MANAGEMENT OF PUBLIC ROAD TRANSPORT SYSTEM IN TRIVANDRUM CITY

Thesis Submitted to the Cochin University of Science and Technology for
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Management under the Faculty of Social Sciences

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This is to certify that the Dissertation titled "Management of Public Road Transport System in Trivandrum City" is a record of research work done by Shri. K. Gopalakrishnan Nair, a part-time student registered for the award of the Degree of Doctor of Philosophy, in the School of Management Studies, Cochin University of Science and Technology during the period of his study.

This dissertation is the outcome of his original work and has not formed the basis for the award of any degree, diploma, associateship, fellowship or other similar title.

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DECLARATION

This is to certify that the dissertation entitled "MANAGEMENT OF PUBLIC ROAD TRANSPORT SYSTEM IN TRANSPORTATION IN TRIVANDRUM CITY" is a record of bonafide research work done by me and that it has not previously formed the basis for the award of any degree, diploma, associateship, fellowship or any other title.

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PREFACE

An efficient passenger road transport system is a boon to any city and an inefficient one its bane. Passenger bus transport operation involves various aspects like passenger convenience, profitability of operation and social, technological and environmental factors. The author's interest in this area was aroused when he conducted a traffic survey of Trivandrum City in 1979. While some studies on the performance of the Kerala State Road Transport Corporation in specific areas like finance, inventory control etc. have already been made, no study has been made from the operational point of view. The study is also the first one of its kind in dealing with the transportation problems for a second order city like Trivandrum. The objective of this research study is to develop a scientific basis for analysing and understanding the various operational aspects of urban bus transport management like assessing travel demand, depot location, fleet allocation, vehicle scheduling, maintenance etc. The operation of public road transportation in Trivandrum City is analysed on the basis of this theoretical background. The studies made have relevance to any medium sized city in India or even abroad.

If not properly managed, deterioration of any public utility system is a natural process and it adversely affects the consumers, the economy and the nation. Making any system more efficient requires careful analysis, judicious decision making and proper implementation. It is hoped that this study will throw some light into the various operational aspects of urban passenger road transport management which can be of some help to make it perform more efficiently.

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SYNOPSIS

Over the centuries, transportation has played an increasingly vital role in the emergence of civilisation. Provision of proper passenger transport facilities is one of the major requirements in any city. An efficient bus transport system provides convenience to the travelling public, contributes indirectly to their quality of life and saves fuel for the nation.

The objective of this research work is to study about the problems connected with the passenger transportation services in Trivandrum City. Trivandrum is a typical 'second order' city, having a fully nationalised bus transport system and a sizeable student population. An analysis of the financial and organisational aspects of Trivandrum City Services is made to form the background of the study. Detailed studies regarding three major aspects of the passenger transport system has been made, viz. (i) Assessment of the travel needs of the public (ii) Operational aspects like depot location, fleet allocation and bus scheduling; and (iii) Maintenance and related aspects. A study of the inter-relationship between town planning and transportation system and its relevance to strategic planning for future has also been made. The role of computerisation in the planning for and operation of public transport systems has also been explored. A comprehensive literature survey on public transportation systems has also been incorporated in the study. A summary of the conclusions and recommendations is also given at the end of the study.

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CHAPTER 1

OVERVIEW OF THE BROADER DIMENSIONS OF THE PROBLEM, SCOPE AND METHODOLOGY

1.1 Introduction

It has often been said that one among the most significant events in the history of mankind has been the invention of the wheel. The development of human civilisation, as we see it today, has been shaped by factors like transport, power, the application of energy in its different forms and of the technology for doing so, etc. among others.

Transportation by land was aided by the domestication of animals such as horses, camels etc. Transportation by water perhaps came still later. The construction of canals was thus a major step in this direction. The invention of steam power and construction of the railway system resulted in more means and facilities for transportation. The conquest of air followed. All these developments in transportation contributed in good measure to the emergence of a society with improved standards of living in other areas of life as well. An easier and more efficient transportation of people and goods meant that it was no longer necessary for people in each locality to limit production and consumption of goods and services to whatever was available locally. Trading became possible within a region, later within a nation and then internationally. The travel horizons of people widened immensely. The mobility of people in area and speed has undergone substantial changes and the speed of these changes has also been on the increase all the time. (Toffler, 18, Chapter 5)

The steam age was quickly overtaken by that of the internal combustion engine, providing man with a new energy source which was so flexible that it completely revolutionised the whole nature of society. This energy source could now be used on land, in sea, and later, with some changes, in the air. Changes in the distribution of goods and services, generation of newer forms of energy, other changes in technology, etc. have all created a civilisation today in which people and goods are moved around the world with ease at speeds 'unimagined' by the ancestors.

The developments in transportation in the last couple of centuries have been so all-pervasive that they have had an impact on every other aspect of the way of living. According to Len Payne, it may not be wrong to say that we have the most mobile society in the history of mankind. (108, p 21)

Alvin Toffler says that per capita movement is a measure of progress, similar to per capita income. (18, p 76) In 1914, a typical American travelled on an average 1640 miles per year. By 1970, this figure increased to 10,000 miles per year. And he lives longer than his father and grandfather. This means that the total amount of travel that he makes during his life-time is several times more than that of his ancestors. On the contrary, agricultural workers, especially women in undeveloped countries, might not have even moved out of their own tiny hamlets during the whole of their lives. Accordingly, just as we divide nations into 'developed' and 'undeveloped', we can also divide people into 'mobile' and 'immobile', taking perhaps mobility as an index of development and better living.

Man's travel requirements arise out of a variety of needs - for going to places of work, for business or family needs, for pleasure etc. For every travel or trip made, there is an origin and a destination. The mode of conveyance will depend upon a variety of factors, such as the distance between places, the need for travel, travel time, comfort, cost of travel etc. Travelling by one's own conveyance may be the most convenient way in some cases, but only a few can afford it and that too, within reasonable distances. The vast majority of the population may, therefore, have to depend upon the public transportation system by road, rail, water, air etc. Apart from the public transportation system, there is also an in-between mode of transport, known as Intermediate Public Transport (IPT) system which consists of hired vehicles, like taxis, autorickshaws, tongas, etc. But these also can often be too expensive for most of the people.

Thus it can be seen that the most important of all transport modes is the public conveyance system, on which the mobility of the common man largely depends. The efficiency of the public conveyance system is measured by the traveller, taking into consideration such factors as cost, speed, comfort, safety, punctuality and adequacy.

Any travel has four components-the traveller, the operator, the vehicle, and the travel network. The operator satisfies the traveller's demand for travel. For travel, the traveller needs a vehicle and goes through a road or other travel network starting from the origin of travel to the destination. These basic components of travel are shown in Figure 1.1

The operation of the urban transport system is not restricted to the user and the operator alone. It has its interrelationship with the society within which it operates, i.e. the social economic and technological environment of the country. Changes in vehicle technology may mean that better and more fuel-efficient engines are made available, which cause lesser atmospheric pollution. On the social side, a well-managed and efficient public transport system contributes to improving the quality of life of the common man. Needless to say, government policies

Fig 1.1 Basic Components of Travel

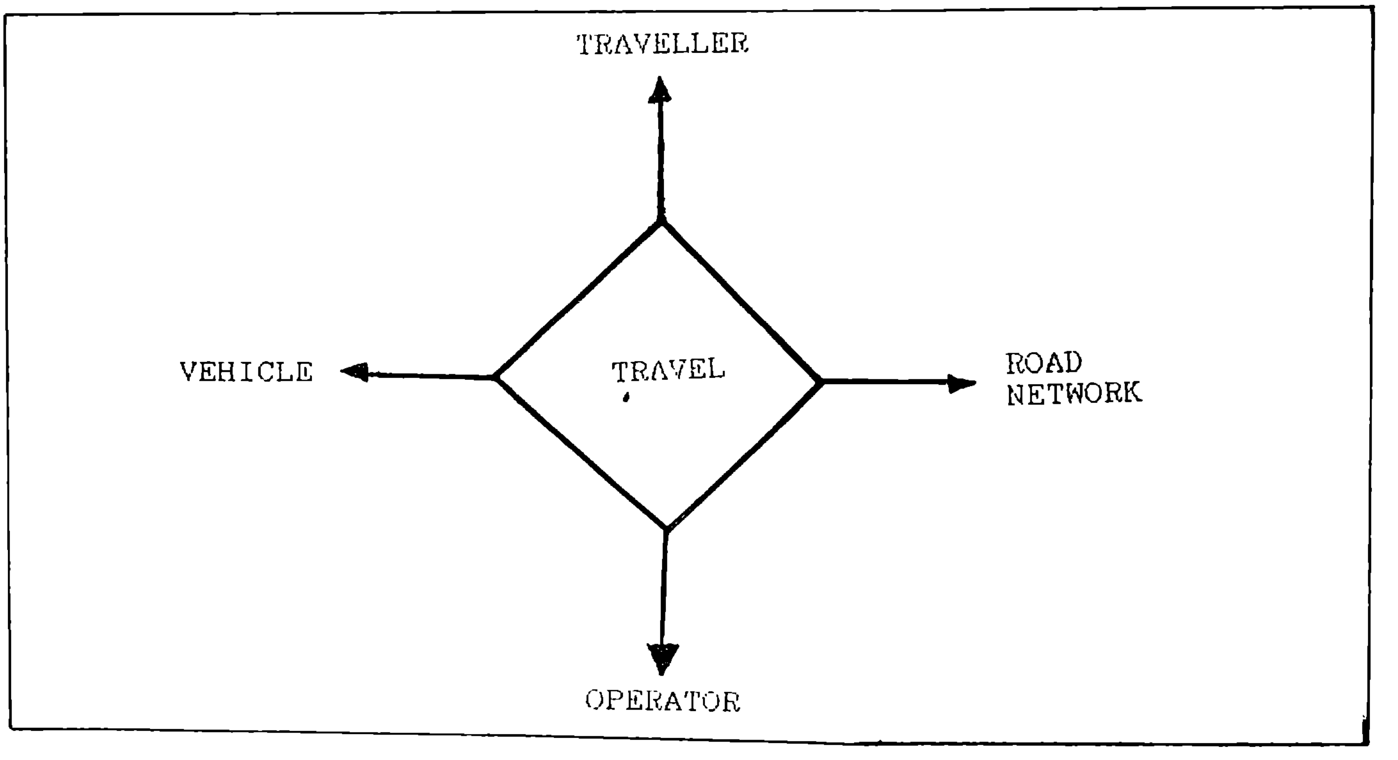
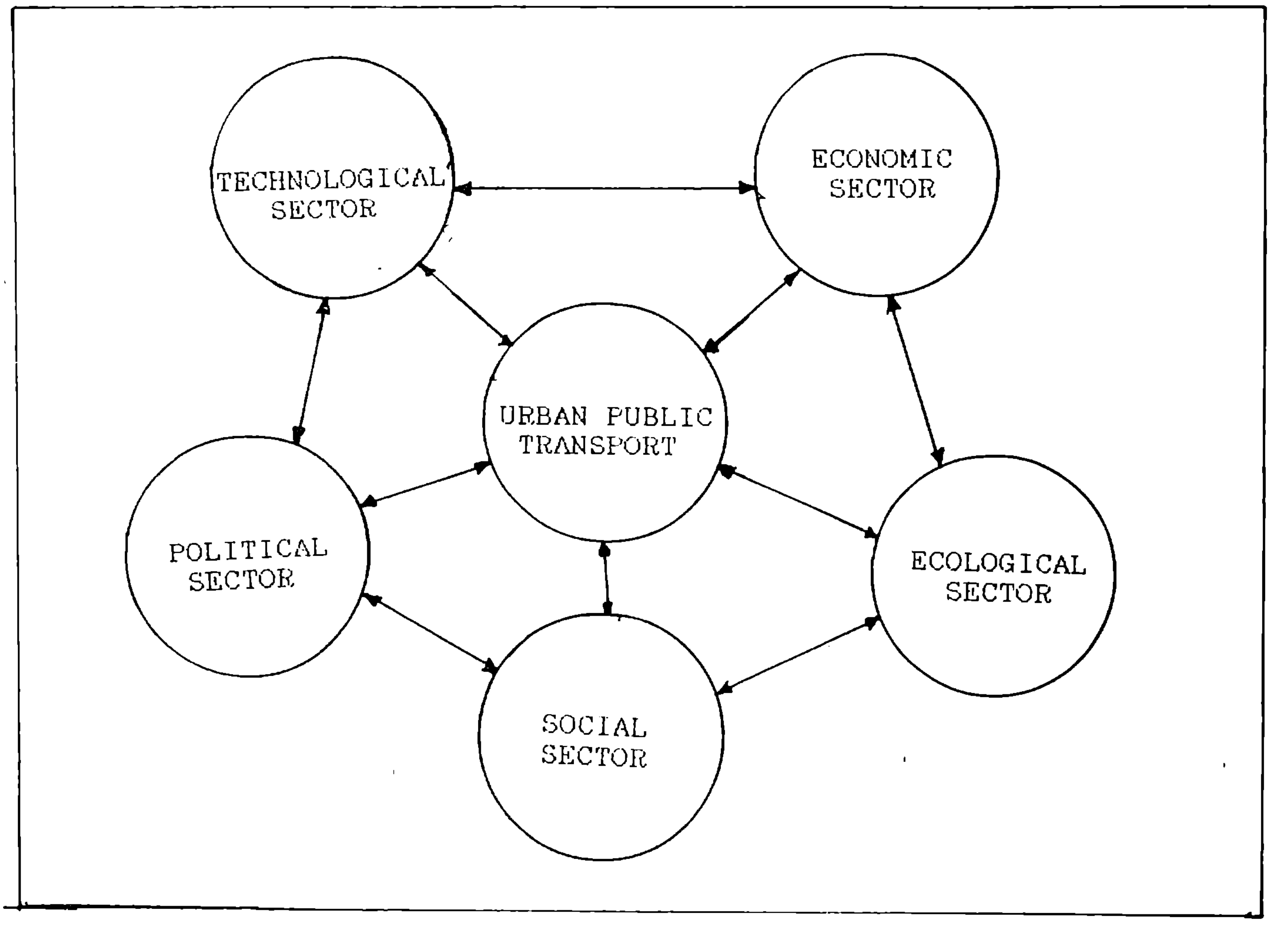


Fig 1.2 Inter-relationship of Urban Public Transport With Other Sectors



regarding nationalisation, fuel prices, bus fares, concessions given to students, vehicle taxes etc. affect transport operation directly. Fig: 1.2 shows the interactions of these different factors on the operation of the urban public transport system.

1.2 Urbanisation

Urban population in India has grown at more than double the rate of growth of the population as a whole during the period 1901-1981. (Figure 1.3) By the turn of the century, we may have nearly 35% of our population living in urban areas. The growth of population in India, urban and rural, according to the Census figures are shown in Table 1.1.

The trends in urbanisation indicate that cities, large or small, are growing fast. They attract large sections of the rural population towards them. If the projections for the year 2001, as shown in Table 1.1 become true, rural population of India will marginally decrease, but the growth of the total urban population will be more than ten crores during the decades 1991-2001. (Patankar, 14, p 6)

While the trend of urbanisation itself is alarming, what is more alarming is that the trend is heavily biased towards the formation of large cities. In the article, "Urban Transport in India", the author points out that of the twelve Indian cities with a population exceeding one million, the decadal increase

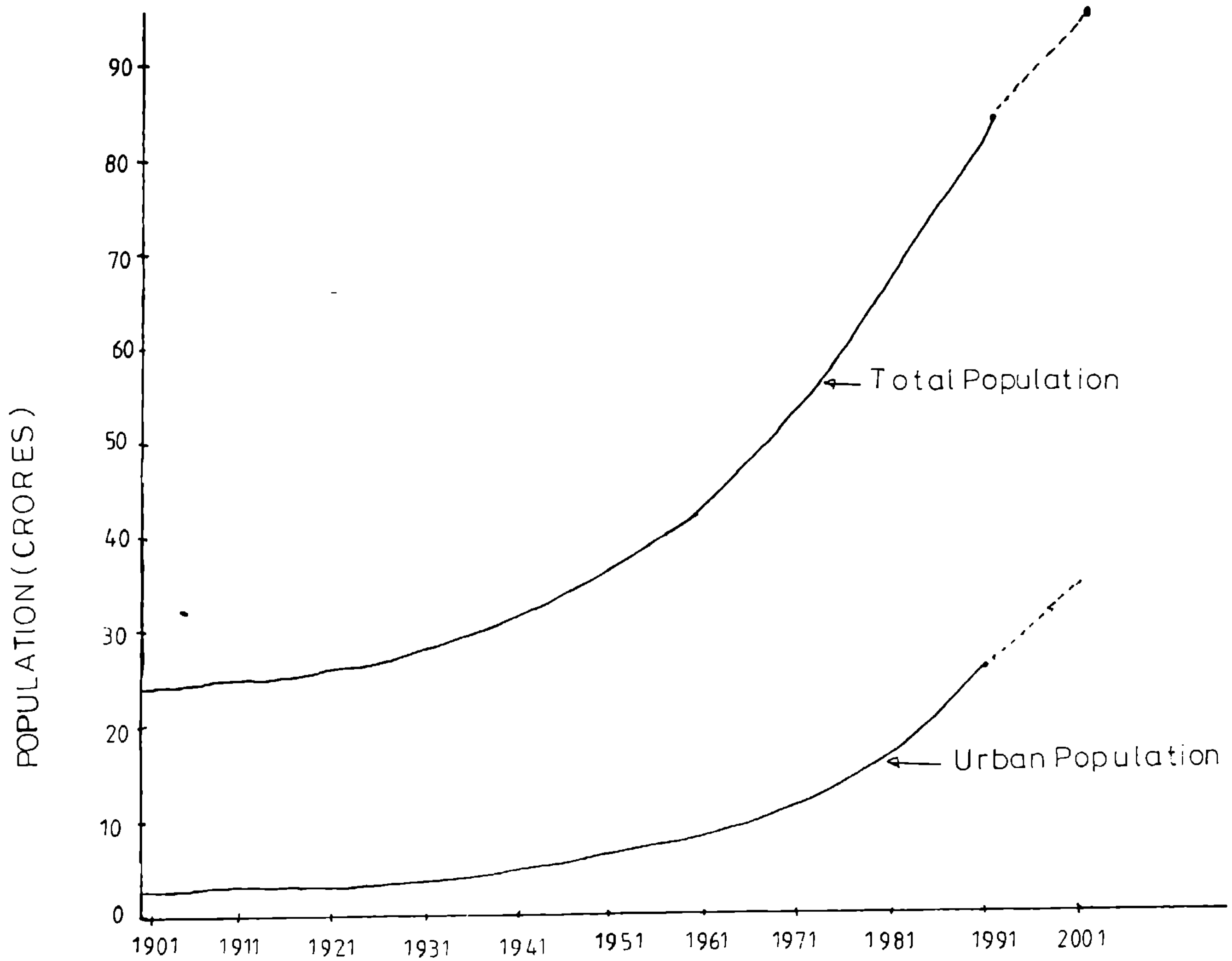
Table 1.1 <u>Growth of India's Population</u>

Census year	Total population (crores)	Urban Population (crores)	Rural population (Crores)	% of Urban Population to total	Growth rate (%)		
					Urban	Rural	Total
1901	23.833	2.585	21.248	10.84	--	--	--
1911	25.201	2.594	22.607	10.29	0.35	6.39	5.73
1921	25.124	2.809	22.315	11.18	8.26	-1.29	-0.30
1931	27.870	3.346	24.541	11.99	19.12	9.96	10.99
1941	31.854	4.415	27.439	13.86	31.97	11.81	14.22
1951	36.095	6.244	29.851	17.30	41.42	8.79	13.31
1961	43.907	7.893	36.014	17.98	26.41	20.65	21.64
1971	54.795	10.909	43.886	19.91	38.22	21.85	24.79
1981	68.858	15.972	52.546	23.31	46.41	19.73	25.04
1991	84.432	21.718	62.714	25.72	35.97	19.35	23.10
2001 *	95.000	34.500	60.500	36.00	58.98	-3.6	12.50

* PROJECTED FIGURES

(Source: Population figures for Census years 1901, 1911,.... to 1991 are taken from Government of India's census figures. Projected population for the year 2001 (medium trend) is taken from P.G. Patankar, <u>Road Passenger Transport in India</u> Central Institute of Road Transport, Pune, 1985, pages 5 and 6)

Fig 1.3 Growth of India's Population During Twentieth Century



during 1971-81 was 41 percent on the average, with Bangalore registering an increase of 75 percent. (148, p 6) These big cities have problems not smaller in magnitude than cities of the developed world, over and above the other problems peculiar to the cities of the developing world. By 1991, according to Census figures, the number of cities having more than one million population has increased to 23. Greater Cochin in Kerala has joined the 'one million club', having moved itself upto the fourteenth position. Table 1.2 shows the details of population of these cities. Population figures of Cochin, Trivandrum and Kozhikode, the three Corporations of Kerala are also shown in the table. Map 1.1 shows the list of cities in India having a population exceeding five lakhs, as per the 1981 Census. All the three cities of Kerala - Trivandrum, Cochin and Kozhikode fall in the category of cities having a population between five lakhs and ten lakhs. These cities are considered as 'second order cities', while cities having a population in excess of one million are called as 'first order cities' or metropolises. Map 1.2 shows the names of cities having a population of more than five lakhs as per the 1991 Census.

Urbanisation invariably brings in problems of transportation. Urban areas have both intracity and city-suburb traffic problems. In the older cities, the

TABLE 1.2
Indian Cities Having a Population of More Than 10 Lakhs as per 1991 Census

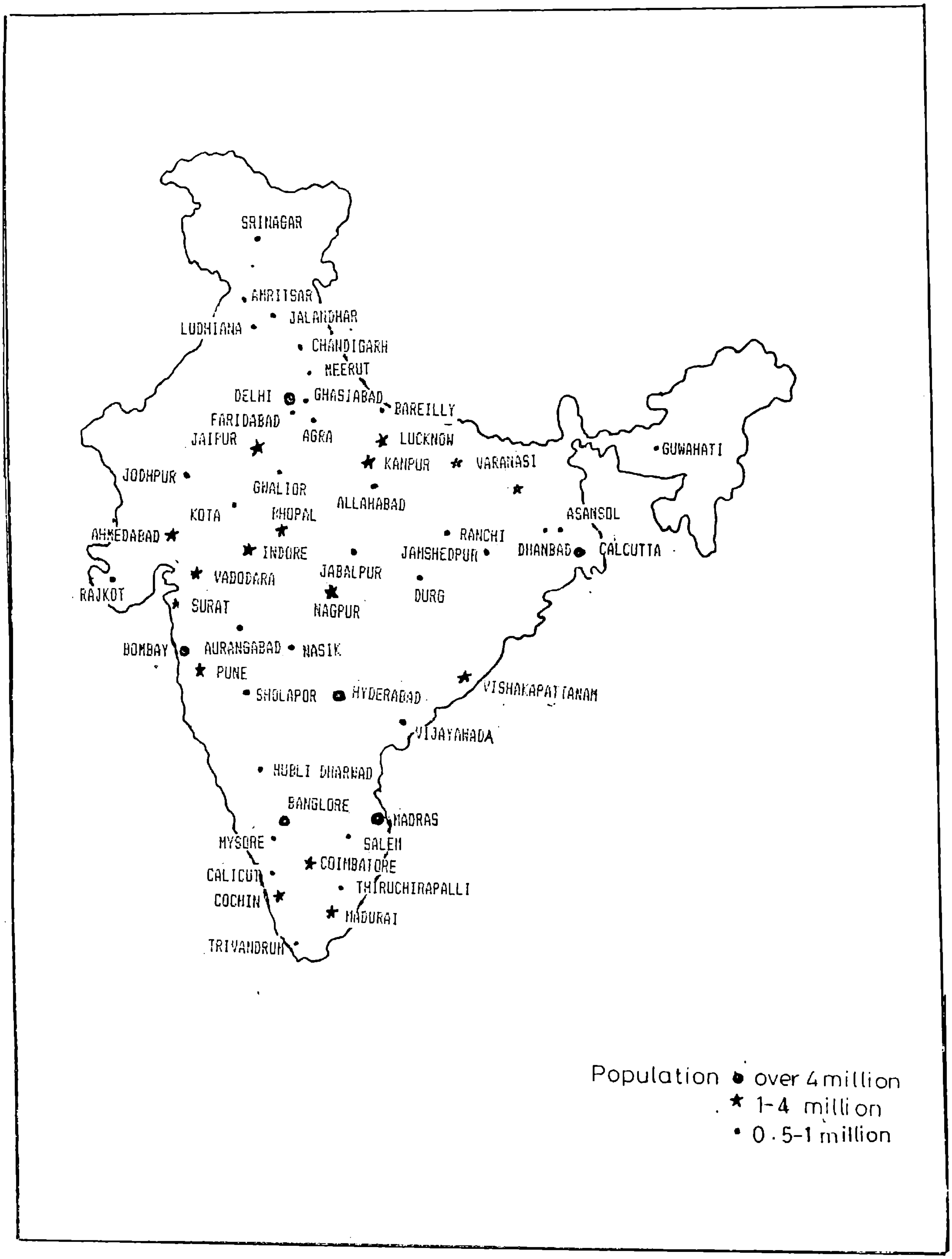
No.	Name of city	Population as per 1991 census
1.	Greater Bombay	1,25,71,720
2.	Calcutta	1,09,16,272
3.	Delhi	83,75,188
4.	Madras	53,61,468
5.	Hyderabad	42,80,261
6.	Bangalore	40,86,548
7.	Ahamedabad	32,97,655
8.	Pune	24,85,014
9.	Kanpur	21,11,284
10.	Nagpur	16,61,409
11.	Lucknow	16,42,134
12.	Surat	15,17,076
13.	Jaipur	15,14,425
14.	Kochi(Greater Cochin)	11,39,543
15.	Coimbatore	11,35,549
16.	Vadodara	11,15,265
17.	Indore	11,04,065
18.	Patna	10,98,572
19.	Madurai	10,93,702
20.	Bhopal	10,63,662
21.	Visakhapattanam	10,51,918
22.	Varanasi	10,26,467
23.	Ludhiana	10,12,062

Population of Cochin corporation - 5,82,030
Trivandrum corporation - 5,23,773
Kozhikode corporation - 4,19,531

(Source: Census of India - 1991, Census Commissioner, Government of India, 1992, page 39)

Map 1.1 Main Indian Cities (1981)

(Source: P.R. Fouracre and D.A.C. Maunder, "A Comparison of Public Transport in Three Medium Sized Cities in India" Central Institute of Road Transport, Pune, 1986)



(Source: <u>Census of India 1991</u> Census Commissioner, Government of India, 1992) administrative areas and the retail and the trading areas have been usually contiguous. Together, they constituted the central business district (CBD). The propensity to stay and work in close proximity to each other has possibly led to the very dense population pattern of these areas. Continuous growth of the cities and of their population, increase the demand for travel. Development of mass transport facilities, however, has not often kept pace with them. By any standard, mass transport facilities are very poor in Indian cities. For bigger cities, the number of buses per 1000 population varies between 0.3 and 0.6, while smaller cities have still lower ratios. However, Trivandrum, having a population slightly over five lakhs, has nearly 470 buses, which makes this ratio almost or close to one, when one considers the population of the Trivandrum City only. (180, p 220) The average travel distances in Bombay, Delhi and Madras are 6.12, 11.92 and 8.15 kilometres respectively. In Trivandrum, for city bus travellers this figure is 7.17 kilometres. (202 pp 102, 106)

Activity locations are concentrated in central areas resulting in tidal flows in one direction during peak hours. As speeds of buses are less than 10 Km/hr, the peak hour congestion leads to bunching of buses and, consequently, the skipping of schedules. Driving in such conditions and that too on poor roads cause frequent breakdowns and accidents and fleet immobilisation upto about 25 percent. Mass parking lots are virtually nonexistent in most cities in India. In most cases, these are also no marked spaces provided for street parking. Carriageway widths are reduced as a consequence. This reduces the manoeuvrability of vehicles on the road. This creates further confusion and lead to more accidents than usual.

1.3 Second Order Cities

As already mentioned, cities having a population between five lakhs and ten lakhs are considered as second order cities in India. As per the 1981 Census, there are 26 such cities in India. These cities are shown in Map 1.1. Many of these cities are State capitals, while others are of industrial or commercial importance.

The development of public transport in the second order cities has followed a different pattern from that in the first order cities. Public transportation has mostly been left to the entrepreneurship of the private operators. The dominance of this sector is also evident in the intermediate public transport systems, comprising mini-buses, autorickshaws, taxis etc. However, Trivandrum is an exception to this with a completely nationalised passenger bus service system since 1975.

Most of these first order or second order cities have not so far undertaken a well planned approach to the development of the public transport system. Only a few of these cities can be considered to have a good public transport system. Ofcourse, in none of these second order cities is there a rail-based, let alone a subway-based, mass transist system.

Considerable debate has been generated about the basic question as to what type of public transport system should be encouraged in a city. The debate is often confused because it involves two quite distinct issues.

1. The extent to which public sector should be involved in the field of public transport system.

2. The technical, environmental and economic aspects of different modes of transport, such as the subways, railways, road transport etc.

Regulatory policy, as well as considerations of operating costs, influence the type of vehicles employed in the public transport services. Under a deregulated system, private operators flourish, as they tend to invest in low cost capital equipments like minibuses and autorickshaws. They are also able to operate a conventional bus service more cheaply than nationalised undertakings because, by and large, they are less constrained by labour laws, union pressure on wage rates, tax demands and safety standards. The comparison among the different systems is complicated by the fact that such transport systems are not used in the same role. Hand rickshaws, cycle rickshaws and autorickshaws are used to provide taxi-like services, giving a higher degree of accessibility, at relatively lower cost. But, the former two types of rickshaws are banned in a number of cities. Minibuses, jeeps, larger four or six-seater autorikshaws and conventional buses are often used to provide stage carrier services, very often illegally, where cost per unit of output is lower, though journey lengths are longer and accessibility poorer.

There should, however, be no doubt that land use planning in these cities should be done in such a way that traffic demand is controlled. Improper planning of the location of offices, business centres and housing colonies complicate the pattern of travel demand and also the average length of travel. For the second order cities, a well-planned transport system can be so designed that a public road transport system supplemented by effective IPT modes can meet more efficiently the traffic demand for a long time to come. It can also ensure that a highly capital intensive rail system is avoided altogether for a long time to come. But how long this might remain adequate and the larger investment that might become unavoidable in future have also to be taken into consideration in making a strategic plan for the future. The lack of such a long term plan can easily be seen in the complications that have arisen in the development of a competent transport system in the larger metropolitan cities like Bombay, Calcutta, Delhi and Madras. This should be avoided and detailed long range planning be introduced as an immediate necessity in second order cities. The transport system can adopt softer options in these cities such as footpaths, cycle tracks, two wheeler tracks, autorikshaws and minibuses to ease the problems of the present. All these modes must be supported by planning for a bus system along routes of heavy mass traffic and demand. Two other criteria that are also to be taken into consideration in designing a mass traffic system are energy consumption and employment potential. As far as the present technology goes, the conventional bus passenger system is more energy efficient when compared to all other travel modes, except the railways, above ground or underground.

