood usage in urban concentrations.

In the midst of these preoccupations, there has been a growing interest in the study of Bangalore as an urban ecosystem. An essential part of such a study must be an understanding of the inflow of various fuels/energy carriers into Bangalore and their utilisation in the city. Obviously, such a study must focus considerable attention on the role of firewood in the Bangalore ecosystem.

There is also the important question of how several energy carriers co-exist and are utilized in a stratified society. In particular, it is important to understand which sections of society use firewood and for what end-uses.

**Department of Industrial Management, Indian Institute of Science, Bangalore-560 012*

*** Reprinted from Economic and Political Weekly, (1983) XVIII, 1757–1770*

Finally, it is necessary to take a view on whether Bangalore's demand for firewood can be satisfied in a sustainable way and whether there are feasible technological alternatives.

These, then, are the various inter-related concerns which have motivated the present study of firewood in Bangalore city.

2. Objectives

A systematic approach to fuels and energy carriers involves a study of entire fuel cycles starting with the generation/production, and going through their transport/transmission and distribution, to utilization and consumption.

The aim of the present study therefore is to understand

1. who are the suppliers of firewood to Bangalore, and the quantities handled by them,

2. which are the transportation modes involved in the firewood supply, and the quantites carried by each of these modes,

3. how the incoming firewood is distributed in the city and the quantities handled by each type of distributor,

4. which are the various categories of consumers, how much each category consumes, and for which end-use,

5. what are the implications of Bangalore's firewood consumption particularly with regard to the environment, transport system, energy costs and foreign exchange, and finally,

6. how the negative impacts of firewood consumption can be reduced.

3. Results

3.1. Firewood Supply

3.1.1. List of Firewood Species

The species of firewood that are commonly being used in Bangalore are listed in Table 1 along with their trade and vernacular names, and their approximate percentages in the total consumption. It is seen that ten species, viz., Casuarina, Haldu, Bijasal, Laurel, Irul, Glabra, Tamarindus, Coffee, Persian Lilac and Kindal account for about 80 per cent of the consumption.

3.1.2. Sources of Supply

Of the total firewood coming into Bangalore, about 50 per cent is from the privately-owned forests of Chintamani, Srinivasapuram, Madanapalle and Chittoor about 120-150 kms away from Bangalore. The main species coming from these places are Tamarindus, Babul, Axlewood, Glabra and Kindal.

About 35 percent of the total firewood inflow to Bangalore comes from private lands in Nelamangala, Anekal, Magadi, Malur, Ramanagaram, Kumbalgud and Bidadi, i.e., from within a radius of 30-40 kms. Casuarina, Eucalyptus and Banyan are the main species coming from these sources.

The government forests in Varahi, Dharwad, Sirsi, Shimoga, Haliyal, Sagar, Mercara, Hunsur and Kankinakote supply about 6-7 per cent of the total firewood consumed in Bangalore. These sources are at distances of 300-400 kms from Bangalore, and the supply is mainly in the form of Haldu, Bijasal, Laurel, Kindal and Glabra.

The remaining 8-9 percent of the total firewood supply comes from the Government forests in Goa. The sources of supply in this category are Collam, Kalay, Sanverdenkachoram and Londa which are at distances of 650-700 kms from Bangalore. The main species supplied by these places are Bijasal, Haldu, Laurel, Kindal, Glabra and Eucalyptus.

These findings are presented in Figure 1 which shows the sources of firewood and their distances from Bangalore, and in Figure 2 which indicates the quantities of firewood supplied from these different sources.

3.1.3. Firewood Supplies

Firewood is supplied to Bangalore by the Forest Department of the Government of Karnataka and by private contractors.

The Forest Department supplies firewood to domestic consumers in Bangalore through Cooperative Societies which receive monthly allotments of firewood from the Forest Department and then sell it to ration-card holders.

The private contractors who supply firewood are of two types:–(i) those who obtain the firewood from the their own lands, and (ii) those who purchase it either from land-owners or from government auctions. These contractors then sell the firewood to retailers through agents.

The average monthly supplies correspond to an average 59 ± 31 tonnes per day from the Forest Department and $1{,}063 \pm 105$ tonnes per day from private contractors, together adding up to a total of 1,122 tonnes per day.

Table 2 gives the monthly quantities of firewood supplied by the Forest Department and by private contractors during the years 1979–80 and 1980-81. During these two years, the monthly average supplies by the Forest Department and the private contractors were 1,809 tonnes and 32,336 tonnes respectively, but the standard deviations were 52.1 per cent and 9.9 percent of these averages. Thus, the private contractors, not only provided 17.9 times the quantity supplied by the Forest Department, but maintanined a far steadier supply.

Figure 3 shows the percentages of total firewood supplied by the Forest Department and private contractors. It is seen that private contractors account for an overwhelming 95 per cent of the firewood inflow to Bangalore.

3.1.4. Transportation Modes

The two principal modes of transporting firewood to the city are railway wagons and trucks, but a small quantity of firewood also comes in by means of bullock carts. In addition, some residents of the city's outskirts cut firewood from roadside trees and bring it in as head-loads.

The bulk (85%) of the firewood is transported to Bangalore through trucks, and this firewood comes predominantly from private lands. About 10 percent of the total inflow comes via rail, and this firewood comes mainly from the government forests in North Kanara and Goa.

Table 3 contains a tabulation of the monthly quantities of firewood transported by railway wagons and trucks during the years 1979-80 and 1980-81. This data indicates that the average monthly quantities of firewood brought in by rail and trucks are 3626 ± 697 tonnes and $30{,}522 \pm 3{,}122$ tonnes respectively. Thus, on the average, trucks transport about 8.4 times the amount brought in by rail.

About 4 percent of the total inflow of firewood comes by bullock carts, and only 1 per cent by head-loads.

The percentage contributions of the different transportation modes is summarized in Figure 4.

3.1.5 Magnitude of Inflow

The magnitude of inflow can be estimated by considering each transportation mode in turn and then summing over all the modes.

(a) Trucks : The quantity of firewood brought into the city by trucks was obtained from the four weigh-bridges on the entry roads to Bangalore. There are two types of weigh-bridges - those that weigh up to 16 tonnes and those that weigh up to 20 tonnes. The average tare or empty weight of a truck was found to be $5.516 + 0.651$ tonnes from a sample of 100 empty lorries. From the 20-tonne weigh-bridge, the weight of a firewood-loaded truck was found to be 17.155 ± 1.357 tonnes from a 100-truck sample - this corresponds to an average firewood load of 11.639 tonnes. Similarly, at the 16-tonne weigh-bridge, the weight of a truck loaded with firewood was determined to be 13.655 ± 1.655 tonnes from a sample of 100 trucks, This works out to an average firewood load of 8.140 tonnes. From this data and from the number of firewood-loaded trucks coming in via the two types of weigh-bridges, the inflow of firewood through trucks is as shown in Table 4.

It is seen that, during the two years 1979-81, an average of 41,616 trucks per year brought into Bangalore 366,263 tonnes of firewood/year, i.e., 1,003 tonnes/day carried by 114 trucks/day, of which 75 percent came in via the 16-tonne weigh-bridges.

(b) Railway Wagons : Wagons of both Southern Railway and South Central Railway are used to transport firewood into the city. Based on a 100-wagon sample from Southern Railway, it was found that the quantity of firewood transported was 11.9 ± 1.3 tonnes/wagon. In the case of the South-Central Railway, their charges are on the basis of 11.5 tonnes/wagon. From this data and the number of wagons used for transporting firewood, the quantity of firewood brought into Bangalore by the railways is as presented in Table 5.

The table shows that, during the two years 1979-81, the railways used on the average 3,716 wagons/year to bring into Bangalore 43,507 tonnes of firewood per year, or 119 tonnes/day carried in approximately 10 wagons/day.

(c) Bullock-carts : On the average, about 100 bullock-carts carry firewood into Bangalore every day. In studies of brick-burning kilns near the city, it has been found that a cart-load of firewood is about 500 kg. Thus, the inflow of firewood via bullock-carts is 50 tonnes per day.

(d) Head-loads: A sample survey indicated that, daily, about 300 people bring head-loads of firewood into the city. Taking an average head-load of 25 kg, the total quantity of firewood flowing into the city via head-loads is 7.5 tonnes per day.

Summing over the quantities of firewood transported by trucks, railway wagons, bullock-carts and head-loads, it appears that the total quantity of firewood carried into Bangalore is $1003+119+50+7.5 \approx 1{,}180$ tonnes per day.

3.2. Firewood Distribution

3.2.1. Distribution Channels

The distribution of firewood in Bangalore (Figure 5) is handled by (1) Cooperative Societies and (2) Commission Agents, with the societies obtaining their supplies from the Forest Department and the agents from government auctions and private lands. The Commission Agents in turn distribute their firewood to retail depots and to direct purchasers.

3.2.2 Magnitudes handled by Distribution Channels

There are in Bangalore 23 Cooperative Societies which handle firewood. In addition, there are 700 registered firewood retail depots, and an approximately equal number of un-registered depots.

The consumers get the bulk (85 per cent) of their firewood from retail depots (Table 6 and Figure 6). Direct purchases from agents and procurement from co-operative societies account for 10 percent and 5 percent respectively. The total quantity of firewood estimated to be handled by all these channels is 1236 tonnes/day.

3.3 Firewood Consumption

3.3.1 Types of Consumers

Bangalore's consumers of firewood can be classified into 11 principal categories: (1) Households, (2) Dyeing factories, (3) Bakeries, (4) Hotels, (5) Industries, (6) Choultries, (7) Hostels, (8) Cremation grounds, (9) Canteens, (10) Road-building, and (11) Soap Factories. The number of consumers in some of these important categories is listed in Table 7.

3.3.2 Household Firewood Consumption in the Survey Samples

A sample of 1000 households was surveyed in the northern and north-western part of Bangalore. It was found that many types of fuel are used for cooking and water-heating. There are three main categories of households :–

- I – Households which use firewood (FW) for both cooking and water heating.
- II – Households which use kerosene (K) or gas (LPG) for cooking and FW for water-heating.
- III – Households which use sources (e.g., electricity, LPG) other than FW for both cooking and water-heating.

The survey showed (Table 8) that only 16.1 percent of the sample households used firewood for both cooking and water-heating, but 65.5 percent did not use any firewood at all either for cooking or for water-heating. It must not, however, be concluded that firewood is irrelevant to the majority of Bangalore's households.

The type of fuel chosen for cooking and water-heating depends – as one would expect – on the household income. Considering casual labourers as special income category, Table 8 shows 80.9 percent of these households depend wholly on firewood for both cooking and water-heating and only 8.2 percent on other fuels which in their case means dung-cakes, twigs and biomass pickings. In complete contrast is the category of households with a monthly income equal to or above Rs. 1000: 87.6 percent of this category use fuels other than firewood, such as electricity, kerosene, LPG, for both cooking and water-heating, and only 1.1 percent use firewood for both tasks.

Another confirmation of this income-dependence of firewood usage is the fact that, out of the 161 households in the sample which rely wholly on firewood, 55.3 percent are casual-labour households, and another 29.2 percent, households with a monthly income of Rs. 500 or less. That is, 84.5 percent of the households which use firewood both for cooking and water-heating come from the households of casual labourers and of those with a monthly income of Rs. 500 or less – and only 3.1 percent of these totally firewood-dependent households belong to those with a monthly income of Rs. 1000 or more.

Since the household income is given by the product of the per capita income and the number of persons in the household, it is necessary to separate the influence of these two factors on the firewood consumption of the household. The survey data was therefore organised so that the annual per capita firewood consumption (APCFWC) in kgs of firewood per year for each of the 1000 households was tabulated along with its per caipta monthly income (PCMI) and the household size (HS), *i.e.*, the number of persons in the household.

A computer analysis was carried out of the data for all the 1000 households **irrespective of whether they used firewood or not.** It was found that there was a negative linear correlation between firewood consumption and per capita income. The linear regression equation turns out to be

$$\text{APCFWC} = 306.141 - 0.542\ \text{PCMI}$$

with a linear correlation coefficient of $r=0.5267$. The standard error of estimate fo 129.778 which means that 95 percent of the 1000 samples fell between 2 parallel lines with the equations

$$\text{APCFWC} = 565 - 0.542\ \text{PCMI}$$

and

$$\text{APCFWC} = 47 - 0.542\ \text{PCMI}$$

The relationship between firewood consumption and per capita income is also summarized in Table 9. It can be concluded from this table that households with per capita monthly incomes of less than Rs. 100, Rs. 100–149 and Rs. 150–199 constitute 14.8 percent, 17.0 percent and 11.0 percent respectively of the sample, but they account for 43.5 percent, 33.5 percent and 12.4 percent respectively of the households using firewood for both cooking and water-heating. Alternatively stated, households with per capita monthly income of less than Rs. 150 are 31.8 percent of the survey sample, but they account for 77 percent of the households which depend on firewood for both cooking and water heating. **The situation is even more clear with households having a per capita income of less than Rs. 200. They constitute 42.8 percent of the sample, but almost 90 percent (actually 89.4 percent) of the households using firewood for cooking and water heating belong to this income group.**

This income-dependence of firewood usage for both cooking and water-heating can be emphasised in other ways.

Firstly, the total firewood dependence index (TFDI) of an income category can be defined thus :

$$\text{TFDI} = \frac{\text{Percent of FW-using HH in the income category}}{\text{Percent of all sample HH which belong to the income category}}$$

A Total Firewood Dependence Index (TFDI) of unity means that the percentage of households totally depending on firewood in a particular income category is exactly the same as the category's percentage in the sample. The indices for various income categories are tabulated in Table 10. It is seen that a per capita monthly income of

Rs. 200 is the demarcation. Below Rs. 200, the income category bears a greater burden of total firewood dependence than the category's proportion in the sample, and above Rs. 200, the income categories have much less dependence than their percentage in the sample. In fact, if the mid-point of the income range is chosen as an independent variable and the total firewood dependence index as the dependent variable, the survey observations show a linear correlation :

TFDI = 3.2815 − 0.0109 x (Mid-point of Income Range) with a very high correlation coefficient of -0.9769. The sign of the correlation coefficient shows that as the value of the mid-point of the income range increases, the total firewood dependence index decreases.

Secondly, the Lorenz curve of the cumulative percentage of firewood-using households *vs.* the cumulative percentage of households in the various income range is highly skewed (Figure 7) showing marked inequality in the burden of dependence on firewood. As expected, the lower-income groups suffer a far greater dependence on firewood.

As mentioned already, the 1000 household sample was confined to the northern and north-western parts of Bangalore. In fact, four specific areas of the city were selected : Mathekere, Yeshwantpur, Malleswaram and Rajajinagar (cf. Fig. 8), and 250 houses surveyed in each of these areas. It was found (Table 11) that the percentage of households using firewood for both cooking and water-heating is very different in the four areas - the percentage is as low as 2.4 percent in Rajajinagar and as high as 47.2 percent in Mathekere. The reason for this large variation becomes evident if one also considers the percentage of households the area with a per capita monthly income of less than Rs. 100, *viz.*, 1.6 percent in Rajajinagar and 38 percent in Mathekere. Indeed, the four areas yield a linear correlation :

(% of HH in an area using FW for C + WH) = 1.4455 + 1.1855 (% of HH in area with pc monthly income < Rs. 100)

with a correlation coefficient of 0.9620. Such a correlation suggests that, if 86 percent of the households in an area have a per capita monthly income of less than Rs. 100, then it is expected that all its households would use firewood for cooking and water-heating.

The detailed data for the four areas is given in Tables 12, 13, 14 and 15. It is a matter for more careful study whether the affluence of the environment affects the choice of fuel for cooking and water-heating. But, in Mathekere where 38 percent of the households have a per capita monthly income of less than Rs. 100, 61 percent of this category use firewood for both cooking and water-heating, whereas in Rajajinagar where 1.6 percent of the household are in the less than Rs. 100 category, only 25 percent of the households in this category are dependent on firewood in this way. It seems that in an affluent neighbourhood the poor try to imitate the rich in fuel choice.

The quantity of firewood consumed and the expenditure on firewood are also of interest.

Table 16 presents the data for the households which use firewood for both cooking and water-heating. It is seen that the average annual per capita firewood consumption for these households is 367.8 kgs/capita/year with a standard deviation of 23.2 kgs/capita/year which is 6.3 percent of the average. Using the January 1982 firewood price of Rs. 0.45/kg, the average expenditure on firewood is Rs. 13.79+ 0.87/capita/month. Further, the per capita monthly expenditure on firewood is a decreasing percentage of the per capita monthly income, constituting in the case of the lowest income group an estimated expenditure of firewood of 17.0 percent of the total inome.

Table 17 shows the corresponding data for households which use firewood only for water-heating. Their firewood consumption is 175 + 11.9 kgs/capita/year corresponding to an expenditure of Rs. 6.59/capita/month. In the case of these households also, the per capita monthly expenditure is a decreasing percentage of the per capita monthly income. The estimated expenditure on firewood for water heating is 9.4 percent of the total income in the case of lowest income group.

The data contained in Table 16 and 17 can be used to estimate the quantity of firewood used for cooking and for water-heating. The estimate is made on the assumption that households which use firewood for both cooking and water-heating use the same amount of firewood for water heating as those households in the same category that use firewood only for water-heating. The results of making this assumption are shown in Table 11 which shows that about 48 $\pm$ 1 percent of the per capita consumption of firewood is used for water heating and 52$\pm$1 percent for cooking. It also appears that, as the per capita income increases, the per capita consumption of firewood for water heating increases in absolute magnitude. This result may be due to an increase in the frequency of hot-water baths with increasing income. Incidentally, the average consumption of 17.8 kg/capita/year = 0.482 kg/capita/day corresponds to 3.9 litres of 50° water/capita/day assuming a firewood calorific value of 4000 kcals/kg, a 5 percent heating efficiency and a cold water temperature of 25°C.

The table further shows that, as the per capita income in firewood-using households increases, the per capita firewood consumption for cooking also increases. It is not clear, howeveer, whether this increase is due to greater food consumption or due to higher consumption of homecooked foods.

Apart from this variation with per capita income, the actual amount of firewood consumed for cooking which is 192.0 kgs/capita/year on the average is low compared to the corresponding figure in rural areas, e.g., an average of 520.4 kgs/capita/year in six specific villages of Kunigal Taluk, Tumkur District, Karnataka[3]. Thus, the per capita firewood consumption for cooking in Bangalore is only 37 percent of the corresponding consumption of villages. It has not been possible, however, to estaiblish whether this reduced consumption is due to the use of dry logs and metal vessels in Bangalore in contrast to moist twigs and mud-pots in villages or due to a greater frequency in urban areas of eating-out in hotels.

In addition to showing a marked dependence on per capita income, the per capita firewood consumption also appears to be affected by the number of persons in the household, *i. e.*, the household size (HS). Taking the 161 households which use firewood for both cooking and water-heating, it is observed that, classifying these households into separate categories each consisting of a particular number of persons, the average monthly per capita firewood consumption (MPCFWC) in kgs/capita/month in each category is linearly correlated with the number of persons in the household *i.e.*, household size, in that category :

$$\text{MPCFWC} = 33.20 - 0.84 \text{ HS}$$

with a correlation coefficient of -0.9564 and a standard error of estimate of ± 0.7002. This interesting observation that the per capita firewood consumption decreases as the number of persons in the household increases is most probably due to the coefficiencies of cooking and water-heating that result from increasing scales of cooking and water-heating.

In view of this effect of household size, it is important to establish whether there is a multiple correlation between the three variables : (1) Annual per Capita Firewood Consumption (APCFWC), (2) Per Capita Monthly Income (PCMI), and (3) Household Size (HS). A computer analysis of the data from the 1000-household sample yielded the following linear regression equation of APCFWC on PCMI and HS :

$$\text{APCFWC} = 405.1 - 0.5 \text{ PCMI} - 24.9 \text{ HS}$$

with a coefficient of multiple correlation of 0.5842.

3.3.3 Domestic Firewood Consumption in Bangalore

The extrapolation of the results obtained from the 1000 household sample to the city of Bangalore has been carried out in the following way. The percentages of households in any income range using firewood for cooking and water-heating and for water-heating only are assumed to be the same for the city as in the sample. Further, the per capita firewood consumption norms obtained in the sample are assumed to hold good for Bangalore. With regard, however, to the percentages of households falling in various income ranges, it has been assumed that the four areas, viz., Mathekere, Yeshwantpur, Malleswaram and Rajajinagar, may not be representative of Bangalore. Advantage, therefore, has been taken of the excellent study of the economic structre of Bangalore which was reported by PrakasaRao and Tewari.[5] These authors have given the 1973-74 picture of the percentages of households in various ranges of per capita monthly income. These percentages have been updated by multiplying the income by a factor of 1.648 to take into account the increases in income since 1973 – this factor has been taken to be 1.648 based upon the Bureau of Economics and Statistics report[6] that the per capita income has increased from Rs. 943 in 1973 to Rs. 1,554 in 1982. There is a serious assumption in this procedure, *viz.*, that the distribution of Bangalore's households over the various ranges of per capita income has not changed over the decade. This is unlikely - inequality is bound to have increased. In effect, therefore, the procedure used here assumes that, in the absence of relevant data, the changes in the distribution of income are small enough to warrant their being ignored in the first approximation.