1.4 <u>Problems of Road Passenger Transport in Second Order Cities</u>

There are a number of problems which the transport operator faces which are particularly applicable to urban areas. In fact, most of the problems mentioned below are applicable not only to second order cities, but to almost all urban areas as well.

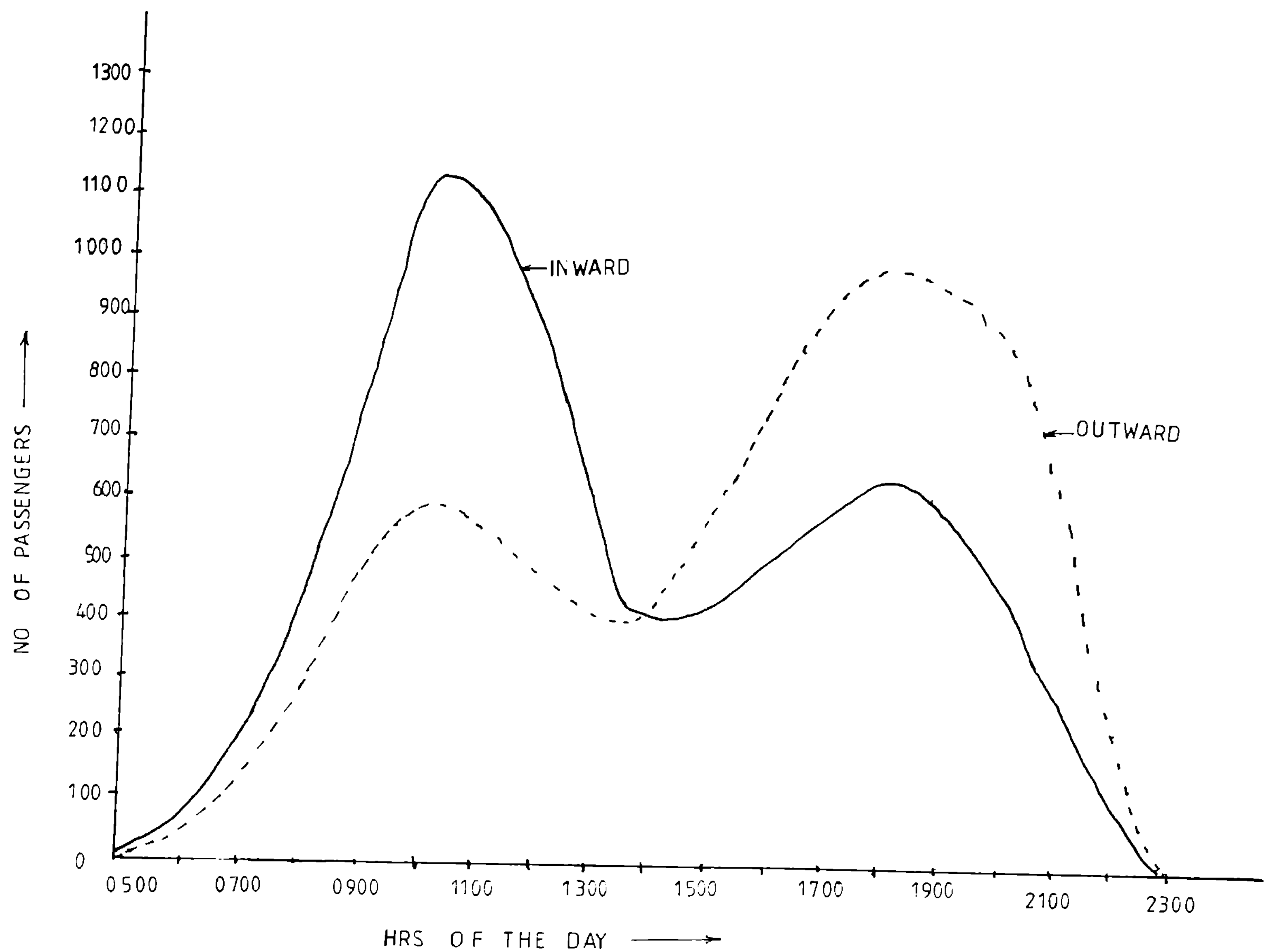
a) Peak hour problem

Since most of the trips made by commuters are for travel between the home and the workplace and back, these are made during the two peak periods of the day, viz., 8 A.M.to 10 A.M. and 4 P.M. to 6 P.M. The traffic pattern in a particular segment in Trivandrum City, as shown in figure 1.4, explains the peak hour situation. The morning peak is sharper, since people have to reach their places of work on time. The evening peak is smoother since after leaving their places of work the commuters may go for shopping or other activities before their return trip. These concentrations of traffic demand make it difficult for the transport operator to meet the total travel demand in a very satisfactory way. While there is heavy rush during peak periods, buses ply with much lower occupancy during off-peak periods.

b) One way empty

This problem is the consequence of the way cities naturally grew in the past and in the subsequent periods of history. All Indian cities have grown outwards from a central nucleus, where offices, shopping centres, etc. came to be concentrated. Due to this, people make their towards city trips in the morning and outward trips in the evening. Because of this inward-outward flow pattern, buses ply almost empty in the outward direction, during the morning

Fig 1.4 Traffic Pattern of a Route in Trivandrum City



hours and inward during the evening hours, thereby causing low capacity utilisation on these trips.

c) Slow moving traffic

One of the many factors which increases the efficiency of any transportation system is speed. If the same vehicle can make more trips using lesser time and thereby earn more, the commuters are also benefited due to lesser travel time and the availability of more trips. But in most of the Indian cities, the speed of buses is very low, especially during peak hours. This is partially due to the narrow roads, mixed or heterogeneous type of traffic, where the fast moving vehicles are slowed by the slow moving ones, traffic congestion and the lack of proper traffic management. Vehicle speeds are then sometimes reduced to 10 km/hr or even less on the heavily congested roads and, still worse, during peak periods. Traffic congestion also leads to more accidents and breakdowns.

d) Improper city planning

As mentioned earlier, city planning has a direct bearing on people's travel requirements. Travel needs and travel distances can be reduced considerably if town planning is more effectively done. Concentration of offices and other facilities in a central place causes people to travel to this place from all the other surrounding areas, causing excessive pressure on the transportation system. Houscolonies, having adequate shopping or entertainment facilities and location of new business centres elsewhere can, to some extent, reduce the travel needs of its residents. Also, providing wider roads - this is possible ofcourse only upto a limit-and provision of convenient parking spaces will aid smoother traffic flows. But there is a limit to doing these beyond a point.

e) Improper vehicle scheduling

Vehicle scheduling is to be done on scientific lines taking into account the travel needs of the public. For this, the first and foremost step will be to make an assessment of travel needs. Origin-destination surveys and traffic volume surveys may require to be conducted, which can form the basis for vehicle scheduling. Computer-aided scheduling methods can be adopted which will optimise vehicle utilisation and satisfy passenger requirements to the maximum possible extent. But in many cities, such scientific vehicle scheduling system is almost non-existent, not to speak of conducting traffic surveys.

f) Bad condition of roads

Proper maintenance and repair of the roads can also contribute to the efficiency of the transport system. The bad condition of the roads contribute to excessive wear and tear, damage to vehicle parts and subsequent breakdown and accidents. Road conditions tend to deteriorate, particularly during monsoon months.

Two other factors which are of particular relevance to Trivandrum City are the following, though these may have a large bearing on transportation problems in other cities as well.

g) Large number of school/college trips

Trivandrum is a city with high concentration of educational institutions. It has a fairly large number of schools and colleges. There are about 40,000 students who avail of concessional bus passes for travel in the Trivandrum City services. Since most of these institutions work between 9.30 or 10.00 A.M. and 3.30 or 4 P.M., the excessive strain it adds to the public transport system can well be imagined. This problem is also more acute during morning peak hours than during evening peak hours.

h) Old vehicles used in the City

The Kerala State Road Transport Corporation has a total fleet of more than 3,400 vehicles, of which about 470 are used for operating the Trivandrum City bus services. Since the effective kilometres operated per day by city buses is very low, the older vehicles are by and large assigned to the city services. They come to the city services, after having practically exhausted in full their capacity for long distance operations. This causes frequent breakdowns of vehicles and subsequent cancellation of trips. They also add substantially to the operating costs. These problems are examined in some detail in relevant chapters subsequently.

This study of the passenger road transport system in Trivandrum City has thus been taken up as typical of the passenger transportation system in most, if not all, second order cities within India and perhaps in a number of other developing countries. This is also perhaps an example of arriving at a policy decisions on nationalisation, without a thorough examination of the resources and financial aspects of the decision. The present study is thus an enquiry into the nature and dimensions of the problems of urban bus transport and possibly to suggest some solutions to these problems.

1.5 The Larger Dimension of the Problem

Kerala State can legitimately take credit for many notable achievements in development compared to the rest of the country. It is the most literate state in the country. The ratio of investment in education to the SDP is the highest for any state in the country. It has a low population growth rate-again the lowest among all the states. Its low rate of infant mortality and the man-woman ratio in the total population are comparable to those of developing countries. It has been able to develop a good health care system. The

'Kerala model' of development has often been very highly commented upon by the World Bank and other international agencies. The State has thus been rated very high on the Physical Quality of Life (PQL) Index. It was noted earlier that a good public transportation system can also, in one sense, contribute in a small measure to the quality of life in any society. It reduces the drudgery of going to attend to work and return and give them thereby a little more time for family life and entertainment.

In Kerala, the capital city of Trivandrum is the only urban area having a fully nationalised passenger road transport system. In other cities and towns within the State, private operators handle most of the intracity passenger traffic. Whatever be the other complaints about the private operators, they are given credit for carrying passengers more efficiently, at least in one respect, viz., that the passengers are able to reach their destinations faster. This convenience is precisely what is most lacking in Trivandrum City now. Complaints about the city services of Trivandrum have been endemic, including their poor working results, the workers' attitude to passengers etc. Only partial and haphazard attempts have been made in the past to rectify the maladies of the system. In fact, the total inadequacy of the passenger transport system in the City is, to some extent, reflected in the excessive proliferation of autorickshaws in the City, which were almost non-existent a decade ago. However, most of the regular travellers find them too expensive even if they take to them in emergencies. They are, therefore, forced to depend more or less completely upon the City's public bus service system.

1.6 <u>Some Salient Points to be Considered in Relation to the Problem</u>

While considering the public transport system in Trivandrum City, it would be helpful if the following are kept in mind:

* Unlike in other cities and towns of Kerala, Trivandrum City services are managed by a single government agency, viz. the KSRTC and any improvement can be effected only through government intervention, or at least with government support.

* Trivandrum City has a population of over five lakhs or more and if the adjoining panchayats which also come under the jurisdiction of the Trivandrum Development Authority are also taken into account, the total population is more than ten lakhs. It is still of a manageable size, from the point of view of public transport operations.

* The actual utilisation factor of vehicles during peak periods is very high - nearly hundred passengers travel in buses which have a seating capacity of less than fifty. But this rate of

utilisation could also be a reflection of the acute scarcity or shortage of adequate services.

* Improvements in city bus operation will help both the passengers and the crew. For passengers, it means a more dependable, punctual and comfortable travel and consequently greater consumer satisfaction. The crew of the buses are relieved of the difficult task of handling the 'unmanageable' crowds that throng the buses, especially during peak periods. A more efficient service may also bring in more revenue and less operating cost, thereby improving the working results of the Corporation.

* About 40,000 students travel in city buses using concession tickets. An assessment of their travel requirements, such as of origin and destination or their peak hours of travel demand can easily be made.

* With improvement in the operation of the Southern Railways, especially on account of the conversion of the meter gauge to the broad gauge system and the introduction of the North-South trains in the Ernakulam-Trivandrum sector, nearly 10,000 people come to Trivandrum City by trains everyday. (195, P 87) A sizeable population among them require bus services for reaching their destination.

* Transportation planning and improvement are not solely the responsibilities of the operator, as many other factors beyond the policy options of the operator

like government policies, changes in technology, energy costs, town planning etc. also affect transport operation.

* Even though this study is about Trivandrum City, and its passenger road transport system, some of the findings can be considered applicable and relevant to some other similar sized cities in India and other developing countries.

1.7 Objectives of the Study

The main aim of this study is look at the problem of the passenger road transport system, mainly from the operator's point of view, and to evolve a scientific and systematic step by step procedure to handle some of the critical problems in its operation.

Broadly, the problem tackled here can be considered to cover five areas.

A. Financial Aspects

The financial performance of the Trivandrum City Services and the consumer reaction to its operation.

B. Assessing Travel Demand

Assessment of travel demand is the immediate basis or foundation on which transportation planning is to be done. The different techniques used for collecting the required data and the different analytical techniques using the data are discussed in the succeeding chapters.

C. Scheduling of Vehicles

The problems and methods that can be employed for determining the optimum location of depots, routing, allocation of buses to depots, the process of making schedules or time tables, and their evaluation.

D. Maintenance Aspects

This may be considered as the 'hardware' of public transport management. The various techniques used in maintenance to improve the availability of the vehicles are considered and how far they can be made applicable to the Trivandrum City Services.

E. Planning for Future

The environment in which a transport system operates is never static. Even a good and efficient system may, over a period of time and under new compulsions in the environment, have to undergo changes. A growing city may make the existing system inadequate over a period of time. Planning the transport system vis-a-vis the growth of the city is indispensable.

Finally, a set of recommendations to improve the existing system, including the use of computers is also given.

1.8 Methodology

Transportation is an area about which a good number of studies have already been done all over the world, especially in the context of the special problems faced by the larger metropolitan cities. A detailed literature survey is given in the next chapter. Techniques and methodologies applied in this research study takes into account the procedure followed in similar studies elsewhere. The use of certain operations research techniques has also been referred to and exemplified in the present study. The usefulness and application of some of these new techniques developed have been demonstrated, using actual or assumed data.

1.9 Source of Data

For data collection and literature survey, the .places visited by the researcher include the following institutions:

1. Central Institute of Road Transport, Pune.
2. Road Transport Research Institute, Madras.
3. National Traffic Planning and Automation Centre (NATPAC), Trivandrum.
4. National Institute for Training in Industrial Engineering (NITIE), Bombay.
5. Indian Institutes of Technology, at Delhi, Kanpur and Madras.
6. Indian Institute of Science, Bangalore.

Reprints of research papers were obtained from Indian National Scientific Documentation Centre (INSDOC), New Delhi. Synopses of many research papers were obtained from Engineering Index. Only published data, which are accessible to all are made use of and the sources of data are mentioned, wherever possible. From the books, articles and papers referred to for the study, about 200 selected items have been included in the bibliography, updated upto December, 1991. In addition, data obtained from an actual field survey which was conducted in 1979 to ascertain the nature of the travel demand in the city and the consumer reaction to the quality of the services provided have also been made use of in this study.

CHAPTER - II

LITERATURE SURVEY

2.1 Introduction

Transportation being an area of wide interest and due to its influence on the different sectors of the economy, a large amount of research work has been done in this area in different parts of the world. To make a comprehensive survey of all the research work done in the field of transportation will, therefore, be difficult. What is attempted here is to take an overall view of the more important work done in the area of urban passenger road transport management and related fields. This survey has been based on the studies conducted in different areas pertaining to the operation of public transport services, such as energy conservation, operating efficiency, passenger convenience, maintenance, planning, etc.

2.2 Financial and Economic Aspects

The financial and economic aspects of public transport operation are dealt with in many research studies. Important statistical data regarding the Kerala State Road Transport Corporation's performance are available from the Corporation's Administration Reports, prepared for each financial year. (190) In addition, Kerala State Planning Board publishes an "Economic Review" every year, covering all facets of Kerala's economy. (196 to 199) "Statistics for Planning" is a publication by the Department of Economics and Statistics, Government of Kerala, which gives important statistical data about Kerala State. (206) Among others, the Public Undertakings Committee is one of the more important legislature committees constituted by the Kerala State Legislature Assembly which reviews the performance of public sector undertakings in the state. The Report of the Public Undertakings Committee on the Kerala State Road Transport Corporation contains many important references about KSRTC's working, both on financial and other matters. (203, 204, 205) B.A. Prakash in his doctoral thesis "A Study of the Economic Assessment of the Performance of the Kerala State Road Transport Undertaking in the Period 1959-71" makes an analysis of the performance of the KSRTC, covering a period of more than a decade, primarily from the financial point of view.(183) "Route Profitability Analysis in a State Transport Undertaking" is a study made in 1991 by Dr. Subhash Vaidya in which the author attempts to compare the relative profitability of different routes operated in an urban area.(158) He also makes an A-B-C classification of various routes, similar to the ABC analysis in inventory control, based on their profitability. "Transit Bus Privatisation and Deregulation Around the World: Some Perspectives and Lessons" is a study by J.R. Meyer and J.A. Gomez-Ibanez in which the pros and cons of privatisation - partial or full - of bus transport are discussed.(77) It has been argued here that deregulation will offer greater benefits since passengers are likely to receive more bus services with little or no increase in fares. They identify the different stages in the evolution of urban bus transport which according to them follows a cycle. Initially, private operators began the bus services and the service network grew. Government regulations are later enforced upon them by which the fares, wages of employees etc. are fixed. Further, growth decreases profitability. Due to this, private operators begin to leave the field or at least do not increase the services in proportion to increase in demand. Government takes over the operation. The services can now survive only with heavy subsidies. It becomes a burden on governments. This situation warrants privatisation again. In the study, "User Costs in Public Transport : A Cost Minimisation Approach", Peter Tisato suggests that to determine the extent of subsidy to be provided in public transport, one will have to find the additional cost the user will have to incur if he were to use the next least costly available mode (IPT) due to the non-availability of public transport. (157) Another study in the same area is, "Transport in Towns : Need for a Scheme of Bus Subsidy", made by Mohinder Singh.(136) The author says that in second order cities, which do not have suburban train service, bus is the common man's conveyance and that all over the world they are operating at a loss. For their survival, they are subsidised even upto sixty percent or more of their operating expenses. He emphasises, however, that economic viability alone cannot be considered as a measure to judge the efficiency of the urban bus system. "Cost and Financial Models for STUs", a study by A.V. Sri Raman and M.V. Bagade, tries to establish a cost model, defining the output and a unit for its measurement.(149) They also identify the costs and their variability vis-a-vis changes in the volume of output. A correlation between productivity index and profit or loss is also established. Another study on investment in transportation is "An Empirical Study on Interregional Transport Plans" by Campisi Domenico, et. al.(40) They highlight the socio-economic benefits a transportation system brings in. In order to assess the economic contributions that a transportation system makes, all factors like growth of productive activities in the region, increasing demand for products and services, transportation costs, trade flow patterns etc. should all be taken into consideration.

2.3 Traffic Surveys

Conducting traffic surveys to assess travel needs and of existing traffic is an important part of transport planning. The book entitled, "Traffic surveys under Indian conditions", written by C. Anantha Padmanabhan gives details of the different types of traffic surveys, and the methodology for conducting them.(2) In 1969, the National Council of Applied Economic Research published the study, "Regional Transport Survey of Kerala" which makes an assessment of travel characteristics by all modes of transport within Kerala.(200) The article, "Methods of Urban Travel Demand Forecasting" by S. Raghavachari, describes the various efforts that have been taken to collect details of a major transportation system, and the entire problem is presented from the consumers' point of view and the various methods to tackle these problems are accordingly classified and discussed.(116) The Bureau of Public Roads, New Delhi has published a procedure manual, "Conducting Household Interviews, O/D Surveys", which gives various guidelines for conducting such surveys.(191) The National Traffic Planning and Automation Centre (NAPTAC) has made a comprehensive survey of the different travel aspects of Trivandrum City in their report entitled, "Traffic Survey of Trivandrum City".(180) This report, prepared in 1979 has been brought out in several volumes, each one dealing with one or more aspects of transport operation in the city. "Optimal Design of Bus Routes and Frequencies in Ahmedabad" by B.R. Marwah et. al., describes the method developed to select routes and assign frequencies for the bus system in Ahmedabad City.(73) "Reorganisation of Routes of Bus Transport System in Bangalore" by N.S Srinivasan et. al., describes the study made about the bus route system in Bangalore City and suggests a reorganisation of the system.(146) "Buses : The Life Line of Delhi" by Taran Jeet Singh gives a picture of Delhi Transport Corporation's operations, based on which the DTC started some new services like 'Sugam seva' and 'Mudrika seva'.(142) In the absence of a suburban passenger railway system, people depend mostly on buses for their travel needs. "Public Transport in India and Developing Countries of Asia" is an article by P.G. Patankar, dealing with the nationalisation of road transport in India, its purpose, benefits obtained and deficiencies.(97)

2.4 Energy Conservation

Transport undertakings have an important role to play in the national effort at energy conservation. Considering the fact that 33 percent of the commercial energy consumption in India is due to the transport sector, this problem of energy conservation in road transport assumes special significance.(12, p 7) India is a net importer of oil. There have been frequent increases in crude oil prices. Transport undertakings generally use diesel oil on account of its steep price differential with petroleum within the country. Diesel efficiency in terms of kilometres per litre among the different transport undertakings varies from 3.00 to 4.95. P.G. Patankar in his article, "Fuel Efficiency Through Optimal Fleet Maintenance" discusses the various measures related to the maintenance of the engine and the vehicles to maximise fuel efficiency. (94) Another study, "Energy Demand Management in the Transport Sector" by the same author gives a picture of the energy consumption in the transport sector as a whole, with details of the sources of the energy and how they are utilised.(93) The study "Energy Aspects of Urban Transport" conducted by V. Nagaraja suggests the different measures by which energy losses can be reduced in urban transport.(83) He suggests, inter alia, restricting the use of personalised transport, use of high octane fuels, increased use of higher capacity vehicles, etc. The paper, "Energetics of Transportation System" by C. Dattari and M. Sidhardha Bhat makes a comparative study of the different modes of transportation used in India. Parameters like specific fuel consumption, mileage, power ratings, capacity, capital and maintenance cost etc. are evaluated for different systems.(45) The study "Diesel Economy Drive in Cholan Roadways" by V. Soman describes the training for drivers in Cholan Roadways to improve their fleet's fuel efficiency.(143) "Energy Conservation in Service Industry - Transport" by

Satyanarayana in 1988 provides many interesting statistical data regarding the energy demand pattern in the whole transport sector. He also suggests various fuel conservation measures like encouraging the use of public transport, better roads, weight reduction of vehicles, reducing aerodynamic drag on vehicles, reduction of rolling resistance, driver training, etc. (130) The paper "Fuel Economy in Vehicles Through Materials and Design Innovations" written by Seetha Bharathi et al describes the various design alterations to effect fuel economy. These include reduction of weight of the vehicles, reducing aerodynamic drag, and rolling resistance, improving engine efficiency and, also, transmission efficiency.(133) "Fuel Conservation - Role of CIRT" (Central Institute of Road Transport) gives details regarding the Institute's activities in this field such as training programmes, consultancy work, conduct of seminars, research and development activities, conduct of studies and their publication, etc.(183) "Fuel Conservation : APSRTC Style" by A. Jagadeesh Prasad published in 1989 deals with the various measures taken by the Andhra Pradesh Road Transport Corporation for improved fuel efficiency. (112) It is stated as essential to develop a 'fuel economy culture' among workers. Awards, publicity, cash rewards (depot-wise) etc. are all parts of this. Technical and managerial controls are also critical.

"Joint Effort of PCRA and STUs in Improving Fuel Efficiency" by S. Srinath Rao describes the five-phase plan which the Petroleum Conservation Research Association (PCRA) implements in selected depots of state transport undertakings. (124) These are: (i). Selecting the depot, (ii). Diagnostic study of the depot, (iii). Implementation of PCRA recommendations, (iv). Follow-up and (v). Evaluation of performance. "Conservation of Fuel Through Traffic Management" highlights the various traffic control measures to conserve fuel, viz, one way streets, tidal operation, i.e. reversible one way streets closure of side streets reducing turning movements and synchronised traffic signals.(91)

2.5 Fleet Maintenance

Proper maintenance of the fleet is one of the most important factors which ensure the smooth operation of services. A. Satyaramachandra, in his article, "How to Ensure Success of a Preventive Maintenance System" lists a number of factors which will improve maintenance efficiency.(131) These include prompt attention to drivers' complaints, proper planning of maintenance, availability of spares and other supplies etc. "Optimum Level of Preventive Maintenance of Vehicles" is a study by M.R.Prasad, in which he compares different possible levels of preventive maintenance and selects the optimum one.(113) A study by K. Gopalakrishnan Nair and K.V. Krishnan Kutty entitled, "A Feasibility Study of Unit Replacement System in a Passenger Road Transport Depot", examines the benefits of reducing the maintenance time of vehicles by unit replacement in certain instances based on data collected in 1984. (85) Anil Dey's paper on "Engine Failure Analysis" describes the benefits of analysing the past failure data to find out and the causes for breakdowns and their prevention. It also suggests a method of quick diagnosis of defects.(46) "Estimating Bus Component Failure System from Censored Sample" is an article written by T.H Maze et. al. which develops a technique to estimate bus component failure distributions in an operational setting.(75) "Failure Analysis of Plain Bearings" by R.K. Mathur and B. Prakash analyses the causes of bearing failures, showing the percentages of their occurrence due to various reasons. The causes of each type of failure is also further analysed in the study.(74)

2.6 Vehicle Replacement

Determination of the most economic replacement age of vehicles is an important factor which affects the maintenance function, as a fleet of older vehicles increase the overall maintenance effort and cost. "Bus Replacement Policy : Fact and Fiction" by M. V. Bagade is a study of the vehicle replacement ages adopted by various state transport undertakings. (28) He points out how the total expenses covering the cost of maintenance, labour, cost of spares, and other repair costs increase with the age of the vehicle. He suggests that separate economic lives should be calculated for tyre, engine, fuel pump, gear box etc. The study on "Comparative Analysis of Techniques for Determination of Bus Replacement Intervals" by G. Amelita Rueda and G. Floyd Miller compares six of the popular models, viz, fleet age profile analysis, average cost analysis, strategic fleet acquisition and retirement model, maintenance cost trend analysis, life cycle cost analysis and the annual maintenance cost limit method and examines how they can be employed to determine the economic life of a vehicle and considers their relative advantages and disadvantages. (125) The paper, "Replacement of Deteriorating Equipment" by R.C. Misra, et. al. uses the concept of overhauling to solve the replacement problem of deteriorating equipment, though the example considered is that of air conditioners.(78) The economic life of air conditioners, calculated in this case study is 14 years.

2.7 Organizational Design

Organisation theorists are of the opinion that there is an ideal organisation for every concern, depending upon the nature of the business it does. Some papers discuss about the organisation structure of transport undertakings. "Types of Organisations and Their Effectiveness" is a paper by M.V. Bagade, in which both the two-tier and the three-tier types of organisations in state transport undertakings are examined. This study, made in 1981, also touches upon the factor of 'manageable size' of an undertaking. (32) "Dynamics of Building an Ideal Organisation" by R. Ganesan discusses the conceptual framework for building organisational structure for an urban transport undertaking.(56) "The Role of Management Services Division" is a study made in 1985, in which the improvements obtained by the working of the Andhra Pradesh Road Transport Corporation by the efforts of its management services division are discussed.(187) "Information System for Bus Fleet Management" by Elliot Gitten et. al. investigates the use of a computerised fleet management information system in the transportation industry. It also examines the state of the art of the fleet management system. (61)

2.8 Urban Transport System in India and Abroad

Study of transport operations in cities, both in India and abroad, will give an idea of how various transport problems are attempted to be solved. Some of the recent papers published in this connection are briefly reviewed here. "Development of Urban Public Passenger Transport in the Cities of U.S.S.R." by

V. Vlassov gives the guidelines used for transport development in U.S.S.R, where 20 to 30 years of forward planning is undertaken.(163) "Planning the Development of Urban Public Transport in U.S.S.R." by V. Vlassov and D.K. Tomlyanovich describes the development of urban transport in an orderly fashion and restricting the use of private vehicles.(164) P.G. Patankar's study on "Brazilian Transportation", prepared during his visit to Brazil in 1983 gives an idea of the several implications of the Brazilian transportation system where 'Gashol', which is derived from vegetable oils, is used as one of the main automobile fuels.(92) A very high priority is given by the Brazilian Government to public transportation. The same author's article, "Urban Transportation in Japan" mentions that no public transportation system operates on a profit in that country.(102) "Public Transport in Dublin" gives the salient features of the public transportation system in Dublin, the capital city of Ireland, which has one third of the country's total population.(114) The City has installed AVM (Advanced Vehicle Monitoring system) which continuously monitors the position of each vehicle from a central control room. Again, P.G. Patankar in his article, prepared in 1985, "Road Transport in India and Other SAARC Countries" makes a survey of the traffic scene in India and other SAARC countries. (100) The article, "Characteristics of

Conventional Public Transport Services in Third World Countries" by D.G. Jacobs et. al., is made after corresponding with seventy bus operators throughout the developing world.(66) The authors find that in most of the third world countries bus operation is in loss due to poor management and inadequate fare structure. The study, "Public Transport in Second order cities in India" by P.G. Patankar and P.R. Fouracre, shows the details of a study conducted in 1985 in three medium - sized cities in India, viz., Baroda, Jaipur and Patna.(98) Each city's public transport system is analysed, taking into account such factors as the influence of government policy, energy consumption, employment generated, etc. "Kolhapur Municipal Transport" by V.S. Shithole and V.V. Mahajan is a study of the bus use characteristics by the residents in one of the wards of Kolhapur town. Relationship between monthly income and bus travel is correlated by the authors.(135) D.K. Halder's article prepared in 1981 entitled, "Calcutta Tramways:Prospects and Retrospects" surveys the operation of the Calcutta Tramways system, which is more than a hundred years old now. (65) Nearly eight lakh passengers are carried by it every day. "Scenario of Road Transport in Kerala" by N.S. Srinivasan makes an overall survey of Kerala's transport scene, by different modes.(147) "Bus Transportation System Planning in a City : A Case

Study" by L. Ganapathy and D. Acharya is a study conducted during 1968 in Bhubaneswar, a city having a population of more than two lakhs.(55) Respondents in five percent of a total of sixty thousand houses were interviewed to collect travel details. A new operating structure of the vehicles is suggested in this article. "Bombay's Transport System" by J.S. D'Souza surveys the transportation problems faced by the metropolitan city of Bombay. (48) In this article, prepared in 1986, he examines the measures to be taken in traffic planning to ensure efficient transportation facilities in coming decades.