Using these arguments, the total domestic consumption of firewood has been estimated to be about 970 tonnes per day (Table 19). Of this daily consumption, households with a per capita monthly income of less than Rs. 200/– per month, which constitute about 60 percent of the households, are estimated to consume about 82 percent of Bangalore's domestic firewood consumption (Table 20). Thus, the burden of firewood usage is greater in the case of lower income groups (Figure 9)

3.3.4 Dyeing Factories

All, except one, of the 176 dyeing factories in Bangalore utilize firewood as fuel. The consumption norm is 8.33 tonnes of firewood/tonne of yarn that is dyed, and the total yarn dyed is about 7.5 tonnes/day (excluding the factory which does not use firewood). Hence, the daily consumption of firewood for all the dyeing factories is 62 tonnes/day.

3.3.5 Bakeries

There are about 1850 bakeries in Bangalore which use firewood for baking bread, biscuits, etc. The firewood consumption norm is 0.583 kgs of firewood for baking 1 kg of maida. The Food and Civil Supplies Department issues, on the average about 60 tonnes of maida/day to the 1150 bakeries which are registered - hence, the firewood consumption of registered bakeries is 35 tonnes/day. There are, in addition, about 700 unregistered bakeries, which according to the Bakeries Association, consume about 1000 tonnes of maida/month. This corresponds to a firewood consumption of about 20 tonnes/day. Thus, the total consumption of firewood is about 5 tonnes/day.

3.3.6 Hotels

There are 1869 hotels in Bangalore of which 659 are of the A and B grades, and 1210 are of the C and D grades. The A and B grades do not use firewood at all. As for the C and D grade hotels, a survey carried out on a sample of 60 hotels showed that about 50 percent of them use firewood and that the average consumption was about 80 kg/day. Thus, the total daily consumption of firewood can be taken as $1210 \times 0.5 \times 0.08 = 48$ tonnes/day.

3.3.7 Industries

The main industries in Bangalore which use firewood for their boilers/furnaces are (1) plywood factories, (2) brick and tile factories, (3) tea factories and (4) small industries.

Of the 2 plywood factories in Bangalore, one uses firewood for its boilers. The consumption norm is 0.25 tones of firewood for drying and hot-pressing 1000 sq. ft. of 1 mm thick plywood. This factory produces about 100,000 sq. ft. of plywood per day and half this quantity is dried and pressed with the heat energy from the combustion of firewood. Hence, the daily consumption is about 12.5 tonnes of firewood/day.

There are four brick and tile factories which use firewood for burning bricks/tiles. The manufacture of 1000 tiles requires 2/3 tonne of firewood, and the total production of these factories is 20 million tiles/year of which one-fourth is burnt with firewood. This corresponds to a firewood consumption of about 9 tonnes/day.

One tea factory used about 8 tonnes of firewood/day for curing tea leaves with a consumption norm of 1.3 kgs FW/kg tea leaves.

There are several small industries which utilize firewood for their furnaces and boilers. It was estimated that the daily consumption of these factories is about 18 tonnes/day.

Thus, the total consumption of firewood by industries is $12.5+9+8+18=47.5$ tonnes/day.

3.3.8. Choultries*

There are some 297 choultries in Bangalore and all of them use firewood for cooking the food served at marriages and other functions. The firewood consumption of choultries can be estimated in two ways. Firstly, there are about 120 auspicious days in a year. It can be assumed that on each of these days about 250 meals are cooked with firewood consumption of about 1 kg./meal. This corresponds to a firewood consumption of $297 \times 520 \times 0.001 = 8{,}900$ tonnes/year. Secondly, a survey of 25 choultries revealed that each choultry uses about 30 tonnes/year. On this basis, about 8,910 tonnes/year or 24 tonnes/day of firewood are utilized by the choultries in Bangalore.

3.3.9. Hostels

The hostels in Bangalore can be divided into three types: Type I for college students and working people, Type II in schools and convents, and type III in aided institutions. All the hostels, barring a few exceptions, use firewood as the fuel for cooking and water-heating, but the type of food prepared in the three–types of hostels

---

**Chamber's Twentieth Century Dictionary : ' Choultry = a hall used as a place of assembly." In this paper, the term is ased to refer to the halls used for weddings and other social/religious functions.*

is associated with differences in per capita energy consumption. A survey was therefore carried out of 96 hostels. It was found that the per capita firewood consumption is 1.5 kg/day in that Type I hostel, 1 kg/day in the Type II hostel and 0.75 kg/day in the Type III institution. From these norms, and the number of inmates in these three types, the daily firewood consumption has been worked out to be about 24 tonnes/day (Table 18)

3.3.10 Cremation Grounds

There are 48 cremation grounds, and it is estimated that about 20 corpses are cremated every day. The firewood requirement per cremation is one bullock-cart load, *i.e.*, about 0.5 tonnes. Hence, the firewood consumption by the cremation grounds is about 10 tonnes/day.

3.3.11 Canteens

There are about 35 major industrial canteens in the city. Apart from 2 or 3 modern establishments, the others use firewood in addition to gas and electricity. The number of users of these canteens is about 36,275 persons/day and the per capita firewood consumption is 0.125 kg/day. Hence, the total firewood consumption is about 4.5 tonnes/day.

3.3.12 Road-building

About 100 drums of tar are heated every day, and each drum requires about 40 kg. this corresponds to a total daily consumption of about 4 tonnes of firewood per day.

3.3.13 Soap Factories

There are about 50 soap factories in Bangalore, approximately half of which use firewood for soap production. The total production of all the soap factories is about 250 tonnes of soap/month and the consumption norm is 0.75 tonnes FW/tonne soap. Soap production, therefore, requires about 3 tonnes/day.

3.3.14 Total Firewood Consumption in Bangalore

It is now possible to assemble the results regarding the firewood consumption of the different categories of consumers in Bangalore. The pattern of firewood consumption in the city is shown in Table 22 and Figure 9 from which it can be seen that, firstly, Bangalore consumes about 1250 tonnes of firewood every day, and secondly, about 78 percent of the total consumption is by households. Further, taking into account the end-uses of firewood consumption by the various consumers, it appears (Table 23 and Figure 10) that only about 5 percent of the total firewood is used for industrial process heat. The bulk of the firewood is used for cooking (42 percent) and water heating (53 percent).

3.3.15 Comparison of Supply, Distribution and Consumption

The daily quantities of firewood supplied, transported, distributed and consumed have been estimated separately and independently in Sections 3.1.3, 3.1.5, 3.2.2. and

3.3.14 respectively. A comparison of these estimates (Table 24) indicates that the average daily requirement of firewood for Bangalore is 1197 tonnes/day with a standard deviation of 51 tonnes/day which is 4 percent of the average. The small value of the coefficient of variation indicates the consistency of the estimates.

4. Discussion

4.1 Implications of Bangalore's firewood Supply and Consumption

4.1.1 Impact on Forests

There is a fundamental difference between firewood usage in cities and towns and that in villages. Rural households depend overwhelmingly on twigs and branches. Thus a recent study by ASTRA in Kunigal Taluk (Tumkur District) showed that most of the households depended on twigs, roots and branches obtained predominantly by gathering. In contrast. Bangalore like all cities and towns uses logs which can be best obtained by the felling of trees. The urban requirement of logs is a consequence of the need to transport the firewood over large distances as a result of which there is a preference for logs with high bulk density rather than twigs with low density. Thus, urban firewood consumption has a much greater negative environmental impact than rural dependence on firewood as a domestic fuel.

With this understanding, it must be noted that the extraction of the enormous quantity of firewood used by Bangalore, viz., about 1200 tonnes/day (about 0.438 million tonnes/year) is unlikely to be carried out in a renewable manner with the extraction rate being equal to the growth rate. The procurement of Bangalore's firewood is most probably achieved by the felling of trees, in which case it corresponds to the deforestation of about 3650 hectares of good forest per year assuming that the growing stock per hectare in such a forest has a high value of 120 tonnes/ha.[7] In other words, about 10 hectares of the best forest would have to be cleared every day to maintain the firewood supply to Bangalore.

4.1.2 Impact on Transport System

The transport of the 1200 tonnes/day of firewood has been reported in Section 3.1.5 to involve an average of 114 trucks and 10 wagons per day. These numbrs must be compared with the findings from a study of the records for October-November 1981 that the total number of trucks and railway wagons bringing freight into Bangalore every day is 630 ± 81 and 125 ± 37. It follows that about 18 percent of the truck and 8 percent of the railway wagon traffic into Bangalore is committed to firewood transport. Thus, in a situation where transport is often a constraint on the economy, a significant fraction of both road and rail transport is tied up with the supply of firewood. There is an opportunity cost associated with the withholding of this truck and wagon capacity from the economy, but this opportunity cost has not been calculated here.

4.1.3 Energy Costs of Firewood Supply

Since large quantities of firewood are being transported into Bangalore by energy-intensive modes of transport (viz., trucks and railway), it would be intersting to estimate the fuel and energy costs of firewood supply to Bangalore (Table 25).

(a) **Trucks:** It has been mentioned (cf. Section 3.1.1) that 35 percent of firewood comes from within a radius of 30–40 kms. This supply is by trucks, and corresponds to about 0.35 × 1200 tonnes/day × 35 kms = 14,700 tonne kms/day. Another 50 percent also comes by truck from places on both sides of the Andhra-Kolar District border about 135 kms from Bangalore. This component corresponds to about 0.50 × 1200 tonnes/day × 135 kms = 81,000 tonne kms/day. Finally, of the 6–7 percent firewood coming from a distance of about 300–400 kms, only about one-third can be considered to be transported *via* truck, and this corresponds to about 0.02 × 1200 tonnes/day × 350 kms = 8,400 tonne kms/day. All this constitutes a total of about 104,100 tonne kms/day which, at an average of 22.04 tonne kms/kg diesel or 18.80 tonne kms/litre of diesel, requires 4.7 tonnes diesel/day (= 1,724 tonnes diesel/year).

(b) **Railway Wagons:** On an average, about 56 tonnes/day of firewood are transported *via* the Southern Railway from Birur junction, 212 kms from Bangalore. This corresponds to 11,872 tonne kms/day. In addition, the South-Central Railway transports about 60 tonnes of firewood/day from around Goa, 680 kms from Bangalore. This corresponds to 40,800 tonne kms/day, leading to a total of 52,672 tonne kms/day for both the railways involved in Bangalore's firewood transport. Using the consumption norm of 154 tonne kms/kg diesel, or 131 tonne kms/litre diesel, the two railways together consume a total of 0.34 tonnes diesel/day (= 125 tonnes/year) or 401 litres diesel/day on firewood transport to Bangalore.

Hence, considering both truck and rail transport, the diesel consumption on Bangalore's firewood transport works out to about 5.1 tonnes/day or 1849 tonnes/year or 2.2 million litres/year.

The energy content of diesel is about 10,670 kcal/litre. Hence, the 5,938 litres of diesel used every day for firewood transport involves an energy cost of 63.36×10^6 kcal/day. On the other hand, the 1200 tonnes of firewood/day is burnt with an efficiency of around 5 percent, which means that at the rate of about 4000 kcal/kg of firewood, the energy delivered is about 240×10^6 kcal/day. Hence, to deliver 100 units of heat enegy from the combustion of firewood for the two main end-uses, *viz.*, cooking and water-heating, about 26 units of energy in the form of diesel fuel have to be expended on firewood transport.

4.1.4 Foreign Exchange Costs

The 2.2 million litres of diesel/year utilized for transporting Bangalore's firewood cost about Rs. 53.25 lakhs at an international rate of $40 per barrel of crude (*i. e.* Rs. 2.42/ litre of diesel). Since about two-thirds of India's oil is imported and paid for in foreign exchange, it can be argued that Rs. 3.55 millions or about $ 400,000 year is the foreign exchange expenditure on supplying Bangalore with its firewood requirement.

4.1.5 A Projection of Bangalore's Firewood Requirement

What has been presented thus far is only the present implications of the city's firewood usage. As the population of Bangalore grows, the requirements of firewood are bound to increase. A graphical extrapolation of Bangalore's population suggests that it will grow to 4.4 million in 1991. This corresponds on a proportionate basis to an estimated firewood demand of about 1760 tonnes/day or 0.642 million tonnes/year. Such an escalation of 47 percent in consumption at the end of a decade would lead to an increase in deforestation to 15 ha/day, in diesel consumption to 3.2 million litres of diesel/year, and in foreign exchange outflow to $587,000 (assuming that the present international price of crude oil does not increase). Even these estimates are based on a continuation of the present pattern and costs of fuel/energy consumption. If, as is likely to be the case, electrical water heating becomes increasingly expensive and/or electrical/LPG/Kerosene cooking becomes more and more difficult because of scarcity of power and petroleum products, then even affluent households may shift to firewood and the demand for firewood may become even larger. Thus, the present pattern of firewood supply and consumption may not be sustainable unless serious steps are taken.

It is worth recalling in this context that Karnataka, has shown a high rate of urbanization. Between 1931 and 1981, Karnataka's total population increased by 184 percent, but its urban population increased by 553 percent. Within one decade from 1971 to 1981, the percentage of Katnataka's urban population to the total population increased from 24.31 percent to 28.91 percent. Hence, even if Bangalore's population is stabilsed by interventionist measures other cities and towns in Karnataka will grow, and generate an increasing demand for firewood, unless the urbanization trend is reversed. Thus, Bangalore's firewood requirment must be seen as part of Karnataka's urban demand for this fuel.

4.1.6 Karnataka's Urban Firewood Consumption

The pattern of firewood consumption in Bangalore can be used to estimate the total consumption of Karnataka's towns and cities (Table 25). For such an estimate, it is necessary to make an assumption regarding the percentage of the households in different classes of cities/towns which use firewood either for water-heating only or for both cooking and water-heating. It seems reasonable to assume that this percentage of firewood consuming households increases as the population of the city/town decreases. Hence it is assumed that all the 17 Class I cities in Karnataka (with a population of 100,000 and above) are like Bangalore and that 45 percent of their households use firewood, and that the corresponding figure is 60 percent in Class II cities with a population of 50,000 to 99,999, 75 percent in Class III cities with population of 20,000 to 49,999, 90 percent in Class IV towns with population of 10,000 to 19,999 and 100 persent in Class V (5000 to 9,999) and Class VI (< 5000) towns. On this basis, and using Bangalore's average daily consumption of 3.63 kg firewood per firewood-using household, Karnataka's cities and towns are estimated to use about 4,710 tonnes of firewood/day in their households. This corresponds to total consumption of about 6,040 tonnes/day if the domestic consumption is 78 per cent of the total as is the case in Bangalore. In other words, the total consumption of firewood in Karnataka's cities and towns can be estimated to 2.2 million tonnes/year.

Thus, Bangalore's firewood consumption is about 20 percent of Karnataka's urban consumption.

4.2 The Forest Department and Control over the Firewood problem

The use of significant quantities of firewood in Bangalore and in other cities and towns of Karnataka has been argued to have four important impacts on the environment and economy :- (1) deforestation, (2) reduction of the capacity of the transport system, (3) diesel consumption, and (4) foreign exchange outflow. All this means that the consumption of firewood is a serious problem, which cannot be ignored because it can only worsen unless it is tackled.

At the outset, therefore, it is worth considering the possibility of control over the supply and/or distribution of firewood. Unfortunately, the present study has shown that the government/public sector has only a marginal control over firewood–the Forest Department is responsible for Karnataka's forests but supplies less than 5 percent of Bangalore's firewood, the Railway transport only about 10 percent of the firewood required by Bangalore, and the Cooperative Societies handle only 5 per cent of the firewood distribution. In contrast, private contractors supply 95 percent of the firewood, truck-owners carry 87 percent of the firewood, and freight and retail depots handle 85 percect of the firewood sales. Thus, except for the growth of firewood for which the responsibilty rests largely with the government (Forest Department), the remainder of the firewood fuel cycle involving the extraction, transport and distribution is mainly in private hands and controlled by the contractor–trucker–retailer nexus. It is also clear that, in the urban context, **firewood is not non-commercial energy**—it is as commercial a form as electricity, oil or coal. In such a situation, it is extremely difficult for the Forest Department to exert any leverage and achieve its objective of rationally managed forests. There appears to be little chance of controlling the situation at the supply-transport-distribution parts of the firewood fuel cycle.

4.3 A Demand–management Approach focussed on End–uses

The chief option therefore seems to involve solutions based on the consumption end of the fuel cycle by highlighting the real origins of the firewood problem.

This task has been simplified by the results on the distribution of firewood consumption over the different categories of consumers from which it is clear that 78 percent of the total firewood is utilized for domestic consumption, and that 82 percent of this firewood is consumed by households where the per capita monthly income is less than Rs. 200 per month. It can also be seen (Table 20) that about 69 percent of the firewood consumed by these households is used for cooking and water-heating. The solution to the problem lies therefore in providing an inexpensive and efficient cooking fuel and/or device for cooking and water-heating to the poorer households in cities and towns. Fortunately, the technological component of this solution can be achieved in several ways.

4.4 Efficient Firewood Stoves for Cooking and Water-heating

The whole question of the efficiencies of firewood stoves used by the overwhelming majority of the country's households has been largely ignored by India's scientists and engineers. Over the past few years, however, there has been an increasing interest in firewood stoves as a crucial part of the concern over rural energy. It rapidly became clear that the problem of increasing the efficiencies of firewood chulas was a non-trivial one and demanded the insights of combustion engineering, heat transfer and furnace design. It now looks[8] as if overall efficiencies as high as 40 percent can be achieved in comparison with the present 5 percent, i.e., only about one-eighth the present input of firewood is required to deliver the same heat energy to the cooking pot. Since about half the firewood used in Bangalore is for cooking, it means that (Table 23) what now requires about 530 tonnes/day can be achieved with 67 tonnes/day.

When the locations at which cooking and water heating are carried out are close together, it is possible to utilize the waste heat from the cooking for heating water. This cascading approach in which the unutilized energy from one task is used for another task is particulary convenient in firewood stoves which can be designed so that on its way to the chimney the wasteheat from cooking section can be used to heat water. This would mean that in households which use firewood for both cooking and water heating, efficient stoves can be installed which accomplish both tasks in a single process.

4.5 Efficient water-heating

Since the cooking of cereals requires the boiling of water, efficient water-heating can be achieved with the same design approach as that used for cooking stoves. In other words, water heating can be achieved with efficiencies as high as 40 percent compared to the percent 5 percent.

4.6 Immediate Reduction of Firewood Consumption

These recent design improvements can lead to substantial reduction in firewood consumption. A rough estimate (Table 23) Indicates that Bangalore's demand of firewood can be brought down to as little as 176 tonnes/day from the present 1250 tonnes/day. Such a reduction requires a large-scale effort to disseminate improved firewood stoves and water heaters. One way of achieving this objective is to mass produce and market perhaps at subsidized prices entire stoves or at least those critical parts of stoves which require rigid adherence to dimensions.

Flat-plate collectors of solar energy can also play a role in reducing the usage of of firewood for water-heating. But, the metallic solar water-heaters are in the same first-cost bracket as electrical water heaters, which means that they will be accessible mainly to households with monthly incomes of above Rs. 500/-. If the potential for solar energy for heating is to be taken advantage of, it is esential that their first cost is brought into the Rs. 25-50 range. Perhaps the only way this can be achieved is by the use of black plastic water-pillows which act both as collectors and water tanks.[9]

4.7 Longer-term measures : Green belts and Sludge/Producer Gas

If high-efficiency firewood – based cook-stoves and/or water heaters and solar water heaters are introduced, the demand for firewood may be drastically reduced, but not eliminated. In the case of Bangalore, the introduction of these devices has been estimated to lead to a demand of about 176 tonnes/day with solar water-heaters. This reduced demand must be sought to be met from energy forests managed in the renewable mode so that the extraction rate is matched to the growth rate.

There are several species of fast-growing firewood crops which are excellent candidates for such energy forests. Their yields vary, but a figure of 10 tonnes/ha/year can be assumed for the present discussion, This figure implies that a reduced demand of 176 tonnes/day or 64,240 tonnes/year requires an energy forest of 6,434 ha or 64.24 km^2 to supply Bangalore with firewood in a sustained renewable manner.

Obviously, if the aim is to reduce diesel consumption for transporting firewood to Bangalore, it would be rational to locate the energy forest as close to Bangalore as possible. One approach is to grow a forest belt around Bangalore's circumference. Using the proposed metropolitan area of Bangalore of 321 km^2, which assuming a circular city, corresponds to a circumference of about 63.5 km, the width of belt turns out to be about 1.0 km. Thus, a 1.0 km wide belt around Bangalore's proposed metropolitan area would provide its requirements of firewood in a sustainable manner.