2.9 Transportation Planning

Planning of urban transport - both at the national level and the individual city level - is dealt with in many studies. This includes the design of route networks. "Planning Problems of State Road Transport-India" by S. Subramonian focuses on some of the planning problems of state road transport undertakings in India.(151) It seeks to examine the environment and the constraints under which state transport undertakings are called upon to operate. "Traffic and Urban Planning in the Future" was one of the themes discussed at the 46th International UITP Congress held at Brussels in 1985.(189) The Congress was of the opinion that for good planning, accurate demographic data and travel data are essential. Also, quality of services should be considered where quantity objectives are met. "Study of Bus Route Planning for Urban Road Network" by Kozo Amano et al, considers the many aspects involved in route planning.(22) Past experience of bus operators is also to be taken into account in routing decisions. "Practice of British Bus Operators in Planning Urban Services" by T.A. Chua and D.T. Silcock is about a survey conducted in 1981 to find out the replanning of major urban networks in United Kingdom and the approaches adopted by the operators concerned.(43) "Transport Planning in Small and Medium-Sized Urban Areas" by Arun Chatterjee and L. William Greco provides some guidance in the direction of the various issues related to transportation planning in small and medium sized cities.(42) The paper also reviews the evolution and changes in the planning process and identifies the major pitfalls that have been discovered and the lessons learned. "Design of Routes, Service Frequencies and Schedules for a Municipal Undertaking" by W. Lampkin and B.D. Salmans describes the reorganisation of a municipal bus undertaking. The reorganised system reduced the fleet size to eighty one percent, the mileage operated by five percent and the crew wage bills by thirteen percent.(70) "Traffic Management in Metropolitan Cities" by K.K. Paul gives a general picture of increasing urbanisation and its subsequent pressure on the transportation system.(107) Several traffic management measures like one-way streets, lane management, synchronised traffic lights, parking control etc. have also been discussed in the paper.

2.10 <u>Vehicle Scheduling</u>

Scheduling of vehicles is probably the most important aspect in the whole field of transport management. Naturally, a good deal of research work has been conducted in this area. A review of some of the most recent research studies is given below.

T.A.S. Vijayaraghavan's study, "Vehicle Scheduling : An Overview of Problems and Issues" mentions about the strategic, tactical and operational aspects of vehicle scheduling.(162) The study entitled "On Bus Schedules" by J.D. Foulkers et. al. discusses about the direction of the flow of passengers in a network, frequency of operation, waiting time of passengers etc.(53) "Routing and Scheduling of School Buses by Computer" by Lawarence Bodin and Lon Berman gives a new procedure for routing and scheduling.(38) This procedure, when implemented and tested successfully, resulted in twenty percent savings in operation. T.J. Gaskel's article, "Bases for Vehicle Fleet Scheduling" deals with the problem of allocation of customers to different routes to optimise operating expenses.(58) "An Algorithm for Bus Scheduling Problem" by J.L. Saha attempts in devising a new schedule for buses operated by a state transport corporation.(126) An algorithm which minimises the total number of schedules to be operated is derived. "Vehicle Scheduling-A case Study" by J.J. Mc Donald is not exactly about passenger bus scheduling, but still it has many striking references to bus fleet operation. (76) The paper deals with the collection of laboratory specimens from different places to a central laboratory. "An Algorithm for Optimal Bus Scheduling" by K. Gopalakrishnan Nair describes a step by step procedure for vehicle scheduling in a city, given the route net work and traffic demand.(84) "TRAMP : A Multi - Depot Vehicle Scheduling System" is a paper by P.J. Cassidy and T.S. Bennet in which 'TRAMP' denotes Transport Routing And Multidepot Problem.(41) The programme developed is not for passenger buses, but for a fleet of vehicles which collects meals from 180 kitchens and delivers it at 390 dining centres. "Scheduling of Vehicles from a Central Depot to a Number of Delivery Points" by G. Clarke and J.W. Wright considers the optimum routing of a fleet of vehicles of various capacities from a central depot to a number of delivery points.(44) The paper develops an iterative procedure that enables the rapid selection of an optimum or near-optimum solution. "Scientific Method to Urban Bus Route Scheduling - A Case Study" by A. Veeraraghavan and N.R.N. Sinha deals with the analysis of traffic demand, prepard during 1988, of a single route of length 8.7 km in Bangalore City between Bangalore Bus station and Jayanagar.(160) "A Key to Bus and Crew Scheduling", by M.V. Bagade gives some general guidelines for scheduling vehicles and crew members to maximise EPKM (Earnings Per Kilometre), EPB (Earnings Per Bus), optimum bus utilisation etc.(27)

2.11 Application of Computers in Transportation Planning

The advent of computers has brought its application in passenger transport management also. Some of the studies dealing with computer applications and computer simulation are mentioned below. "A Game/ Simulation for Transport Management" by Aaron Adiv describes how a simulation program can be used for educating citizens about transportation problem in their neighbourhood.(21) "Traffic Simulation Studies : A Review" by B.K. Katti and B. Raghavachari, prepared in 1985 reviews traffic simulation studies done in India and elsewhere and points out that computer simulation is a powerful, flexible and practical way to study complicated traffic problems.(67) "Simulation Study of Bus Transport" by J. Victor David and S. Moses Santhakumar attempts to look at the theory and practice of traffic simulation of a bus service on a particular route and suggests possible improvements.(161) "Corporate Simulation of an Urban Bus System" by R.

Ganesan and S. Ramani discusses developing a simulation model of an urban system to evaluate various policy alternatives, planned service levels, fare structures and replacement periods, the system response being the income generated.(57) "Computer Assisted School Bus Scheduling" by R.D. Angel et. al. attempts to schedule the school buses with objectives like (i) minimising the number of routes, (ii) minimising route length, (iii) no overloading of buses; and (iv) minimum travel timings.(23) "Computer Scheduling of Vehicles from Over One or More Depots to a Number of Delivery Points" by Antony Wren and Allen Holliday is about scheduling of vehicles from a number of depots to customers, subject to considerations of load, distance and time of operations.(24) "The Vehicle Scheduling Problem and Monte Carlo Simulation" by G.M. Buxey discusses a new method of planning the routes of a fleet of carriers, subject to maximum load restrictions. (39) It is derived from a combination of wellknown savings heuristic rule and Monte Carlo simulation. "Computerisation in State Transport Undertakings" by Arun Mokashi published in 1988, discusses the recent cost hikes in clerical operations which makes computerisation cost effective and also brings about other computational benefits.(81) It also lists the various areas where computerisation can be effectively implemented. "Computerisation Strategy and Organisation of EDPs in

STUs" by G.S. Gill discusses the various areas where computerisation can be effectively used. The study made in 1990, compares the bottom-up and top-down approach. (60) Some possible organisational structures of the EDP department are also discussed in the paper.

2.12 O.R. Applications

Operations research (O.R) is a field of knowledge which was mostly developed during the Second World War and in subsequent periods. Its applications have today spread to cover a number of areas. The use of computers and the facility they provide for quick data processing enhance the utility of O.R. further. Some papers dealing with O.R. applications in transport are reviewed here.

"Intraurban Optimisation Through Operations Research" by Santhosh Sharma describes how O.R. techniques can be employed for designing an intraurban bus operating system that could optimise carrying capacity.(134) S.R. Tapade's paper "Linear Programming as an Aid to Fleet Allocation" shows how the transportation algorithm can be used to assign buses from various depots to various operating centres so as to minimise the total dead kilometres.(155) The same author's study on "Requirement of Maintenance Facilities in Depots:An application of Queuing Theory" shows how queuing theory can be applied to minimise the waiting time of buses in two facilities, viz, (i) inspection pits and (ii) washing platforms.(156) J.G. Weston's paper, "Operations Research in London Transport", explains how various O.R. techniques are gainfully being utilised in solving the problems relating to vehicle availability, level of spares, ticketing systems, etc. (165) "A Goal Programming Approach to Road Transport Management" by V.N. Patkar and S.K. Modak shows how goal programming which is a modification of linear programming can be used to assign buses from their depots to operating centres so as to minimise dead kilometres.(106) Further, for other objectives like ensuring that (i) all buses are sent from depots; (ii) each terminal is supplied with at least sixty percent of the buses required; and (iii) the demand at any one terminal is completely met etc. can all be satisfied through goal programming. Another similar paper, "Efficient Allocation of Buses to Depots : A case study" by B.G. Raghavendra and M. Mathirajan deals with allocating buses in Bangalore City, which has 1200 buses and nine depots.(118) Here again, in the study the dead kilometre distance from depot to operating centre was minimised, and a savings of 1241.7 km per day was achieved.

2.13 Interfirm Comparisons

Interfirm comparison is a very versatile tool to analyse the performance of organisations. Since all major states in India have their own public road transport undertakings, studies can be conducted about their performance individually and/or collectively. One good source of data for interfirm comparison of state transport undertakings is the Central Institute of Road Transport's publication "Performance Statistics of STUs", which gives all important statistical data, compiled for each financial year. Presently, reports upto 1990-91 are available. (201, 202) Some of the findings from such interfirm comparisons were as follows.

"Criteria for Evaluation of STUs" by S.S. Murthy compares the performance of fifteen STUs, based on 1983-84 figures, taking into consideration various productivity measures like effective kilometres operated, operating cost per bus, earnings per kilometre, vehicle utilisation etc.(82) "Comparative Analysis of the Performance of STUs" is a report by the Planning Commission which also compares the performance of the STUs, using more or less the same parameters.(194) STUs are also ranked according to their performance. "State Transports Struggle for Survival" by M.V. Bagade explains the reasons why almost all STUs are operating at losses.(31) He points out the reasons like high tax incidence, compulsion to operate uneconomic routes, high establishment cost, inadequate fare structure etc. M. Shivaji Singh's study, "Are STUs Successful in Optimising Their

Operations?" is mainly concerned with the seat kilometres operated as a criterion for measuring the performance of the STUs. He points out that the seat kilometres operated, seat kilometres cancelled, and seat kilometres occupied can be taken as a measure of the productivity of operations.(139) The operation of APSRTC for ten years on the basis of such a criterion is analysed in this study. The study "Financial Problems of Nationalised Transport" by A.V. Raman also attempts to explain the reasons for the operating losses of STUs.(121) He argues that the losses are not real since, according to him, taxes and interest paid by STUs should also be taken into account in computing profits and losses. "Resource Utilisation Index : A Case Study of MSRTC" by M.V. Bagade points out the many productivity indices that are valid in analysing passenger road transport operation, such as productivity of vehicles, productivity of manpower, productivity of fuel, spares etc. (30) "Success Story of Rajasthan SRTC" by Gyan Prakash Pilania lists the various productivity measures taken by Rajasthan State Road Transport Corporation which made it earn profits.(109) This report, made in 1985, mentions about various aspects like better capacity utilisation, improved quality of service, effective inventory control and performance budgeting. "Comparative Study of Certain Traffic Parameters in Selected STUs" by Ch.

Hanumantha Rao compares some important operational parameters like kilometres operated per bus per day, load factor, traffic staff and total staff per bus, crew productivity, regularity and punctuality in operations, fate of complaints lodged, etc. based on performance data during the year 1981-82 to 1987-88. (122) "Performance Index of State Road Transport Undertakings" by A.K.Bhatia also measures productivity, using such factors, as fleet utilisation, vehicle output measured in terms of kilometres per bus per day, load factor, and fuel efficiency etc. (36) "Alternative Evaluation Criterion for STUs as Public Entreprises" by M.G. Pathak emphasizes the fact that profit is not to be used as the sole measure of efficiency in STUs, since they purposely make book losses for getting benefits like non-payment of income tax, the volume of bonus to be paid to employees, as a ready excuse for price hike. (105) In this study made in 1990, he suggests alternate criteria like value added, i.e. the collections from operations, cost, overall benefits to the economy, managerial appraisal, inter-organisational comparisons, etc.

2.14 Future Scenario

"Road passenger Transport : A Peep into Future" by P.G. Patankar surveys the future scenario of transport scene in India.(99) The author says that the IPT (Intermediate Passenger Transport) mode will continue to play an important role in city transport systems in India. In discussing the directions in the development of urban transport, he reviews many aspects like land use planning, traffic management, pedestrian precincts, parking areas, etc. In "Future Transport Technologies in Metropolitan Cities with Special Reference to Delhi" R.G. Gupta considers the different hypotheses with respect to Delhi traffic, with varying traffic volume and varying traffic management systems.(64) Rajesh Pilot's study, "Passenger Road Transport : 2001 AD" looks forward to the transport scenario and the options that may be available to the transportation system by the turn of the century.(111) He also touches upon the growing urbanisation rate, energy crisis, newer technology etc. to advocate the new role to be played by the public systems in the transport sector. "Challenges to Future Urban Transportation Planning" by Joseph L. Schofer identifies some key issues and choices facing urban transportation planning and planners during the eighties.(132) Among these are selection of the mode, appropriate role for analytic models, implementation processes, and styles of planning. "Urban Transportation in India" by N.S. Srinivasan and D. Babu Paul makes a comprehensive survey of the urban transport scene in India. (148) It makes a review of the urbanisation process, growth of vehicle population, and the demand for mass transport. This study, made in 1983, also suggests some steps to be taken to meet the future demand of passenger transportation. In his study "Urban Transport : The Search for Viable Options" P.Sudarsanan argues that transport planning should be an integral part of urban planning, which will mean careful allocation of activities to minimise travel needs.(153) "Management of Metropolitan Transport systems" by P.B. Kelkar provides many statistical data regarding the future prospects of urban transport.(68) It also surveys the modal split of transportation in big cities. A.T. Amstrong Wright's article, "Transport Problems in Dense Urban Areas" is a study made with particular reference to Hong Kong, which is one of the most thickly populated metropolises in the world.(25) This city tries to improve the traffic situation by taking various measures like traffic management schemes, area traffic control, public transport priority measures and restraints on private transport. "Gamut of Urban Transportation Systems" by M.V. Bagade adopts the systems approach and points out that the entire gamut of the urban transportation systems has several internal subsystems acting independently, having an interlink in such a manner that changes in one will affect others.(29) "Perspective Planning for Transport" is a Planning Commission report which points out that in future, key features of the transport scene will be (i) upgrading of technology and modernisation of road transport, (ii) introduction of multiaxled vehicle for freight operations; (iii) State-of-the-art of buses and bus bodies; (iv)safety improvements; and (v)upgradation of two-wheeler technology.(182)

2.15 Conclusion

The above literature survey is only illustrative of the different aspects that have necessarily to be taken into consideration in making an assessment of the economic value of the public transport systems. Reference has also been made to the application of the newer techniques that have been brought in for making such an evaluation. The newer techniques are also very relevant with regard to effecting greater economy and efficiency in operations and, at the same time, have better response to consumer needs. In conducting the present study, these aspects have been kept in mind so that a deeper understanding of the problems faced by the city bus transport system in Trivandrum and in finding solutions for them can perhaps be made.

CHAPTER - III

TRIVANDRUM CITY BUS SERVICES: ORGANISATIONAL SET UP

3.1 Introduction

Trivandrum is the capital of Kerala. It became the capital of the erstwhile princely state of Travancore in 1745, when the capital was shifted from Padmanabhapuram situated in the present day Kanyakumari District of Tamilnadu. It remained so upto 1949 and, thereafter, it became the capital of the Travancore-Cochin State. It become the capital of Kerala, when the State was formed in 1956. In addition to being the capital, it is also one of the more important tourist destinations in South India. It has also a large number of educational institutions and can be truely called as an educational city. Since there are a large number of State and Central Government offices in the City, it can also be called an office-goers' city.

Trivandrum has a population of 5,23,773 as per the 1991 census, with an area of 74.93 sq.km. It has a density of population of 8074 persons per sq.km. It is a typical medium-sized 'second order city'. Important statistical data regarding the city are given in Table 3.1. Trivandrum is also a 'bi-lingual city' with a sizeable Tamil-speaking population.

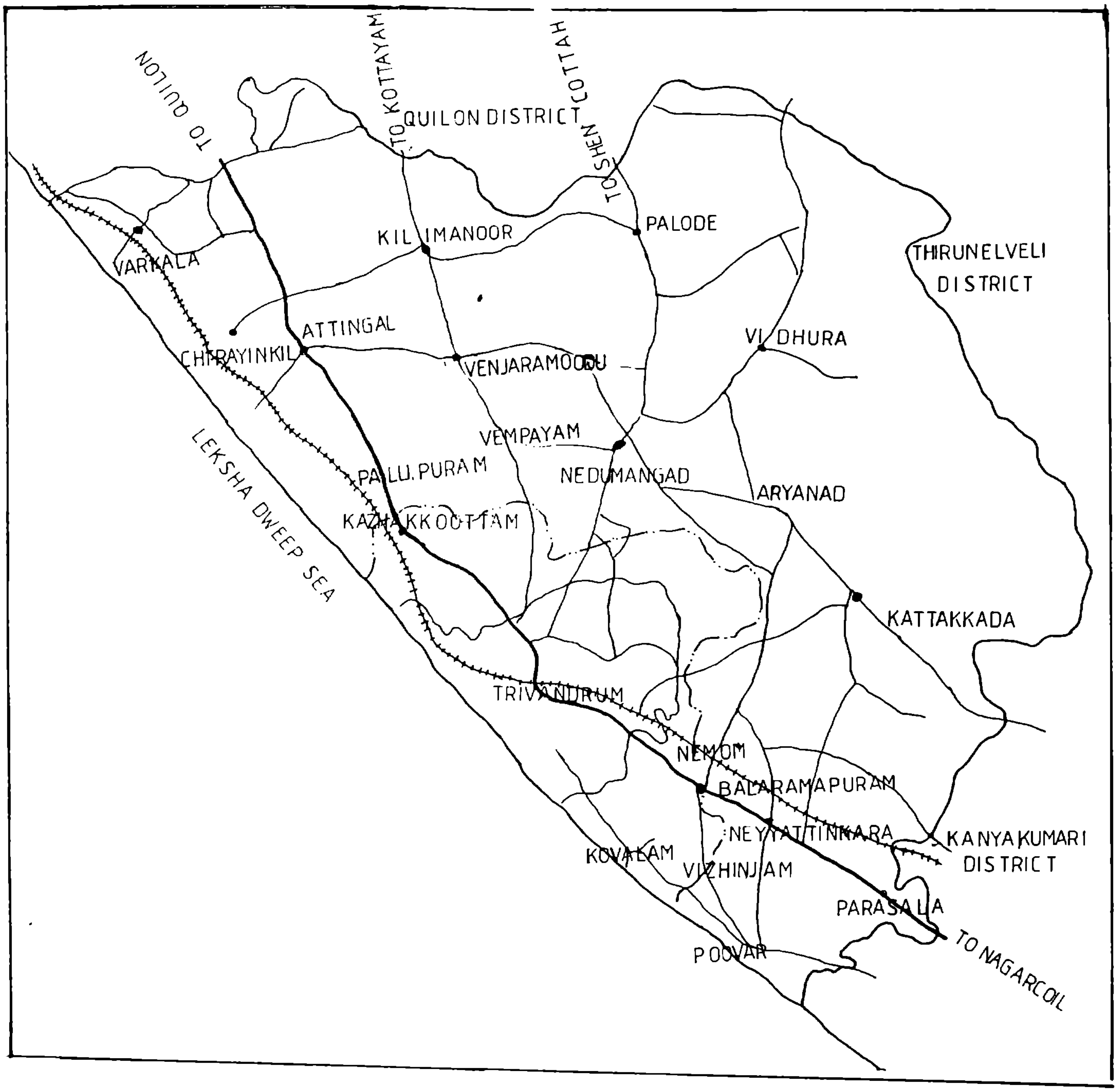
3.2 Geographical Aspects

Geographically, Trivandrum is a sea coast city, right on the Arabian Sea, at the southern end of the Kerala State. It is only 88 kilometres away from the land's end of India - Kanyakumari or Cape Comorin. Its latitude and longitude are 8° 25' North and 76° 55' East. It is also the capital of the Trivandrum District, the southernmost among Kerala's 14 districts. Trivandrum district has an area of 2192 sq.km. and a population of 29.39 lakhs, according to the 1991 census. It comprises four taluks - Neyyattinkara, Nedumangad, Chirayinkil and Trivandrum. Apart from being the State capital, Trivandrum is also thus a district and taluk capital.

Trivandrum enjoys a tropical climate throughout the year and the temperature hardly goes above 34°C or falls below 20°C. The annual rainfall is 2137 mm as per the 1991 data. While part of the rains is brought about by the south-west (onward) monsoons, the remaining part is due to north-east (returning) monsoons. The Neyyar, Karamana and Vamanapuram rivers flow through this district. They are not, however, very large rivers.

Broadly, the district can be divided into three geographical regions: the coastal region, the midland region and the hilly region. Map 3.1 shows Trivandrum District with its more important places. All these places are connected by roads. National Highway-47 and the broad gauge railway line, connecting Trivandrum to various important cities in India can be

Map 3.1 Trivandrum District



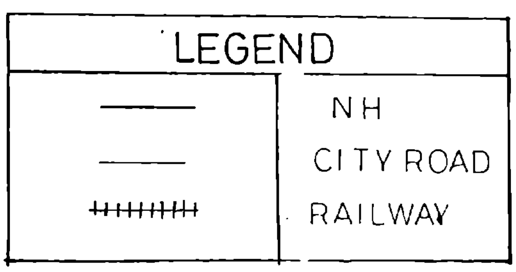


Table 3.1

TRIVANDRUM CITY: BASIC STATISTICAL DATA

Total Area of Trivandrum Corporation - 74.93 sq.km

(Land Area - 64.87 sq.km)

Present Population - 5,23,773 (1991 census)

Population Density - 8074 persons / sq.km

Population Growth

Census year	1961	1971	1981	1991	2001
Popul- ation	2,39,815	4,09,627	4,83,086	5,23,773	6,56,320

Number of wards in the Trivandrum Corporation - 50

Length of motorable roads - 330 Km

(Sources: Govt. of India, Census: 1991, page 236 Development plan for Trivandrum 2001 pages 44, 99)

Educational Institutions (as on 1991)

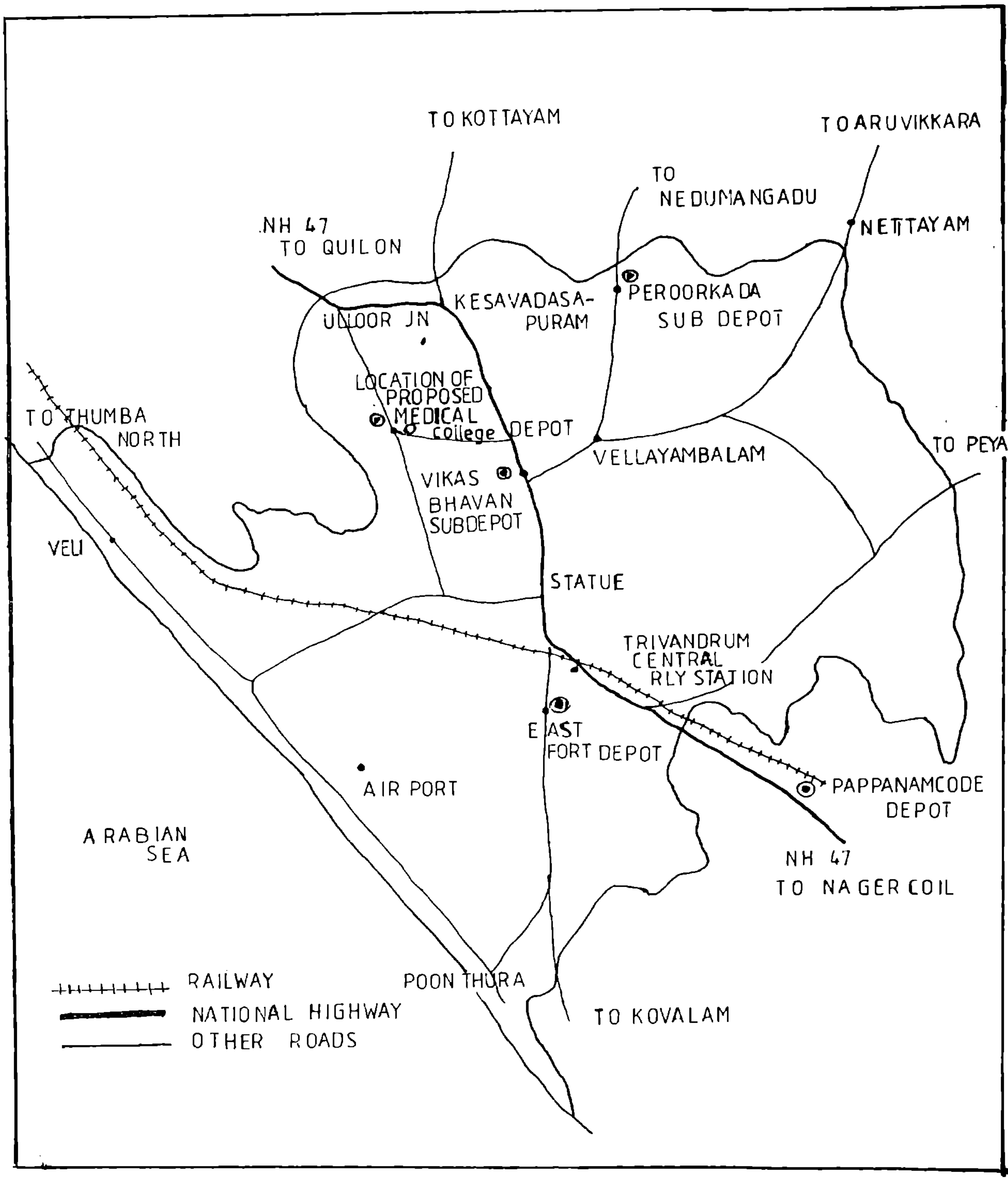
Lower Primary Schools	-	55
Upper Primary Schools	-	27
High Schools	-	47
Colleges	-	14
Total		143

(Source: Department of Town Planning, Government of Kerala Development plan for Trivandrum 2001 page 54) seen in the map. Being the district and taluk capital, Trivandrum City attracts considerable passenger traffic from all places of the district. The floating population is, therefore, very large.

Agriculture is the main occupation of the people. The north-eastern part consists of a number of rubber and tea plantations concentrated in the hilly region. Otherwise, the main crops are coconuts and paddy.

Map 3.2 shows the boundaries of Trivandrum City. The area comprising places like East Fort, Thampanoor and Statue Junction can be considered as the heart or Central Business District of the City. The City is spread all around this CBD. The location of the four bus depots of KSRTC's City Services is shown in the map. It can be seen that while East Fort and Vikas Bhavan depots are in the centre of the city, the Peroorkada depot is located in the north-eastern boundary and the Pappanamcode depot is located outside the city limits, on its south eastern side. It is often said of Trivandrum that, like Rome it is built on seven hills. It is thus that Trivandrum, even though a sea coast city, has an undulating terrain of hillocks and valleys. Due to this, the roads are not level. This topography aids the flow of rainwater during the monsoon season, but has roads with such a high gradient which are not advantageous from the transport

Map 3.2 Trivandrum City - Boundary Map



operator's point of view. There are also low lying areas in the city among the hillocks which get flooded during heavy rains, causing hindrance to traffic until the flooding rain water recedes. The rain water is also a great scourer, cleaning up the streets after the rains. But every time after the rainy season, the condition of the roads becomes very bad. A good amount of money has, therefore, to be spent on road repairs after the monsoon rains, which is not always available with the City authorities. There are no marshy or water-logged areas as such in the City as most of the area of the City has laterite soil on which multi-storied buildings can be constructed without major structural problems.

The City has grown outwards in different directions from the central nucleus. Its growth is restricted only on the western side due to the Arabian Sea. This is perhaps one reason why too many high-rise buildings do not come up in Trivandrum, unlike in other urban centres, where the idea of high-rise residential flats or apartments have become quite common. There are, ofcource, other traditional cultural factors which due not favour the high-rise appartment culture in Kerala, though there are recent indications that this culture of independent houses is changing due to the desire of people to live in the heart-land of the City, but are constrained by the increasing land prices.

The land-use pattern of the city area is shown in Table 3.2. Nearly 60 percent of the land area is used for residential purposes. Since there are only a few industries in the City, the industrial area accounts for only 2.17 percent of the total area. Trivandrum City has about 10 percent of its area as paddy fields, but even these areas are, in recent times, being converted as residential colonies.

Trivandrum City's adjoining areas can be considered as semi-urban areas, almost being small satellite townships though not planned as such. The Trivandrum urban area includes officially seven more panchayats as may be seen from Table 3.3. The Trivandrum metropolitan area or the Greater Trivandrum area also includes another eight panchayats. In all, there are thus fifteen panchayats, in addition to Trivandrum Corporation constituting Greater Trivandrum. Map 3.4 shows Trivandrum City and adjoining panchayats. The external boundary of the map shows the area under Trivandrum Metropolitan Area. The seven panchayats forming a part of Trivandrum Urban area, are mainly located in the coastal belt. Daily commuters in Trivandrum City include the residents of these panchayats also, in addition to the regular city-dwellers.

3.3 Population

Trivandrum City's present population of about

Table 3.2

Land Use Pattern in Trivandrum City
(Total land area in Trivandrum Corporation:64.87sq.kms)

Category	Percentage
Residential area	59.04
Paddy field	9.60
Public & Semi-public area	8.86
Parks & open space	7.84
Transportation area	7.73
Industrial area	2.17
Water course area	2.11
Restricted area	1.73
Commercial area	1.32
Total	100.00

(Source: Department of Town Planning, Govt. of Kerala. Development Plan for Trivandrum 2001 page 48)

Table 3.3 Trivandrum Urban Area

'Trivandrum Urban Area' consists of seven adjoining panchayats also. These are as follows.

No.	Name of Panchayat	Population (1991 census)	Area (Sq.Kms)
1.	Cheruvikkal	21,223	8,24
2.	Kazhakuttam	12,512	19.47
3.	Kovalam	25,275	12.6
4.	Sreekaryam	17,238	23.73
5.	Thiruvallam	31,890	13.60
6.	Thumba	32,911	16.03
7.	Vattiyoorkavu	33,595	10.62

(Source: Govt. of India Census 1991 page 234)

Trivandrum City Region

Trivandrum City Region (Metropolitan Area) under the jurisdiction of Trivandrum Development Authority Covers 8 more panchayats. These are:

1.	Ullor	2.	Chettivilakom
3.	Vengannor	4.	Kalliyoor
5.	Nemom	6.	Pallichal
7.	Vilappil	8.	Vilavvorkal

Total area of 'Trivandrum City Region' - 296.17 Sq.Km.

Table 3.4 Trivandrum District - Important Data

Area	-	2192 Sq.Km.
Population (1991 Census)	-	29.39 Lakhs.
Density of population	-	1341 persons/Sq.Km.

Trivandrum District is divided into 4 Taluks:

Trivandrum, Nedumangad, Chirayinkil & Neyyattinkara,

It has 4 Municipal Towns: Varkala, Attingal, Nedumangad, and Neyyattinkara.

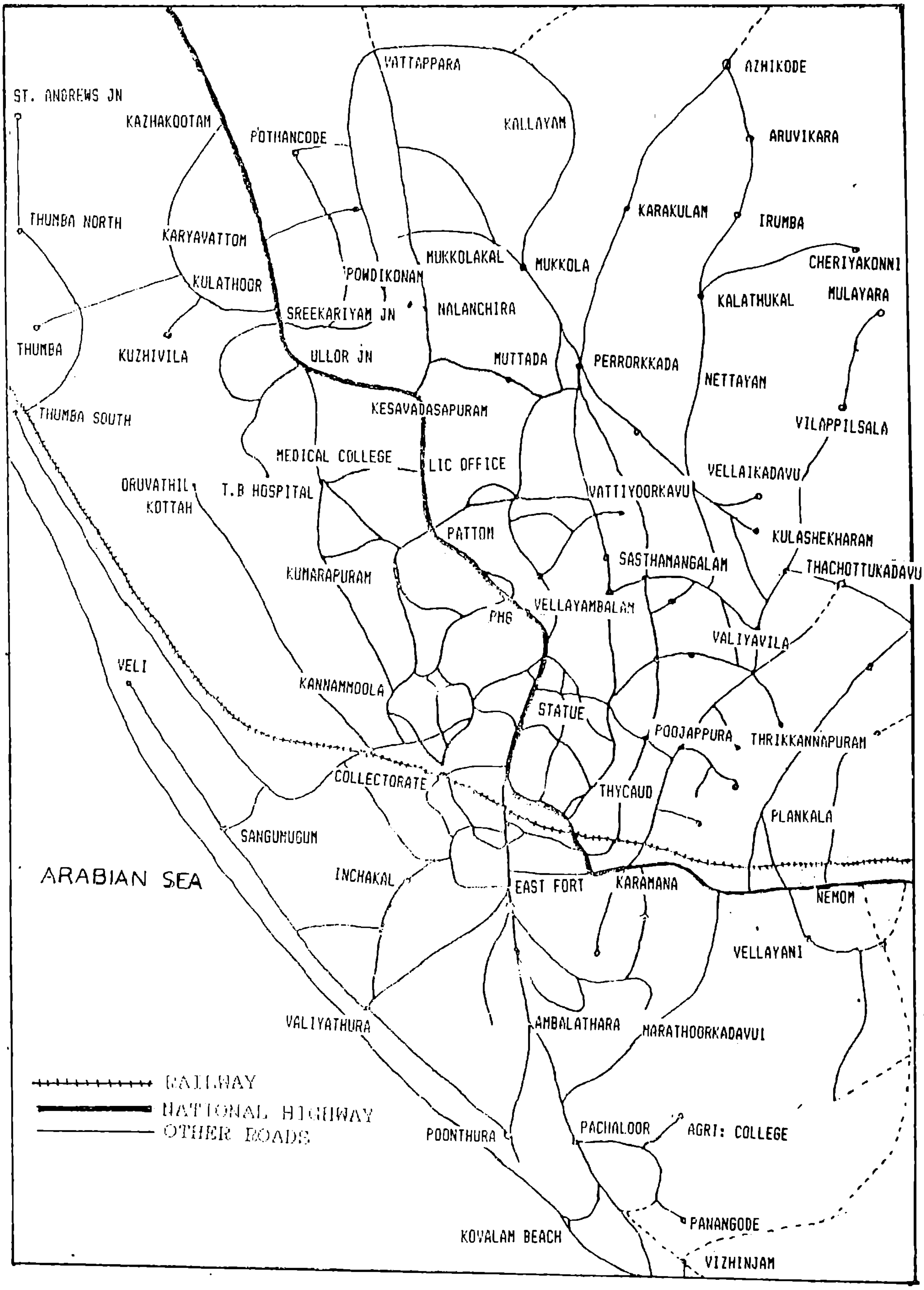
Motor Vehicles in Trivandrum District as per their registration (Selected Categories Only)

Cars	-	21,435
Two - Wheelers	-	53,134
Auto Rickshaws	-	7,818
Taxis	-	3,135
Trucks	-	3,838
Private Buses	-	239
Private Buses (Contract carriages)	-	1,802

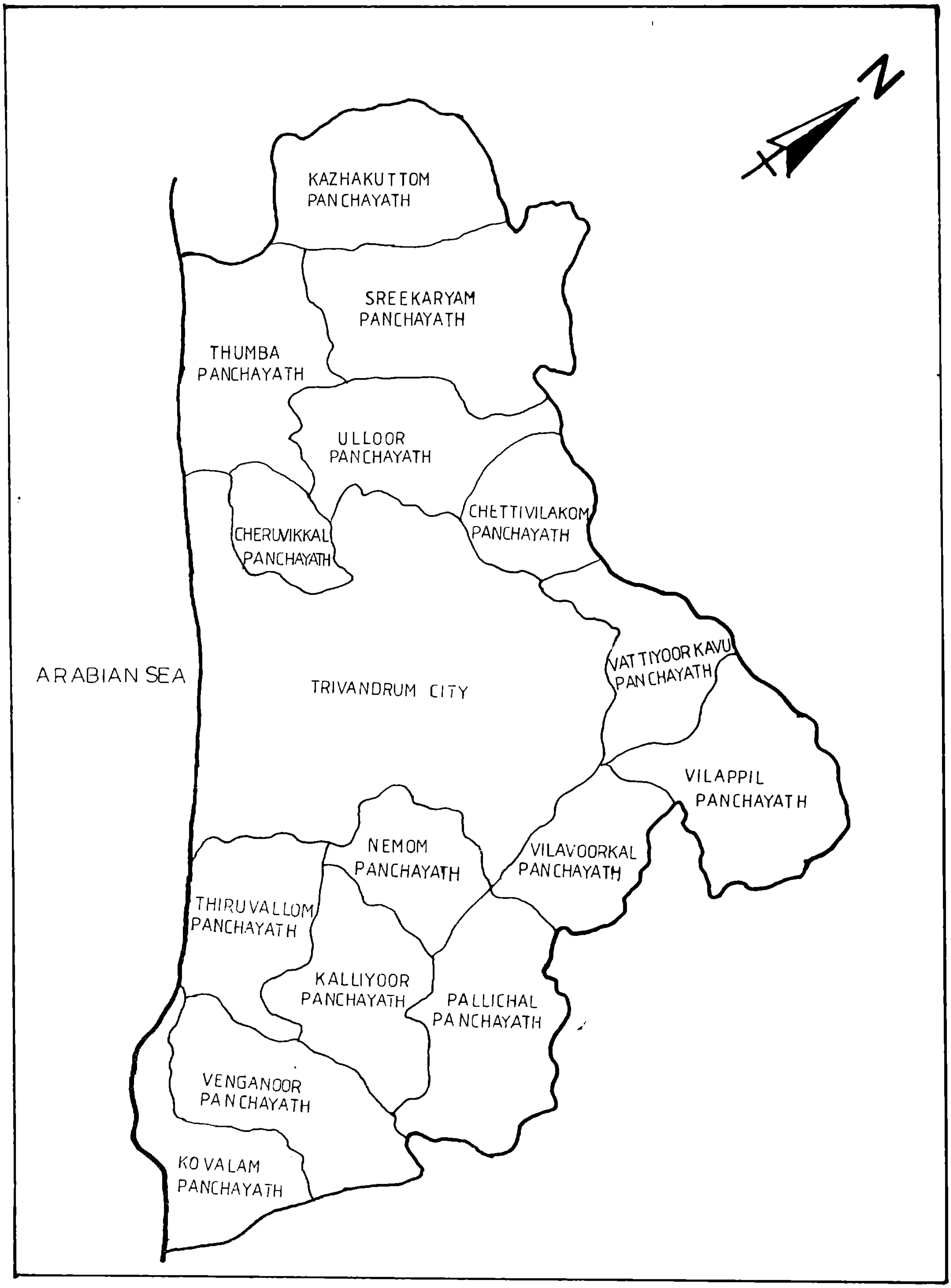
(Source: State Planning Board, Trivandrum.

Economic Review 1991 page 217)

Map 3.3 Trivandrum City - Road Map



Map 3.4 Trivandrum City and Adjoining Panchayats Constituting the "City Region"



5.25 lakhs does not show a highy rate of growth. If we consider that the population of the City was only 2,39,815 in 1961, the yearly growth rate taking 1961 as the base year, has been only 3.95 percent. Decadeal growth rate for the three previous decades works out to 70.81 percent for 1961-1971, 17.93 percent for 1971-1981 and 8.42 percent for 1981-1991. The high growth rate seen for 1961-1971 is largely on account of the addition of 17.19 sq.km to the area of Trivandrum City during this period by ceding parts of some adjacent panchayats to the city.

The Department of Town planning, Government of Kerala has made different estimates about the population of Trivandrum for the year 2001. The most conservative among them projects it at 656,320. None of the projections puts the population in 2001 beyond 7 lakhs. (195, p 101)

As has been mentioned already Trivandrum has a large number of office goers and students. The employment pattern of the city projected for the year 2001 is as follows: Administrative sector: 31 percent, Industrial sector: 16 percent, Commercial sector: 16 percent and Service sector, including all other categories: 37 percent. (195, p 102) Since there are very few industrial workers who may have to work during different shifts, most of the travel requirements are during the day time, creating the usual pattern of bimodal traffic problem, with two peaks during the day.

3.4 Road Network

Map 3.3 shows the road network of Trivandrum City. The general pattern is 'centre to outwards' type. National Highway-47 runs right through the City. It connects Trivandrum with Quilon on the northern side and with Nagercoil on the southern side. Among the roads, the National Highway carries the maximum number of passengers. The next important road is the MC Road (Main Central Road) which deviates from the National Highway at Kesavadasapuram within Trivandrum City itself and connects the City to places like Kottarakkara and Kottayam on the north. There are also other important roads from Trivandrum leading to Nedumangad, Kattakkada, and Kovalam. The broad-gauge railway line linking Cape-Comorin and Eranakulam passes through the City. Trivandrum Central is an important station on the railway map. Pettah and Kochuveli are two other railway stations located within the City limits. The railways carry about 10,000 passengers to the Trivandrum Central Station and about 2000 passengers to the Pettah station every day. (195, p 49) A major portion of these passengers also depend upon the City bus services to reach their destinations. Inter-city moffusil bus services are also operated from Trivandrum Central Bus Depot to places like Quilon, Kottarakkara, Neyyatinkara, Nedumangad, Kattakkada etc.

People coming to Trivandrum City from these places also make use of City bus services to reach their places of work. In addition to radial roads, there are also link-roads connecting the radial roads.

Trivandrum City's road network, constructed mainly during the pre-independence period, has become quite inadequate today, considering the increase in population. Even the main arterial roads have only a width for two-lane traffic. The traffic jams created during peak periods are stifling with a mix of cyclists, autorickshaws, two wheelers, motor cars, trucks and buses. Traffic control is done by the City police. Automatic traffic signals installed previously have been replaced by manual control, as they are seen to be more effective. The City has a comparatively low cycle population, mainly because of the hilly terrain of the city. However, a large number of autorikshaws add to the strain on the existing traffic system.

3.5 <u>Town Planning</u>

Travel needs of the people in any City are greatly influenced by the location of offices, housing colonies, shopping centres etc. Haphazard development and unplanned growth have led to unmanageable situations in public transport. The first master plan for the development of Trivandrum City was prepared in 1966 by the Department of Town Planning. The plan period covered 20 years. It was approved by the

Government of Kerala in 1971. This formed the basis of the second master plan prepared in 1991. Trivandrum Development Authority is the implementing agency of the scheme proposed in the master plan. It has already identified some areas for immediate development, such as Cantonment, Medical college, etc. and the construction work is in progress.

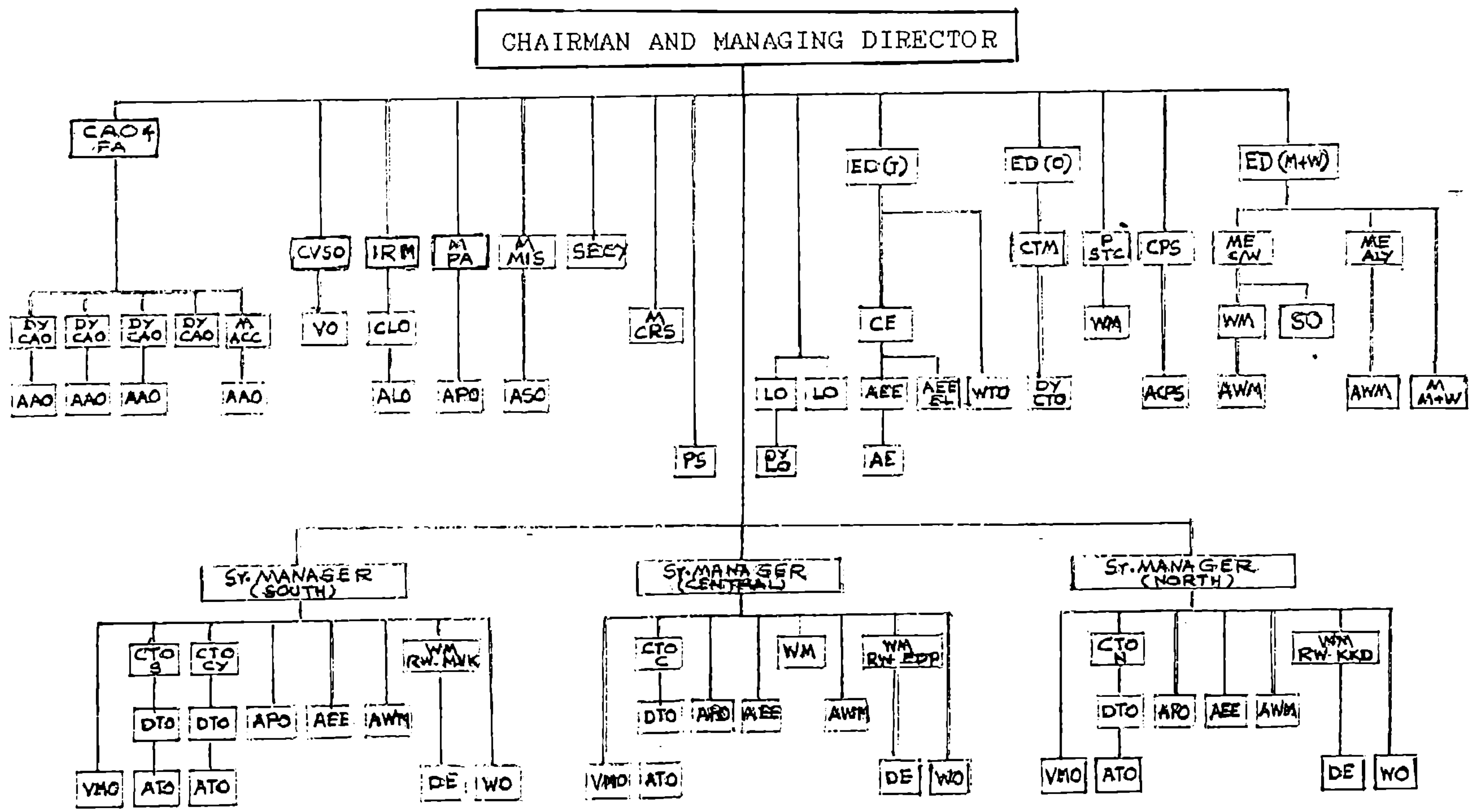
As already mentioned, Trivandrum is also an educational city which can boast of a large number of colleges and schools, as shown in table 3.1. The vast majority of students depend upon the City bus services to reach their educational institutions and back home. As was noted earlier, about 40,000 students make use of the monthly concession tickets issued to students by the City transport authorities. The concession ticket charges are extremely low. It is only about 15% of the regular bus fares. A few institutions operate their own school or college buses, but the vast majority of students depend on the public transport system. Many 'Students Only' services are operated by KSRTC during peak hours, but these are also of limited significance compared to the total demand.

3.6 <u>Trivandrum City Services</u>

Government owned bus services were first started in the erstwhile Travancore State in 1938 with the Trivandrum-Nagarcoil route getting nationalised. Sixty buses, manufactured in England, were brought in a knocked-down condition and were then re-assembled here. Mr. E.G. Salter, who was an Assistant Operating Superintendent in the London Passenger Transport Board, was appointed as the chief of this government bus service department. Bus transport operation was managed by the Transport Department of the Government until 1965, when the Kerala State Road Transport Corporation was formed. It made profits during the first two years of its existence, but thereafter, it has been operating on loss. The current annual losses incurred by the Corporation is of the order of Rs.25 to 30 crores. Nearly half of this loss is contributed by the Trivandrum City Services. The capital investment in KSRTC is shared between the State and Central Governments in the ratio of 4:1, which was subsequently changed to 2:1. As on 31.3.91, the Corporation had a fleet strength of 3413 buses and a staff strength of 30,360 (Table 3.6).

The organisational set up of the Corporation at the top management level is shown in Fig. 3.1. For the convenience of operation, different regions are divided into depots, sub-depots and operating centres. Trivandrum City services consist of two depots and two sub-depots. The depot level organisational set up is shown in Fig.3.2. It has three major functions- administrative, operational and maintenance. The administrative staff, the operating crew such as

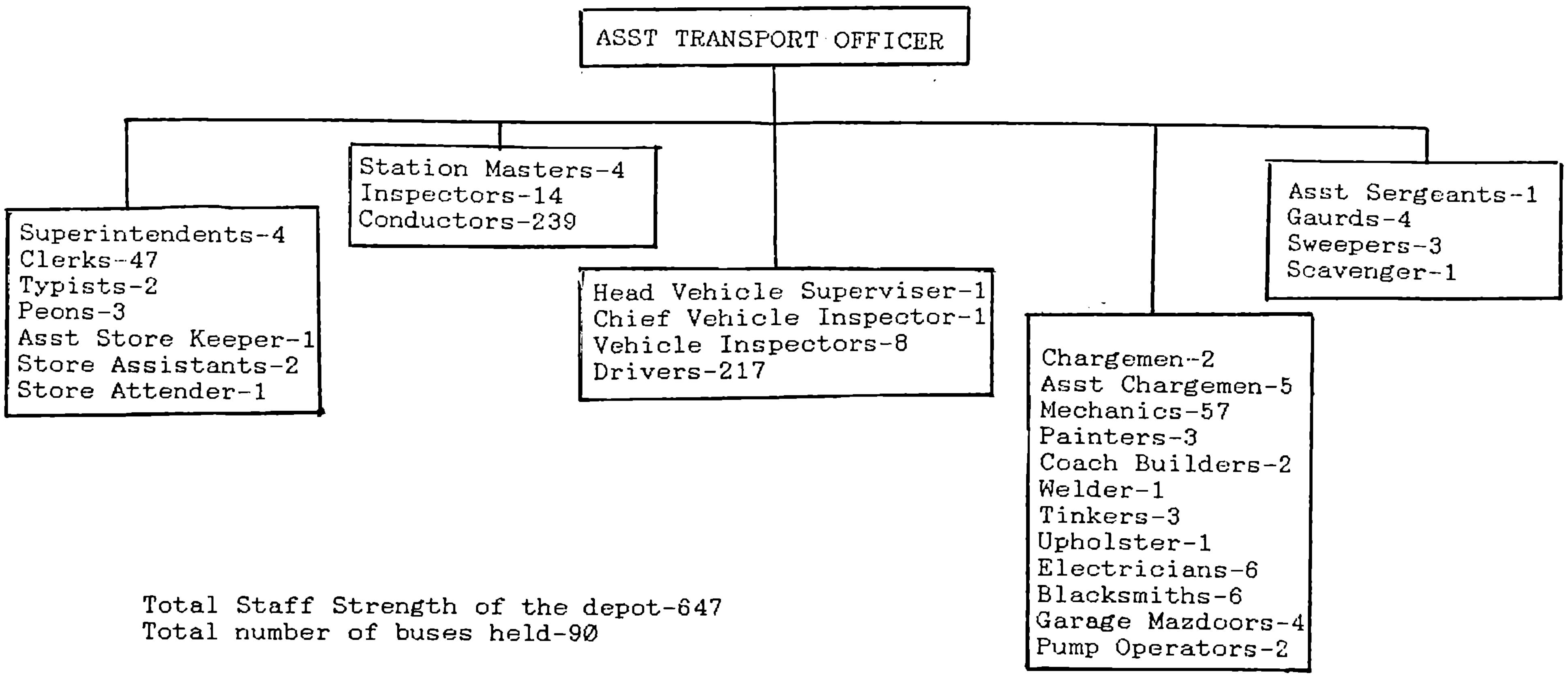
Fig 3.1 Top Management Organisation Chart of Kerala State Road Transport Corporation



AAO	- Asst. Accounts Officer
AEE	- Asst. Executive Engineer
ALO	- Asst. Labour Officer
APO	- Asst. Personnel Officer
ASO	- Asst. Statistical Officer
ATO	- Asst. Transport Officer
AWM	- Asst. Works Manager
CAO & FA	- Chief Accounts Officer & Financial Adviser
CE	- Chief Engineer (Civil)
CLO	- Chief Labour Officer
CPS	- Controller of Purchases & Stores
CTM	- Chief Traffic Manger
CTO	- Chief Traffic Officer
CVSO	- Chief Vigilance & Security Officer
Dy CAO	- Deputy Chief Accounts Officer
DE	- Depot Engineer
Dy LO	- Deputy Law Officer
DTO	- District Transport Officer
ED(M&W)	- Executive Director (Maintenance & Works)
ED(O)	- Executive Director (Operations)
ED(T)	- Executive Director (Technical)
IRM	- Industrial Relations Manager
LO	- Law Officer
M(CRS)	- Manager (Customer Relations & Sports)
ME	- Mechanical Engineer
M(MIS)	- Manager (Managment & Information Systems)
M(PA)	- Manager (Personnel & Administration)
PS	- Private Secretary
PSTC	- Principal, Staff Training Centre
SECY	- Secretary
SO	- Safety Officer
VMO	- Vehicle Mobility Officer
VO	- Vigilance Officer
WM	- Works Manager
WO	- Welfare Officer
WTO	- Water Transport Officer

Fig 3.1 Continued - Abbreviations Used in Top Management Organisation Chart of KSRTC

Fig 3.2 Organisation Chart of Vikas Bhavan Depot (as on 31.3.91)



Total Staff Strength of the depot-647
Total number of buses held-90

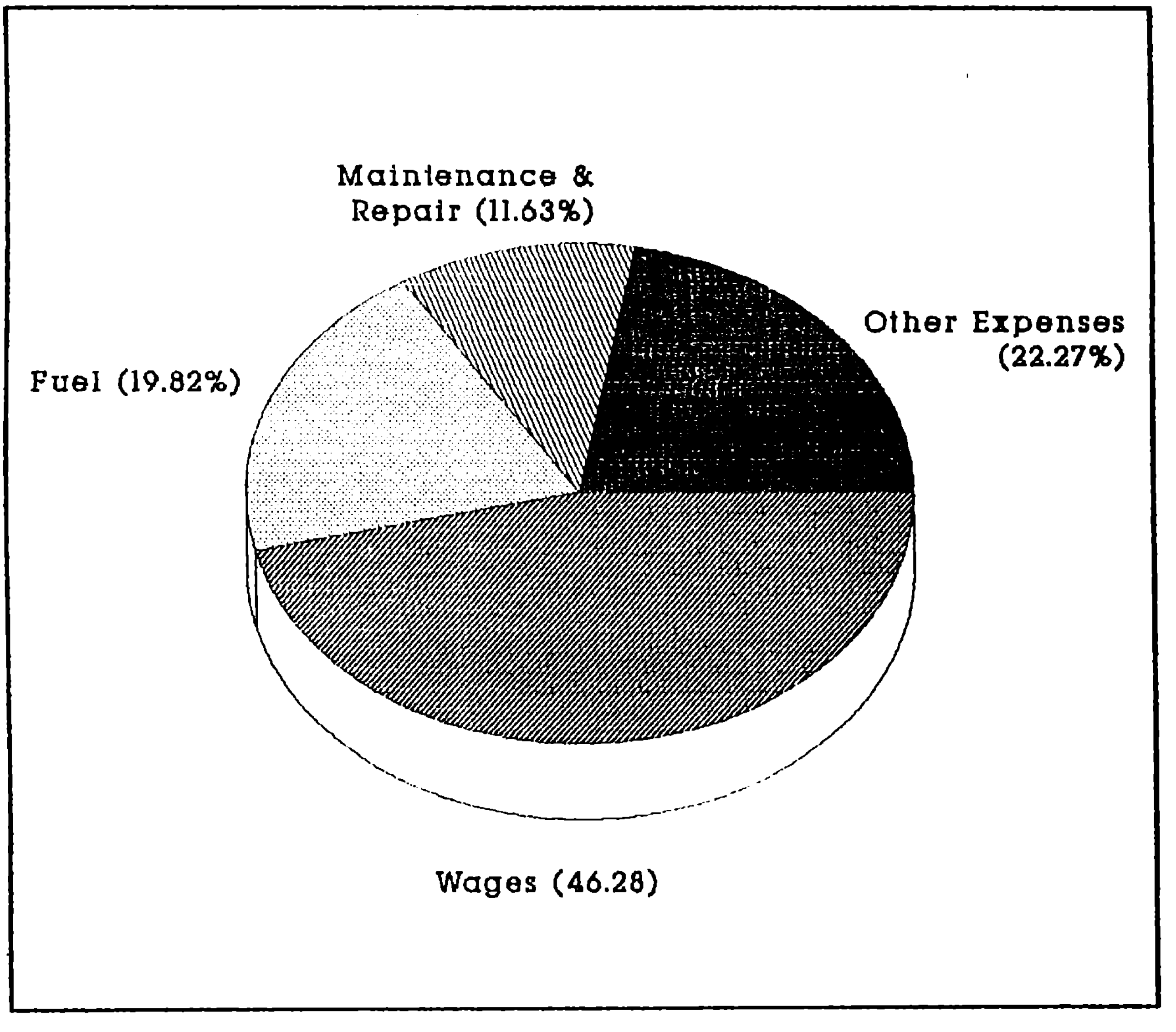
conductors and drivers and the maintenance staff, man the three functional areas. The expenditure pattern of the Corporation is illustrated in Figure 3.3. It can be seen that nearly fifty percent of the expenditure go for wages. One fifth of the total expenditure is accounted for by the fuel bill.

3.7 Pattern of Operation

Trivandrum City services are operated from four depots: East Fort, Pappanamcode, Vikas Bhavan, and Peroorkada. A limited number of private buses used to operate in the City until December 1975, but since then Trivandrum City is served only by the KSRTC City Services. Important data regarding the city services are given in Table 3.5. The sub-depots at Vikas Bhavan and Perrorkada are of comparatively recent origin and were set up as the Corporation came to realise gradually the benefits of having depots at different locations in the City. The East Fort depot was already in existence when KSRTC was formed in 1965. The Pappanamcode depot was established in November 1971. The Perrorkada and Vikas Bhavan depots were opened in May, 1985. Another depot near the Medical College is in the implementing stage.

The duty hours of the operating crew of conductors and drivers are of eight hours duration in a day. But the actual 'steering time' works out to only six and a half hours, since 30 minutes each are given

Fig 3.3 KSRTC - Expenditure Pattern (1990-91)



(Source: State Planning Board Trivandrum
Economic Review 1991 page 79)

Table 3.5

Vital Statistics About Trivandrum City Services

Trivandrum City services are operated through 4 depots: Trivandrum City, Pappanamcode, Vikas Bhavan and Peroorkada.

Name of depot	Buses held	Schedules operated	Kilometres operated (x 10,000)	Passengers carried per day	EPKM (Rs)	Earnings per vehicle per day (Rs)
East Fort	181	165	90.72	1,84,487	5.72	1009
Pappanamcode	130	118	67.90	1,20,320	5.63	926
Vikas Bhavan	90	78	53.89	84,443	4.85	1023
Peroorkada	60	57	35.13	66,975	5.21	984
Total	467	418	274.64	4,56,22		

Name of depot	Kilometres operated per per bus per day	% of vehicle utilisation	Average route length (km)	Average trip length of passengers (km)	Average earnings per passengers (Rs)
East Fort	176.4	81.0	8.48	7.6	77.0
Pappanamcode	164.3	87.9	12.2	8.1	87.1
Vikas Bhavan	211.2	80.0	15.1	8.0	84.8
Peroorkada	188.8	83.0	15.6	.7	74.9

Average kilometres operated per day per bus - 162.3 Km

Average EPKM (Earnings per kilometre) -Rs. 5.35/-

(This works out to 73.49% of CPKM - cost per kilometre)

Fare rate for city services - 13 Ps/Km
(Subject to a minimum of 70 Ps)

Key figures based on 1990-91 Statistics
(Source: State Planning Board, Economic Review 1991 Trivandrum. (page 220, 221)

for 'sign-on' and 'sign-off' and further a 'break' of 30 minutes is awarded during the duty as per the Motor Vehicle Act.

The operation of a vehicle during 24 hours is called a 'schedule'. In Trivandrum City, usually two crew-pairs of two conductors and two drivers are required to operate one bus schedule. City buses start operation at 5.00 A.M. and continue upto 11.00 P.M. The frequency of operation is compara-tively less during the early morning hours and the late evening hours. While most of the schedules are operated on double duty with two crew pairs for each, at least some buses are operated for one duty only in a day. This operation will be during peak hours only and is called a 'double-spell' service. While most of the buses come back to their respective depots at the end of the day, at least some buses remain at the terminal points overnight. These are called 'stay buses'. They start their services back to the City depots during early morning. This is because the early morning traffic is towards the City and not very much from the City. The stay services thus help to avoid idle trips early in the morning and late in the evening. A few 'Limited-stop', 'Ladies only' and 'Students only' trips are also operated from various depots.

The present fare charged in the city services is at the rate of 13 paise per kilometre, subject to a minimum of 70 paise. The whole route network is divided into different sections or inter-fare stages between fare stage points. The conductors keep a journey bill, in which they are required to write the numbers of tickets of various denominations issued at the beginning of each fare stage. With this, the total number of passengers in the bus at any time can be determined and hence, ticketless travellers, if any, can be detected. The journey bill can thus be used to assess the travel pattern of passengers. The operation of City buses is not strictly restricted to the City area alone. It extends to the adjoining panchayats too. Actually, people in these areas make use of City buses, and to a lesser extent, the services of the moffusil buses also.

3.8 Organisational and Personnel Aspects of City Services

The Kerala State Road Transport Corporation has a three-tier administrative set up, with a central, regional and depot level organisation. However, the depots are the activity centres, where more than 88 percent of the personnel are employed. These are classified as depots, sub-depots and operating centres, depending upon the number of vehicles held by each of them. As on 31-3-91, KSRTC had 29 depots, 27 sub depots and 10 operating centres. (190, 1990-91, p 11) Among these, the Trivandrum City Services consisted of two depots viz. East Fort and Pappanamcode and two sub depots viz. Vikas Bhavan and Peroorkada.

The personnel of the Corporation can be classified into four broad categories, viz. (i). the higher division or managerial staff (ii).the administrative or office staff (iii). the operating Staff; and (iv). the mechanical staff. Table 3.7 shows the number of personnel in each category and the same is illustrated in Figure 3.4. Table 3.8 also shows the break up of the staff strength in the Trivandrum City Services depots.

Fig 3.1 shows the top management organisational set up of KSRTC. Transport operations are divided into three regions:South, Central and North with headquarters at Trivandrum, Eranakulam and Calicut respectively. Each of these regions is under a senior manager. In addition to the depots in the region, he also supervises the activities of a regional workshop in his area. Among functional areas, the Chief Accounts Officer heads the financial function. There are managers in other functional areas like Industrial Relations, Personnel & Administration, Management Information Systems etc. There are three Executive Directors-Technical, Maintenance and Works and Operations. Trivandrum City Services come under the jurisdiction of Senior Manager (South). There is a Chief Traffic Officer for the City Services and the

Table 3.6

Some Important Data Regarding KSRTC

KSRTC Carries 22% of Kerala's bus passenger traffic.