Such forest belts around Bangalore and other cities would eliminate the four negative impacts of the present pattern of firewood consumption, *viz.*, deforestation, reduction of the capacity of the transport system, diesel consumption, and foreign exchange outflow. If, however, the firewood from these forest belts is used directly in stoves and/or water-heaters, one major socio-economic problem will persist; different sections of society will continue to use different fuels, the rich will use LPG for cooking and the poor firewood, albeit with improved stoves. There is a sound technical reason for the preference of the rich - gas cooking is far more convenient in the matter of quick lighting of the fuel and of ease in turning-down (or up) the heat output. It may be necessary at that stage to replace the direct supply of firewood from the forest belt with the gasification of wood to generate producer gas which can then be piped to homes. If such a piping system is installed, the producer gas can be supplemented with methane-rich biogas obtained from the treatment of the city's sewage*[10].

5. Conclusions

The quantity of firewood used in Bangalore is not only considerable, but it is associated with major environmental impacts and transport, energy and foreign exchange costs. Further, there is every likelihood that the requirements of firewood will grow substantially when even the present pattern of usage of this fuel is unsustainable. The point is that firewood is a biomass resource, but it is being extracted in a non-renewable manner. The origins of the problem lie in the fact that the bulk of the firewood is consumed in the poorest households for cooking and water-heating.

All this constitutes further illustration of a well-known phenomenon [11]: economic inequalities result in negative environmental impacts at both ends of the income spectrum–the rich degrade the environment through a wasteful and irrational use of resources, and the poor through the necessity of having to survive at the expense of the environment. In the case of Bangalore's firewood consumption, the prices of other fuels/energy carriers are much higher than firewood (Table 26) and therefore the poor have no alternative to firewood for cooking and water-heating. Also, they cannot gather firewood as their counterparts do in villages. It is this predicament of the poor which has been exploited by the private contractor-trucker-retailer nexus. But, the major social cost of this private enterprise is environmental degradation in the form of deforestation.

The use of firewood in Bangalore also illustrates another principle [12]: Energy consumption in an income-stratified society is far higher than would be the case in an egalitarian system. This is because of the inefficiency with which energy is used by the poorest sections in contrast to the efficient fuels/devices used by the rich. In the case of cooking for example, the efficiency of firewood stoves used by the poor is only about one-fifth that of the LPG stoves in the homes of the affluent. Thus, the over-all energy consumption for cooking in Bangalore's households would be much less if there are efficiency improvements in the cooking fuels/devices used by its poor.

In addition, the transport of firewood for Bangalore is also associated with the consumption of a high-quality petroleum-based fuel, *viz.*, diesel, and an expenditure of foreign exchange on account of oil imports.

**Unfortunately, this sewage gas cannot meet all the cooking energy requirements of the city – the quantity of sewage gas on a per capita basis can only meet about 20 percent of the per capita requirement of gas for cooking.*

Thus, there are heavy social costs arising from Bangalore's poor having no alternative to firewood for cooking and water-heating. Even this firewood is indirectly subsidized through the subsidy on diesel prices* and through the cost of firewood only including the costs of extracting, transporting, distributing and retailing firewood but not the cost of growing trees. Despite these hidden subsidies, the poorest sections of Bangalore have to spend as much as 17 percent of their income on firewood. If the subsidies are removed as an isolated measure unaccompanied by other positive measures to provide fuel to the poor, it is obvious that their hardship will increase even more. Thus, the simple "remove-the-subsidies and-get-the prices-right" approach of agencies like the World Bank will seriously aggravate the sufferings of the poor.

The only viable alternative is to assign the highest priority to satisfying the energy needs of the poor, in particular their need for inexpensive fuels/devices for cooking and water-heating. Fortunately, the technical means of achieving this objective are available; what are necessary are the political will and the implementation machinery to provide the poor with inexpensive fuels/devices for cooking and water-heating. Only then can the environmental degradation, tying-up of transport capacity, unnecessary consumption of high-quality diesel fuel and foreign exchange expenditure be avoided. Firewood in Bangalore is therefore one more illustration of the fact that the root cause of society's problems is the existence of grave economic inequalities–hence, the solution to these problems consists of measures to satisfy basic needs and remove these inequalities.

ACKNOWLEDGEMENTS

A study of this type would have been impossible to execute without the co-operation and interest of a large number of officials. The authors would like to express their gratitude to all these individuals, and in particular, to the following persons:

1 Sri S. Shyamsunder, I.F.S., Chief Conservator of Forests (Gen),
2 Sri B. K. Jagadish Chandra, I.F.S., Conservator of Forests.
3 Sri B. Natarajan, I.F.C., Deputy Conservator of Forests,
4 Sri Ram Prakash, Silviculturist, Central Zone.,
5 Sri M. Deve Gowda, Range Officer, Forest Mobile Squad,
6 Sri M. N. Seshagiri Rao and Sri S. Jagannath, Senior Clerks, Aranya Bhavan,
7 Sri S. Ramanadha Chetty, Research Officer, Special Studies Division, Planning Department, Bureau of Economics and Statistics, Government of Karnataka,
8 Dr. V. J. Victor, Assistant Director, Indian Plywood Industries Research Institute, Bangalore,

**This subsidy is indicated by the fact that diesel prices are not on par with petrol prices–as is the case in industrialized countries – but are lowered to the price of kerosene.*

9 Sri B. N. Betkerur, Labour Commissioner, Government of Karnataka,

10 Sri N. Raghurama Reddy, Headquarters Assistant to Joint Director, Food and Civil Supplies Department, Goverment of Karnataka,

11 Sri K. M. Chandrasekhar Rao, Foreman (Diesel), Southern Railway,

12 Sri M. S. Sripada Rao, Sri Satyanarayana and Sri Vasudevaiah, Clerks, Railway Goods' Shed,

13 Sri Venkatarangappa, Weigh-bridge Owner,

14 Sri Chennakesava, Corporation Weigh-bridge Manager,

15 Sri M. Bhaskar, President, Firewood and Charcoal Co-operative Society,

16 Ms. T. R. Hemavathi, Research Assistant, Forest Research Laboratory,

17 Sri K. Rajanikanth, School of Automation, Indian Institute of Science,

18 Sri K. V. J. Rao, Scientific officer, Mechanical Engineering Department, Indian Institute of Science.

REFERENCES

1 Anon (1974): "Report of the Fuel Policy Committee," Planning Commission, Governtment of India

2 Anon (1978): "Survey of Rural Energy Consumption in Northern India," National Council of Applied Economic Reseach.

3 ASTRA (1982): "Rural Energy Consumption Patterns—A Field Study," *Biomass, vol.* 2, *No.* 4 (1982) 255

4 Sumithra, G (1981): "Analysis of 1977–78 National Sample Survey on Household Energy Consumption (32nd Round)–Karnataka". Perspective Planning Division, Planning Department, Government of Karnataka.

5 Prakasarao, V.L.S., and Tewari. V.K., (1979): "The Structure of an Indian Metropolis – A Study of Bangalore," Allied Publishers, New Delhi.

6 Bhat, R. G., Director, Bureau of Economics and Statistics, Government of Karnataka (Private Communication).

7 Anon (1979): "Report of the Working Group on Energy Policy", Planning Commission, Governmet of India.

8 Kumar, R., Lokras, S. S., Jagadish, K. S., and Sudhakar Babu, D. S. (1982) (Private communication).

9 Reddy, A.K.N., and Krishna Prasad, K (1977): "Techonological Alternatives and the Indian Energy Crisis," *Economic and Political Weekly.* XII, pp. 1965–1402.

10 Reddy, A.K.N., (1980) : "Alternative Energy Policies for Developing Countries: A Case Study of India," p. 289–351 in World Energy Production and Productivity (eds.) Bohm, R. A Clinard, L. A., and English, M. R., Ballinger Publishing Co., Cambridge (Mass) USA.

11 Reddy, A. K. N., (1979) : "Technology, Development and the Environment – a Re-appraisal,'' United National Environment Programme, Nairobi.

12 Goldemberg, J (1982), : "Energy Issues and Policies in Brazil," Annual Review of Energy, Vol. 7.

PART II: CHARCOAL**

1. Introduction

The present paper is part of a series devoted to understanding the sources, supply, transport, distribution and consumption of Bangalore's energy. Whereas the previous part dealt with firewood, the treatment here is devoted to the energy carrier, **charcoal**. These two studies – it is hoped – will present a picture of Bangalore's use of and dependence on trees and forests as energy sources.

In the parlance of energy analysis, firewood and charcoal are referred to as "non-commercial energy", though in an urban setting they are marketed commodities. Despite this, these two sources are usually neglected in discussions of energy which are generally confined to electricity and petroleum derivatives. Thus, the studies reported here represent the correction of an imbalance in the analysis of the energy sector of cities.

2. Objectives

The specific objectives of the present study are to understand

(i) the places from where Bangalore's charcoal supply comes,

(ii) the transportation mode (s) utilized by the supply,

(iii) the magnitude of charcoal transported,

(iv) the suppliers and distributors of charcoal and the quantities handled by each type of supplier/distributor,

(v) the various categories of consumers, the consumption by each category and the end uses of charcoal, and

(vi) the implications of Bangalore's charcoal consumption with regard to the environment, transport system, etc.

3. Results

3.1 Production of Charcoal

Charcoal is obtained when wood is heated out of contact with air to temperatures of about 400°C. Almost all species of wood can be carbonized to give charcoal, but it requires mature dense wood to produce good charcoal. In contrast, rotten and old wood gives a light product, and stems and branches yield soft bulky charcoal.

Charcoal can be produced in distillation plants where byproducts such as woodgas, methanol, acetic acid and woodtar are recovered in addition to charcoal. But, it can also be produced in simple kilns made of metal, brick-work or even earthwork.

The charcoal that is supplied to Bangalore is produced by traditional methods in either above-ground **stack** kilns or underground pit **kilns**. For both these types of klins, a layer of vegetation (grass or leafy branches) and earth inhibits the air infiltration into the kiln. Details regarding the construction and operation of these traditional kilns are given in Appendix 1.

3.2 Species used for Charcoal Production

Table 27 provides a list of species that are being used to produce the charcoal being supplied to Bangalore. It appears that the species Prosopis juliflora is the predominant source accounting for about one-fourth of the total charcoal supply.

3.3 Sources of Bangalore's Charcoal

Charcoal is supplied to Bangalore not only from locations within the state but also from areas in TamilNadu and Andhra Pradesh (Fig 11). Table 28 lists the locations from where charcoal is supplied, their distances from Bangalore and their contributions to the total supply. It is seen that about half of Bangalore's charcoal comes from Andhra Pradesh and about 70% from distances of over 220 kms.

3.4 Charcoal Suppliers

The suppliers of charcoal are of two categories:

(i) **manufacturers** of charcoal who make supplies to the distributors in Bangalore;

(ii) **contractors** who purchase charcoal from the manufacturers and supply it to the distributors.

3.5 Transportation Mode

Trucks are the only transportation mode used for carrying charcoal to Bangalore. Charcoal is filled in bags and loaded on to trucks. The number of bags transported per trucks is 215 ± 2.

3.6 Magnitude of Charcoal supplied to Bangalore

A sample of 50 bags was studied to find that a bag contains 33.6 ± 2.3 kgs of charcoal. Using this information and also the monthly quantities of charcoal transported into Bangalore from April 1981 to March 1982, it turns out (Table 29) that a total of 48,441 tonnes of charcoal was brought into Bangalore during that year. This supply involved a monthly transport of 4037 ± 637 tonnes in 574 ± 100 trucks and 122, $117 \pm 19{,}285$ bags, This would correspond to an average daily inflow of 132.7 tonnes of charcoal in about 19 trucks and 4015 bags.

3.7 Distribution of Charcoal

The mechanism of distribution of charcoal is shown in Figure 12. The distribution is through 12 commission agents in Bangalore who receive charcoal from either manufacturers or private contarctors and distribute it to the 376 charcoal depots. They also make direct supplies to industries and to some hotels.

Nearly 75% of the charcoal supplied to Bangalore is through contractors while the direct supplies from manufacturers account for 25%. The commission agents who recive all this charcoal in turn channel 80% of the total inflow to retail depots. They supply the remaining 20% directly to bulk consumers.

3.8 Charcoal Consumption in Bangalore

3.8.1 Categories of Consumers

The consumers of charcoal in Bangalore can be classified into the following ten categories: (1) households, (2) hotels, (3) industries, (4) coffee-and tea-stalls, (5) sweet-stalls, (6) laundries, (7) Karnataka Electricity Board, (8) choultries, (9) blacksmiths, and (10) gold-and silver-smiths.

3.8.2 Domestic Consumption in a 1000-Household Sample

A sample survey was conducted to study charcoal consumption in Bangalore's households, and in particular, to obtain an idea of the percentage of households that are using charcoal, the average consumption per household, and the dependence of this consumption upon the per capita monthly income of the household. The sample consisted of 1000 households with 250 households selected from each of the suburbs: Malleswaram, Mathikere, Rajajinagar and Yeswanthpur, located in the northern and north-western parts of Bangalore.

The overall results of the survey are presented in Table 30 from which it can be seen that 106 households, i.e., 10.6% of the sample, use charcoal either wholly, or partially along with another fuel. Of these 106 households, 28.3% depend wholly on charcoal and use it for both cooking and water-heating, in contrast to 42.5% who depend on charcoal for cooking only, and 29.2%, for water-heating only.

The table also shows that there is a clear-cut income-dependence in charcoal consumption. The percentage of households (in a particular income range) that use charcoal either wholly or partially varies with income range (Figure 13). In particular, the percentage of households using charcoal seems to rise slightly with income and then decline sharply. In other words, charcoal consumption seems to be based towards the middle-income groups rather than the poorest or richest sections.

The income-dependence of charcoal consumption can be brought out in two other ways. Firstly, the total charcoal dependence index (TCDI) for an income category can be defined thus:

$$\text{TCDI} = \frac{\text{Percentage of totally charcoal-using HH in the income category}}{\text{Percentage of all sample HH which belong to the income category}}$$

A TCDI of unity means that the percentage of households totally depending on charcoal for both cooking and water-heating in a particular income category is exactly the same as the category's percentage in the sample [of course, this index can be avoided by choosing the same number of households from each income group.] A TCDI of greater then unity shows that the income groups bears a greater burden of dependence than warranted by its percentage in the sample. The TCDI's for various income groups are prsented in Table 31 from which it is seen that it is the households with a per capita monthly income of less than Rs. 200 which bear a greater burden of charcoal consumption than their percentage in the sample. Incidentally, these households which constitute 42.8% of the sample of 1000 households account for 73.3% (*i.e.*, almost three-quarters) of the households which are totally dependent on charcoal.

The TCDI decreases with an increase in income according to the regression equation.

TCDI = 2.2151 – 0.0054 (Mid point of PCMI range) with the coefficient of correlation being r = 0.9491.

Another way of showing the income dependence of charcoal consumption is by drawing the Lorenz curve(cumulative percentage of charcoal-using HH *vs* cumulative percentage of households) and observing the departure of the curve from the straight line representing equal distribution of the charcoal burden. The Lorenz curve (Figure 14) shows the greater concentration of totally charcoal–dependent households amongst the low–and middle-income groups.

Thus far, the description has been restricted to the number (and percentage) of charcoal-using households. When the charcoal quantities are considered, the results are as shown in Table 32. Firstly, it is seen that the sum of the average per capita annual charcoal consumption (kgs/year/capita) for cooking only and for water-heating only, *viz*, 100.3 and 78.2 kgs/year/capita respectively, are equal (to within 2.8%) to the corresponding figure i.e., 173.7 kgs/year/capita, for cooking plus water – heating. This suggests – as has been observed that cooking and water–heating are done in separate devices, and their charcoal consumption is additive. Secondly, there appears a definite increase in per capita charcoal consumption with per capita monthly income The per capita consumption of the richest group is 20–24% higher than in the poorest group. In fact, the per capita charcoal consumption is linearly correlated with the mid-point of the per capita monthly income range, the coefficients of correlation being above 0.97 (Table 33). The reason for this increase in charcoal consumption is not yet clear - perhaps, it is due to increased food consumption with increased income.

The price of a charcoal bag in 1981–82 was Rs. 30–35 depending upon the quality of charcoal. Using a figure of Re. 1 per kg, it is estimated that the percentage of per capita monthly income that would have to be spent on charcoal consumption would **decrease** with an increase in per capita monthly income. That is, the poor would have to spend a greater percentage of their earnings on charcoal. This trend is found irrespective of whether the charcoal consumption is for cooking and water-heating, for cooking only or for water-heating only (Table–34). For example, in the case of charcoal for cooking and water–heating, assuming a mean per capita monthly income group of Rs. 50, the ≤ Rs. 100 income group would have to spend as much as 25.6% of their monthly income on charcoal compared to only 4.0 % for those with a per capita monthly income of ≥ Rs. 400.

The survey has also shown (Tables 35–38) that the pattern of charcoal consumption is not the same in the four suburbs : Malleswaram, Mathikere, Rajajinagar and Yeswanthpur. For example, only 4.7% of the Mathikere households with a per capita monthly income of less than Rs. 200 use charcoal, in contrast to 64.7% of the Rajajinagar households belonging to the **same** income group. Whether this is an effect of the social environment has to be established. It is clear, however, that the income distributions are quite different in the four areas (Figure–15)–Mathikere is obviously the poorest area and Rajajinagar, the richest suburb.

3.8.3 Domestic Charcoal Consumption in Bangalore

The extrapolation of the results obtained from the 1000–household sample to the city of Bangalore can be achieved in the following way. Firstly, it can be assumed that the 1000–household sample represents the whole city with regard to the **percentages** of households in any income range using (a) only charcoal for both cooking and water-heating, (b) charcoal only for cooking and (c) charcoal for water-heating only. Secondly, the per capita charcoal **consumption norms** observed in the sample are considered to be valid for Bangalore. Thirdly, it is conceded that the income distribution for the 1000–household sample may not be representative of Bangalore. Hence, as has been done in the work by the present authors on firewood consumption in Bangalore (cf. Part I), the excellent study of Prakasarao and Tewari on the economic structure of Bangalore has been used as a basis. This study yielded the 1973–74 picture of the percentages of households in various income groups of per capita monthly income, but these percentages have been updated* to allow for increases of income since 1973. As emphasised in the previous paper on firewood, this procedure assumed that the income distribution in Bangalore has not changed over the past decade. This is unlikely but, in the absence of data on the changes, the procedure used here is tantamount to considering distributional changes to be small enough to warrant neglect in the first approximation.

It turns out (Tables 39, 40 and 41) that Bangalore's charcoal consumption is estimated to be 17,999 tonnes per year for households which use only charcoal for both cooking and water–heating, 13,562 tonnes per year for households which use charcoal for cooking only and 7,070 tonnes per year for households which utilize charcoal for water–heating only. This adds up to a total of 38,631 tonnes per year which would correspond to an average daily consumption of about 105.8 tonnes of charcoal for the domestic sector.

The contributions of different income groups to Bangalore's domestic charcoal consumption is shown in Table 42. It is seen that households with a per capita income of less than Rs. 200 per month which constitute about 60% of Bangalore's households, are estimated to consume about two–thirds of its charcoal consumption. Hence, charcoal consumption appears to be shared in a reasonably egalitarian manner, but for the fact that groups with a per capita monthly income greater than about Rs. 300 use a smaller share than would be indicated by their share of the population.

**The updating has involved multiplication by the factor of 1.948 taken from the Bureau of Economics and Statistics.*

3.8.4 Hotels

There were (at the time of the survey) 1082 vegetarian hotels (58%) in Bangalore in contrast to the number of non–vegetarian hotels which was 787 (42%). A sample survey conducted on 5% of the total number of hotels showed that 60% of the non–vegetarian hotels used charcoal at an average consumption rate of about 30 Kg per day. In the case of vegetarian hotels, only 25% of them used charcoal and with an average consumption of 20 Kg per day. Hence, the daily consumption of charcoal by Bangalore's hotels can be taken as

$(1082 \times 0.25 \times 0.02) + (787 \times 0.60 \times 0.03) = 19.6$ tonnes/day.

3.8.5 Industries

(i) Agarbathi Industries : Charcoal powder is used for the preparation of incense sticks in agarbathi manufacturing units of which there are abuot 500 in Bangalore. Each unit consumes on an average about 10 Kg of charcoal per day, which means that the consumption of charcoal by Bangalore's agarbathi units is about 5.1 tonnes/day.

(ii) Bangalore Industrial Gases and Chemical Corporation : This industry consumes about 1.6 tonnes of charcoal per day.

(iii) Grindwel Norton Ltd. This factory consumes an average of one tonne of charcoal per day.

There are other small industries which use charcoal for their boilers; their total consumption will be taken to be a third of the above three categories. Hence, the total consumption of charcoal consumed by Bangalore's Industries can be taken as about 10.0 tonnes/day.