Total number of buses held	- 3413
Total number of employees	- 30360 (as on 31.3.9)
Number of employees per bus	- 9
Average seating capacity per bus	- 54
CPKM (Cost per kilometre)	- Rs 7.28/-
EPKM (Earnings per kilometre)	- Rs 6.17/- (84.75% of CPKM)
Fuel Consumption (average KMPL)	- 3.18 Km/litre of diesel

(Source: State Planning Board, Trivandrum. Economic review 1991 pages 79, 80)

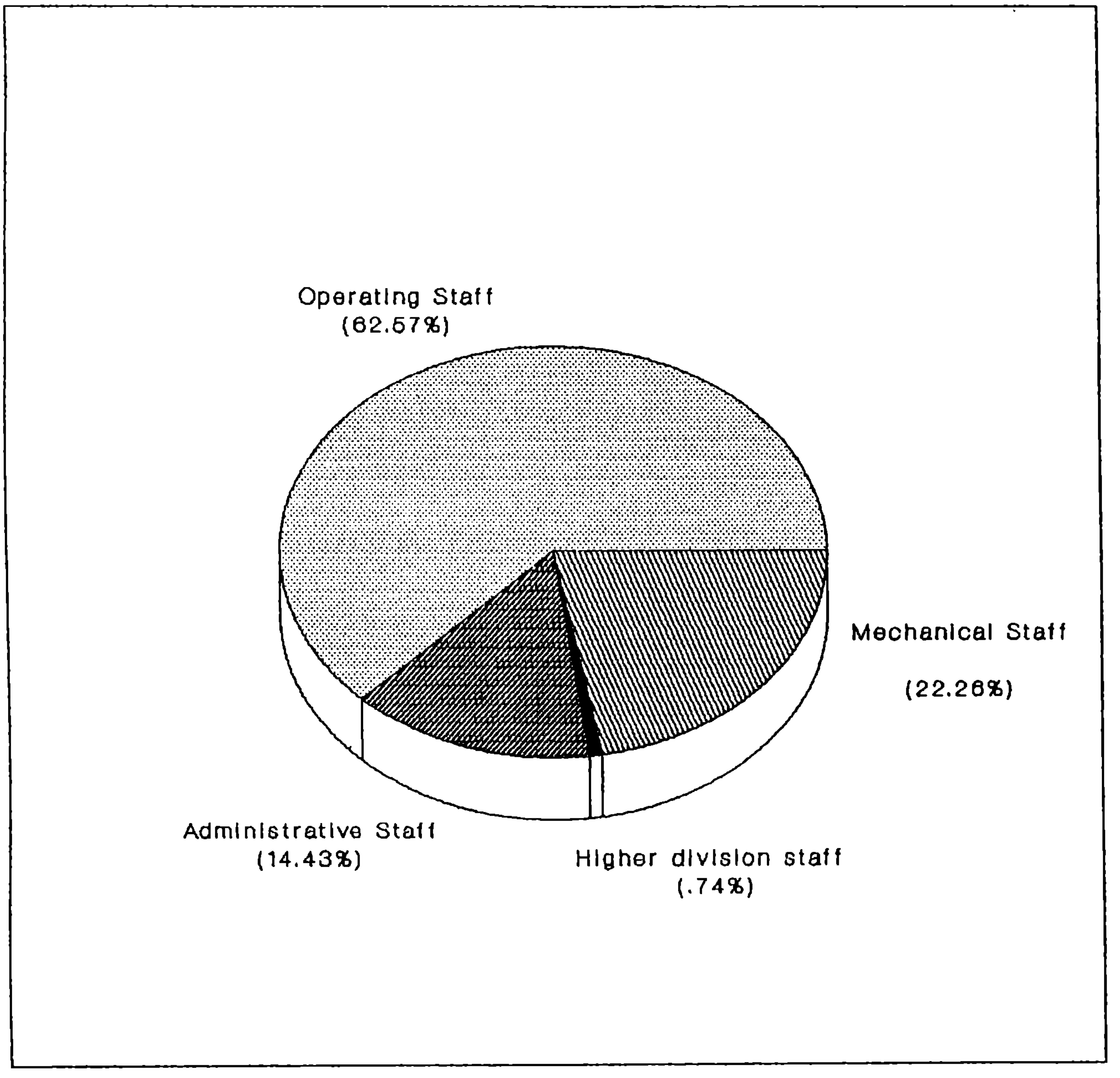
Table 3.7

Staff Pattern of KSRTC (as on 31-3-91)

Category		Number	Percentage
Higher Division Staff		228	.74
Administrative Staff (white collar)		4420	14.43
Operating Staff (Khaki collar)		19162	62.57
Mechanical Staff (Blue collar)		6820	22.26
	Total	30,630	100.00

(Source: KSRTC, Trivandrum. Administration Report 1990-91, page 51)

Fig 3.4 Staff Pattern of KSRTC



(Source: KSRTC, Administration Report 1990-91, p 51) four bus depots of the City Services come under him.

The depot level organisational set up is shown in Figure 3.2, taking Vikas Bhavan sub-depot as an example. The total staff strength of this depot is 647. This depot is headed by an Assistant Transport Officer. The personnel can be classified into five categories: (i) the administrative or office staff (ii).the operating staff such as the conductor, inspectors and station masters (iii). other operating staff such as the drivers, vehicle inspectors; (iv). the mechanical staff; and (v). the security or watch and ward staff. Table 3.9 shows the consolidated staff pattern, which is also illustrated by the pie-chart given in Figure 3.5.

Looking at the top management and depot level organisation charts, it can be seen that KSRTC has a fairly large line organisation with very little staff divisions. Most of the state transport undertakings in India have similar organisational structure with two-tier or three-tier set ups. However, in many organisations, the staff functions are divided into separate departments, with the department heads reporting to the chief executive.

3.9 Wage Structure and Industrial Relations

As already seen, the operating staff, consisting mainly of the drivers and conductors constitute a major part of the workforce of any

Table 3.8

Total Staff in City Services depots

Depot	88-89	89-90	89-91	Ratio of depot staff: buses held for the year 1990-91
East Fort	1267	1294	1396	7.7
Pappanamcode	824	856	890	6.6
Vikas Bhavan	595	591	647	7.1
Peroorkada	445	443	457	6.9
Total for city services	3131	3184	3390	7.26
Total for KSRTC	30101	29960	30630	7.9
City services staff as a % of total	10.4	10.63	11.06	

(Source: KSRTC, Trivandrum. Administration Reports 1988-89, 89-90 and 90-91)

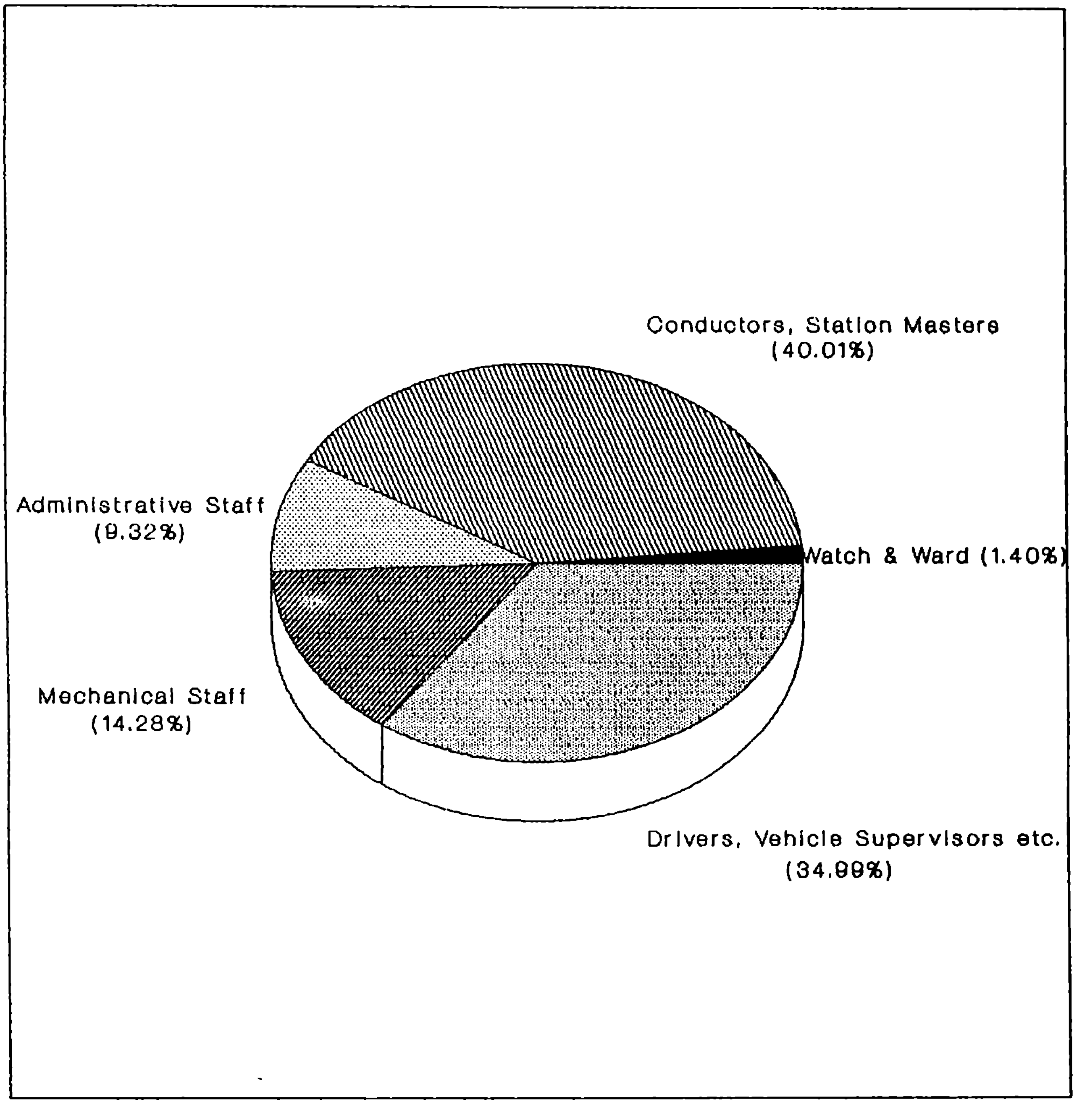
Table 3.9

Staff Pattern of Vikas Bhavan sub depot

	Category	No	Percentage of total
1.	Administrative Staff	61	9.43
2.	Conductors, Station masters, Inspectors, etc.	258	39.88
3.	Drivers, Vehicle Inspectors, etc	227	35.08
4.	Mechanical Staff	92	14.22
5.	Watch & Ward	9	1.39
	Total	647	100.00

(Source: Data collected by the author)

Fig 3.5 Staff Pattern in Vikas Bhavan Depot of Trivandrum City Services



(Source: Data Collected by Author)

passenger transport undertaking. The staff:bus ratio is an important factor, considering the fact that nearly fifty percent of the expenditure of KSRTC is on account of its wage bill. The Corporation has a high staff:bus ratio. This is evident from the observation of the Public Undertakings Committee Report of 1986 which states that while this figure for KSRTC is as high as 11.5, while the all India norm is only 7.5. (202, p 6) However, as on March 1991, the KSRTC had a fleet strength of 3413 and a total staff strength of 30630, which works out to a staff:bus ratio of 8.97 only. This is due to a progressive reduction in this ratio over the past few years when fresh recruitments were stalled. However, looking at table 3.10 it can be seen that KSRTC's staff:bus ratio is nearly nine, while other undertakings have this ratio as less than eight only. The average monthly salaries are comparable with that of other corporations. Hence it can be seen that the comparatively higher wage bill of KSRTC is due to higher staff:bus ratio which in turn, depends mainly on the prevailing work norms of the operating staff regarding duty hours, leave facilities etc.

Being the second biggest public sector employer in Kerala, second only to the Kerala State Electricity Board, the KSRTC has a workforce, well organised under different trade unions. With their political patronage, the bargaining power of these

Table 3.10

Total Staff and Fleet Strength of some Transport Corporations (as on March '91)

	Name of Undertaking	Fleet Strength	Total staff	Staff:Bus Ratio	Average Monthly salary per employee	Salary Expenditure as a % of total expenditure
1	Maharashtra SRTC	15,769	110036	6.97	2423	29.92
2	Karnataka SRTC	8,824	58401	6.62	2549	33.76
3	Andhra Pradesh SRTC	14,298	112052	7.84	2349	39.85
4	Gujarat SRTC	8244	54481	6.61	2768	39.26
5	Kerala SRTC	3413	30630	8.97	2582	46.44

(Source: Central Institute of Road Transport, Pune. Performance Statistics of State Transport Undertakings 1990-91 pages 13, 137) unions was instrumental in getting comparatively better service conditions for KSRTC employees compared to other public or private road transport undertakings. Even though there are several trade unions, only one union enjoys the status of a 'recognised' trade union, having more than 25% of the workforce under its fold. Monthly consultative meetings with the representatives of the recognised trade union are arranged where issues relating to the employee grievances and other issues pertaining to workers' participation in management are taken up for discussion. State-wide strikes by employees have been rare in recent years, the last one being in 1974. For example, there was no such state-wide strike during the year 1990-91 but some depot-wise strikes of employees may take place, on local issues which are usually settled in two or three days. On the whole, the number of labour days lost due to strike by employees is not a major problem for KSRTC. In the City Services also, strike by employees has rarely been a major problem. However, disruption of services due to bandh calls, political disturbances, student agitations etc. affect the city bus services also as in the case of other business and commercial establishments.

CHAPTER - IV

THE TRIVANDRUM CITY SERVICES: FINANCIAL AND OPERATIONAL PERFORMANCE

4.1 Urban Transport Operation as a Commercial Proposition

Transport services can be viewed as commercial venture, where concepts like investment, rate of return, operating cost, income, profit etc. are applicable. Even a production-consumption pattern can be conceived, where the operator produces seat kilometres for which the traveller is the customer. However, efficiency of the operation depends on the ability of the operator to provide travel facilities at the right time and at the right place. If this is not available, the traveller may choose an alternate mode of travel. The success of the transport operator depends upon assessing the travel needs properly, and providing it to the required extent.

For any business operation to be economically viable, the income generated must be more than the expenses incurred. Presently, this has become almost impossible to achieve in urban transport operation mainly because when compared to intercity services, it can operate only fewer kilometres per bus per day. This is true of the KSRTC Trivandrum City Services also. For example, during the year 1990-91, while the Trivandrum Central depot which operates long distance services was able to achieve an average performance of 384 kilometres per bus per day, the East Fort Depot of Trivandrum City Services could operate only 176.4 kilometres on the average which is less than fifty percent of Trivandrum Central Depot's performance. (199, p 221) At the same time, the fare charged per kilometre for long distance services like that for the Fast Passenger and Express services are substantially higher than for the city services, which makes the city operation still more uneconomic. This situation is true of urban transport operations everywhere (136, p12)

There are certain other factors also in urban transport operation which contribute to its low earnings. For example, there is the problem of one-way empty operation, with comparatively low load factors even during peak periods out of and into the city in the morning and evenings. The stoppage and disruption of services due to the frequent jathas and demonstrations in the main city also contributes to the poor rate of vehicle utilisation and low earnings in the Trivandrum City Services. Damages to buses during protest, demonstrations and the large number of student travellers using concession tickets are other factors contributing to the high losses and low earnings particularly relevant to Trivandrum.

As in the case of any other services,

transport operation can also improve its operations only if it can generate sufficient surplus. Loans from financing institutions and even capital contribution from the Central Government are available only to profitable transport undertakings.

It may, however, be noted that even while making losses, it contributes to the state's exchequer by paying motor vehicle taxes and sales tax on items purchased like fuel, spares, tyres etc. It also makes possible for people to travel by the cheapest possible way and engage themselves in other productive activities. While a city bus charges only 13 paise per kilometre, the cheapest IPT (Intermediate Public Transport) mode in Trivandrum like an autorikshaw which can carry a maximum of three passengers at a time, charges Rs. 2.10 per kilometre, which works out to an average of 70 paise per kilometre per passenger. Fuel consumption-wise also, while a bus carrying sixty passengers can run at least four kilometres using one litre of diesel, an autorikshaw can operate about twenty kilometres using one litre of petrol. Considering the fuel consumed per passenger kilometre, a bus thus is four times more fuel efficient than an autorikshaw. It is true that a bus is more fuel efficient than two wheelers, motor cars etc. Even the most fuel efficient motor cycle can only provide 160 passenger kilometres for a litre of petrol. Hence any efficient bus transport system saves energy for the nation. While analysing the economics of operation, the factors mentioned above should also be given due consideration, in addition to mere profit and loss figures.

4.2 Capital Employed in Bus Operation

The fixed expenses of bus operation consists of mainly the following items:

1. Vehicles
2. Land and buildings
3. Plant and machinery for maintenance, repair, etc.

Of the total assets employed by the Kerala State Road Transport Corporation, 82 percent is contributed by investment in the acquisition of vehicles, 15 percent in land and buildings for vehicles and workshops and the rest in the plant, machinery and equipments for maintenance. (190, 1990-91, p 35) In transport operation, the turnover/investment ratio is rather high. With fixed assets valued at about Rs. 130 crores, KSRTC had an earnings of 173 crores during the financial year 1990-91. Hence turnover/investment ratio works out to 1.33.

During the same year, the Corporation suffered a loss of Rs. 31 crores in its operations, which works out to more than fifteen percent of the total operating expenses. Table 4.22 shows the pattern of income and expenditure of KSRTC during the year

1990-91. Single journey ticket fares contributed to nearly 97 percent of the total income. Salaries and related expenses accounted for nearly 50 percent of the total expenses. Other major expenses are the fuel bill and consumptionof materials like spareparts, tyres etc.

Table 4.23 shows a consolidated balance sheet of the corporation as on 31.3.91. Of the total capital contribution of about seventy crores, 75 percent was contributed by the State Government and the rest by the Central Government. In addition, loans are taken from State Government, LIC and also from the public. Reserves and provisions are mainly capital asset reserve, provision for vehicle tax etc. Since KSRTC has a water transport wing also, its contribution is also shown in capital and liabilities columns.

The fixed assets of the corporation were valued at 130 crores. Other details like current assets, bank and cash balance etc. are also shown. As was noted earlier, more than 80 percent of the value of the investment of KSRTC is in its vehicles. The total value of the fleet depends upon its age pattern also. This means that if the average age of the fleet is more, its value will be comparatively less.

As shown in Table 4.1, as on 31.3.91, KSRTC had a fleet of 3413 buses, of which 467 vehicles were employed for operating the City Services. The total fleet of the KSRTC is valued at Rs 107 crores. This

Table 4.1 Fleet Strength of City Services
(As on the last day of the financial year)

Name of Depot	87-88	88-89	89-90	90-91
East Fort	154	165	176	181
Pappanamcode	106	112	124	130
Vikas Bhavan	76	84	82	90
Peroorkada	58	58	60	66
Total	394	419	442	467
Total for KSRTC	3219	3240	3313	3413
City Services' Total as % of KSRTC	12.24	12.93	13.34	13.68

(Source: KSRTC Administration Report 1988-89 and 1990-91 pages 70, 62)

Table4.2 Age Pattern of KSRTC Vehicles as on 31-3-91

Age	Number of buses	%
Upto 2 years	551	16.14
2-4 years	761	22.29
4-6 years	282	8.26
6-8 years	643	18.85
8-10 years	412	12.08
10-12 years	434	12.72
12-14 years	281	8.24
14-16 years	48	1.42
Total	3413	100

(Source: KSRTC Administration Report 1990-91, p 87)

Average Age of Vehicles : 6.25 years

works out to a value of Rs. 3.13 lakhs per vehicle, the average. In proportion the value of vehicles operated for city services works out to Rs. 14.8 crores. However, this value will be a little lower than this amount since the city services have a fleet of comparatively older age vehicles when compared to the KSRTC as a whole. The age pattern of the KSRTC buses and of the Trivandrum City Services buses are shown in Table 4.2 and 4.3, and also in figures 4.1 and 4.2. It can be seen that the the City Services fleet has vehicles even as old as 16 years. While KSRTC itself has an aged fleet compared to other state transport undertakings, Trivandrum City Services has a fleet which is still older. Further discussions regarding the average age of fleet and the replacement age of vehicles have been made in Chapter-7. The total investment in the Trivandrum City Services calculated in proportion to its fleet size will be around Rs. 17.78 crores. The calculation of the rate of return based on capital invested is not relevant here since KSRTC is a loss making organisation.

4.3 <u>Analysis of Revenue</u>

The income from passenger bus operation depends on the following factors:

1. Number of vehicles operated
2. Carrying capacity of vehicles
3. Load factor of vehicles

Table 4.3 Age Pattern of City Services' Vehicles as on 31-8-91

Age	Number of buses	%
Upto 2 years	8	1.71
2-4 years	41	8.78
4-6 years	28	5.99
6-8 years	85	18.22
8-10 years	53	11.35
10-12 years	79	16.91
12-14 years	123	26.34
14-16 years	50	10.70
Total	467	100

(Source: Data Collected by Author)

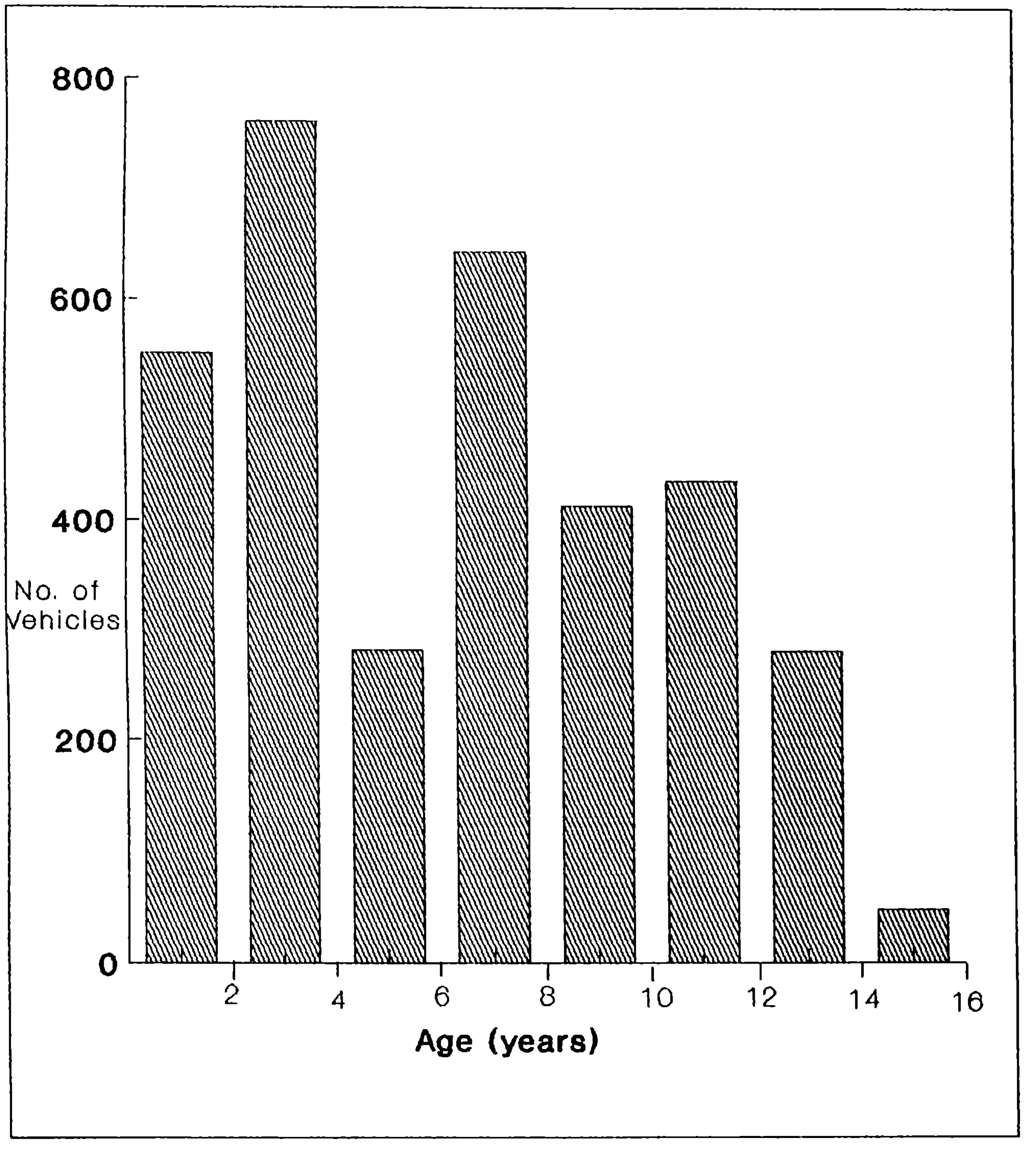
Average Age of Vehicles - 9.76 years

Table 4.4 Fleet Strength of Trivandrum City Services Depots: Average Number of Buses held and of Buses on Road

Name of Depot	Average Number of Buses Held			Average Number of Buses on Road		
	88-89	89-90	90-91	88-89	89-90	90-91
East Fort	161.9	169.4	173.9	137.1	142.6	141.9
Pappanamcode	107.2	117.8	128.8	101.2	108.3	113.2
Vikas Bhavan	77.3	81.6	87.4	66.7	68.6	69.9
Peroorkada	58.7	59.2	61.4	52.7	50.0	51.0
Total	405.1	428	451.5	357.7	369.5	375
Total for KSRTC	3186.1	3223.0	3343.6	2705.3	2713.2	2703.2

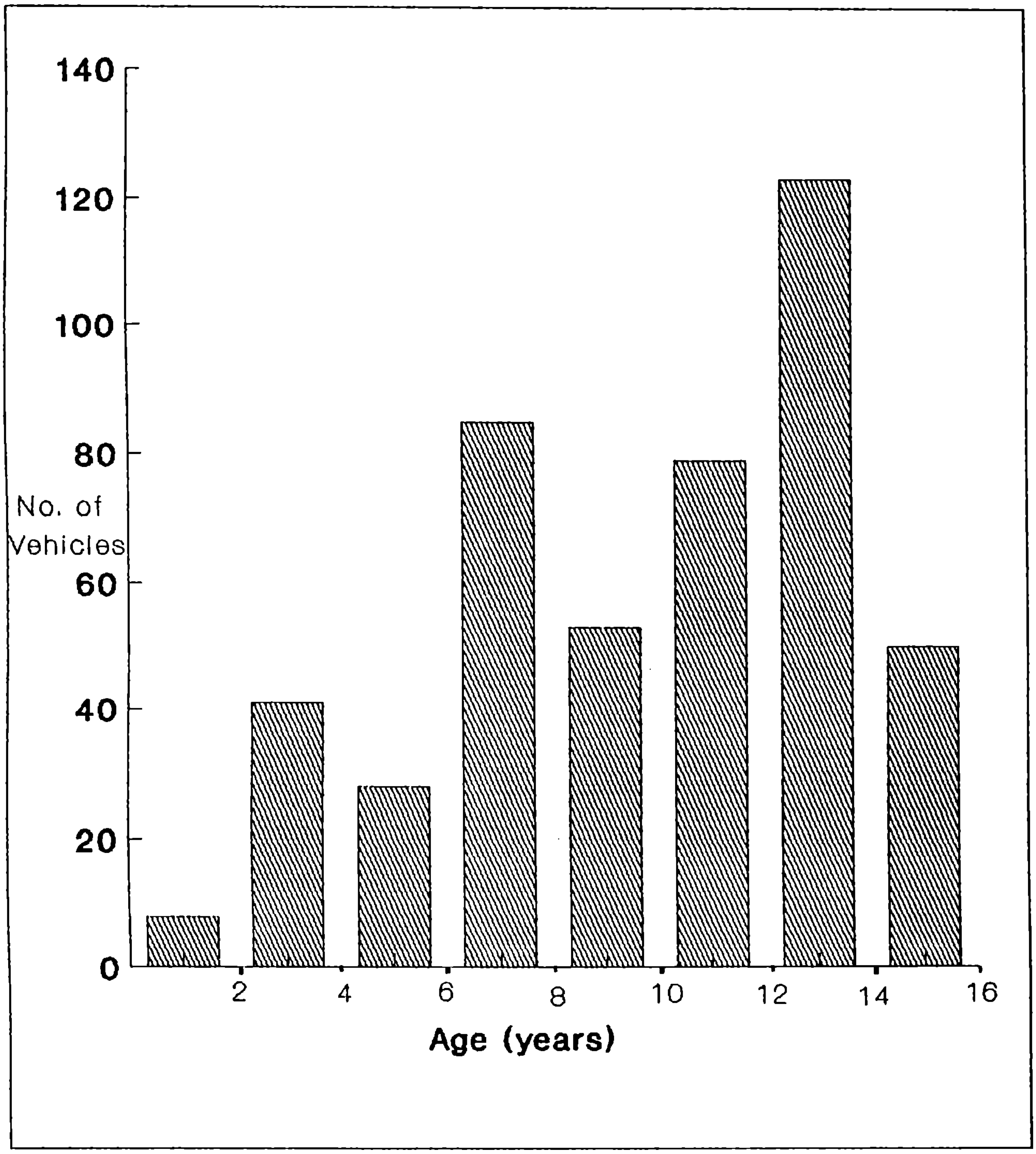
(Source : KSRTC Administrative Report 1990-91, p 64)

Fig 4.1 Age Pattern of KSRTC Vehicles as on 31.3.91



(Source: KSRTC Administration Report 1990-91 p 87)

Fig 4.2 Age Pattern of City Services Vehicles as on 31.8.91



(Source: Data Collected by Author)

4. Kilometres operated per vehicle per day
5. Fare charged per passenger per kilometre.

The number of vehicles operated per day depends on two factors - fleet strength and number of vehicles available for operation per day. In an ideal condition, when all vehicles are in good condition, all of them can be put on road and the fleet utilisation will be hundred percent. Figures regarding fleet strength, average number of vehicles held, average number vehicles on road and percentage fleet utilisation of City Services vis-a-vis KSRTC as a whole etc. are shown in Tables 4.1,4.4 and 4.5.

In any bus depot, the total number of buses held will be constantly changing due to acquisition of new vehicles and retirement of old vehicles. The average number of vehicles is calculated as the average of such vehicles held during the accounting year. Similarly, buses available for services every day will also be varying. The average number of buses sent for service every day during the year is taken as the average number of buses on road. The ratio between these two parameters is calculated as percentage fleet utilisation. A high percentage utilisation of almost hundred indicates an ideal condition, which of course is difficult to attain. From the tables, it can be seen that the fleet strength of city services is about

Table 4.5 Percentage Fleet Utilisation

Name of Depot	1988-89	1989-90	1990-91
East Fort	84.6	84.2	81.0
Pappanamcode	94.4	91.9	87.9
Vikas Bhavan	86.2	84.0	80.0
Peroorkada	89.6	84.5	83.0
Average for City Services	88.29	86.33	83.05
Average for KSRTC	85.0	84.2	80.9

(Source:KSRTC Administration Report 1990-91, p 66)

Table 4.6 Carrying Capacity of Vehicles (Including permitted standees) and Percentage Load Factor (Based on Carrying Capacity)

Name of Depot	Carrying Capacity of Vehicles			Percentage of Load Factor		
	88-89	89-90	90-91	88-89	89-90	90-91
East Fort	52.1	50.5	53.7	109.8	119.3	102
Pappanamcode	48.1	49.6	53.4	97.9	103.7	112
Vikas Bhavan	50.3	49.7	53.5	90.0	92.3	91.7
Perrorkada	49.1	49.5	53.7	90.8	102.9	87.6
KSRTC (as a whole)	54.8	54.9	55.7	--	84.6	88

(Source:KSRTC Administration Report 1990-91,p 67,84) thirteen percent of the fleet strength of KSRTC. The fleet utilisation ratio for City Services is slightly better than the KSRTC average. This means that the availability of buses in City Services is better than for the Corporation as a whole, in spite of their comparatively older age.

As for the carrying capacity of vehicles, Table 4.6 provides the comparative data regarding the depots under the Trivandrum City Services and of the KSRTC as a whole. In the Trivandrum City Services, the carrying capacity of the vehicles is calculated as 1.5 times the seating capacity. This means that 50 percent of the seating capacity is accounted for by standees. Standees permitted in moffussil buses is 25 percent of the seating capacity. It can be seen that the carrying capacity of city service vehicles is slightly less, since the number of seats in vehicles is usually reduced when they are converted as city service buses. This reduction in the seating capacity of buses enables more standing space for passengers in a bus.

The load factor is calculated as the ratio between the revenue earning passenger kilometres and the product of the carrying capacity of the bus and the kilometres operated. Data regarding the percentage load factor of vehicles in the depots of Trivandrum City Services, and KSRTC as a whole is given in Table 4.6. Here again, it can be seen that the load factors of the city services is higher when compared to KSRTC averages. The load factor values are as high as 119 percent, and this indicates that the peak period load factor will be still higher indicating heavy over-crowding in buses. While analysing the journey bills, it was noted that there were instances when the number of passengers in a vehicle was as high as 120 at a time. This overcrowding of buses during peak periods also indicates that the bus services provided are not adequate in comparison to travel demand.

The kilometres operated per vehicle per day will mainly depend upon the route structure of the services, the speed of vehicles, occurrence of breakdowns, accidents etc. Table 4.7 shows the kilometres operated per day per vehicle for the depots of the City Services, and of the KSRTC as a whole. This figure for KSRTC, over the years, is in the order of 280 to 300 kilometres. Guruvayoor depot's average is as high as 445.6 kilometres and Trivandrum Central depot's corresponding figure is 384 kilometres. (190, 1990-91, p 221) Against this background, depots of Trivandrum City Services have logged only 180 kilometres per bus per day. This low vehicle utilisation is the single most important factor which contributes to the low earnings of city services. The main reason for this low rate of kilometres operated is the slow operating speed of vehicles, frequent stops and the short route

Table 4.7 Vehicle Utilisation (Kilometres Operated per Vehicle per day

Name of Depot	1988-89	1989-90	1990-91
East Fort	172.1	167.9	176.4
Pappanamcode	179.4	173.6	164.4
Vikas Bhavan	209.9	206.8	211.2
Perporkada	176.3	186.4	188.8
Average for City Services	181.85	179.28	180.92
Average for KSRTC	270.0	288.3	282.9

(Source: KSRTC Administration Report 1990-91, p 67)

Table 4.8 Average Route Length of City Services' Depots

Name of Depot	1988-89	1989-90	1990-91
East Fort	14.4	8.4	8.4
Pappanamcode	12.1	12.4	12.2
Vikas Bhavan	15.1	15.1	15.1
Perporkada	15.6	15.6	15.6
KSRTC (as a whole)	44.8	44.8	44.8

(Source: KSRTC Administration Report 1990-91 p 72) lengths. While a fast passenger service may cover about 50 kilometres in an hour, a city bus will be able to cover only 12 to 15 kilometres. Details of average route lengths are shown in Table 4.8. It can be seen that while KSRTC's average route length is 44.8 kilometres, for the city services it varies between 8 to 16 kilometres. Factors such as slow running speeds, frequent stoppages and short route lengths are inherent disadvantages in any urban transport operation. As already seen, the passenger fare charged in city services is also the lowest at 13 paise per kilometre which also results in low earnings and bigger losses.

While analysing the revenue earned by passenger bus depots, factors like accidents, breakdowns, and punctuality of operation of buses are also to considered. Tables 4.9, 4.10 and 4.11 show these data for Trivandrum City Services' depots in comparison to KSRTC's operation as a whole. Accidents are calculated per one lakh gross kilometres, which includes both revenue earning kilometres and dead kilometres. From Table 4.9 it can be seen that KSRTC's average accident ratio is around 1.6, while the corresponding figures for Trivandrum City Services' depots vary between 1.3 and 2.1. On the whole, these accident rates are thus comparable to KSRTC's average figures.

Table 4.9 Occurrence of Accidents in City Services Depots (Number of Accidents per One Lakh Gross Kilometres)

Name of Depot	1988-89	1989-90	1990-91
East Fort	1.7	2.1	1.4
Pappanamcode	2.1	2.6	2.1
Vikas Bhavan	1.5	1.5	1.3
Perporkada	1.3	2.0	1.9
KSRTC (as a whole)	1.8	1.5	1.8

(Source:KSRTC Administration Report 1990-91, p 78)

Table 4.10 Occurrence of Breakdowns in City Services' Depots (Number of breakdowns per 10,000 effective Kilometres)

Name of Depot	1988-89	1989-90	1990-91
East Fort	0.7	0.93	0.7
Pappanamcode	0.6	0.7	0.8
Vikas Bhavan	0.8	0.63	0.5
Perporkada	1.0	1.19	0.9
KSRTC (as a whole)	0.9	0.9	0.8

(Source:KSRTC Administration Report 1990-91, p 80)

Table 4.11 Irregularity of Operation (% of Irregularity in Departures and Arrivals)

Name of Depot	Departure			Arrival		
	88-89	89-90	90-91	88-89	89-90	90-91
East Fort	13.0	3.4	3.0	12.3	2.6	2.57
Pappanamcode	11.7	14.0	11.2	12.4	16.7	12.4
Vikas Bhavan	15.8	15.3	11.3	15.3	21.1	17.8
Peroorkada	10.6	1.6	6.9	1.6	0.7	7.4
KSRTC (as a whole)	14.5	12.2	10.3	18.7	14.1	11.5

(Source:KSRTC Administration Report 1990-91, p 82)

Table 4.12 Passenger Earnings (in Rs Crores)

Name of Depot	1987-88	1988-89	1989-90	1990-91
East Fort	3.53	4.24	4.61	5.18
Pappanamcode	2.27	3.23	3.44	3.82
Vikas Bhavan	1.98	2.22	2.30	2.61
Peroorkada	1.27	1.50	2.00	1.83
City Services Total	9.53	11.19	12.35	13.44
KSRTC Total	119.81	145.26	152.14	166.15
Share (%) of City Services	7.95	7.71	8.13	8.1

(Source : KSRTC Administration Reports 87-88, 88-89, 89-90, 90-91 pages 104, 120, 114, 84)

Occurrence of breakdowns is calculated per 10,000 effective kilometres. As per Table No. 4.10, it can be seen that the figures corresponding to City Services depots are comparable to those of KSRTC's average figures.

Irregularity of operation is measured according to the percentage of irregular departures and arrivals. Table 4.11 gives the details for Trivandrum City Services and for the KSRTC as a whole. Here again, the individual values are comparable to KSRTC's total figures.

It is clear that increased accidents, breakdowns and irregularity of operation will adversely affect the earnings of any bus operation. However, since these parameters for Trivandrum City Services are comparable to those of KSRTC's figures, these can not be considered as factors contributing to the lower earnings of the City Services.

Finally, in Tables 4.12, 4.13, and 4.14 the annual earnings of depots, earnings per vehicle per day and EPKM of vehicles are shown. It can be noted that the average earnings per day of city services' buses is only just about sixty percent of the average value for the KSRTC as a whole. EPKM is also consistently lower than that of the KSRTC's average values.

From an analysis of all these facts it can be seen that two main factors which contribute most to the

Table 4.13 Earnings per Vehicle per Day (Rs)

Name of Depot	1988-89	1989-90	1990-91
East Fort	704.88	718.41	785.16
Pappanamcode	791.22	761.90	805.9
Vikas Bhavan	724.11	771.14	795.62
Peroorkada	708.19	916.08	760.24
Average for City Services	732.27	767.27	789.45
Average for KSRTC	1228.29	1258.14	1333.74
Average of City Services as a % of KSRTC's Average	59.61	60.98	59.19

(Source:KSRTC Administration Reports 1988-89, 89-90, 90-91 pages 120, 114, 84)

Table 4.14 EPKM (Earnings per Kilometres) of City Services

Name of Depot	1988-89	1989-90	1990-91
East Fort	4.93	5.28	5.72
Pappanamcode	4.48	5.02	5.63
Vikas Bhavan	4.34	4.46	4.85
Peroorkada	4.42	5.04	5.21
City Services Average	4.71	5.12	5.43
KSRTC Average	5.07	5.32	5.95
City Services Average as a % of KSRTC's Average	92.9	96.2	91.26

(Source: KSRTC Administration Reports 1988-89, 89-90, 90-91 pages 120, 114, 84) low earnings of the city services are low vehicle utilisation- kilometres operated per bus per day - and the comparatively low EPKM for buses in the City when compared to the KSRTC as a whole.

4.4 <u>Expenditure Pattern</u>

In any transport undertaking, the major items of expenditure can be classified into four categories. Theses are: 1) Wages 2) Fuel Costs 3) Stores, including all items purchased like tyres, spare parts etc. and 4) Other expenses including vehicle taxes, permit fee, insurance, depreciation, interest, etc.

Table 4.15 gives a break up of these expenses for KSRTC during the three financial years, 1988-89, 89-90 and 90-91. It can be seen that about fifty percent of the total expenditure was on wages. However, from the table it can be seen that this percentage has progressively decreased over the years. This has been on account of a reduction in the staff:bus ratio.

Tables 4.16 and 4.17 show the staff strength in the different depots of the City Services and the staff:bus ratios in these depots. It can be seen that the staff:bus ratio in Trivandrum City services is more or less the same as KSRTC's overall staff:bus ratio.

Twenty percent of the operating expenses are on fuel. Table 4.18 shows the fuel consumption figures (kilometres per litre) for City Services' buses which also are almost at the same level as KSRTC's overall

Table 4.15 Expenditure Pattern of KSRTC

Item	1988-89		1989-90		1990-91	
	Amount	%	Amount	%	Amount	%
Wages	88.42	51.39	89.28	49.00	94.09	46.27
Fuel	31.99	18.59	33.13	18.20	40.29	19.82
Stores	21.85	12.72	22.13	12.15	23.63	11.63
Other Items	29.77	17.30	37.48	20.59	45.30	22.28
Total	172.03	100	182.02	100.00	203.32	100

(Source: KSRTC Administration Reports 88-89, 90-91 pages 132, 91)

Table 4.16 Total Staff in City Services Depots

Name of depot	1988-89	1989-90	1990-91
East Fort	1267	1294	1396
Pappanamcode	824	856	890
Vikas Bhavan	595	591	647
Peroorkada	445	443	457
Total	3131	3184	3390
KSRTC Total	30101	29960	30630
Staff Strength of City Services as a % of KSRTC	10.40	10.63	11.06

(Source:KSRTC Administration Reports 1988-89, 89-90, 90-91 pages 56, 50, 52)

Table 4.17 Depot Staff:Bus Ratio

Name of Depot	1988-89	1989-90	1990-91
East Fort	7.4	7.4	7.7
Pappanamcode	7.3	6.9	6.8
Vikas Bhavan	7.3	7.2	7.2
Peroorkada	7.6	7.4	6.9
City Services Average	7.47	7.2	7.26
KSRTC Average	8.3	8.0	7.9

(Source: KSRTC Administration Reports 1988-89, 89-90, 90-91 pages 56, 60, 62)

Table 4.18 Fuel Consumption in City Services' Buses (KMPL- Kilometres per Litre)

Name of Depot	1988-89	1989-90	1990-91
East Fort	3.98	3.98	3.95
Pappanamcode	3.41	3.30	3.34
Vikas Bhavan	3.82	3.75	3.31
Peroorkada	3.62	3.29	3.56
City Services Average	3.72	3.63	3.565
KSRTC Average	3.70	3.66	3.65

(Source : KSRTC Administration Reports 1988-89, 89-90, 90-91 pages 113, 92, 88) figure. This is in spite of the fact that City Service's fleet are comparatively older in age and that the city services operations are likely to involve more frequent bus stops and lower speed and therefore more lower gear driving.

Depot-wise expenditure figures are not readily available in the Administration Reports of KSRTC. Overhead expenditure incurred on common facilities like regional workshops, central works etc. are to be suitably apportioned to each depot. The salary expenses of the chief office and other similar staff are also to be suitably allocated. Figures of direct expenses such as of wages of the operating staff and fuel expenses in each depot are however available from the annual administration reports. It was noted earlier that the breakdown rate and accident rate of City Service's buses are comparable to the corresponding figures for the KSRTC as a whole. It will therefore be possible to allocate overhead expenditures to the individual depots on the basis of their fleet strengths.

In Table 4.19, the total expenditure incurred by the four City Services depots are estimated taking into account these factors. It can be seen from this Table that nearly fifty percent of the total losses incurred by KSRTC as a whole is contributed by the operation of the City Services. It may also be noted

Table 4.19 Losses Incurred by City Services

Item	1988-89	1989-90	1990-91
Income (Rs Crores)	11.19	12.37	13.45
Expenditure (Rs Crores)	22.24	24.28	27.81
Loss of City Services (Rs Crores)	11.05	11.91	14.36
Loss of KSRTC (Rs Crores)	23.15	25.71	30.99
Loss of City Services as a % of KSRTC's losses	47.73	46.32	46.33

(Calculations based on KSRTC Administration reports 1988-89, 89-90, 90-91)

Table 4.20 Effective Kilometres operated (Lakhs)

Name of Depot	1988-89	1989-90	1990-91
East Fort	86.11	87.39	90.72
Pappanamcode	66.30	68.65	67.90
Vikas Bhavan	51.12	51.75	53.88
Peroorkada	33.89	33.98	35.13
Total	237.42	241.77	247.63
Total for KSRTC	2865.02	2855.74	2791.69
City Services' Share (%)	8.28	8.46	8.87

(Source:KSRTC Administration Report 1990-91 p 58) from Table 4.1 that the City Services have about forteen percent of the total fleet strength, while it is evident from Table 4.20 that the kilometres operated by it are less than nine percent and consequently, the City Services' earnings are only slightly more than eight percent of KSRTC's total earnings. This may be noted from Table 4.12 given earlier.

4.5 Urban Bus Operation in Other Cities in India

It will be interesting to compare the performance of Trivandrum City Services with that of other similar urban bus transport organisations in India. The Central Institute of Road Transport, Pune has brought out a comparative report, entitled "Performance Statistics of State Transport Undertakings" (201, 202). Data required for interfirm comparison is taken from these reports. In Table 4.21, the operational details of the Delhi Transport Corporation, BEST Undertaking, Bombay, the Calcutta State Transport Corporation, Pallavan Transport Corporation, Madras City, Pune Municipal Transport and Chandigarh Transport Undertaking are given, in addition to that of Trivandrum City Services.

Comparing the fleet strength, it can be seen that all except the Chandigarh Transport undertaking have a larger fleet strength than that of the Trivandrum City Services, Delhi Transport Corporation alone has a fleet strength of nearly 4400 buses.

Table 4.21 Comparison of performance of Trivandrum City Services With Similar Urban Bus Services in India During 1990-91

Name of Bus Services	Population As Per 1991 Census Lakhs	Fleet Strength	Average No. Of Buses Held	Average No. Of Buses On Road	Fleet Utilis-ation
Trivandrum City Services	5.23	467	451	375	83.1
Delhi Transport Corporation	83.75	4392	4403	3722	84.5
BEST Undertaking (Bombay)	125.71	2712	2612	2143	82.0
Pallavan Transport Corporation (Madras)	53.61	2296	2310	2006	86.8
Calcutta State Transport Corporation	109.16	1096	1048	843	80.4
Pune Municipal Transport	24.85	564	561	495	88.1
Chandigarh Transport Undertaking	5.74	357	--	--	--

(Source: Performance Statistics of State Transport Undertakings 1990-91 and KSRTC Administration Report 1990-91)

Name of Bus Services	Average Seating Capacity	Average Distance Travelled by Passengers (Km)	% Occupancy Ratio Based On Seating Capacity	% Load Factor Based On Carrying Capacity
Trivandrum City Services	33.7	7.17	146.39	97.69
Delhi Transport Corporation	61 (DD) 36 (DD)	11.92	157.51	95.71
BEST Undertaking (Bombay)	59	6.12	92.80	70.20
Pallavan Transport Corporation (Madras)	44	8.15	129.50	82.60
Calcutta State Transport Corporation	45	8.94	116.98	90.76
Pune Municipal Transport	46.25	7.32	95.14	72.96
Chandigarh Transport Undertaking	52.26	19.54	100.93	82.82

Table 4.21 (Continued)

Name of Bus Services	Kilometres Operated Per Bus Per Day	Fare Charged	Fuel Consumption (KMPL)	Operating Staff per Bus
Trivandrum City Services	180.92	13 Ps/Km	3.565	6.73
Delhi Transport Corporation	219.2	50 Ps upto 6 Km 100 Ps 6-16 Km 150 Ps above 16 Km	3.8	6.92
BEST Undertaking (Bombay)	208.9	20 Ps/Km (average)	3.07	9.06
Pallavan Transport Corporation (Madras)	227	10 Ps/Km average	3.50	6.37
Calcutta Transport Corporation	169.9	15 Ps/Km	3.08	7.77
Pune Municipal Transport	221.1	18 Ps/Km (average)	3.51	7.85
Chandigarh Transport Undertaking	--	50 Ps upto 5 Km 100 Ps above 5 Km	--	4.81

Table 4.21 (Continued)

Name of Bus Services	Average Salary Per Employee Per Day (Rs)	% Regularity	EPKM (RS)	CPKM (Rs)	EPKM / CPKM X 100
Trivandrum City Services	73	83.27	5.43	7.32 (KSRTC)	74.18
Delhi Transport Corporation	75	93.60	4.12	9.75	42.25
BEST Undertaking (Bombay)	72.53	89.40	10.96	13.95	78.56
Pallavan Transport Corporation (Madras)	78	90.40	6.76	7.68	88.02
Calcutta Transport Corporation	73.50	67.84	5.33	12.27	43.44
Pune Municipal Transport	--	--	8.3	9.0	92.22
Chandigarh Transport Undertaking	68.15	--	--	--	--

Table 4.21 (Continued)

Table 4.22 Details of Income and Expenditure of KSRTC During the Year 1990-91

Income		Expenditure	
Item	Amount in in Rs Lakhs	Item	Amount in Rs Lakhs
1. Single journey ticket fare	16678.17	1. Salaries & Allowances	7687.65
2. Season ticket fare	127.84	2. Welfare and supervision	1331.03
3. Contract service	52.47	3. Bonus	390.35
4. Post mail service	10.90	4. Stores	2363.98.
5. News paper conveyance charges	1.39	5. Fuel	4029.55
6. Non operating revenue	361.95	6. Vehicle tax	699.21
Total	17232.72	7. Surcharge	69.92
		8. Permit fee, licence fee etc.	53.02
		9. Rent, rate & taxes	15.29
		10. Depreciation	1097.88
		11. Debt charge	1626.71
Loss for the year 1990-91	Rs. 3099.90 lakhs	12. Interest on capital contribution	418.53
		13. Other charges	339.31
			20332.62

(Source: KSRTC Administration Reports 1990-91)

Table 4.23 Consolidated Balance Sheet of KSRTC as on 31.3.91

Capital & Liabilities		Properties & Assets	
Item	Rs Lakhs	Item	Rs Lakhs
1. Capital contribution	6854.82	1. Fixed assets	13018.94
2. Loans	6607.62	2. Investments	0.22
3. Funds	7783.88	3. Current assets	1007.23
4. Reserves & provision	1762.48	4. Advances & deposits	93.30
5. Deposits with the corporation	42.62	5. Sundry debtors	276.03
6. Capital liabilities	3208.89	6. Prepaid expenses	0.48
7. Revenue liability for purchase of spares and other utilities	691.91	7. Suspense account	1648.91
8. Current liabilities	4349.08	8. Bank and cash balance	1284.06
9. Suspense accounts	301.30	9. Deficiency net revenue account appropriation	
10. Water transport A/C	59.30	(a) KSRTC	18919.31
		(b) Water transport	170.41
Total	35954.49	Total	35954.49

(Source: KSRTC Administration Report 1990-91)

Transport Undertakings in both Bombay and Delhi have also a sizeable number of double decker buses. All these urban areas under comparative reference have a higher population figures than that of Trivandrum, with Greater Bombay and Greater Calcutta have populations exceeding one crore each. The average seating capacity of the Trivandrum City Services, which is only 33.7, is the lowest among all the transport undertakings considered. The fleet utilisation ratio, which is calculated on the basis of the average number of buses held and the average number of buses on the road, at a time for Trivandrum is comparable to that of other urban transport undertakings. However, the percentage regularity of the Trivandrum City Services, which is only of the order of 83.27 percent is quite low when compared to the figures for other undertakings. The bus fare charged varies widely among the different urban city services. The lowest bus fare is charged by the Delhi Transport Corporation, which is between six paise per kilometre and ten paise per kilometre, depending upon the length of the journey. Some organisations have a telescopic fare structure, similar to that of the railways, with the rate per kilometre decreasing as the length of journey increases. The maximum rate is charged by BEST Undertaking, which, on the average charges around twenty paise per kilometre. On the whole, Trivandrum City Service's fare of thirteen paise per kilometre comes some where in the middle among these different undertakings.

With regard to the kilometres operated per bus per day, which is an important factor influencing the total earnings, the Trivandrum City Services rank lowest, excepting for the Calcutta State Transport Corporation. The city bus services of Delhi and Madras have the highest figures for kilometres operated, which is around 220 kilometres per bus per day. The average length of journey per passenger also varies widely, with theshortestjourney length being in Bombay and the longest in Chandigarh. The Trivandrum City Service's average journey length of 7.17 kilometre is comparatively on the lower side. The occupancy ratio of the bus services, which is obtained by dividing the passenger kilometres by seat kilometres, Trivandrum City Services has one of the highest figures at 154.41 which is second only to that of the Delhi Transport Corporation's figure of 157.51. If the same ratio is calculated based on the carrying capacity of vehicles, Trivandrum City Services has the highest figure of 103.04 percent. While the figures mentioned above are average figures, it is clear that peak load figures will be still higher and it is clear that Trivandrum City Services' buses are one of the most overcrowded among all similar services in the country.

As has been noted above, the two main constituents in the operational expenditure of any transport undertaking are the wages paid to employees and the fuel bill. The ratio of operating staff to buses held and the average salary per employee per day are shown in the Table 4.21. It can be seen that these figures for Trivandrum City Services are by and large comparable to that of other urban bus transport undertakings. The fuel consumption figures (KMPL-Kilometres per litre) also are comparable.

Comparing the income and expenditure through EPKM (earnings per kilometre) and CPKM (cost per kilometre), it can be seen that all the urban services are operating at a loss. Maximum losses are made by Delhi Transport Corporation and Calcutta State Transport Corporation. In the case of these undertakings their income is less than fifty percent of their expenditure. The Trivandrum City Service's corresponding figure of 74.18 percent is more or less similar to the corresponding figures of other corporations. It can be seen that the 'minimum loss maker' is the Pune Municipal Transport, which has an income:expenditure ratio of Ø.92. It is also noteworthy that unprofitable operation is not restricted to urban transport undertakings alone in India. Only very few public sector transport undertakings in India are operating on a profit at present. Either they are managed inefficiently or transportation by public services is highly subsidised in the country.

Summing up, the income-expenditure pattern of the Trivandrum City Bus Services and its loss making trend is common to all urban transport undertakings in India. The most important reason for their low earnings is perhaps, the comparatively lower number of kilometres operated per bus per day. Other factors contributing to this situation in Trivandrum and some other cities include the very large number of student passengers who enjoy concessional fare which may be as low as 15 percent of the normal fare, the higher operating cost of a bus fleet of comparatively older age, etc. The Trivandrum City Services have vehicles which are as old as 16 years and the average age of the whole fleet is 9.76 years. If all the older vehicles are replaced at an estimated economic age of even seven years the average age of the fleet will be only 3.5 years.(203, p 15) It may be noted that more than 75 percent of the buses in the City Services are already beyond this economic replacement age of seven years. At the same time, from KSRTC's point of view, it may be logical to operate newer buses on long distance routes which have better earnings per kilometre and where vehicle utilisation is better. However, the unviable financial situation of Trivandrum City Services is also characteristic of the urban bus transport operation in India and abroad, even if there may be some special factors aggravating the situation for the KSRTC's Trivandrum City Services operation.

4.6 Inadequacy of Trivandrum City Services

One of the most important factors which measures the efficiency of operation of bus services is whether it provides adequate service to the travelling public or not. KSRTC's Trivandrum City Services have a monopoly of the bus service in Trivandrum City and its suburban areas covering a total population of more than 10 lakhs. Over the years, it has been a fact that Trivandrum City Services have not been able to provide adequate service to the travelling public. This observation is due to the various factors mentioned below:

1. Complaints from travelling public which regularly appear in newspapers.

2. Crowded bus stops where people wait for buses for long periods, especially during peak periods.

3. Overcrowded buses as have been proved even by available statistics. The average occupancy rate in Trivandrum City Services expressed as a function of carrying capacity which is estimated as 1.5 times the seating capacity is nearly 98 percent. (202, p 109) This being an average value, it is obvious that the occupancy ratio during peak periods is still higher.

4. Complaints regarding the City Services raised in the Kerala State Legislative Assembly, and also as mentioned in the Public Undertakings Committee reports. (203, p 57)

5. Growth of the autorikshaw population in Trivandrum City. There are more than 4000 autorikshaws having licence to operate within Trivandrum city with at least another 1000 operating in suburban areas. Together, they provide 15,000 seats (considering three seats per autorikshaw) which must be considered as a parallel IPT (Intermediate Public Transport) mode. The total seats in Trivandrum City Services buses is only about 28,000 and the autorikshaws have more than fifty percent of the carrying capacity of the city bus services.

6. Public complaints regarding inadequacy of bus services recorded during a traffic survey of Trivamdrum City conducted by the researcher for the present study. (178, p 3)

In contrast, Cochin and Kozhikiode in Kerala are served by private buses. Whatever be their other negative aspects, they are able to ensure that travellers reach their destinations more or less on time. The poor operation of Trivandrum City Services in comparison with the non-nationalised transport services in Cochin and Kozhikode is usually taken as a convenient example to highlight the inefficiency of the public sector vis-a-vis the private sector.

4.7 Problems Faced by Trivandrum City Services

The problems and challenges faced by Trivandrum City Services are manifold. On the one hand, the services provided are not adequate to meet the demand of the passengers, especially during peak periods. It has to serve the passengers of not only the city area, but the adjoining panchayats also. From the financial point of view, providing more city buses will only add to the operating losses of KSRTC as the investment called for will be very high. This is mainly due to the fact that while a city bus runs only 162.3 kilometres per day, as against the Corporation's average of 283 kilometres (Table 4.7). Average earnings per kilometre for city buses is only Rs. 5.43 as against KSRTC's average of Rs. 5.95 (see Table 4.14) in spite of the overcrowding. Comparatively older vehicles are used in the city services, which are slower, less fuel efficient and more breakdown and accident prone. The large number of student passengers, who enjoy very low concessional fares add to the problem. Narrow roads and traffic congestions contribute to the low operating speed of the vehicles, especially in the heart of the City. Other problems like the unplanned growth of the City, the one-way empty operations, peak hour problem etc. add to the traffic problems in Trivandrum City and of the Trivandrum City Services of the KSRTC. An attempt to analyse and suggest some possible solutions to these problems is made in the subsequent chapters of the study.

CHAPTER - V

ASSESSMENT OF TRAVEL DEMAND

5.1 Travel needs of People

An assessment of the travel needs of the passengers is the basis for any transport planning programme. It is the foundation on which the whole edifice of the transportation system is built up and if it is not sound, the whole structure will be weak. Transport facilities are to be provided according to the requirements of the user population. If demand and supply are not compatible, it may lead to dissatisfaction of the travelling public or operating losses or both.

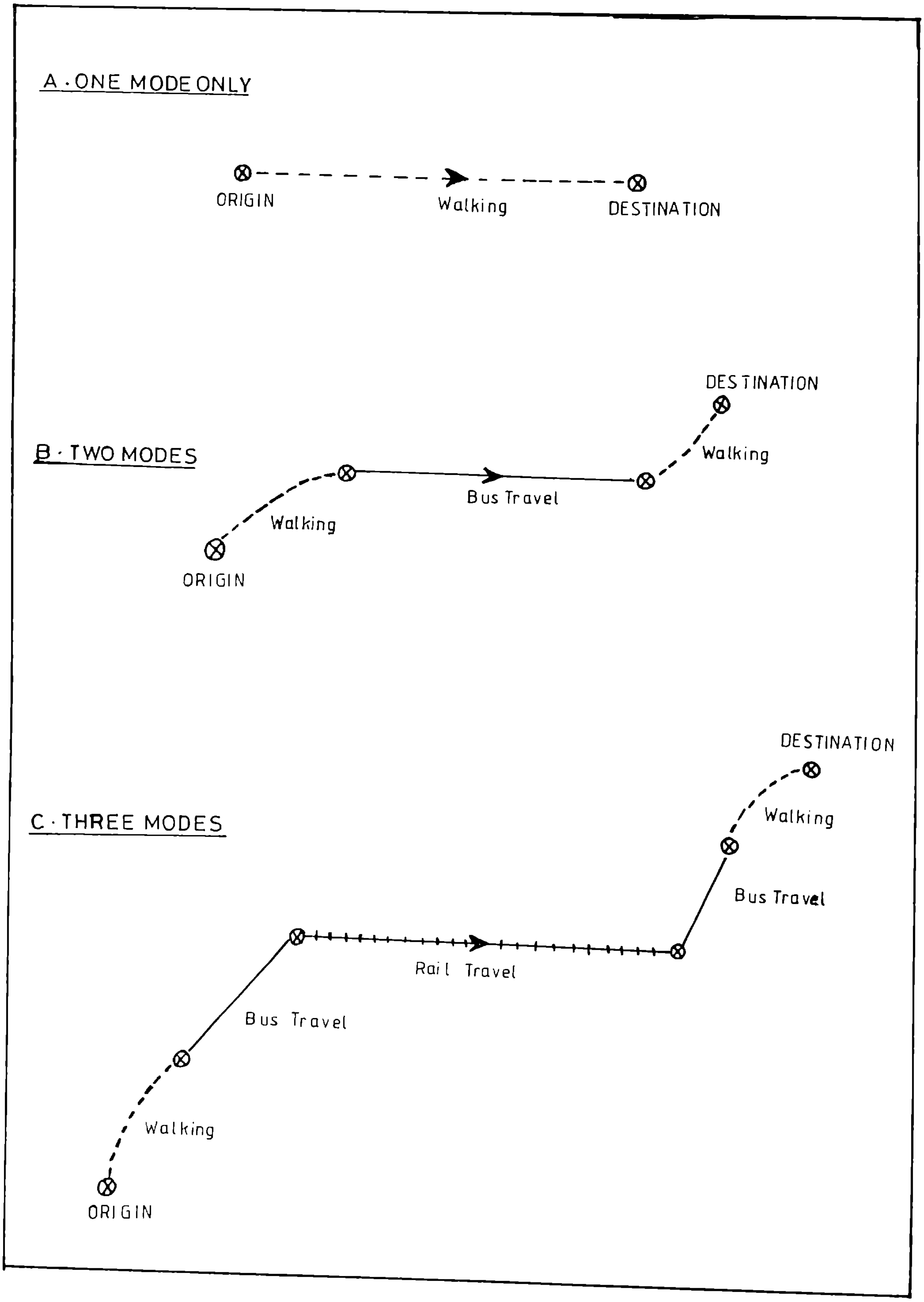
Travel requirements arise due to a variety of reasons such as going to places of work, going to educational institutions, shopping, entertainment, meeting social obligations, family and business needs, etc. While travel for work or study has a more definite and fixed pattern and can, therefore, be more easily assessed, other types of travel are not that regular and hence their assessment is more difficult. To satisfy their travel demand, people may use different modes of travel such as walking, cycling, travelling by train or bus, etc. This 'modal split' will depend upon relative advantages of the different modes, considering such factors as the need and urgency of travel, cost of travel, travel time, convenience etc. In different situations, people may have to make use of different modes of travel to reach their destination and meet their needs. The different travel modes are depicted in Fig 5.1. In case A, the traveller uses only one mode, while in case B he uses two modes and in case C, he uses three different modes.