3.8.6 Coffee and Tea-stalls

The numbers of coffee- and tea-stalls in Bangalore were 254 and 495 respectively. A sample survey covering 5% of the total number of Coffee and Tea–Stalls revealed that 25% of the coffee–stalls and 75% of the tea–stalls were using charcoal. The quantity of charcoal consumed per day was about 10 kgs for a coffee stall and 15 kgs. for a tea–stall. Thus, the total consumption of charcoal by Bangalore's coffee and tea–stalls works out to be.

$[(254 \times 0.25 \times 0.01) + (495 \times 0.75 \times 0.015)] = 6.2$ tonnes/day

3.8.7 Sweet-stalls

When a sample survey was conducted covering 5% of the total number of 346 sweet-stalls, it was found that 60% of the stalls used charcoal, with a daily consumption of above 15 kgs per stall. The daily consumption from Bangalore's sweet stalls works out therefore to $(346 \times 0.6 \times 0.015) = 3.15$ tonnes/day.

3.8.8 Laundries

There were about 615 laundries in Bangalore at the time of survey and all of them used charcoal to press clothes. On an average each laundry consumed about 5 kg/day, and therefore, the total quantity of charcoal consumed by laundries comes out to be about 3.1 tonnes/day.

3.8.9 Karnataka Electricity Board

While erecting poles for the transmission/distribution of electricity, the Karnataka Electricity Board digs pits (to receive the poles) and then fills the pits with charcoal (on the average 15kg per pit) for grounding. The number of poles erected and therefore groundings done by the Electricity Board in Bangalore is 3200 per month. The consumption of charcoal for this end–use may therefore be taken as 1.6 tonnes per day.

3.8.10 Choultries

There are 302 choultries in the city where marriages and other functions take place on about 120 auspicious days in a year. During these functions, charcoal is used for making coffee and tea. The total quantity of charcoal that is consumed by the choultries is estimated to be about 5 kg. per choultry per function day, which works to about 181 tonnes per year, *i.e.*, an average of 0.5 tonnes per day.

3.8.11 Blacksmiths

There are about 97 Blacksmiths in Bangalore who use charcoal for their furnaces. Each smith use about 2 kgs. of charcoal in addition to rice–husk and dung cakes. This means that the quality of charcoal consumed by black smith comes out to be about 0.2 tonnes per day.

3.8.12 Gold-and Silver-smiths

About half of the 214 gold-and silver-smiths in Bangalore use charcoal to melt gold-and silver. Their daily consumption is about 1 kg. per smith, resulting in a total charcoal consumption by Bangalore's gold-and silver-smiths of about 0.2 tonnes per day.

3.8.13 Total Charcoal Consumption in Bangalore

If the consumption of the different categories of consumers of charcoal in Bangalore is summed, a figure of about 150.3 tonnes per day is obtained (Table 43). Further, charcoal consumption is obtained by households which account for about 70% of the total and domestic, hotel and industry sectors together constitute 90% of the charcoal used in Bangalore with all the other categories constituting a mere 10%.

3.9 End–Uses of Charcoal Consumption

The consumption of various categories of charcoal consumers can be disaggregated into the following types of end–uses:– (i) cooking, (ii) water–heating, (iii) process heating, and (iv) miscellaneous. Table 44 presents this disaggregation which shows that 58. 1% of the total charcoal goes for cooking, 31. 9% for water–heating, and the remaining 10% for process heat and miscellaneous end–uses such as electrical grounding.

3.10 Comparison of Supply, Transport, Distribution and Consumption of Charcoal

Table 45 presents the average daily quantities of charcoal which have been separately and independently estimated to be supplied, transported, distributed and consumed in Bangalore. The quantities correspond to an average of 142 tonnes per day with a standard deviation of 7 tonnes per day which is 5 percent of the average. The small value of the coefficient of variation bears testimony to the consistency of the estimates regarding different estimates of the fuel cycle.

3.11 Prices of charcoal

The pattern of change in charcoal prices over the past decade is shown in Table 46. The main feature of this pattern is the two main periods of price escalation around 1974 and 1979 which can be ascribed to the two "oil shocks".

4. Discussion

4.1 Impact on Forests

The efficiency of conversion of oven-dry wood into charcoal is about 30% in the type of kilns used to produce Bangalore's charcoal. The average daily charcoal requirement of the city is about 142 tonnes which implies that about 473 tonnes of wood have to be carbonized every day to meet Bangalore's charcoal requirements. Assuming a liberal estimate of about 120 tonnes of wood per hectare of cleared forest, it seems that about 4 hectares of forest would have to be cleared each day to keep Bangalore supplied with its charcoal demand.

4.2 Impact on the Transport System

The transport of charcoal is carried out entirely with trucks. On the average, about 19 trucks per day, i.e., about 3% of the 630 trucks bringing freight into Bangalore, are involved in this transport.

4.3 Energy Cost of Charcoal Supply

As was done in the case of firewood, it is of interest to estimate the energy expenditures associated with the supply of charcoal to Bangalore. This estimation is presented in Table 47 which shows that 1.289 tonnes or 1.511 kiloliters of diesel have to be used every day to transport Bangalore's charcoal. This corresponds to an annual requirement of about 470 tonnes of diesel.

Further, the energy content of the average daily consumption of 1.511 kilolitre of diesel is 16.1×10^6kcal per day on the basis of 10,670 kcal per litre. This expenditure of energy leads to the supply of 142 tonnes of charcoal which have an energy content of 965.6×10^6 kcal taking the calorific value of charcoal as 6800 kcal per kg. But, not all this energy which is released upon the combustion of charcoal is utilized for the desired end-use, *e.g.*, cooking. Assuming 15 percent thermal efficiency of the end-use devices, the energy delivered by charcoal combustion is 144.8×10^6 kcal per day in comparison with 16.1×10^6 kcal per day of diesel energy used to supply the charcoal

In other words, to deliver 100 units of energy through the combustion of charcoal about 11 units of energy in the form of diesel are being expended.

4.4 Foreign Exchange Costs

The annual consumption of 0.55 million litres of diesel corresponds at a rate of Rs 2.42 per litre of diesel to Rs. 1.34 millions, two-thirds of which may be considered to be in the form of foreign exchange for diesel imports. That is, the annual foreign exchange expenditure on diesel for charcoal transport may be taken as about $90,000.

4.5 A Projection of Bangalore's Charcoal Requirement

If the present trend of Bangalore's population growth is graphically extrapolated, the result is an estimated population of 4.4million in1991. On a proportionate basis, this projected population would require 208 tonnes per day of charcoal which in turn corresponds to the deforestation of 5.8 hectres of forest, an inflow of 27 trucks per pay and a diesel consumption of 0.81 million litres per year.

5. Conclusions

A comparison of the main features of charcoal and firewood consumption is given in Table 48. By considering the main impacts of Bangalore's Charcoal Consumption of its population and on the environment, transport system and diesel requirement,it can be concluded that Bangalore's use of charcoal is a smaller problem than the dependence on firewood. But, it is neither a very much smaller nor an insignificant problem. Further, the fact that charcoal is a more egalitarian fuel than firewood means that the charcoal problem can be given a lower priority than the firewood issue. Charcoal is used roughly for the same end-uses as firewood, *viz.*, cooking and water-heating. Actually, charcoal is, compared with firewood, used more for cooking than for water-heating. Hence, the charcoal problem has to be tackled on the same lines as firewood, that is, attention has to be focused on more efficient end-use devices for cooking and water-heating and/or alternative fuels. In addition, it is important to achieve charcoal production with better efficiencies and with collection/utilization of the volatile by-products.

TABLE 1

List and Distribution of Firewood Species commonly used in Bangalore

Sl. No.	Botanical Name	Trade Name	Local Name	Percent
1	Casuarina equisetifolia	Casuarina	Survey	30
2	Adina cardifolia	Haldu	Yettiga	15
3	Pterocarpus marsupium	Bijasal	Honne	
4	Terminalia alata	Laurel	Mathi	
5	Xylia xylocarpa	Irul	Jambe	
6	Pongamia pinnate	Glabra	Honge	12.5
7	Tamarindus indica	Tamarindus	Hunse	12.5
8	Coffea arabica	Coffee	Coffee	10
9	Melia azedarach	Persian Lilac	Bevu	
10	Terminalia paniculata	Kindal	Hulve	
11	Acacia arabica	Babul	Jali	5
12	Anogeissus latifolia	Axlewood	Dinduga	5
13	Eucalyptus globulus	Eucalyptus	Nilagiri	5
14	Ficus bengalensis	Banyan	Ala	5

TABLE 2

Quantities of Firewood (in Tonnes) Supplied by the Forest Department and Private Contractors

Month		Forest Department		Private Contractors	
		1979–80	1980–81	1979–80	1980–81
April	....	2,459	2,913	30,716	29,811
May	....	1,683	1,612	32,416	37,315
June	....	2,877	1,934	32,606	38,986
July	....	2,949	609	34,307	32,831
August	....	1,385	1,325	35,613	37,464
September	....	2,173	2,229	30,193	28,782
October	....	943	1,432	36,234	30,731
November	....	1,826	1,540	29,954	28,645
December	....	263	2,447	33,909	31,935
January	....	3,689	2,770	30,669	27,933
February	....	788	680	31,368	26,103
March	....	—	2,901	35,189	32,351
Tonnes/year	....	21,035	22,392	3,93,174	3,82,887
Tonnes/month	....	1,809$\pm$942		32,336$\pm$3,203	
Tonnes/day	....	59$\pm$31		1,063$\pm$105	

TABLE-3

Monthly Quantities of Firewood (in Tonnes) transported by Railway Wagons and Trucks

Month	Railways		Trucks	
	1979–80	1980–81	1979–80	1980-81
April	3,333	5,293	29,842	27,431
May	2,660	2,992	31,439	35.995
June	3,383	3,153	32,100	37,767
July	3,973	3,622	33,284	29,818
August	3,328	3,050	33,670	35,739
September	3,737	3,128	28,629	27,874
October	3,853	3,284	33,324	28,879
November	3,333	3,518	28,448	26,667
December	3,943	4,333	30,229	30,049
January	5,161	3,391	29,197	27,312
February	3,318	2,359	28,837	24,424
March	4,220	4,649	30,969	30,603
Tonnes/Years	44,242	42,772	369,968	362,558
Tonnes/month	3,626±697		30,552±3,122	
Tonnes/day	119±23		1,003±103	

TABLE 4

Number of Firewood-Loaded Trucks and Quantity of Firewood brought

		Number of trucks/year	Tonnes of Firewood	
			Per Year	Per Day
1979–80				
Weigh-bridge	16 tonne	34,262	278,893	764
	20 tonne	7,825	91,075	250
TOTAL		42,087	369,968	1,014
1980–81				
Weigh-bridge	16 tonne	33,243	270,598	741
	20 tonne	7,901	91,960	252
TOTAL		41,144	362,558	993
Annual Average				
Weigh-bridge	16 tonne	33,753	274,745	753
	20 tonne	7,863	91,518	251
TOTAL/YEAR		41,616	366,263	1,004
TOTAL/DAY		114		

TABLE–5

Number of Firewood–Loaded Railway Wagons and Quantity of Firewood brought into Bangalore

	Number of Wagons	Tonnes of Firewood	
		Per Year	Per Day
1979–80			
Southern Railway	1,762	21,035	58
South–Central Railway	2,018	23,207	64
TOTAL	3,780	44,242	122
1980–81			
Southern Railway	1,875	22,383	61
South–Central Railway	1,775	20,389	56
TOTAL	3,650	42,772	117
Annual Average			
Southern Railway	1,819	21,709	59
South–Central Railway	1,897	21,798	60
TOTAL	3,716	43,507	119

TABLE–6

Quantities handled by Different Firewood Distribution Channels

Category	Number	Tonnes/Day	%	
Cooperative Societies	23	61	4.9	
Retail Depots–Registered	700	700	56.6	85.2
Retail Depots–Unregistered	700	353	28.6	
Direct Sales/Purchases	15 trucks	122	9.9	
TOTAL		1,236	100	

TABLE-7

Firewood Consumers of Various Categories in Different Parts of Bangalore

	Category	North	South	East	Central	West	North East	TOTAL
1.	Households	193,000	161,229	163,715	76,664	—	—	594,608
2.	**Hostels**							
	a) College and working class	6 (1,370)	22 (2,483)	6 (2,468)	9 (1,452)	— —	— —	43 (7,773)
	b) Schools and Convents	7 (519)	2 (420)	17 (1,721)	5 (519)	— —	— —	31 (3,179)
	c) Aided	14 (1,489)	29 (3,522)	13 (1,619)	32 (5,810)	— —	— —	88 (12,440)
3.	Major Canteens	6 (3,642)	5 (1,037)	13 (12,716)	11 (18,880)	— —	— —	36 (36,275)
4.	Dyeing Factories	21	20	4	92	34	5	176
5.	**Bakeries**							
	a) Registered	219	205	170	183	128	245	1150
	b) Unregistered	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	700
6.	Choultries	52	47	61	58	39	40	297
7.	Soap Factories	5	9	1	12	10	13	50
8.	**Hotels**							
	a) A & B Grade	105	89	127	110	153	75	659
	b) C & D Grade	210	108	295	161	332	104	1210

Figures in brackets refer to numbers of individuals using institution/facility.

TABLE–8

Distribution of Households in Survey Sample according to Income and Fuels used for Cooking and Water-heating

Household Income (Rs.)	No. & % of Households using particular Fuels			TOTAL
	C – FW WH – FW	C – K/LPG WH – FW	C } Other WH }	
Casual Labourers	89 (80.9)[a] [55.3][b]	12 (10.9) [6.6]	9 (8.2) [1.4]	110 (100.0) [11.0]
< 500	47 (32.6) [29.2]	51 (35.5) [27.7]	46 (31.9) [7.0]	144 (100.0) [14.4]
500–999	20 (6.8) [12.4]	70 (23.9) [38.0]	203 (69.3) [31.0]	293 (100.0) [29.3]
≥ 1000	5 (1.1) [3.1]	51 (11.3) [27.7]	397 (87.6) [60.6]	453 (100.0) [45.3]
TOTAL	161 (16.1) [100]	184 (18.4) [100]	655 (65.5) [100]	1000 (100.0) [100]

a) Figures in round brackets, e.g., (80.9), refer to the percentage contribution of the particular fuel (s) (corresponding to the column) to the **households in that income category.**

b) Figures in square brackets, e.g., [55.3], refer to the percentage contribution of that income category to **all the households using the particular fuel (s) corresponding to the column.**

TABLE–9

Distribution of Households in Survey Sample according to per Capita Monthly Income and Firewood Usage

Per Capita Monthly Income (Rs.)	No. and % of Households using Particular Fuels			Total
	FW for C & WH	FW only for WH	No FW Consumption	
<100	70 (47.3) [43.5]	33 (22.3) [17.7]	45 (30.4) [6.9]	148 (100.0) [14.8]
100–149	54 (31.8) [33.5]	35 (20.6) [18.8]	81 (47.6) [12.4]	170 (100.0) [17.0]
150–199	20 (18.2) [12.4]	26 (23.6) [14.0]	64 (58.2) [9.8]	110 (100.0) [11.0]
200–249	12 (9.9) [7.5]	29 (24.0) [15.6]	80 (66.1) [12.3]	121 (100.0) [12.1]
250–299	3 (2.5) [1.9]	43 (35.5) [23.1]	75 (62.0) [11.5]	121 (100.0) [12.1]
300–349	2 (1.4) [1.2]	20 (14 5) [10.8]	116 (84.1) [17.8]	138 (100.0) [13.8]
≥350	– (0.0) [0.0]	– (0 0) [0.0]	192 (100.0) [29.3]	192 (100.0) [19.2]
TOTAL	161 (16.1) [100]	186 (18.6) [100]	653 (65.3) [100]	1000 (100.0) [100]

TABLE–10

Total Firewood Dependence Indices of Households in Different Ranges of Per Capita Monthly Income

1	2	3	4	5
Per Capita Monthly Income (Rs.)	Mid-point of Income Range	% of HH in the category	% of HH in the category using firewood for C + WH	TEDI (= Column 4 / Column 3)
< 100	50	14.8	43.5	2.94
100–149	125	17.0	33.5	1.97
150–199	175	11.0	12.4	1.13
200–249	225	12.1	7.5	0.62
250–299	275	12.1	1·9	0.16
300–349	325	13.8	1.2	0.09
≥ 350	—	19.2	—	—
TOTAL		100	100	

TABLE–11

Variation of Firewood Usage in Different Areas of Bangalore

Area	No. of HH surveyed	% of HH using FW for C+WH	% of HH with Rs. 100 per capita monthly income
Mathekere	250	47.2	38.0
Yeshwantpur	250	10.4	17.2
Malleswaram	250	4.4	2.4
Rajajinagar	250	2.4	1.6

TABLE 12

Per Capita Monthly Income and Firewood Usage in Mathekere Sample

Per Capita Monthly Income (Rs.)	Sample Households	Households using Firewood			
		For Cooking and Water-heating		For Water-heating only	
	Number (%)	Number	%	Number	%
< 100	95 (38.0%)	58 (49.2%)	61.10	19 (41.3%)	20.0
100—149	91 (36.4%)	43 (36.4%)	47.2	17 (37.0%)	18.7
150—199	25 (10.0%)	11 (9.3%)	44.0	3 (6.5%)	12.0
200—249	11 (4.4%)	4 (3.4%)	36.3	2 (4.3%)	18.1
250—299	13 (5.2%)	1 (0.85%)	7.5	5 (10.9%)	38.4
300—349	10 (4.0%)	1 (0.85%)	10.0 —	— —	— —
≥ 350	5 (2.0%)	— —	— —	— —	— —
TOTAL	250 (100%)	118 (100%)	47.2	46 (100%)	18.4

TABLE 13

Per Capita Monthly Income and Firewood Usage in Yeshwantpur Sample

Per Capita Monthly Income (Rs.)	Sample Households	Households using Firewood			
		For Cooking and Water-heating		For Water-heating only	
	Number (%)	Number	%	Number	%
< 100	43 (17.2%)	9 (34.6%)	21.0	12	28.0
100—149	58 (23.2%)	8 (30.8%)	14.0	11	18.0
150—199	43 (17.2%)	4 (15.4%)	9.3	12	27.9
200—249	46 (18.4%)	3 (11.5%)	15.2	11	23.9
250—299	26 (10.4%)	1 (3.8%)	3.8	7	26.9
300—349	18 (7.2%)	1 (3.8%)	5.5	4	22.2
≥ 350	16 (6.4%)	—	—	—	—
TOTAL	250 (100%)	26 (100%)	10.4	57 (100%)	22.8

TABLE 14

Per Capita Monthly Income and Firewood Usage in Malleswaram Sample

Per Capita Monthly Income (Rs.)	Sample Households	Households using Firewood			
		For Cooking and Water-heating		For Water-heating only	
	Number %	Number	%	Number	%
> 100	6 (2.4%)	2 (18.2%)	33.3	2 (4.2%)	33.3
100—149	18 (7.2%)	2 (18.2%)	11.1	6 (12.5%)	33.3
150—199	32 (12.8%)	3 (27.3%)	9.3	9 (18.8%)	28.1
200—249	46 (18.4%)	3 27.3%)	6.5	8 (16.7%)	17.0
250—299	47 (18.8%)	1 (9.0%)	2.1	12 (25.0%)	25.5
300—349	51 (20.4%)	—	—	11 (22.9%)	21.5
≥ 350	50 (20.0%)	—	—	—	—
TOTAL	250 (100%)	11 (100%)	4.4	48 (100%)	19.2

TABLE–15

Per Capita Monthly Income and Firewood Usage in Rajajinagar Sample

Per Capita Monthly Income (Rs.)	Sample Households	Households using Firewood			
		For Cooking and Water-heating		For Water-heating only	
	Number (%)	Number	%	Number	%
< 100	4 (1.6%)	1 (16.7%)	25.0	—	—
100—149	3 (1.2%)	1 (16.7%)	33.3	1 (2.9%)	33.3
150—199	10 (4.0%)	2 (33.3%)	20.0	2 (5.7%)	20.0
200—249	18 (7.2%)	2 (33.3%)	11.1	8 (22.9%)	44.4
250—299	35 (14.0%)	—	—	19 (54.3%)	54.3
300—349	59 (23.6%)	—	—	5 (14.3%)	8.4
≥ 350	121 (48.4%)	—	—	—	—
TOTAL	250 (100%)	6 (100%)	2.4	35 (100%)	14

TABLE–16

Variation with Per Capita Monthly Income of Firewood Consumption and Expenditure on Firewood of Households (in Sample) using Firewood for both Cooking and Water-heating

Per Capita Monthly Income (Rs.)	Number of households	Number of house holds using FW for C+WH	FWC for C+WH		Expenditure on FW for C+WH (Rs./capita/month)	Expenditure on FW as % income (in brackets)
			Kgs/HH year	Kgs/Capita/year		
< 100	148	70	1713.1	329.4	12.35	17.0 (50)
100–149	168	54	1666.0	351.8	13.19	10·6(125)
150–199	112	20	1675.3	359.7	13.49	7.7(175)
200–249	121	12	1882.5	379.6	14.23	6.3(225)
250–299	120	3	1890.0	391.0	14.66	5.3(275)
300–349	138	2	1878.5	395.5	14.83	4.6(325)
≥ 350	193	—	—	—	—	—
TOTAL	1000	161	1784.2 ±100.5(5.6%)	367.8 ±23.2(6%)	13.79 ±0.87(6.3%)	

TABLE–17

Variation with Per Capita Monthly Income of Firewood Consumption and Expenditure on Firewood of Households (in Sample) using Firewood for Water-heating only

Per Capita Monthly Income (Rs.)	Number of households.	Number of HH using FW only for WH	FWC for Water-heating		Expenditure on FW for WH (Rs./capital/months)	Expenditure on FW as % income (in brackets)
			Kgs/HH/year	Kgs/capita/year		
> 100	148	33	920.2	162.4	6.09	9.4 (50)
100–149	168	35	931.8	164.3	6.16	4.9(125)
150–199	112	28	889.6	168.6	6.32	3.6(175)
200–249	121	29	820.3	177.2	6.64	3.0(225)
250–299	120	39	832.4	188.9	7.08	2.6(275)
300–349	138	17	763.1	193.6	7.26	2.2(325)
≥ 350	193	—	—	—	—	—
TOTAL	1000	181	859.6 ±59.7(6.9%)	175.8 ±11.9(6.7%)	6.59 ±0.45 (6.8%)	

TABLE–18

Firewood Consumption for Cooking and for Water-heating in Households (in Sample) belonging to Various Ranges of Per Capita Monthly Income

Income/ Capita/ month (Rs.)	For Cooking and Water-heating (kgs/year)		For Water-heating only (kgs/year)		For Cooking only (kgs/year)	
	Per HH	Per Capita	Per HH	Per Capita	Per HH	Per Capita
< 100	1713.1	329.4	920.2	162.4 (49.3%)	729.2	167.0 (50.7%)
100–149	1666.0	351.8	931.8	164.3 (46.7%)	734.2	187.5 (53 3%)
150–199	1675.3	359.7	889.5	168.6 (46.9%)	785.7	191.1 (53.1%)
200–249	1882.5	379.6	820.3	177.2 (46.7%)	1062.2	202.4 (53.3%)
250–299	1890.0	391.0	832.4	188.9 (48.3%)	1057.6	202.1 (51,7%)
300–349	1878.5	395.5	763.1	193.6 (49.0%)	1115.4	201.9 (51.0%)
≥ 350	—	—	—	—	—	—
Average	1784.2	367.8	859.6	175.8 (47.8%)	914.2	192,0 (52.2%)
Standard Deviation	±100.5	±23.2	±59.7	±11.9 (± 1.1%)	±166.2	±12.6 (± 1.1%)

TABLE–19

Estimation of Domestic Firewood Consumption in Bangalore

PCMI (1981)	% of HH in range	No. of HH in range	% of HH using FW for C+WH	No. of HH using FW for C+WH	APHFWC* (tonnes/HH/year)	FWC for C+WH (tonnes/day)	% of HH using FW for WH only	No. of HH using FW for WH only	APHFWC (tonnes/HH/year)	FWC for WH only (tonnes/day)
< 100	31.9	189,680	47.3	89,719	1.713	421.1	22.3	42,564	0.920	107.3
100—149	12.7	75,515	31.8	24,014	1.666	109.6	20.6	14,699	0.932	37.5
150—199	15.6	92,759	18.2	16,882	1.675	77.5	23.6	16,559	0.890	40.4
200—249	17.6	104,651	9.9	10,360	1.883	53.4	24.0	22,405	0.820	50.3
250—299	8.6	51,136	2.5	1,278	1.890	6.6	35.5	19,631	0.832	44.7
300—349	10.0	59,461	1.4	832	1.879	4.3	14.5	8,191	0.763	17.1
≥ 350	3.6	21,406	—	—	—	—	—	—	—	—
TOTAL	100	594,608	24.1	143,085		672.5	20.9	124,049		297.3

Total Bangalore Domestic Consumption=672.5+297.3=969.8 Tonnes/day

*APHFWC=Annual Per Household Firewood Consumption

TABLE–20

Distribution of Bangalore's Domestic Firewood Consumption over various Income Groups

PCMI (1981)	Households %	Cum. %	Firewood Consumption C+WH	WH only	Total	(Tonnes/day) %	Cum.%
<100	31.9	31.9	421.1	107.3	528.4	54.5	54.5
100—149	12.7	44.6	109.6	37.5	147.1	15.2	69.7
150—199	15.6	60.2	77.5	40.4	117.9	12.2	81.9
200—249	17.6	77.8	53.4	50.3	103.7	10.7	92.6
250—299	8.6	86.4	6.6	44.7	51.3	5.3	97.9
300—349	10.0	96.4	4.3	17.1	21.4	2.1	100.0
≥350	3.6	100.0	—		—	—	100.0
TOTAL	100.0		672.5	297.3	969.8	100.0	

TABLE–21

Firewood Consumption in Hostels

Type of Hostel	Nature	Number	Inmates	DPCFWC* (Kgs/Cap/day)	FWC tonnes per day
I	For Colleges and working people	43	7,773	1.5	11.7
II	Schools and convents	31	3,179	1.0	3.2
III	Aided institutions	88	12,440	0.75	9.3
	TOTAL	162	23,392		24.2

*DPCFWC=Daily per capita firewood consumption.

TABLE–22

Distribution of Bangalore's Firewood Consumption over various Consumers

Sl. No.	Consumer		Daily Consumption (tonnes/day)	% of Total Consumption	Cumulative %
1	Households	....	970 0	77.5	77.5
2	Dyeing Factories	....	62.0	5.0	82.5
3	Bakeries	....	55.0	4.4	86.9
4	Hotels	....	48.0	3 8	90.7
5	Industries	....	47.5	3 8	94.5
6	Choultries	....	24.0	1.9	96.4
7	Hostels	....	24.0	1.9	98.3
8	Cremation Grounds	....	10.0	0.8	99.1
9	Canteens	....	4.5	0.4	99.5
10	Road Building	....	4.0	0.3	99.8
11	Soap Factories	....	3.0	0.2	100.0
			1,250.0	100.0	

TABLE 23

End-uses of Firewood Consumption in Bangalore

Consumer	Firewood Consumption (Tonnes/day)			
	Total	Cooking	Water heating	Process heat
Households	970 (84)[a]	375 (47)	595 (37)	....
Dyeing Factories	62 (8)	....	62 (8)	....
Bakeries	55 (7)	55 (7)	....	....
Hotels	48 (6)	48 (6)	....	....
Industries	47.5 (47.5)	....	....	47.5 (47.5)
Choultries	24 (3)	24 (3)	....	....
Hostels	24 (3)	24 (3)	....	....
Cremation grounds	10 (10)	....	....	10 (10)
Canteens	4.5 (0.5)	4.5 (0.5)	....	....
Road-building	4 (4)	....	....	(4) (4)
Soap factories	3 (3)	....	....	3 (3)
TOTAL %	1250 100 (176)	530.5 42 (66.5)	657 53 (45)	64.5 5 (64.5)

a : Figures in brackets refer to reduced firewood consumption if efficiency improvements are incorporated – cf. sections 4.4 to 4.6.

TABLE–24

The Supply, Transportation, Distribution and Consumption of Bangalore's Firewood

Aspect	Tonnes/day
Supply	1122
Transportation	1180
Distribution	1236
Consumption	1250
Average & Standard Deviation	1197 ± 51

TABLE–25

Estimate of Karnataka's Urban Firewood Consumption

Type of city/town	No. of cities/ towns	Population	Households (@ 4.9/HH)	% using firewood	Domestic FWC (Tonnes/ day) (@ 3.63 kg/HH/day)
	Bangalore	2,913,537	594,608	45	970
Class I (≥100,000)	17	6,276,732	1,280,966	45	2090
Class II (50,000–99,999)	11	692,067	141,239	60	308
Class III (20,000–49,999)	64	1,901,578	388,077	75	1057
Class IV (10,000–19,999)	100	1,471,483	300,303	90	981
Class V (5,000–9,999)	42	307,999	62,857	100	228
Class VI (<5000)	16	61,750	12,602	100	46
TOTAL*		10,711,609	2,186,044		4710

*Inclusive of Bangalore.

TABLE-26

Comparative costs of Various Fuels/Energy Carriers for Cooking/Water heating

Fuel/Energy Carrier	Units	Unit Price	Calorific content of unit (in GJ[a])	Cost of Primary Energy[b] (Rs/GJ)
Firewood	Kg	Rs. 0.45	0.0167	26.89
Charcoal	Kg	Rs. 1.00	0.0290	34.49
Kerosene	Litre	Rs. 2.00	0,0446	44.80
LPG	Cylinder (15 Kg LPG)	Rs. 53.30	0.7406	71.97
Electricity	KWh	Rs. 0.42[c]	0.0036	116.67[c]
		Rs. 0.20[d]	0.0036	55.56[d]

a : 1 GJ = 10^9J.

b : These costs do not take into account efficiencies of devices, i. e., they are not the costs of delivered energy.

c : Regular electricity charges.

d : Electricity charges for All-electric Homes.

TABLE-27

List of Species that are used for the production of charcoal

Sl. No.	Botanical Name	Trade Name	Local Name	%
1.	Prosopis juliflora	Mesquite	Bellarijali	25
2.	Aegle marmelos	Bel	Bilipatre	
3.	Anogeissus latifolia	Axlewood	Dinduga	
4.	Azadirachta indica	Neem	Bevu	30
5.	Acacia nilotica	Babul	Jali	
6	Acacia leucophloea	Reunjha	Bilijali	
7.	Adina cordifolia	Haldu	Yettiga	
8.	Butea monosperma	Palas	Muttuga	30
9.	Mangifera indica	Mango	Mavu	
10.	Tamarindus indica	Tamarind	Hunase	
11.	Trewia mudiflora	Gutel	Katkambala	
12.	Terminalia alata	Laurel	Mathi	15
13.	Memecylon edule	Anjani		

TABLE 28

Sources of Charcoal Supply to Bangalore and their contributions

Sl. No.	Source	Distance from Bangalore (kms)	Tonnes supplied during 1981-82	% of total supply
1.	Ananthapur	220	17,681	36.5
2.	Chickamagalur	250	15,937	32.9
3.	Dhankina Kota	70	7,751	16.0
4.	Chittoor	180	7,072	14.6

TABLE-29

Quantity of charcoal transported to Bangalore
(April 1981 - March 1982)

Sl. No.	Month	Number		Bags per truck	Tonnes of charcoal per month
		Charcoal bags	Trucks		
1.	April	144,595	676	213.9	4,776
2.	May	148,435	693	214.2	4,907
3.	June	125,495	585	214.5	4,149
4.	July	126,545	597	212.6	4,184
5.	August	122,625	569	215.5	4,053
6.	September	96,750	451	214.5	3,199
7.	October	103,270	478	216.0	3,414
8.	November	92,995	441	210.9	3,074
9.	December	102,960	470	219.0	3,404
10.	January	128,660	597	215.5	4,253
11.	February	119,785	558	214.7	3,960
12.	March	153,290	776	214.0	5,068
13.	Average	112,117	574	214.6	4,037
14.	St. Deviation	19,285	100	1.9	637
15.	Coeff. of variation	17.2%	17.4%	0.9%	15.8%
16.	ANNUAL TOTAL	1,465,405	6,831		48,441 (a)

(a) : 48,441 Tonnes/year 132.7 Tonnes/day

TABLE–30

Per Capita Monthly Income of Households (HH) in Sample and their Pattern of Charcoal Consumption

PCMI (Rs.)	No. of HH	HH using charcoal either wholly or partly		HH using charcoal for both cooking and water heating		HH using charcoal for cooking only		HH using charcoal for water heating only	
		No.	%	No.	%	No.	%	No.	%
< 100	148 [14.8%]	15 [14.1%]	11.4	8 [26.7%]	5.4	4 [8.9%]	2.7	3 [9.7%]	2.0
100–149	170 [17.0%]	23 [21.7%]	12.3	10 [33.3%]	5.9	7 [15.6]	4.1	6 [19.4]	3.5
150–199	110 [11.0%]	17 [16.0%]	15.4	4 [13.3%]	3.6	9 [20.0]	8.2	4 [12.9]	3.6
200–249	121 [12.1%]	19 [17.9%]	15.7	3 [10.0%]	2.5	9 [20.0]	7.4	7 [22.6]	5.8
250–299	120 [12.2%]	16 [15 1%]	13.3	2 [6.7%]	1.7	8 [17.8]	6.7	6 [19.4]	5.0
300–349	138 [13.8%]	10 [9.4%]	7.2	2 [6·7%]	1.4	5 [11.1]	3.6	3 [9.7%]	2.2
≥ 350	193 [19.3%]	6 [5.7%]	3.1	1 [3.3%]	0.5	3 [6.7%]	1.5	2 [6.5%]	1.0
TOTAL	1000	106	10.6	30	28.3*	45	42.5*	31	29.2*

* These percentages are with respect to the 106 charcoal-using households

TABLE–31

The Total Charcoal Dependence Index of Households using Charcoal for both Cooking and Water-heating

PCMI (Rs.)	Mid-point of Income Range	%HH in Income Range	%HH in Income Range totally dependent on charcoal for C+W	TCDI (column 4 ÷ colum 3)
< 100	50	14.8	26 7	1.80
100–149	125	17.0	33.3	1.96
150–199	175	11.0	13.3	1.21
200–249	225	12.1	10.0	0.83
250–299	275	12.0	6.7	0.55
300–349	325	13.8	6.7	0.49
≥ 350	400	19.2	3.3	0.17

TABLE–32

The Dependence of Charcoal Consumption (kgs/year) on Per Capita Monthly Income

PCMI (Rs.)	Mean HH Size	Kgs/year for C+WH		Kgs/year for C only		Kgs/year for WH only	
		Per HH	Per Capita	Per HH	Per Capita	Per HH	Per Capita
< 100	5.3	813.6	153.6	476.4	90.0	368.9	69.6
100—149	4.9	788.4	160.8	470.4	96·0	346.9	70.8
150—199	4.9	829.2	169.2	476.4	97.2	370.4	75.6
200—249	4.4	760.8	172.8	444.0	100.8	343.2	78.0
250—299	4.3	799.2	186.0	453.6	105.6	356.9	83.0
300—349	4.1	747.6	182.4	428.4	104.4	344.4	84.0
≥ 350	3.8	724.8	190.8	414.4	108.0	328.3	86.4
Average	4.5	780.5	173.7	415.9	100.3	351.3	78.2
St. Deviation	0.5	34.7	12.6	22.6	5.8	14.0	6.1
Coeff. of variation	11.1%	4.4%	7.3%	5.0%	5.8%	4.0%	7.8%

TABLE–33

Dependence of Per Capita Charcoal Consumption (PCCC) upon the Mid-point of the PCMI Range

PCCC (kgs/year/capita)	a	b	r
For cooking and water-heating	148.8	0.11	0.9716
For cooking only	88.8	0.05	0.9621
For water-heating only	66.1	00.5	0.9788

TABLE–34

Dependence of Per Capita Monthly Expenditure (PCME) upon Per Capita Monthly Income

		For Cooking and Water-heating		For cooking only		For Water-heating only	
PCMI (Rs.)	Mean PCMI (Rs.)	PCME (a) (Rs.)	% of income	PCME (Rs.)	% of income	PCME (Rs.)	of income
< 100	50	12.80	25.6	7.50	15.0	5.80	11.6
100–149	125	13.40	10.7	8.00	6.4	5.90	4.7
150–199	175	14.10	8.1	8.10	4.6	6.30	.6
200–249	225	14.40	6.4	8.40	3.7	6.50	2.9
250–299	275	15.50	5.6	8.80	3.2	6 90	2.5
300–349	325	15.20	4.7	8.70	2.7	7.00	2.2
≥ 350	400	15.90	4.0	9.00	2.3	7.20	1.8

TABLE–35

Pattern of Charcoal Consumption in the Malleswaram Area

PCMI (Rs.)	No. of HH	No. of HH using charcoal	charcoal for C+WH		Charcoal for C only		Charcoal for WH only	
			No	%	No	%	No	%
< 100	6	4	3	50	....	....	1	16.7
100–149	18	9	2	11.1	4	22.2	3	19.7
150–199	32	6	1	3.1	3	9.4	2	6.3
200–249	46	5	....	....	3	6.5	2	4.3
250–299	47	3	....	....	2	4.3	1	2.1
300–349	51	4	2	3.9	2	3.9	....	....
≥ 350	50	2	....	....	1	2.0	1	2.0
TOTAL	250	33 (13.2%)	8	3.2	15	6.0	10	4.0

TABLE–36

Pattern of Charcoal Consumption in the Mathikere Area

PCMI (Rs.)	No. of HH	No. of HH using Charcoal	charcoal for C+WH		Charcoal for C only		Charcoal for WH only	
			No.	%	No.	%	No.	%
< 100	95	3	3	3.2	—	—	—	—
100—149	91	4	2	2.2	1	1.1	1	1.1
150—199	25	3	—	—	3	12.0	—	—
200—249	11	5	1	9.1	2	18.2	2	18.2
250—299	12	1	1	8.3	—	—	—	—
300—349	10	2	—	—	1	10.0	1	10.0
≥ 350	6	1	1	16.7	—	—	—	—
TOTAL	250	19 (7.6%)	8	3.2	7	2.8	4	1.6

TABLE–37

Pattern of Charcoal Consumption in the Rajajinagar Area

PCMI (Rs.)	No. of HH	No. of HH using Charcoal	charcoal for C+WH		Charcoal for C only		Charcoal for WH only	
			No.	%	No.	%	No.	%
< 100	4	4	2	50.0	1	25.0	1	25.0
100—149	3	3	2	66.7	—	—	1	33.3
150—199	10	4	2	20.0	1	10.0	1	10.0
200—249	18	5	1	5.6	2	11.1	2	11.1
250—299	35	6	1	2.9	3	8.6	2	5.7
300—349	59	2	—	—	1	1.7	1	1.7
≥ 350	121	3	—	—	2	1.7	1	0.8
TOTAL	250	27 (10.8%)	8	3.2	10	4.0	9	3.6

TABLE–38

Pattern of Charcoal Consumption in the Yeshwanthpur Area

PCMI (Rs.)	No. of HH	No. of HH using Charcoal	charcoal for C+WH		Charooal for Conly		Charcoal WH only	
			No.	%	No	%	No	%
< 100	43	6	2	4.7	3	7.0	1	2.3
100—149	58	5	2	3.4	1	1.7	2	3.4
150—199	43	4	1	2.3	2	4.7	1	2.3
200—249	46	4	1	2.2	2	4.3	1	2.2
250—299	26	6	—	—	3	11.5	3	11.5
300—349	18	2	—	—	1	5·6	1	5.6
≥ 350	16	—	—	—	—	—	—	—
TOTAL	250	27 (10.8%)	6	2.4	12	4.8	9	3.6

TABLE–39

Estimation of Domestic Consumption in Bangalore by Households which use only Charcoal for both Cooking and Water-heating

PCMI (Rs.)	% of HH in the range	No. of HH in the range	% of HH using charcoal for C + WH	No. of HH using charcoal for C+WH	Norm for C+WH (tonnes/HH/year)	ACC (C+WH) (tonnes/year)	DCC (C+WH) (tonnes/day)
< 100	31.9	189,680	5.4	10,243	813.6	8333.7	22.8
100—149	12.7	75,515	5.9	4,455	788.4	3512.3	9.6
150—199	15.6	92,759	3.6	3,339	829.2	2768.7	7.6
200—249	17.6	104,651	2.5	2,616	760.8	1990.3	5.4
250—299	8.6	51,136	1.7	869	799.2	694.5	1.9
300—349	10.0	59,461	1.4	832	747.6	622.0	1.7
≥ 350	3.6	21,406	0.5	107	724.8	77.6	0.2
TOTAL		594,608		22,461		17,999	49.2

TABLE–40

Estimation of Domestic Consumption in Bangalore by Households which use Charcoal for Cooking only

PCMI (Rs.)	% of HH in the range	No. of HH in the range	% of HH using charcoal for cooking only	No. of HH using charcoal for cooking only	Norm for cooking (tonnes/ HH/ year)	ACC (C) (tonnes/ year)	DCC(C) (tonnes/ day)
< 100	31.9	189,680	2.7	5,121	476.4	2,439.6	6.7
100–149	12.7	75,515	4.1	3,096	470.4	1,456.4	4.0
150–199	15.6	92,759	8.2	7,606	476.4	3,623.5	9.9
200–249	17.6	104,651	7.4	7,744	444.0	3,438.3	9.4
250–299	8.6	51,136	6.7	3,426	453.6	1,554.0	4.3
300–349	10.0	59,461	3.6	2,141	428.4	917.2	2.5
≥ 350	3.6	21,406	1.5	321	414.4	133.0	0.4
TOTAL		594,608		29,456		13,562	37 2