Every travel has an origin and a destination and also a timing. Considering the timing of the travel, it can be either a destination-oriented travel or an origin-oriented travel. If the person wants to reach the office at 10.00 A.M., there are three important parameters in his travel : 1.the origin 2.the destination and 3.the time he has to reach the office, let us say, before 10.00 A.M. He may like to begin the journey as late as possible, provided he reaches the office on time. This is an example of destination-oriented travel.

If his return trip from office is taken into consideration, he may leave office at 5.00 P.M. and may want to reach home as fast as possible but, there is mostly a little more flexibility about this time. This is an origin-oriented travel.

The time taken by him for these journeys will depend upon the mode of travel he chooses such as walking, cycling, going by his own car or a rented conveyance, going by bus, etc. While walking and cycling is possible only for comparatively short

Fig 5.1 Travel Using Different Modes



distances, passenger bus travel is the cheapest mode of travel for the common man, especially when the distance to be covered is long.

Needless to say, spatial locations of various facilities in a city such as schools, shopping centres, etc. will decide the travel requirements of its citizens. For the residents of self-contained townships, travel requirements outside their work requirements may be much lesser.

Many mathematical models have been developed by researchers to explain and predict travel patterns between two places. The 'Gravity model' is the most important among them. (6,pp 199-209) It is adapted from the law of gravity advanced by Sir Isaac Newton in 1686. The model states that:

$$F_{12} = G \frac{M_1 M_2}{d^2}$$

Where F_{12} = The gravitational force between bodies 1 and 2.

M_1 = Mass of body - 1

M_2 = Mass of body - 2

d = Distance between bodies 1 and 2

G = A constant

This is modified to assess the travel requirements between two areas as:

$$T_{12} = K \frac{P_1 P_2}{d^2}$$

Where T_{12} = Travel requirements of people between areas 1 and 2

P_1 = Population of area - 1

P_2 = Population of area - 2

d = Distance between areas 1 and 2

K = A constant which is a measure of the 'attraction' between these two places, and depends upon the various facilities that are available in them such as schools, shopping centres, entertainment centres, offices, etc.

Even though many mathematical models are available to predict travel patterns, survey of the actual trips made by the passengers is the best way to assess the travel requirements in a city.

5.2 Various Methods of Assessing Travel Demand

While an exact assessment of the travel requirements in a city is a difficult task, various methods have been used for the same. Some of the more important methods are the following.

(i) Traffic volume survey

(ii) Cordon survey

(iii) Origin/Destination survey

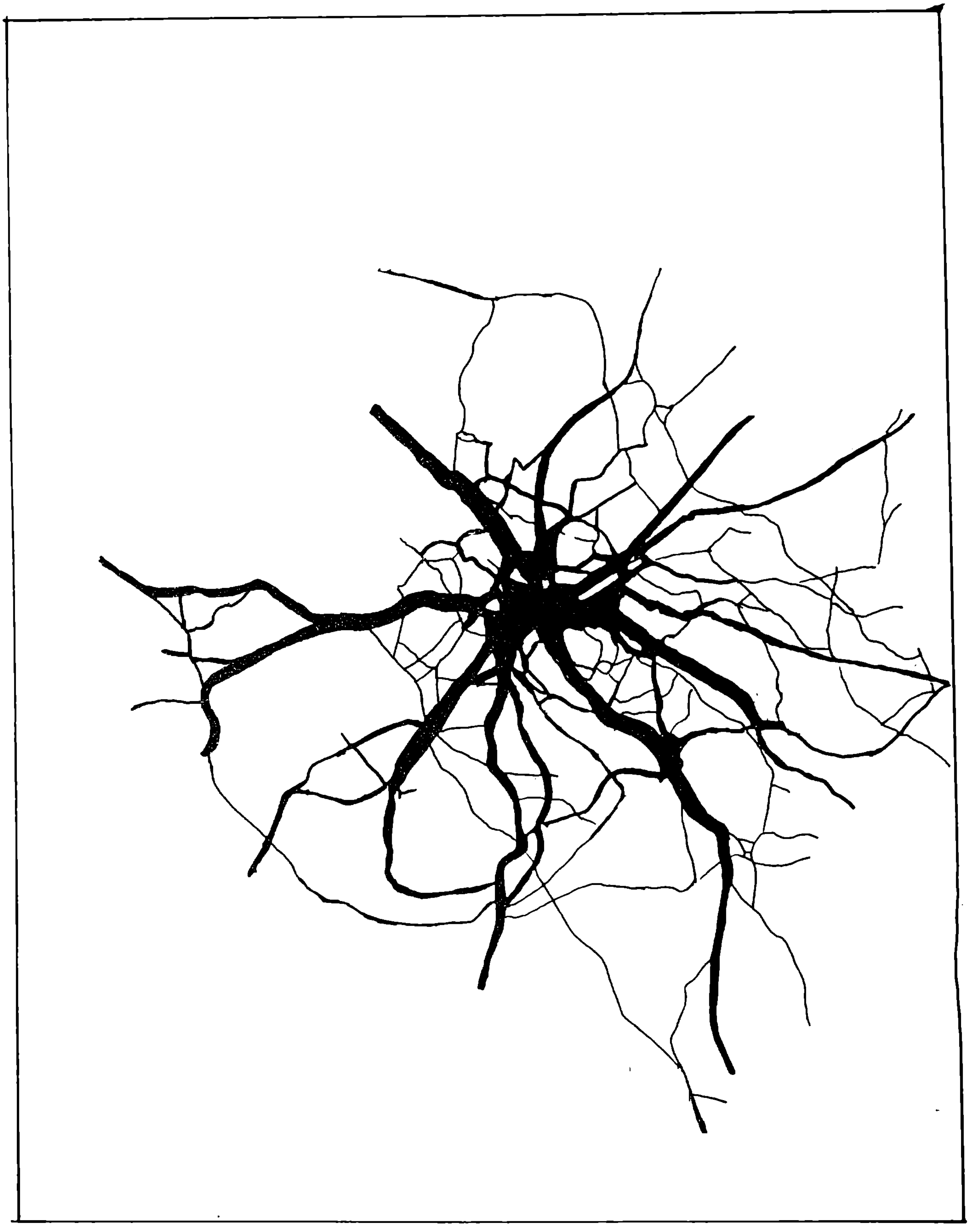
(iv) Way-bill analysis

(i) In a traffic volume survey, the volume of flow of passengers through different segments along each road is shown, for a given period of time -

month, day or hour. While the chart which shows traffic flows during the whole month gives only an overall picture showing the relative importance of the flow through various paths, daily and hourly flow charts are required for determining the number of vehicles to be provided for the different timings. Fig 5.2 shows an example of a traffic volume diagram. In a traffic volume diagram, width of the routes are drawn proportional to the traffic volume through it. Traffic volume can be estimated, based on data collected from various trips operated by buses from a depot. From a traffic volume diagram, 'traffic contours', that is the line joining all points having equal traffic volume, can also be drawn. Traffic contours, which are similar to survey contours, i.e. the line joining places of the same elevation, give very useful information regarding travel patterns in a city.

(ii) In a cordon survey, the various areas of the city are divided into 'cordons'. Traffic surveyors are posted at all roads which lead into this cordon. The number of passengers in all the buses coming into this cordon is counted. Figure 5.4 shows an example of a cordon survey. Thus, the whole city can be divided into different cordons. The traffic flow into all these cordons will give a complete picture of the traffic pattern. (6, pp 22-33)

Fig 5.2 Traffic Volume Diagram in a City



(WIDTH OF THE LINE IS PROPORTIONAL TO THE TRAFFIC FLOW THROUGH THAT ROUTE)

Fig 5.3 Traffic Contours

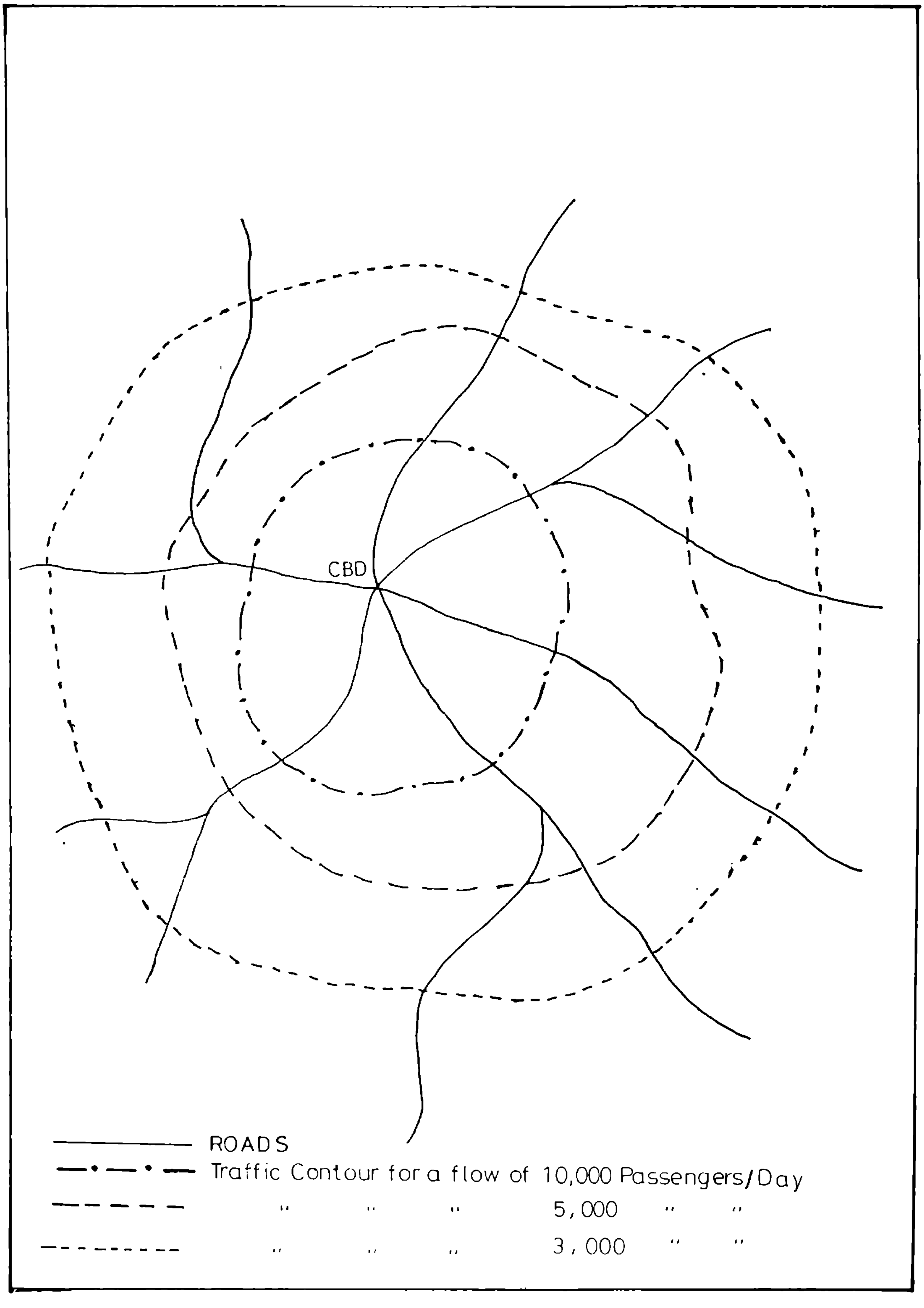
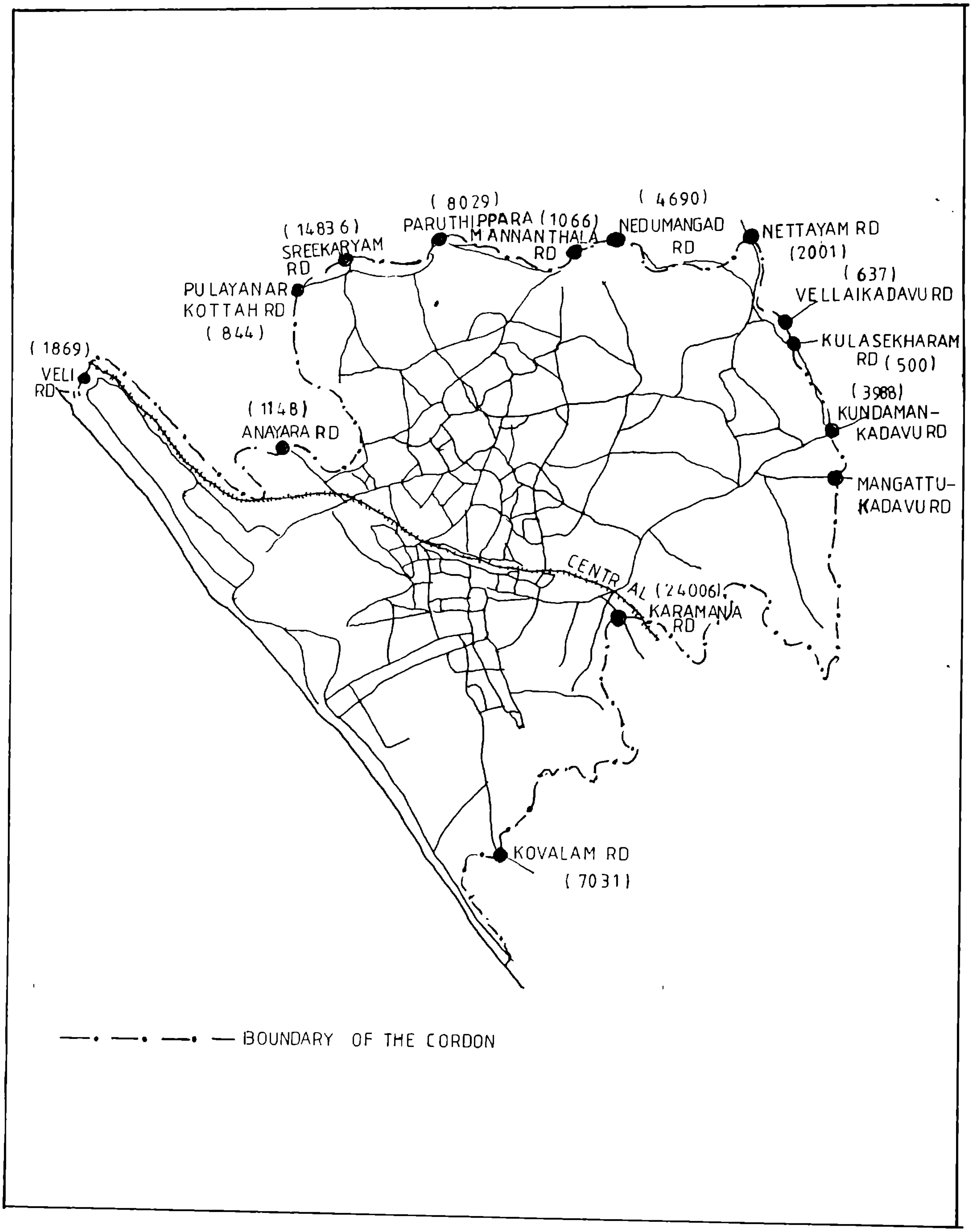


Fig 5.4 Cordon Survey Showing Traffic Inflow into the City

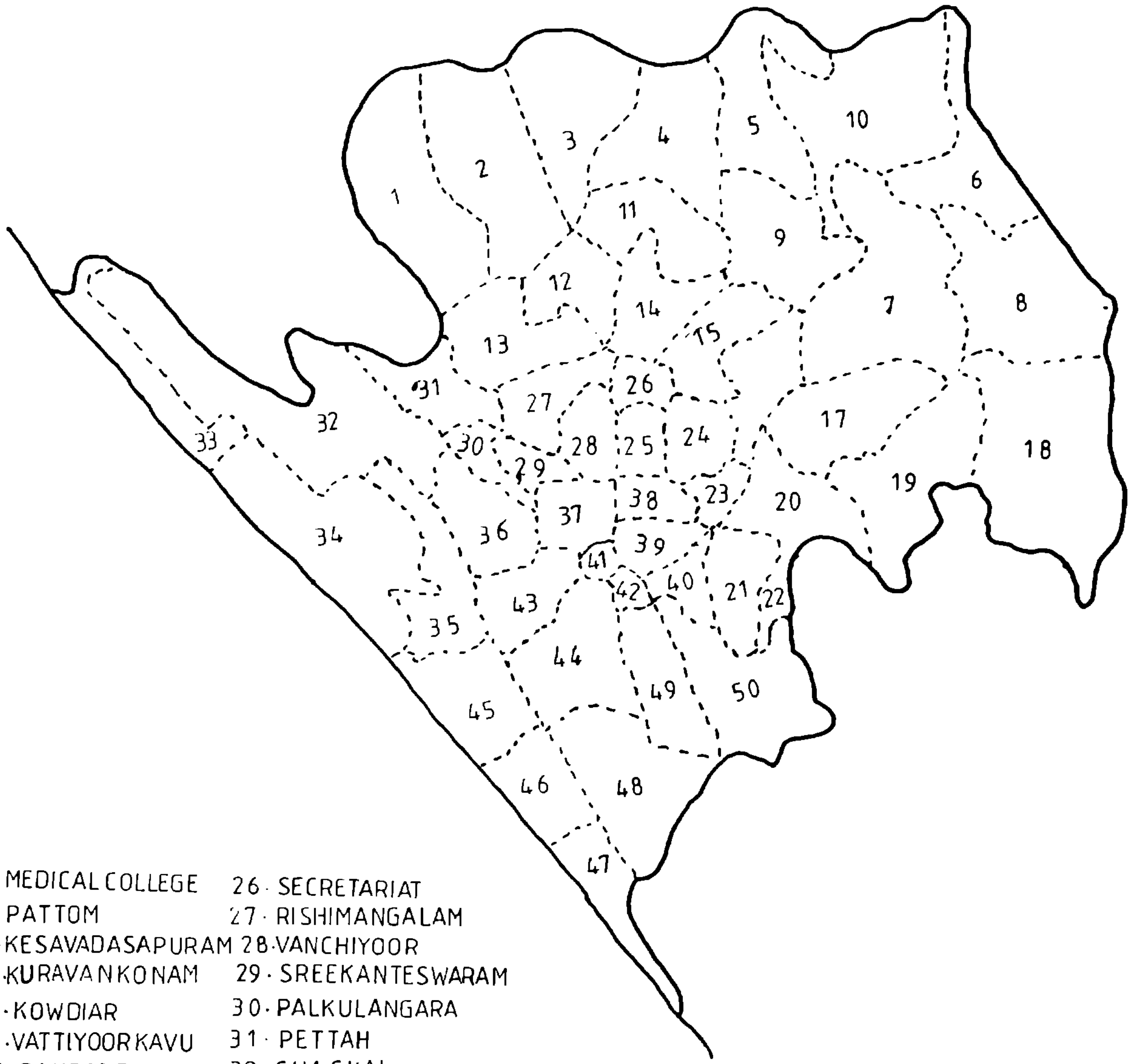


(SOURCE Traffic Survey Conducted by National Traffic Planning and Automation Centre, Trivandrum)

(iii) Traffic flow diagram and cordon survey are flow oriented only, since they do not specify the origin and destination of travellers. In fact, a commuter may sometimes have to travel in two or three buses to reach his destination. A survey which assesses the origin and the destination of travellers is the most valuable traffic data that can be collected. In a city, there are as many origins/destinations as the number of bus-stops in that city. Even in a medium-sized city like Trivandrum, there are about a thousand bus-stops. A comprehensive origin-destination survey for Trivandrum will be a matrix in the order of 1000 x 1000 size.

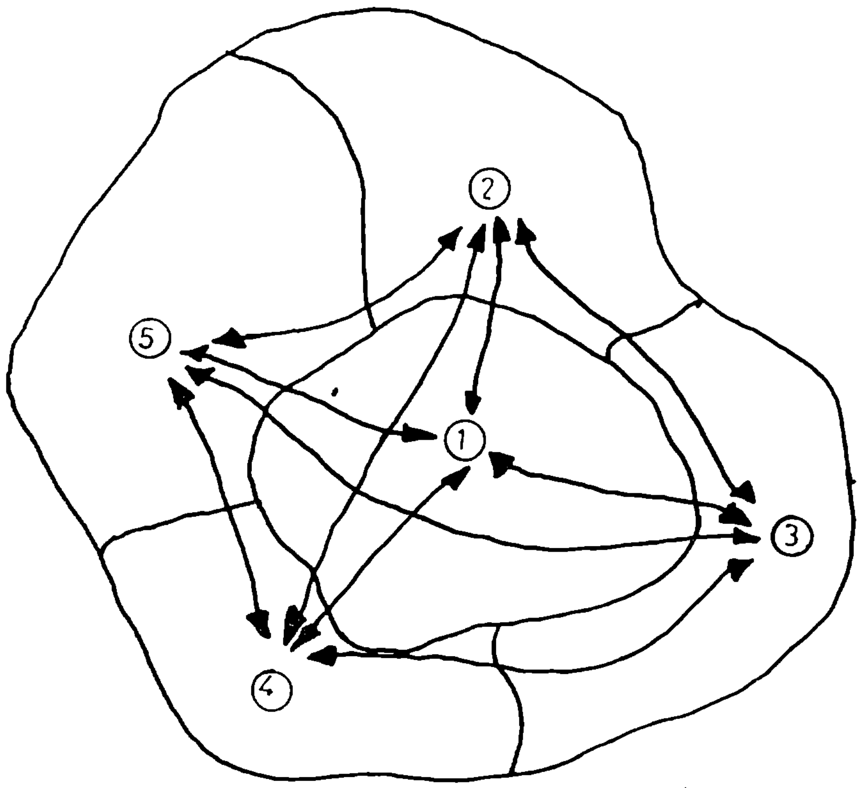
To make an O/D survey simpler, the whole city is divided into different zones. In Trivandrum City, these zones can be the different 'wards' of the City Corporation itself. The Trivandrum Corporation has fifty wards as shown in Fig 5.5. In addition, another twenty zones can also be considered for areas lying outside the city limits. Hence, a 70 x 70 matrix, when properly made, will give us an idea of the travel pattern in the city. Fig 5.6 shows an O/D matrix and an O/D map of an area having only six zones. It may be noted that an O/D matrix does not show details of intra-zone travels, since it basically gives the inter-zone travel relationships. This is why the diagonal cells in the O/D matrix have no entries. Personal

Fig 5.5 Travel Zones (Wards) in Trivandrum City



1 · MEDICAL COLLEGE
2 · PATTOM
3 · KESAVADASAPURAM
4 · KURAVANKONAM
5 · KOWDIAR
6 · VATTIYOORKAVU
7 · PANGODE
8 · THIRUMALA
9 · SASTHAMANGALAM
10 · KANJIRAMPARA
11 · NANTHANCODE
12 · KUNNUKUZHI
13 · KANNANMOOLA
14 · PALAYAM
15 · VAZHUTHACAUD
16 · JAGATHY
17 · POOJAPURA
18 · THRIKANNAPURAM
19 · MUDAVANMUGAL
20 · KARAMANA
21 · NEDUNGAD
22 · THALIAL
23 · VALIACHALA
24 · THYCAUD
25 · THAMPANOOR
26 · SECRETARIAT
27 · RISHIMANGALAM
28 · VANCHIYOOR
29 · SREEKANTESWARAM
30 · PALKULANGARA
31 · PETTAH
32 · CHACKAI
33 · VELI
34 · SANGUMUGOM
35 · VALLAKADAVU
36 · PERUNTHANI
37 · FORT
38 · CHENTHITTA
39 · CHALAI
40 · KURIATHY
41 · PUTHEN ST
42 · MANACAUD
43 · SREEVARAHAM
44 · KAMALESWARAM
45 · VALIATHURA
46 · BEEMAPALLI
47 · PUNTHURA
48 AMBALATHURA
49 KALLIPANKULAM
50 · KALADY

Fig 5.6 Typical O/D Matrix and O/D Map



FROM \ TO	1	2	3	4	5
1	–	2000	3100	1055	2402
2	2004	–	1050	1802	1603
3	3202	1020	–	2730	2840
4	1068	1940	2740	–	3000
5	2503	1608	2902	3010	–

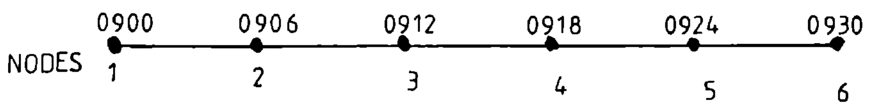
CELL VALUES SHOW THE NUMBER OF PASSENGERS BETWEEN DIFFERENT REGIONS EVERY DAY interviews with travellers at the bus stops is the only method to get the origin/destination data. While one interviewer may be sufficient in a small bus stop, more personnel may be required in the larger or busier bus stops to conduct this survey. Similarly, while one person may be sufficient to conduct the survey during off-peak periods, more people may be required to interview commuters during peak periods.

(iv) Analysis of 'way bills' kept by conductors gives very valuable information which shows the details of travel made by all passengers in one trip. The only approximation we have to make is that while passengers travel on a 'bus stop to bus stop' basis, we can get the data in a 'node to node' basis only. Since we know the starting time and running time of the trip, the time when the bus reaches each node can also be calculated. A demand matrix can be prepared from a way bill showing the details of passengers travelling from each node to subsequent nodes. While the onward journey will give data for the half part of a demand matrix, data for the remaining half will be provided by the return journey. Other details like the total number of passengers in any link or interfare stage, the time of the boarding and alighting of passengers, total amount of fare collected during the trip, etc. can also be calculated from the way bill.

Fig 5.7 shows a typical way bill and the analysis of the same to get various possible data. This route consists of five links or interfare stages and six nodes. A passenger who purchases a ticket of minimum denominations of seventy paise can travel four links, Hence there are tickets of three denomination only - 70 paise, 80 paise and 100 paise. The number of tickets sold can be found as the difference between the closing number and the opening number of the tickets. The number of tickets sold can be multiplied by their denomination, and the total of these will give the amount collected during the trip.

A half-matrix of size 6 x 6 shows the details of passengers on a node to node basis. The total number of passengers in each link can be found by adding the suitable cell values as shown in the figure. This can also be plotted as a diagram showing the total number of passengers in each link. The only disadvantage of this analysis is that we assume that all travellers make use of their ticket to the fullest extent, which may not be true in all cases.

A route network showing all the nodes in a city is also to be prepared to get an idea of different routes on a node to node basis. Fig 5.8 shows the route network of Trivandrum City, showing the farestages or nodes. A farestage network can be prepared using the route map of the city, and the fare stage tables.