TABLE–41

Estimation of Domestic Consumption in Bangalore by Households which use Charcoal for Water-heating only

PCMI (Rs.)	% of HH in the range	No. of HH in the range	% of HH using charcoal for WH only	No. of HH using charcoal for WH only	Norm for WH (tonnes/ HH/year)	ACC (WH) (tonnes/ year)	DCC (WH) (tonnes/ day)
< 100	31.9	189,680	2.0	3,794	368.9	1,399.6	3.8
100–149	12.7	75,515	3.5	2,643	346.9	916.9	2.5
150–199	15.6	92,759	3.6	3,339	370.4	1,236.8	3.4
200–249	17.9	104,651	5.8	6,070	343.2	2,083.2	5.7
250–299	8.6	51,136	5.0	2,557	356.9	912.6	2.5
300–349	10.0	59,461	2.2	1,308	344.4	450.4	1.2
≧ 350	3.6	21,406	1.0	214	328.3	70.3	0.2
TOTAL		594,608		19,925		7,070	19.3

TABLE–42

Share of Different Income Groups in the Domestic Consumption of Bangalore's Charcoal

PCMI (Rs.)	% of HH	ACC (Total) (tonnes/year)	% of Consumption
< 100	31.9	12,172.75	31.50
100–149	12.7	5,885.90	15.23
150–199	15.6	7,629.46	19.74
200–249	17.6	7,512.01	19.44
250–299	8.6	3,161.36	8.18
300–349	10.0	1,989.89	5.15
≥ 350	3.6	280,91	0.72
TOTAL	100.0	38,632.30	100.00

TABLE–43

Share of Various Categories of Consumers to Bangalore's Charcoal Consumption

Sl. No.	Category	Average Daily Consumption	
		Tonnes/day	% of Total
1.	Domestic	105.8	70.4
2.	Hotels	19.6	13.0
3.	Industries	10.0	6.7
4.	Coffee- and Tea-stalls	6.2	4.1
5.	Sweet-stalls	3.1	2.1
6.	Laundries	3.1	2.1
7.	Electricity Board	1.6	1.1
8.	Choultries	0.5	0.3
9.	Blacksmiths	0.2	0.1
10.	Gold & Silver-smiths	0.2	0.1
	TOTAL	150.3	100.0

TABLE–44

The Supply, Transport, Distribution and Consumption of Bangalore's Charcoal

Aspect	Average Daily Quantity (Tonnes/day)
Supply	133
Transport	140
Distribution	144
Consumption	150
Average	142
Standard Deviation	7

TABLE–45

End–uses of Charcoal Consumption in Bangalore

Consumer	Cooking	End–use Water-heating	Process Heat	Misc.	Total
Households	64.6 (a)	41.2 (b)	....	....	105.8
Hotels	....	....	....	....	19.6
Industries	....	....	4.9	5.1	10.0
Coffee–& Tea–stalls	....	6.2	....	....	6.2
Sweet-stalls	3.1	....	....	....	3.1
Laundries	....	....	3.1	....	3.1
K.E.B	....	....	....	1.6	1.6
Choultries	....	0.5	....	....	0.5
Blacksmiths	....	....	....	0.2	0.2
Gold–& Silversmiths	....	....	....	0.2	0.2
TOTAL	87.3 (58.1%)	47.9 (31.9%)	8.0 (5.3%)	7.1 (4.7%)	150.3

a) – From Table 15, 0.97 kgs/HH/day for water-heating. ∴ 0.97 × 22461 HH in Table 13=21.8 tonnes/day for water-heating in HH which use only charcoal for cooking and water-heating. ∴ 49.2 – 21.8=27.4 tonnes/day for cooking in these HH+37.2 tonnes/day (Table 14) for cooking in HH which use charcoal only for cooking = 64.6 tonnes/day for cooking,

b) – 19.1 from Table 15+21.8 from (a) = 41.1 tonnes/day for water-heating.

TABLE–46

The Prices* of Charcoal during the period 1972–1982

Month		1972–73	73–74	74–75	75–76	76–77	77–78	78–79	79–80	80–81	81–82
April	Rs.	9.50	12.50	16.00	19.00	22.50	24.00	25.50	26.50	29.00	33.50
May		9.75	12.50	16.50	20.00	22.50	23.50	25.50	27.00	29.00	33.50
June		10.50	13.00	16.50	20.00	23.00	24.00	25.50	27.00	29.00	33.50
July		10.50	13.00	17.00	21.50	23.00	24.50	25.00	27.00	30.50	34.50
August		10.00	14.00	16.50	22.00	23.00	24.50	25.00	27.00	30.00	34.50
September		10.00	13.75	17.00	22.00	23.00	24.50	25.50	27.50	31.00	34.50
October		10.50	13.50	17.00	21.50	23.50	24.50	26.00	27.00	31.50	35.00
November		11.00	14.00	17.25	21.50	23.50	25.00	26.00	27.50	31.50	36.00
December		11.00	14.50	17.50	22.50	23.00	25.00	26.50	27.75	32.00	36.00
January		11.25	15.00	17.50	22.00	23.75	25.00	26.50	29.00	32.00	35.50
February		11.25	15.00	18.00	22.00	23.75	25.25	26.75	29.00	33.00	36.50
March		12.00	16.00	19.00	23.00	23.50	25.50	26.50	29.00	32.00	37.50
AVERAGE		10.60	13.90	17.15	21.40	23.15	24.60	25.85	27.60	31.00	35.00
% increase over previous year			31.1	23.4	24.8	8.2	6.3	5.1	6.8	12.3	12.9

* Price/bag in Rupees

TABLE–47

Energy Costs of Charcoal Supply to Bangalore

Source	% of supply	Tonnes/ day	Distance (kms)	Tonnes-kms/day	Diesel kgs/day	Consump-tion litres/ day *
Ananthapur	36.5	51.8	220	11,396	517	606
Chickamagalur	32.9	46.7	250	11,675	530	621
Dhankina Kota	16.0	22.7	70	1,589	72	85
Chittor	14.6	20.8	180	3,744	170	199
Total	—	142	—	28,404	1,289	1,511

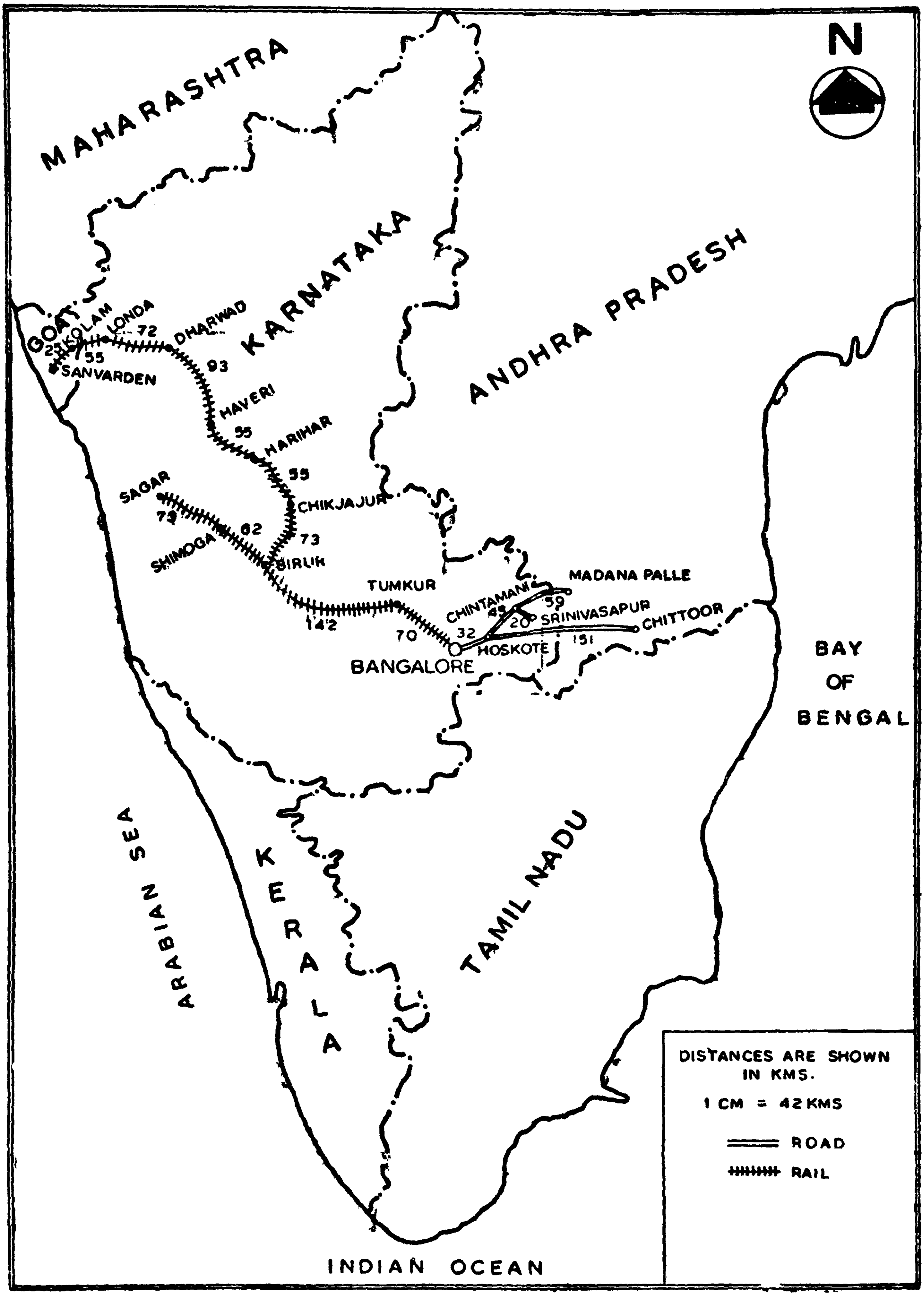
* Norms of 22.04 tonne kms/kg diesel and 18.80 tonne kms/litre of diesel have been used.

TABLE–48

Comparison of Bangalore's Charcoal and Firewood Consumption

Sl. No.	Feature	Unit	Firewood	Charcoal	Charcoal / Firewood (%)
1.	Average daily consumption	tonnes/ day	1,197	142	12
2.	Wood equivalent of average daily consumption	,,	1,197	473	40
3.	% of Bangalore's HH utilizing the source	%	45	12	27
4.	Forest equivalent	ha/day	10	4	40
5.	Diesel requirement	tonnes/ day	5.1	1.3	25
6.	% of source used for cooking	%	42	58	138
7.	% of source used for water heating	%	53	32	60

FIG. 1. FIREWOOD SOURCES AND THEIR DISTANCES FROM BANGALORE



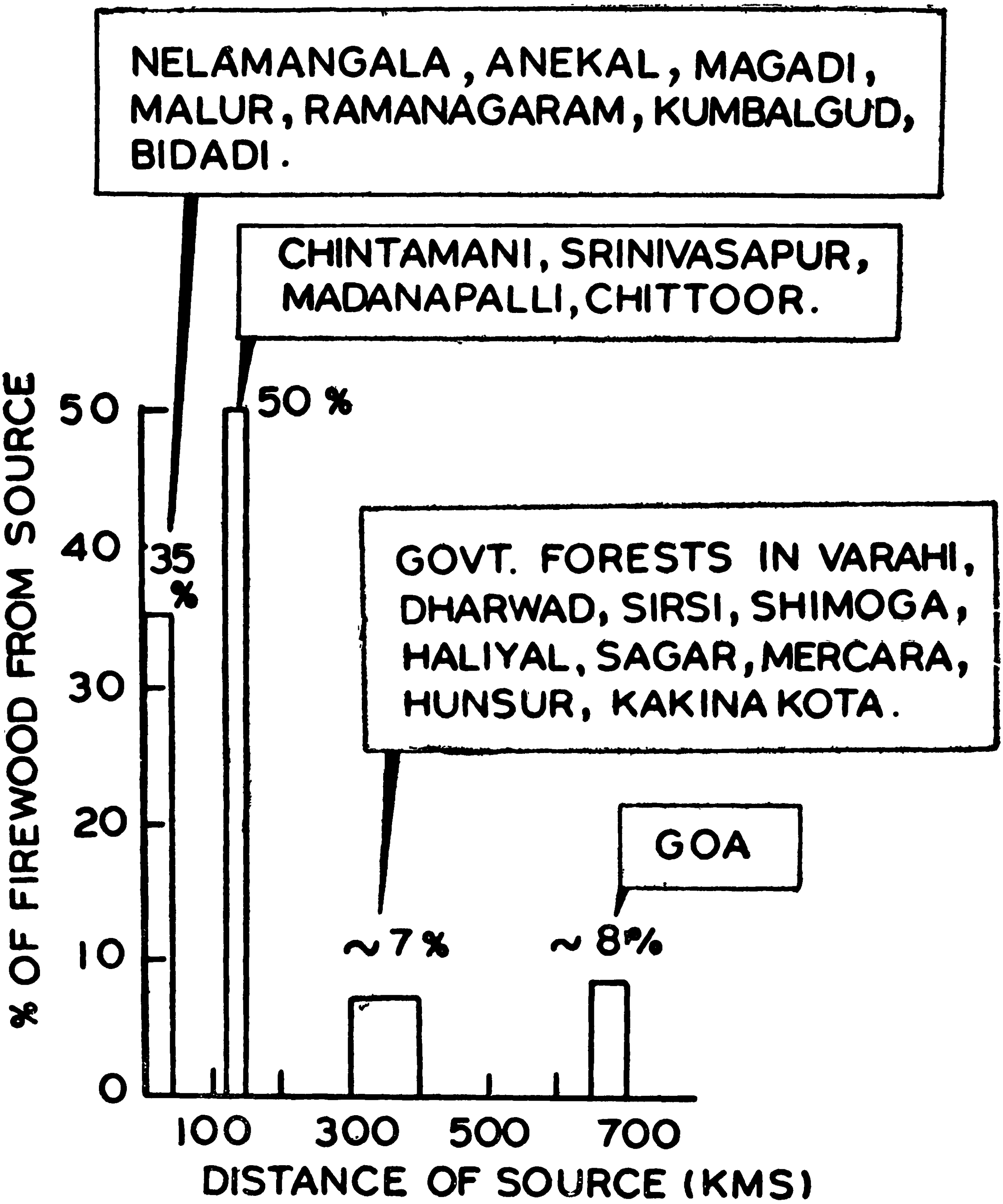


FIG. 2. DISTRIBUTION OF FIREWOOD SUPPLY WITH RESPECT TO DISTANCE OF SOURCE.

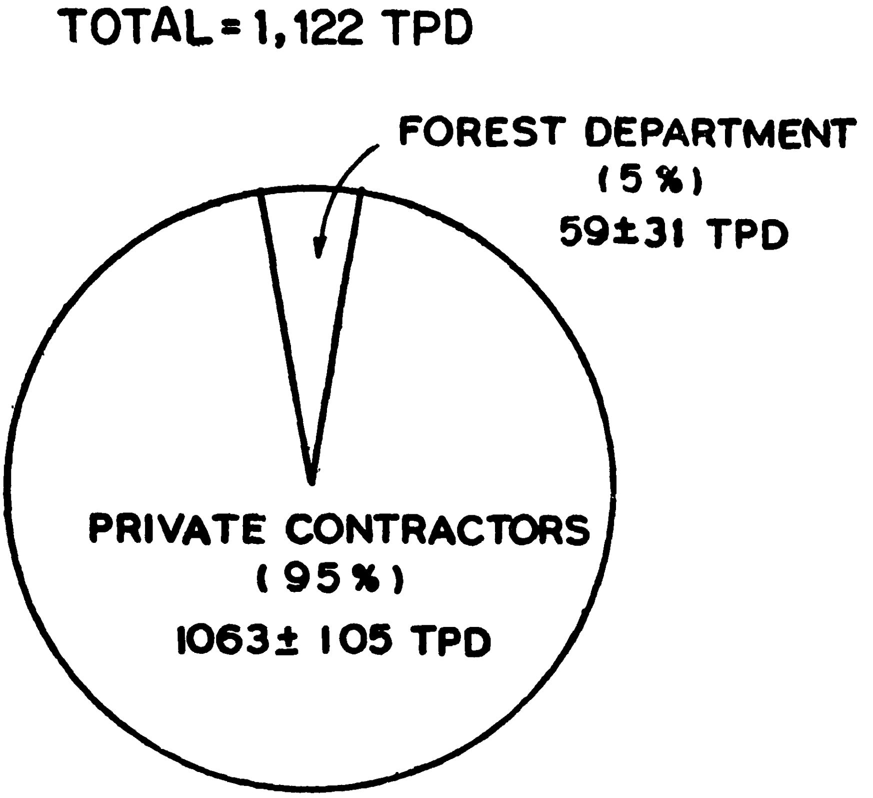


FIG. 3. CONTRIBUTION OF FOREST DEPARTMENT AND PRIVATE CONTRACTORS TO FIREWOOD SUPPLY TO BANGALORE.

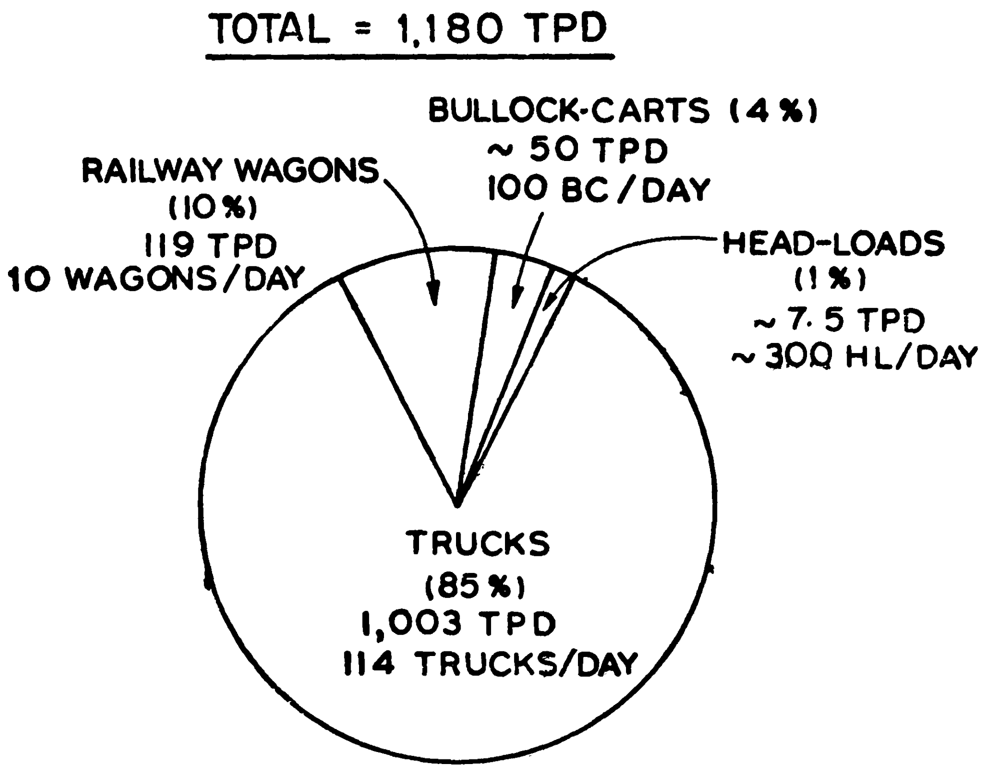


FIG. 4. CONTRIBUTION OF VARIOUS TRANSPORTATION MODES TO TRANSPORT OF FIREWOOD TO BANGALORE

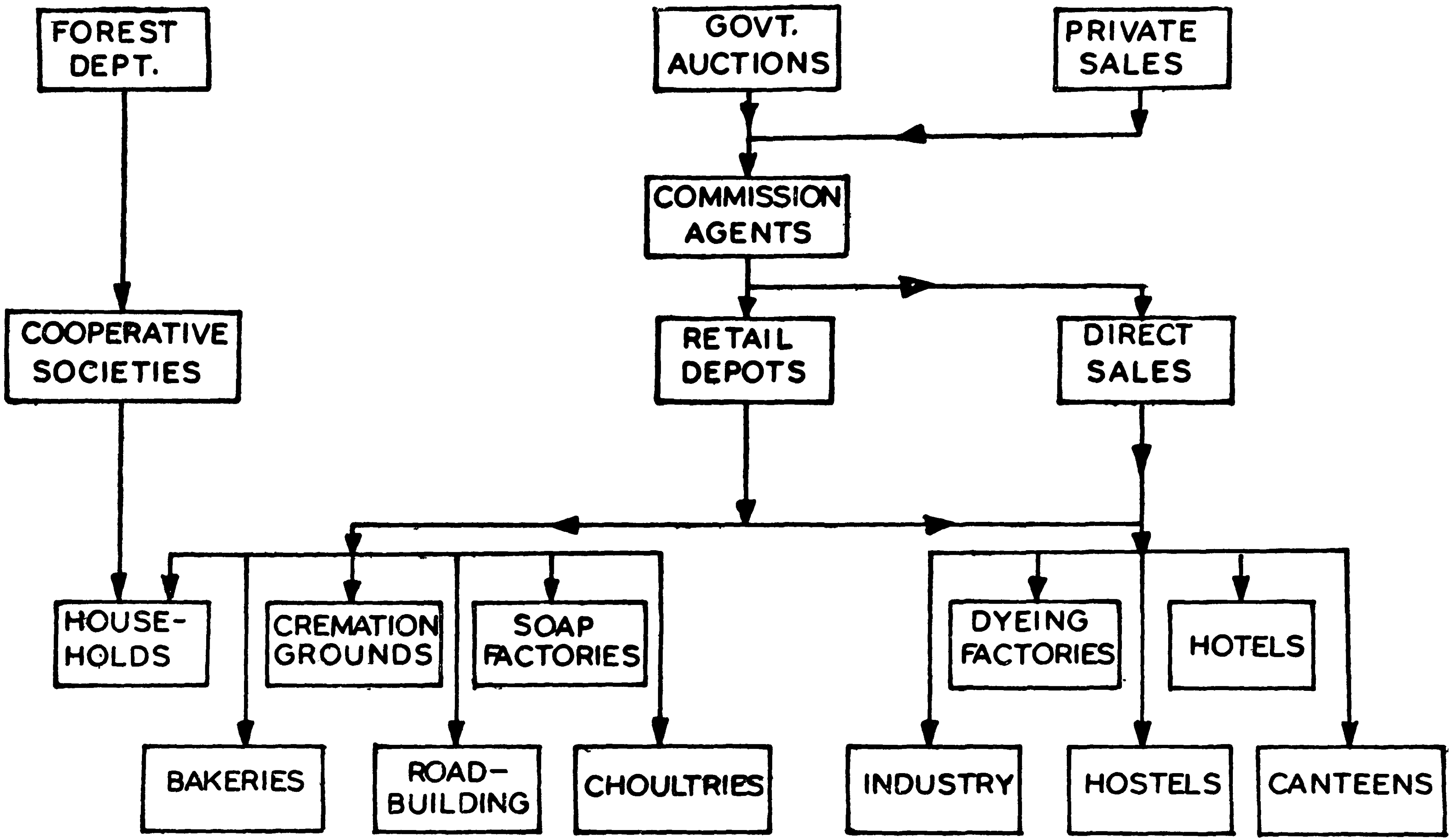


FIG. 5. CHANNELS OF DISTRIBUTION OF FIREWOOD IN BANGALORE

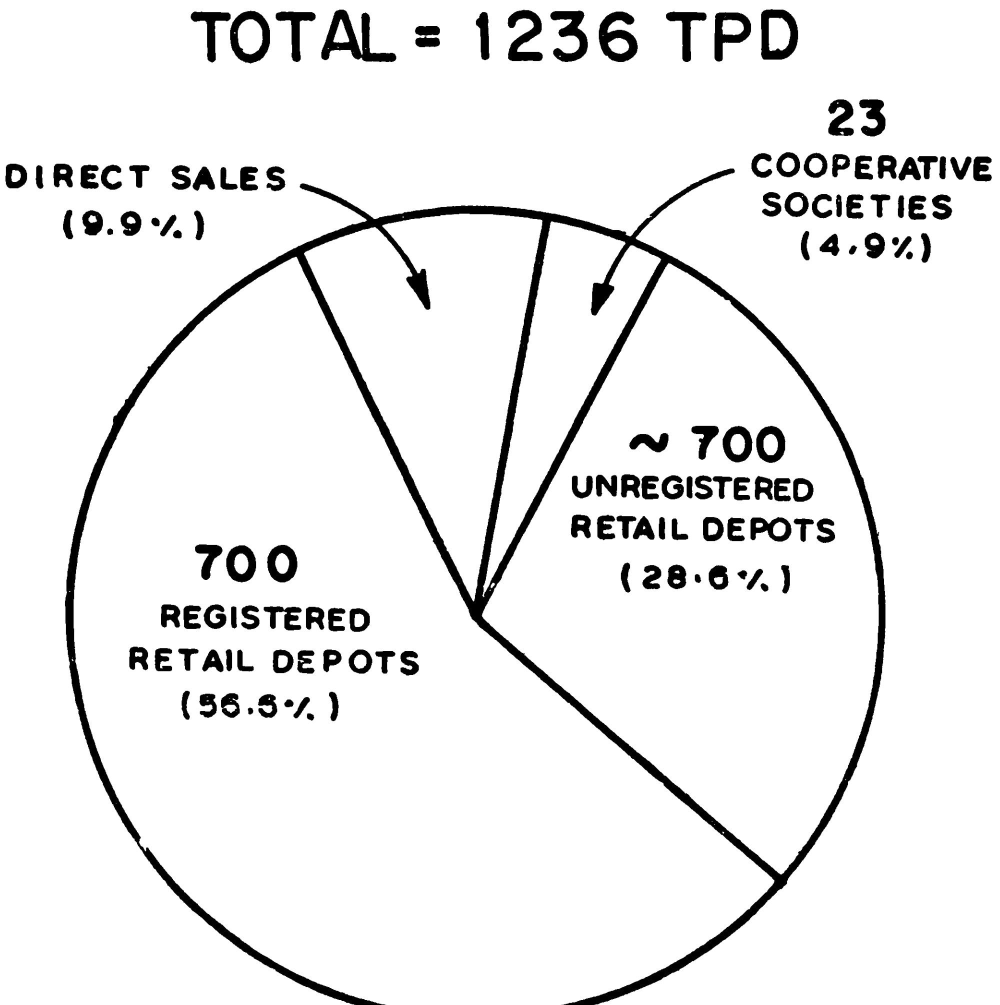


FIG. 6. SHARES OF DIFFERENT DISTRIBUTION CHANNELS IN FIREWOOD SALES.

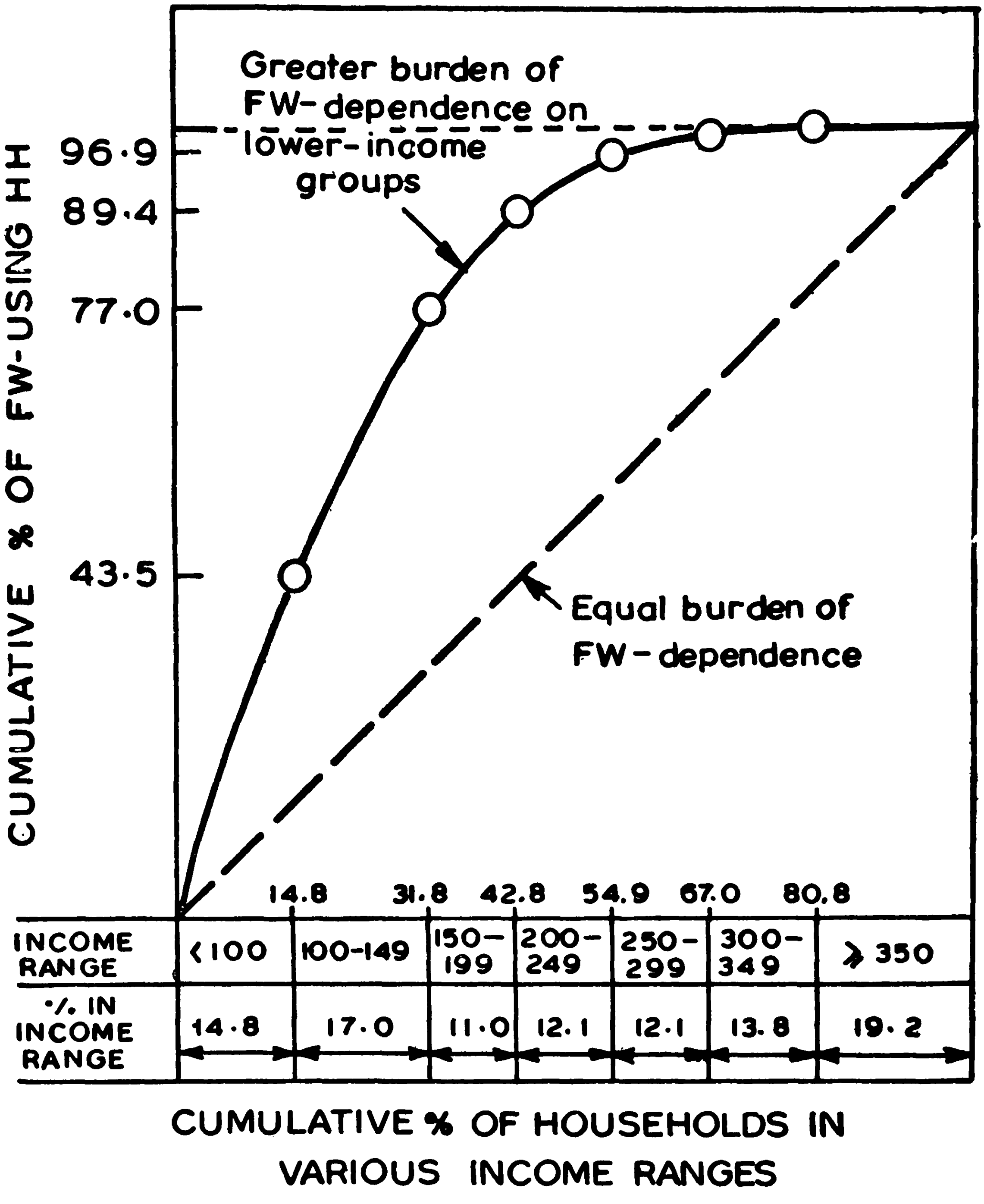


FIG. 7. THE INCOME-DEPENDENCE OF FIREWOOD USAGE.

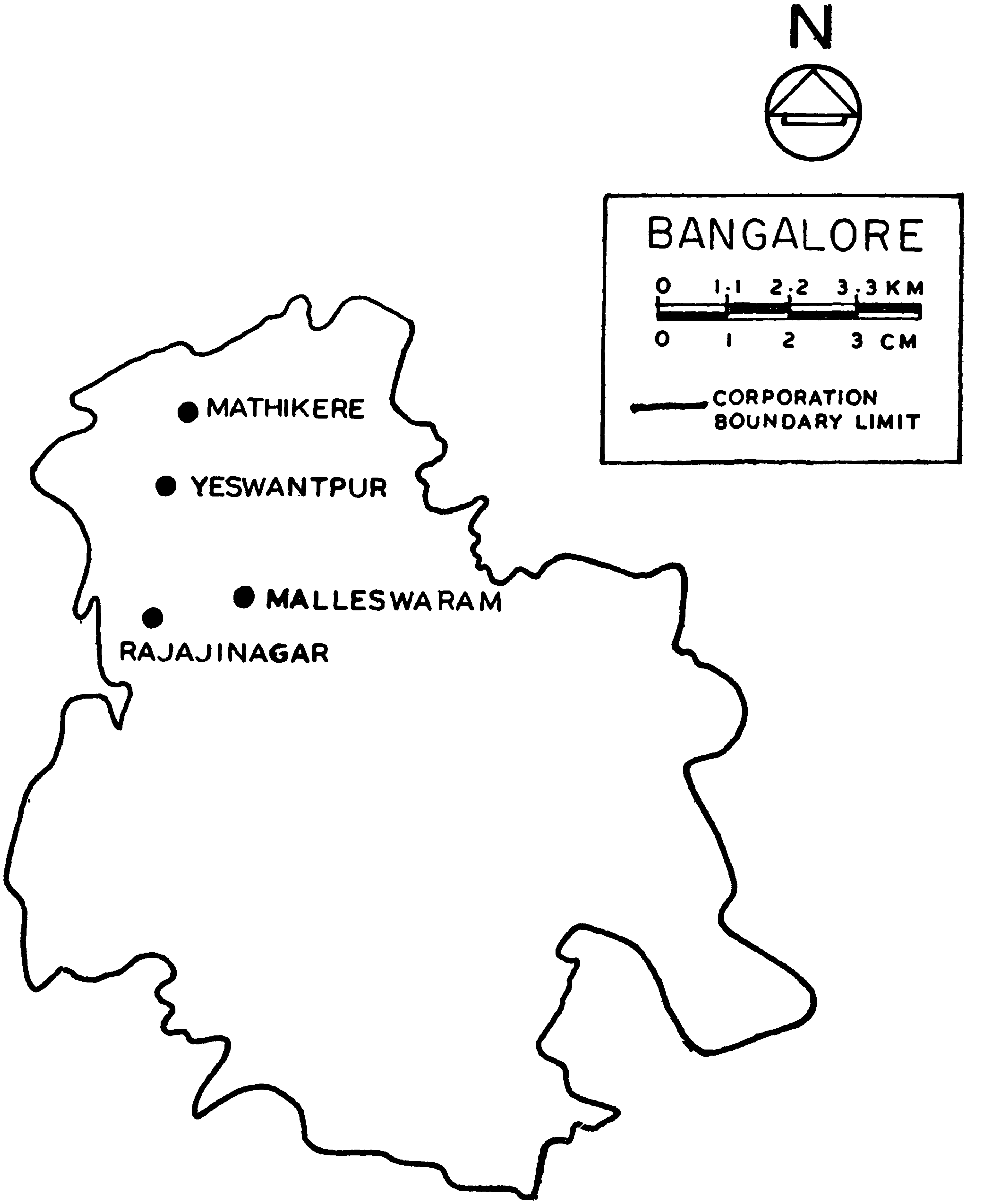


FIG. 8. MAP OF BANGALORE MUNICIPAL CORPORATION SHOWING THE FOUR AREAS WHERE THE HOUSEHOLD SAMPLE SURVEY WAS CONDUCTED.

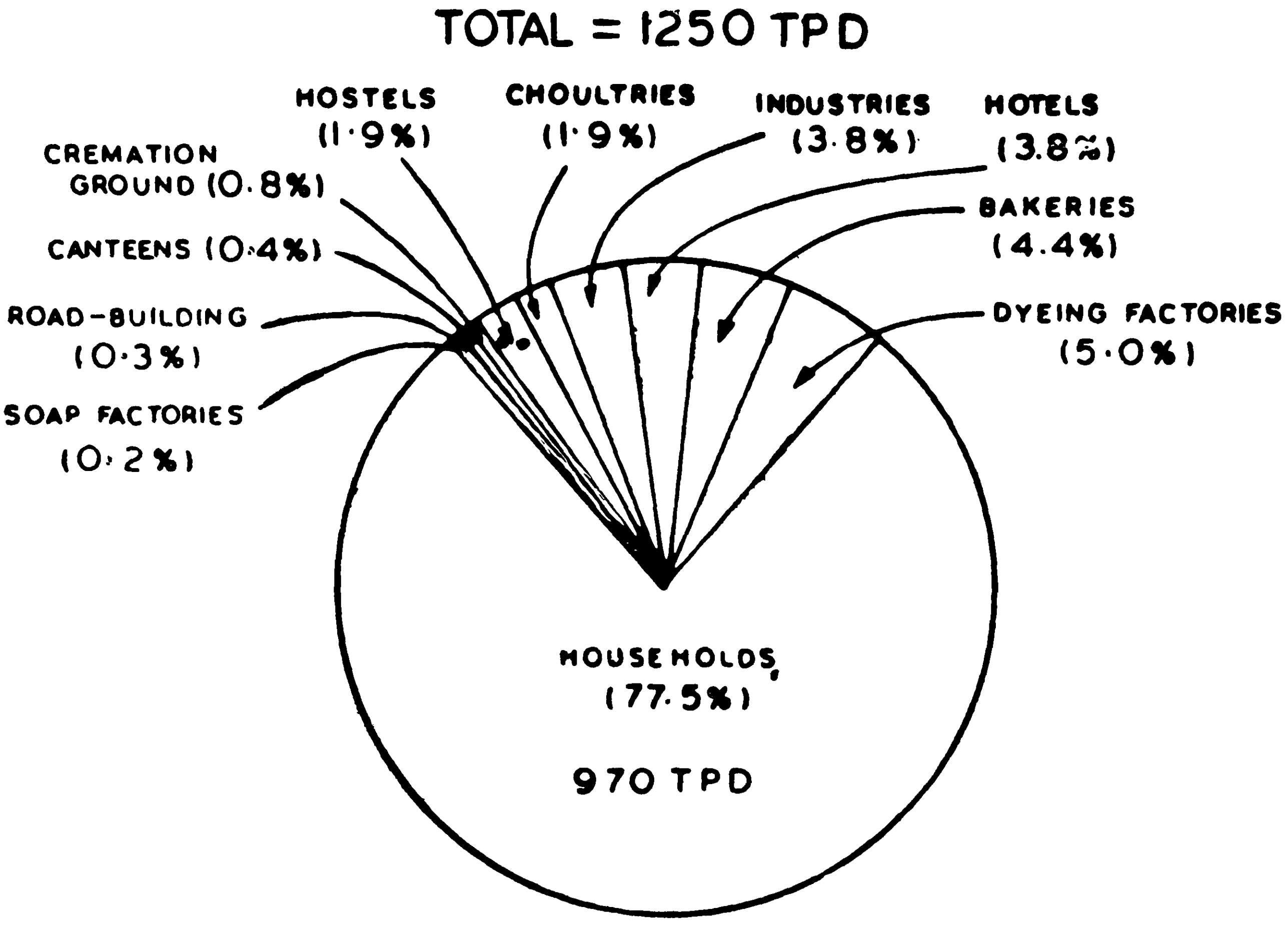


FIG 9. SHARE OF VARIOUS CONSUMERS IN BANGALORE'S FIREWOOD CONSUMPTION.

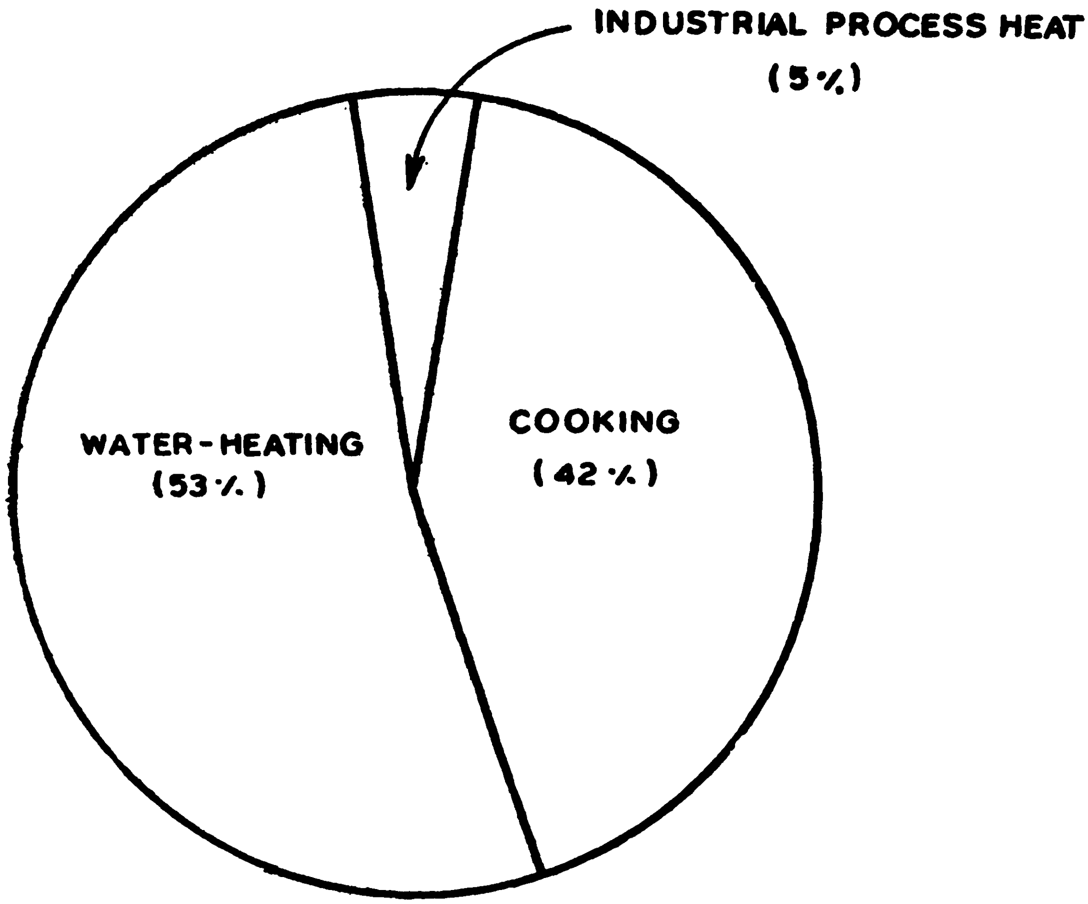
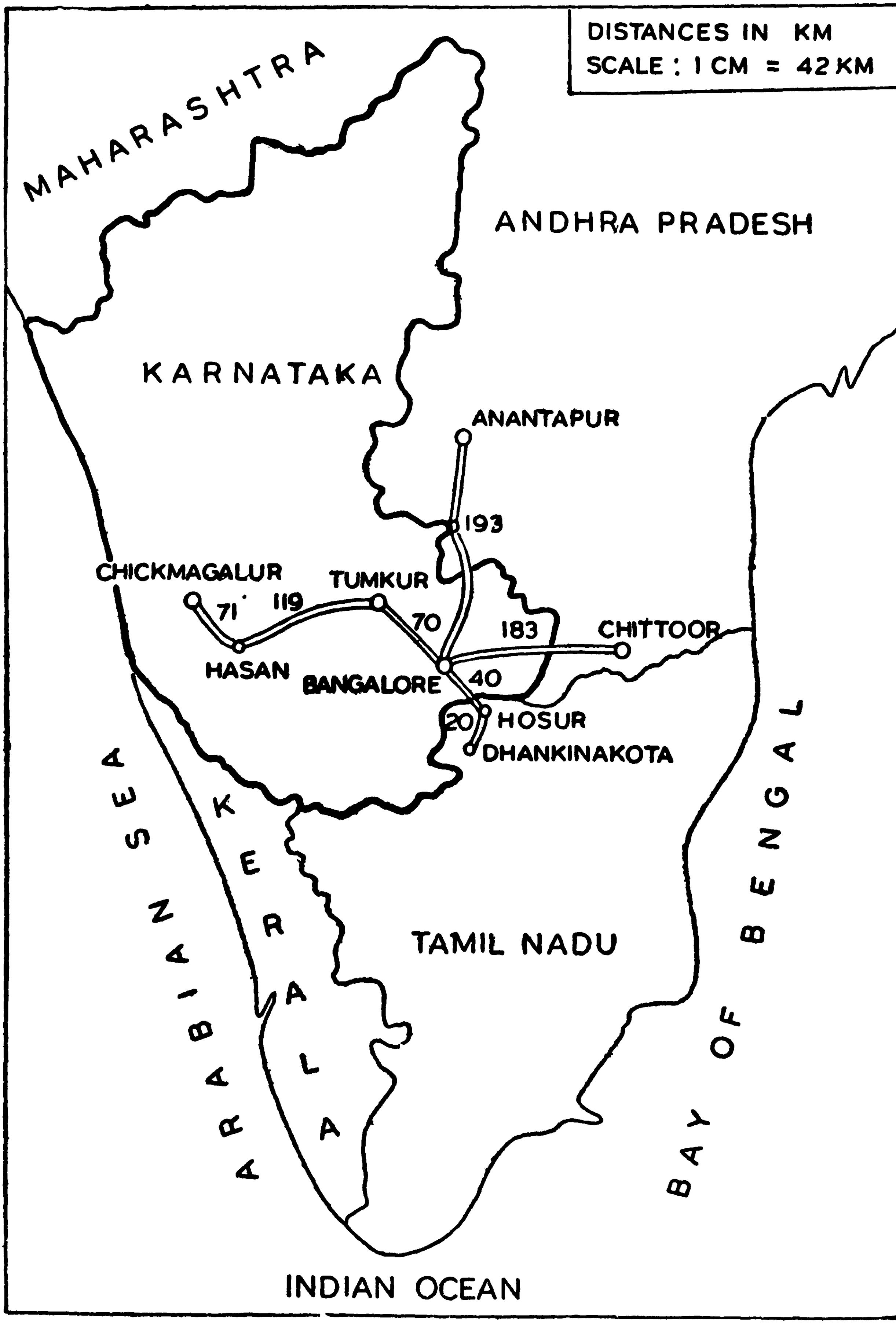


FIG. 10. END-USE ANALYSIS OF BANGALORE'S FIREWOOD CONSUMPTION

FIG. 11. CHARCOAL SOURCES AND THEIR DISTANCES FROM BANGALORE



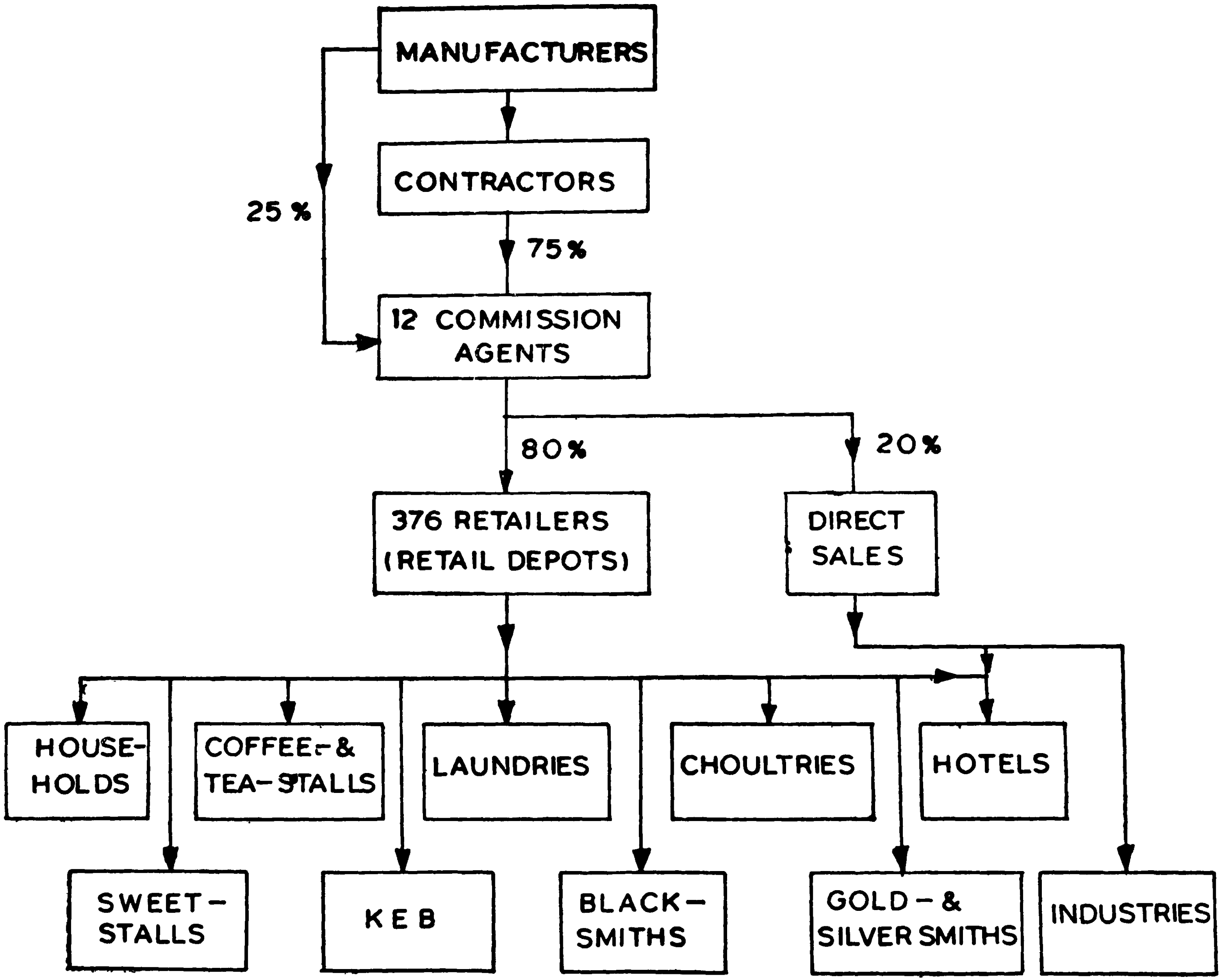


FIG.12. CHANNELS OF DISTRIBUTION OF CHARCOAL IN BANGALORE

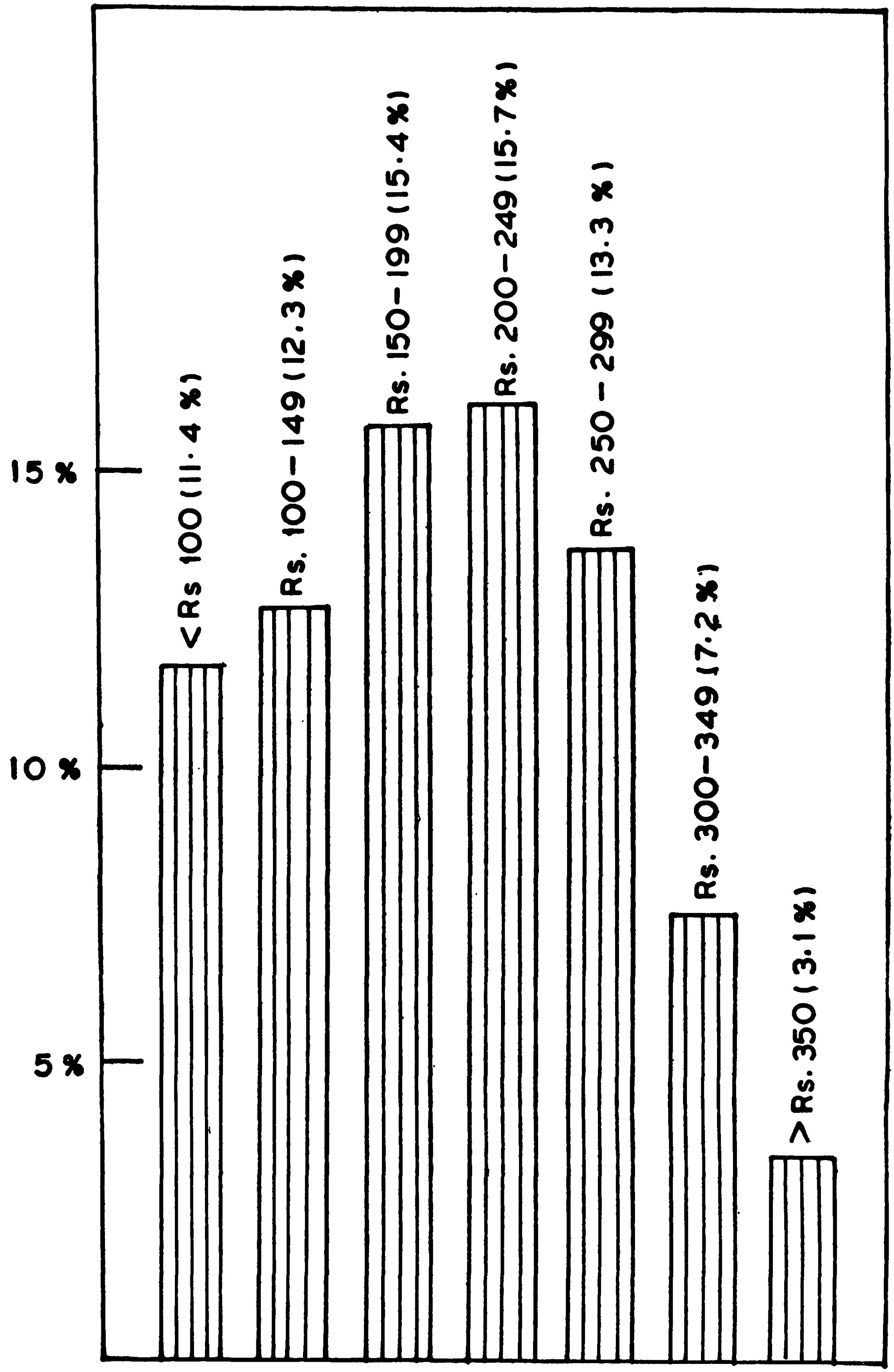


FIG. 13. PERCENTAGE OF SAMPLE HOUSEHOLDS IN VARIOUS INCOME RANGES DEPENDING ONLY ON CHARCOAL FOR BOTH COOKING AND WATER HEATING.

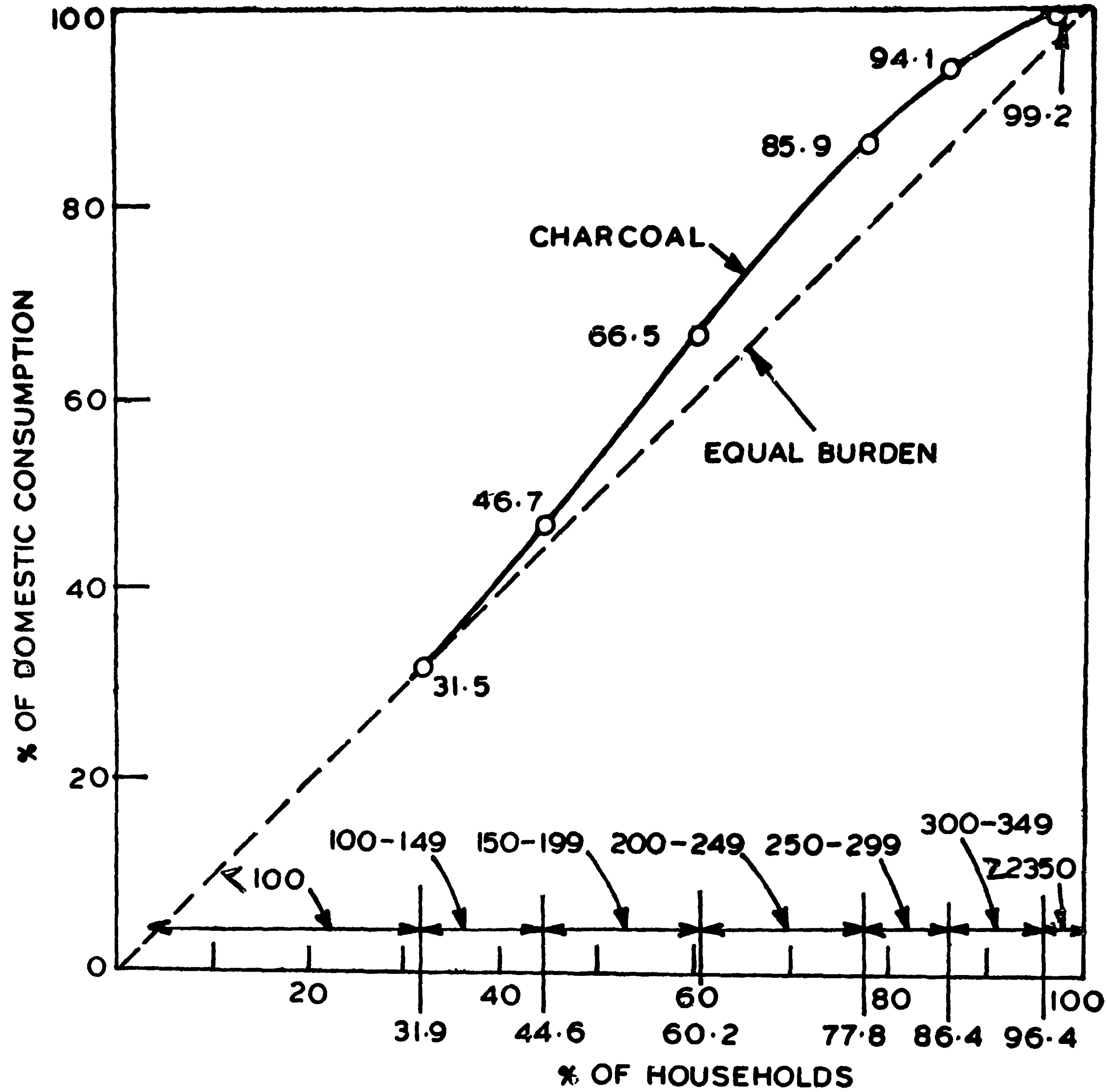


FIG. 14. CHARCOAL CONSUMPTION BY BANGALORE HOUSEHOLDS

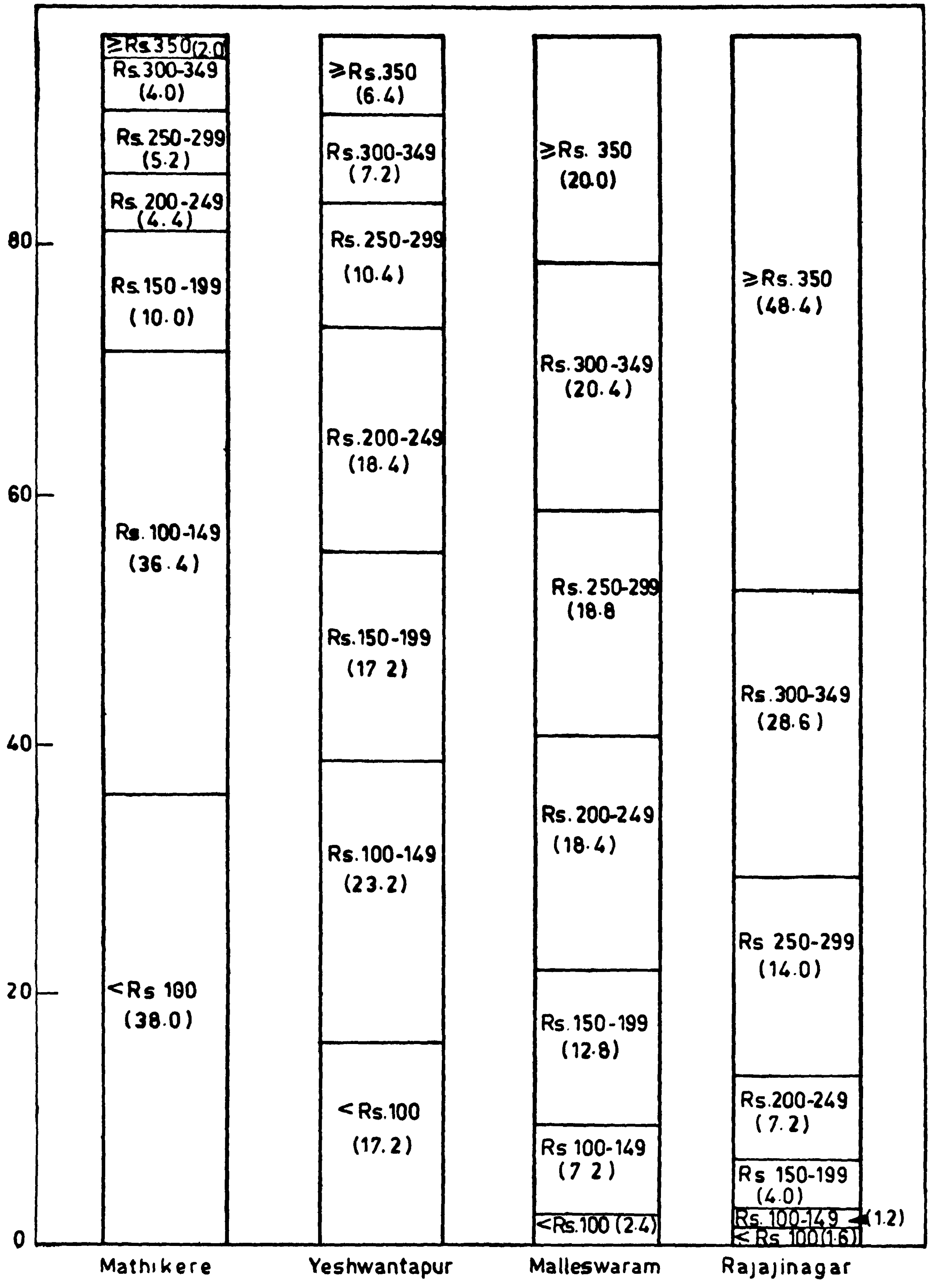


FIG. 15 - PERCENTAGES OF SAMPLE HOUSE HOLDS IN VARIOUS INCOME RANGES

ESSAYS IN THE SERIES

Vol. 1

1. Impact of Colonialism on the Economic Structure of Indian Cities : Bangalore 1800-1900
   – *Narenda Pani, Tara Anand and Vinod Vyasulu*
2. The Industrial Structure of Bangalore
   – *Vinod Vyasulu*
3. Waste Recycle Industry in Bangalore
   – *Abdul Aziz*

Vol. 2

1. A Study of the Climate of Bangalore
   – *A. Mani*
2. Slumming of a Metropolis
   – *H. Ramachandran*
3. Mosquito Control in Bangalore City
   – *T. Ramachandra Rao*
4. A Study on Corporation of the City of Bangalore
   – *M. Nageswara Rao*

Vol. 3

1. Transportation in Bangalore-I
   – *M. S. V. Rao*
2. Transportation in Bangalore-II
   – *N. Murali Mohan*
3. The Energy Sector of the Metropolis of Bangalore
   – *Amulya Kumar N. Reddy*

Vol. 4

1. The Food Supply System of Bangalore
   – *Sukumar Muralidharan*
2. Supply, Distribution and Consumption of Milk in Bangalore
   – *Thomas P. Benjamin*
3. Water Supply to Bangalore City
   – *D. K. Subramanian*
4. A Study of Elementary Education in Bangalore City
   – *S. Nayana Tara*