EAST FORT - JAWAHAR NAGAR

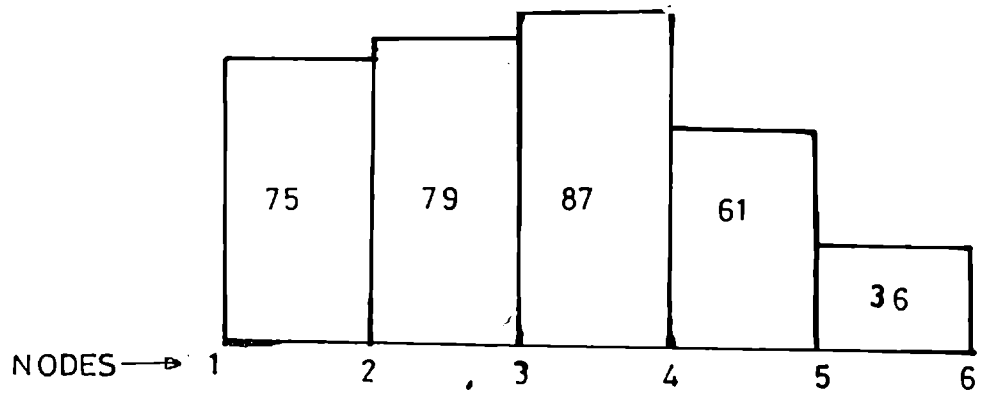
TICKET DENOMI-NATION(PS)	OPENING NUMBERS	POINT ENTRIES								ENDING NUMBERS	TOTAL TICKETS	VALUE	
		1	2	3	4	5	6	7	8				
70	8005	38	38	46	53	54				8054	49	34	30
80	0641	67	71	71	71	71				0671	30	24	-
100	3576	92	92	92	92	92				3592	16	16	-
										TOTAL	95	74	30

WAY BILL

	1	2	3	4	5	6
1	0	-	-	8038-8005 = 33	0667-0641 = 26	3592-3576 = 16
2		0		-	-	0671-0667 = 4
3			0	-	-	8046-8038 = 6
4				0		8053-8046 = 7
5					0	8054-8053 = 1
6						0

DEMAND MATRIX CORRESPONDING TO THE WAY BILL

Fig 5.7 A Typical Journey Bill and its Anaysis (Continued)



NUMBER OF PASSENGERS IN EACH LINK

LINK 1-2

	2	3	4	5	6
1	-	-	33	26	16

TOTAL= 75

LINK 2-3

	3	4	5	6
1	—	33	26	16
2	—	—	—	4

TOTAL = 79

LINK 3-4

	4	5	6
1	33	26	16
2	—	—	4
3	—	—	6

TOTAL= 87

LINK 4-5

	5	6
1	25	16
2	—	4
3	—	6
4	—	7

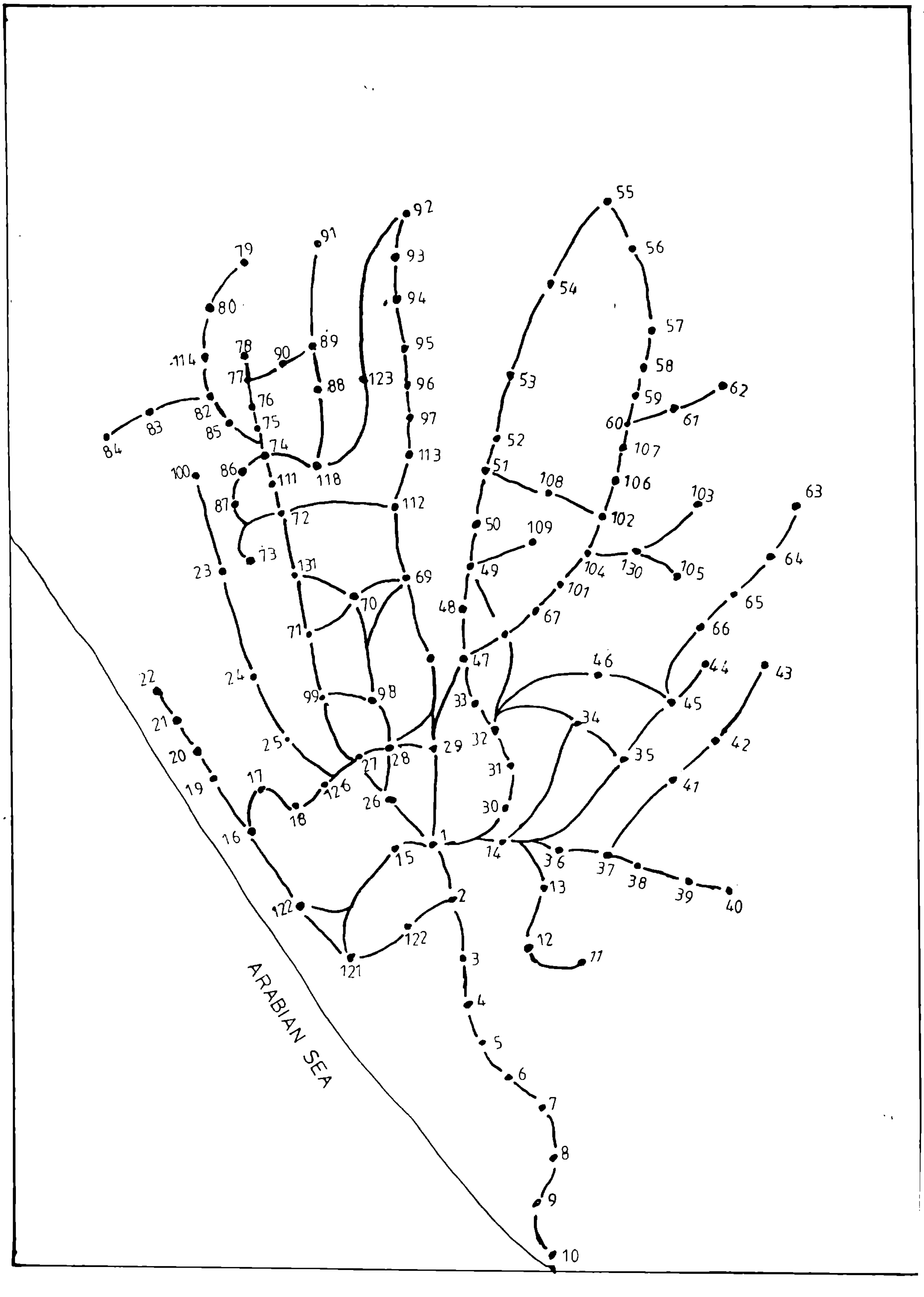
TOTAL= 61

LINK 5-6

	6
1	16
2	4
3	6
4	7
5	1

TOTAL=36

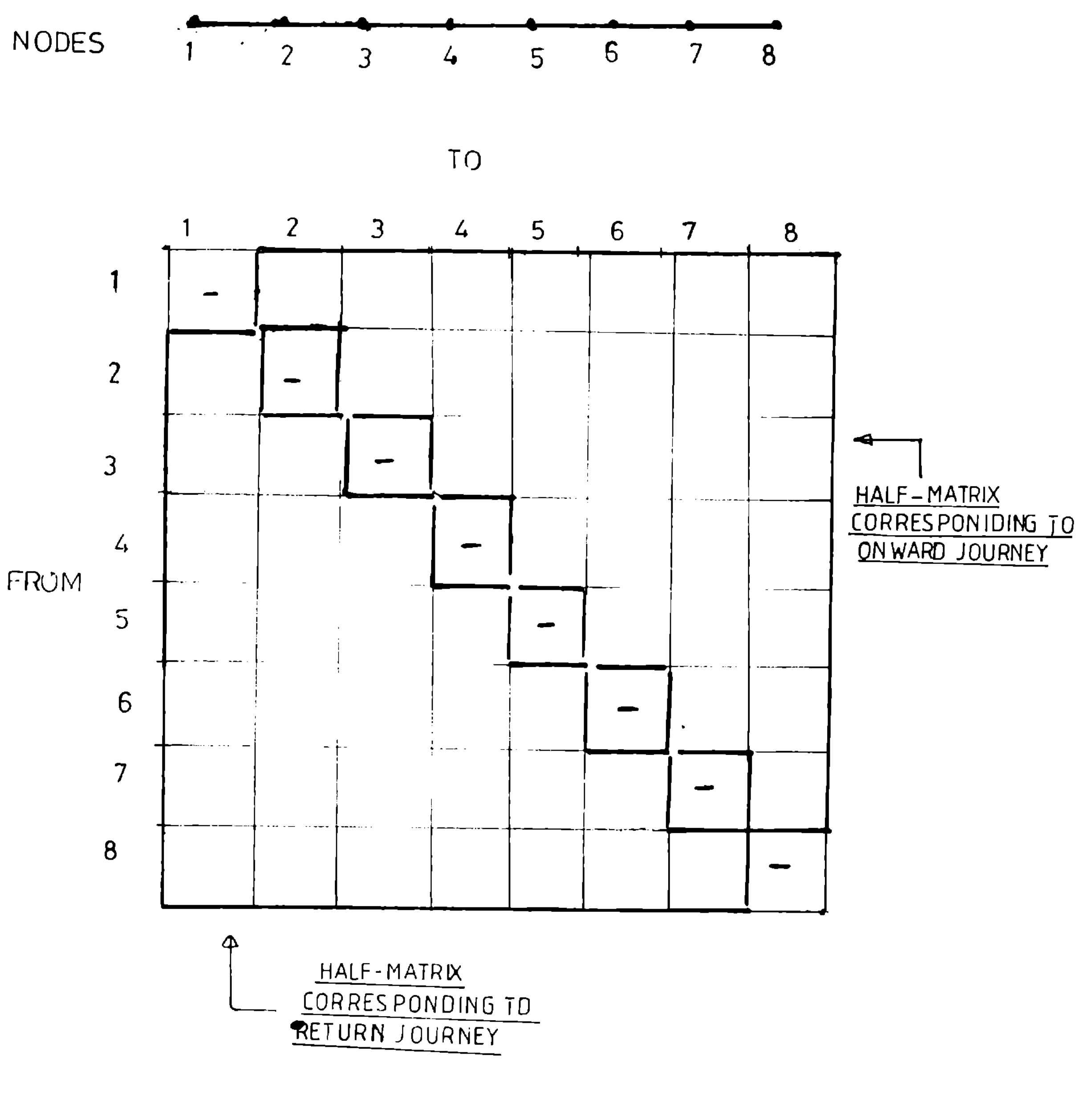
Fig 5.8 Traffic Network Showing Farestages



1. EAST FORT
2. MANACAUD
3. AMBALATHARA
4. THIRUVALLAM
5. 4TH MILESTONE
6. PACHALLOR LPS
7. PARAVILLA
8. VELAR
9. CONCHSHELL INDUSTRIES
10. KOVALAM BEACH
11. MARUTHOORKADAVU
12. KULATHARA
13. SINGARATHOPE
14. KILLIPPALAM
15. WEST FORT
16. BEACH
17. ALLSAINTS COLLEGE
18. RUBBER FACTORY
19. KANNANTHUR CHURCH
20. VETTUKADU CHURCH
21. KOCHU VELI
22. VELI
23. VENPALAVATTAM
24. VALIYA UDAYESWARAM
25. KUDAVOOR
26. KAITHAMUKKU
27. PATTOR
28. GENERAL HOSPITAL
29. STATUE
30. NEW THEATRE
31. THYCAUD SASTHAMCOIL
32. TAGORE CENTINARY HALL
33. BAKERY JUNCTION
34. JAGATHY
35. POOJAPURA MANDAPAM
36. NEERMANKARA
37. PAPPANAM CODE
38. KARAKKA MANDAPAM
39. NEMOM
40. PRAVACHAMBALAM
41. MALAYAM
42. VILAVOORKAL
43. MALAYANKIL
44. MANGATTU KADAVU
45. THIRUMULA JUNCTION
46. PANGODE
47. MUSEUM
48. YMR JUNCTION
49. DEVASWAM BOARD
50. KAWADIYAR
51. PEROORKADA
52. PURAVOOR KONAM
53. KARAKULAM BRIDGE
54. ARUVIKKARA 8TH MILE
55. AZHIKODE 9TH MILE
56. VATTAKKALAM
57. ARUVIKKARA WATER WORKS
58. ARUVIKKARA SCHOOL
59. IRAMBA
60. KALATHUKAL
61. ERAYAMCODE
62. CHERIYAKONNI
63. MULAYARA
64. VILAPPILSALA
65. PEYAD
66. KUNDAMAN KADAVU
67. SASTHAMANGALAM
68. PATTOM JUNCTION
70. POTTAKKUZHI
71. KUMARAPURAM
72. ULLOOR JUNCTION
73. PULAYANAR KOTTA
74. SREEKARYAM
75. PANGAPPARA HEALTH CENTRE
76. PANGAPPARA BRIDGE
77. KURISADY JUNCTION
78. UNIVERSITY CENTRE
79. KAZHAKUTTOM
80. ATTINKUZHY
82. MANVILA
83. MADATHIL
84. KUZHI VILA READING ROOM
85. ENGINEERING COLLEGE
86. LOYOLA COLLEGE
87. CHERUVIKKAL
88. CHEMPAZHANTHY
89. CHENKOTTUKONAM
90. THUNDATHIL
91. POTHENCODE
92. VATTAPPARA
93. MUKKAMPALA
94. MARUTHOOR
95. MANNANTHALA
96. KOTTAMUGAL
97. NALANCHIRA
98. KARUVALIKKUNNU
99. KANNAMMOLA
100. ORUVATHILKOTTA
101. KANJIRAMPARA CHURCH
102. MANNARKONAM
103. VELLAIKADAVU
104. THOPPUMUKKU
105. KULASEKHARAM
106. NETTAYAM
107. KACHANI TEMPLE
108. MANNAMOOLA
109. JAWAHAR NAGAR
111. PONGUMMOODU
112. KESAVADASAPURAM
113. PARUTHIPPARA
114. KULATHOOR
115. PMG JN.
118. KARIYAM
120. MUKKOLAKKAL
121. VALIYATHURA
122. THOPE
123. POWDIKONAM
126. KANJIRAVILAKOM
130. MUNNAMOOD
131. MEDICAL COLLEGE

Fig. 5.8 (Contd) List of Fare-Stages

Fig 5.9 Demand Matrix
(Corresponding to an Onward and Return Journey)



Using way bill analysis, complete data regarding passengers travelling in either direction along a link throughout the day can be calculated. This 'flow data' can be prepared for the whole day, with any time interval, say 15 minutes, 20 minutes etc. If the buses are operated from 5.00 A.M to 11 P.M., and if this period of 18 hours is divided into 72 'quarters' of 15 minutes duration each, the number of passengers travelling in one direction can be shown by a matrix of size 4 x 18. This is shown in Fig 5.10.

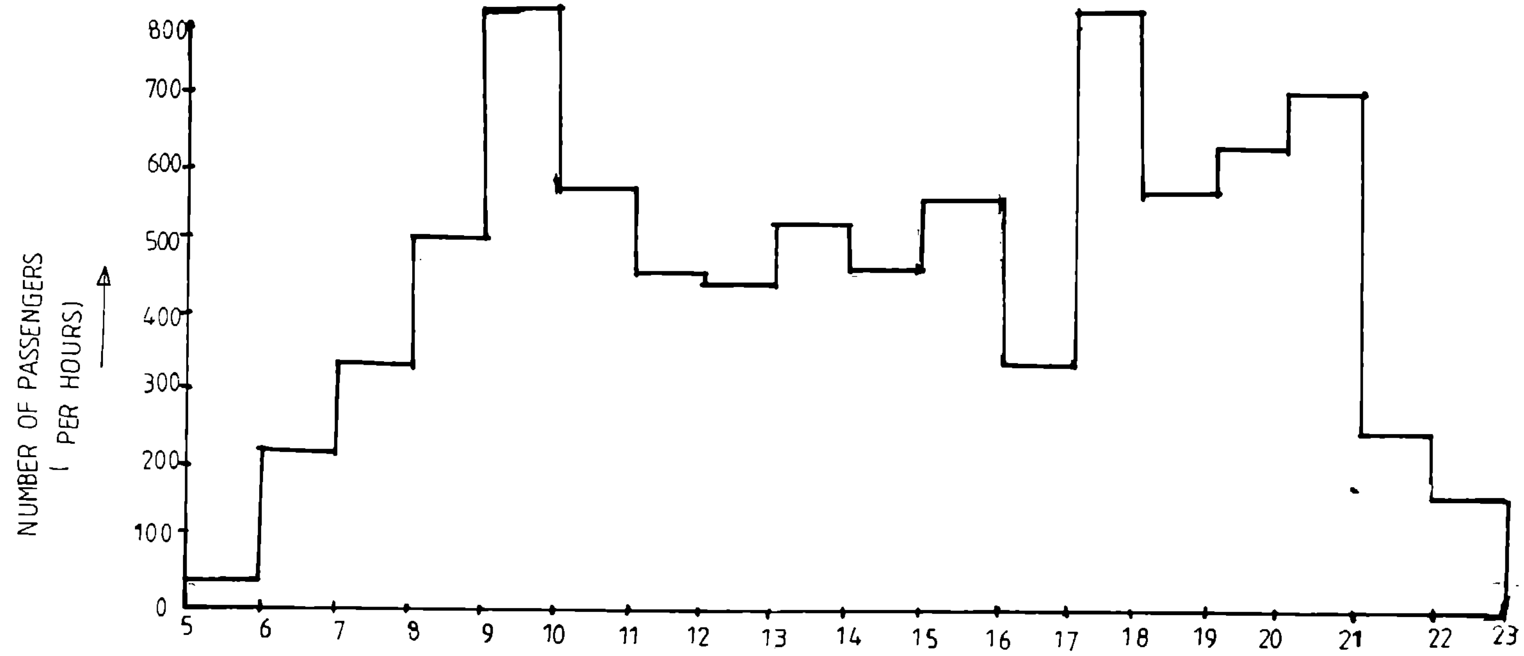
The passenger flow on an hourly basis is also shown in the same figure. This is done by adding the four cell values in each column and plotting it as a histogram. The two peaks - morning and evening - can be seen in the histogram. The maximum flow of 821 passengers per hour occurred during the time interval, 9.00 A.M. to 10.00 A.M. If the link is named 3-4, it shows that the flow is from node 3 to node 4, while a similar data for the link 4-3 will show the flow details in the opposite direction. The merging of such data in all the links along a route can be used to determine the number of buses to be operated along that route.

5.3 Variations in Travel Pattern

Variations in travel pattern can be classified into five types:

(1) Daily variation (Diurnal)

Fig 5.1Ø Traffic Flow Through a Link in One Direction and its Graphical Representation



TIME→	5-6	6-7	7-8	8-9	9-10	10-11	11-12	12-13	13-14	14-15	15-16	16-17	17-18	18-19	19-20	20-21	21-22	22-23
1ST QUARTER	–	8	50	137	198	17	72	114	158	152	92	49	121	275	191	80	31	40
2ND QUARTER	–	52	114	104	175	34	156	74	187	140	102	39	253	97	157	154	68	67
3RD QUARTER	11	113	64	134	220	178	205	124	117	102	227	10	307	128	156	317	93	48
4TH QUARTER	21	48	108	102	228	194	33	138	51	67	148	122	134	78	127	149	66	–
TOTAL	32	221	336	477	821	581	466	450	513	461	569	317	815	578	628	699	258	155

(ii) Weekly variation (Within a week)

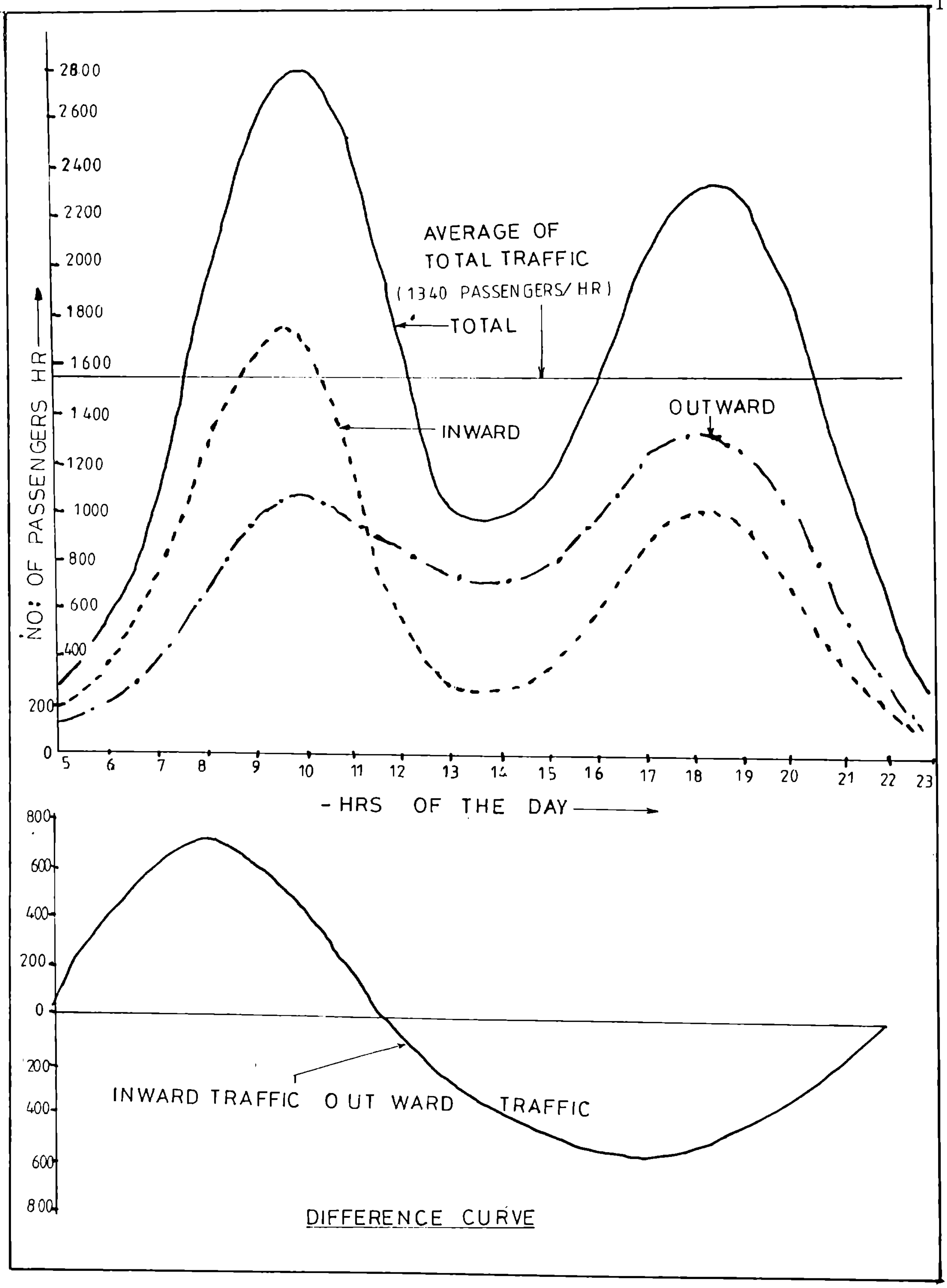
(iii) Monthly variation (During a month)

(iv) Yearly variation (During an year or seasonal variation)

(v) Long range variation (Over a longer period of several years)

(i) Daily variation shows the pattern of change in travel demand throughout the day. The peak periods and slack periods can be identified, and the time intervals which require additional trips can be decided. A 'total traffic curve' and 'difference curve' which shows the difference between inward and outward traffic can also be drawn. This is shown in Fig 5.11. These graphs can be drawn if the hourly flow of traffic in both directions along a link are known. First we draw the 'inward' and 'outward' curves, by joining the corresponding points by a smooth curve. Then the total of inward and outward values is calculated for each hour, and the total passenger traffic curve can be drawn. Average number of total passengers per hour can be found by dividing the total passengers by the total duration of operation. In Fig 5.11 the total hours of operation is 18 hours, and the average value works out to 1540. Instead of taking the total, if the difference between the inward and outward flow is taken, a 'difference curve' can be drawn which shows the period

Fig 5.11 Diurnal Variation of Traffic Along a Link



when inward flow is greater than the outward flow, and vice versa. These curves, in other words, indicate the volume and pattern of traffic within a day.

(ii) Weekly variation is the variation of traffic during the different days of the week. While traffic will be more or less the same during the week days - Monday through Friday, Saturdays may show a different pattern, since it is a working day for State Government and related offices, but is a holiday for educational institutions and offices functioning on a five-day week basis, such as the Central Government and certain commercial offices. Due to this, travel pattern on Saturdays will be a mix of holiday traffic and of people going to work and returning. Sundays and other public holidays show an altogether different pattern when compared to week days and Saturdays.

(iii) Monthly variation is concerned with changes in travel pattern during a month. For example, Trivandrum City being a city of office goers, the majority of whom receive monthly salaries, there is also seen a variation in ticket collection, with a pattern of a slightly larger number of trips being made during the beginning of the month than during the month end.

(iii) Yearly variation is concerned with changes in travel pattern among the different months or seasons during an year. This may be due to the climatic changes in an year or due to the consequent or other types of changes in economic activities. In Kerala, the four major seasons are the southwest monsoon period (June-August), the post-monsoon and northeast monsoon period (September-November), the winter period (December-February) and summer (March-May). Seasonal changes are likely to be less pronounced in intracity travel when compared to intercity travel.

(v) A very significant type of variation in the travel pattern is the change over a period of time of several years. The general trend in urban passenger traffic is one of continuous growth and expansion. This is due to various reasons like the growth of population, changes in the style and standard of living of the people, changes in people's travel habits, etc. However, it is not always necessary that bus travel in a city increases with time. When better travel modes are available, as for example, the commissioning of a new suburban train service or a large increase in passenger bus fares, it is likely that there can be a decrease in the travel demand in the urban bus network. It is also related to the general growth or decline of a town or city.

Due to the changes mentioned above, it is clear that travel demand in a city is never a static one. It is ever changing. A traffic survey made now will be obsolete within a few years. It is desirable that traffic surveys are conducted in a city periodically, say every three or four years for proper transportation planning within the city.

5.4 Conducting Traffic Surveys

The conduct of traffic surveys requires know-how, manpower, money and time. The cost of the traffic survey will depend upon the type of survey to be conducted, the extent of data to be collected and the nature of the subsequent analysis. The sample size to be selected is an important criterion. From the statistical point of view, the sample size, expressed as a percentage of the whole population or universe, can be small if the population which is to be surveyed is fairly homogeneous. If it is completely homogeneous, a small sample will be sufficient. For example, since milk and water mix well, analysis of a small sample of milk taken from a large tank, containing several hundred litres of milk, can tell accurately the water content, if any, in it. While this may be one type of limiting condition, the other limiting condition is that of a completely heterogeneous population. In such a case, a census (100 percent) survey may have to be conducted to get authentic information. The problems pertaining to the conduct of traffic surveys have been discussed at length by S. Anantha Padmanabhan. (2)

In Trivandrum City, it is estimated that there are about five lakh journeys performed everyday, using the city services.(209, p 220) This implies that at least 2.5 lakhs of passengers travel in the city buses every day. In addition, there are about 40,000 students who take 80,000 trips, using concession tickets. While the origin/destination data regarding these concession holders can be correctly ascertained, a sizeable percentage of the passengers have to be interviewed to get any authentic data about their travel pattern. This will require considerable expense and manpower. In a city like Trivandrum, cordon survey may be comparatively easier, since there are only about 20 'entry points' into Trivandrum City, considering the city boundary as the cordon. If, on an average five people are posted at each of these points on a day, two hundred mandays will be sufficient to conduct the cordon survey for one day, on a two-shift basis. However, more manpower will be required if this survey is to be conducted for several cordons, and also when the cordon survey is to be conducted for more than one day. As far as waybill analysis is concerned, nearly 10,000 trips are conducted every day by the city buses, and hence an equal number of waybills are written by conductors, every day. If 15 minutes are required to analyse one waybill, 2500 man hours will be required to analyse one day's waybills. It will be necessary that at least three or four day's waybills are analysed to obtain reliable data.

Collection of data is only one part of the traffic survey. Subsequent processing and analysis of data also require considerable skill and manpower. Computers can be gainfully utilised for data entry, analysis, and interpretations.

In any case, the total cost of conducting a traffic survey will depend upon a number of factors as follows.

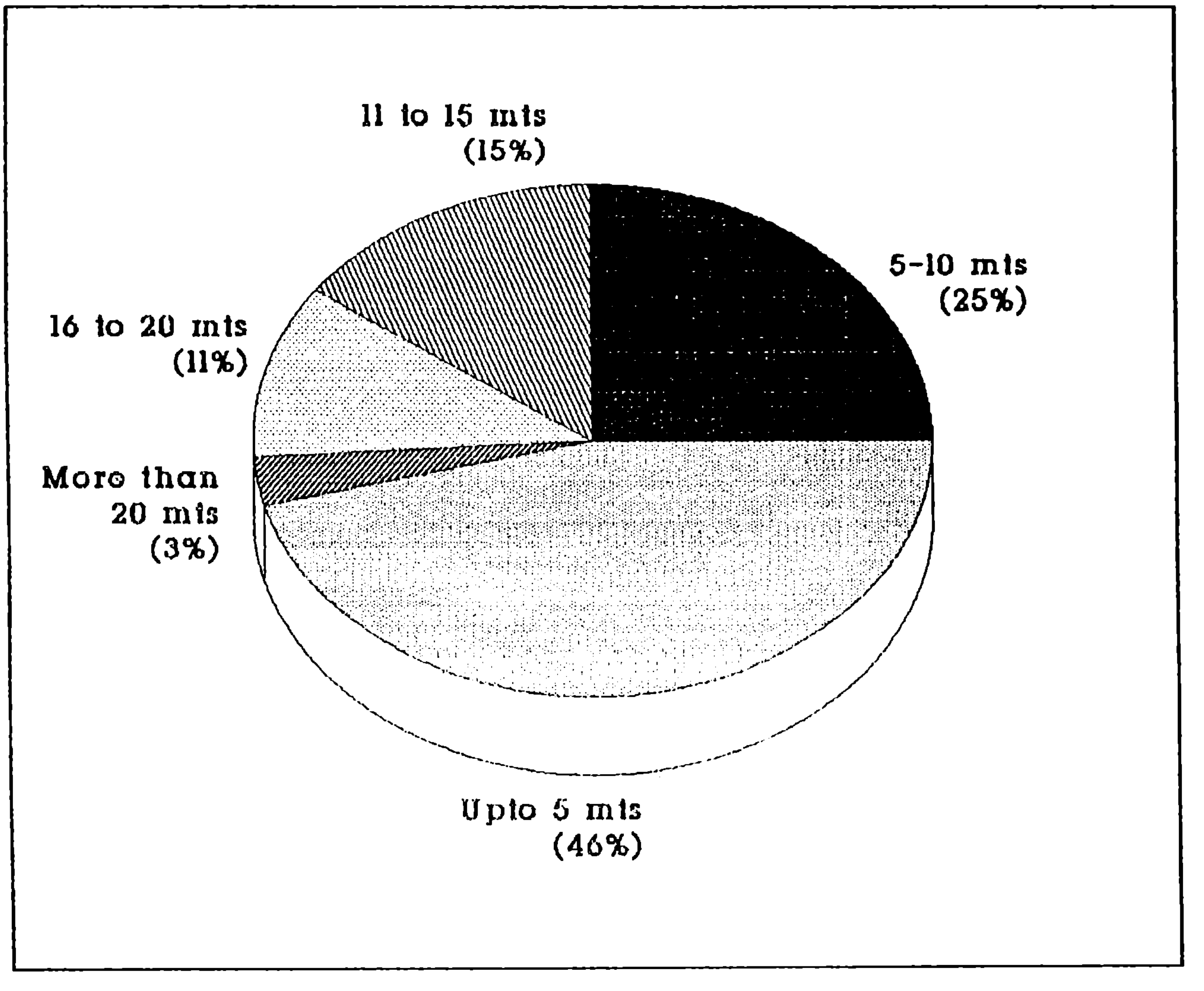
1. Types of survey(s) to be conducted (O/D survey, cordon survey, way bill analysis, etc.)
2. Sample size (20 percent, 40 percent etc.) of the commuter population to be covered.
3. The number of days during which data collection is to be done (applicable to cordon survey, and way bill analysis)
4. Remuneration to be paid for interviewers, and other personnel.
5. Extent of computer facilities made use of.
6. Extent of analysis to be done using this data and subsequent data to be generated as results of the traffic survey.

In any case, the minimum cost of conducting one traffic survey in a city like Trivandrum is likely to be in the order of Rs. 1 to 1.5 lakhs.

Other than the different types of traffic surveys mentioned above, traffic related socio-economic surveys are also sometimes conducted, either to get supplementary information for passenger bus planning or as a part of the total transportation planning in a city. These are discussed in more detail by John W. Dickey in his book entitled "Metropolitan Transport Planning", Chapter 7. (6) The data collected in such surveys include parameters like private vehicle ownership by households, purpose of travel such as going to work, shopping, returning from work, etc., income level of households, other transport modes available and their cost, etc. These have already referred to earlier and in Fig 5.12, 5.13 and 5.14. The pie charts show the waiting time of passengers, purpose of trip of passengers and their activity status. These data are compiled by observing/ interviewing a suitable sample of bus passengers. These data will give valuable information, complementary to traffic survey data, for the purpose of transport planning. (10, pp 608-610)

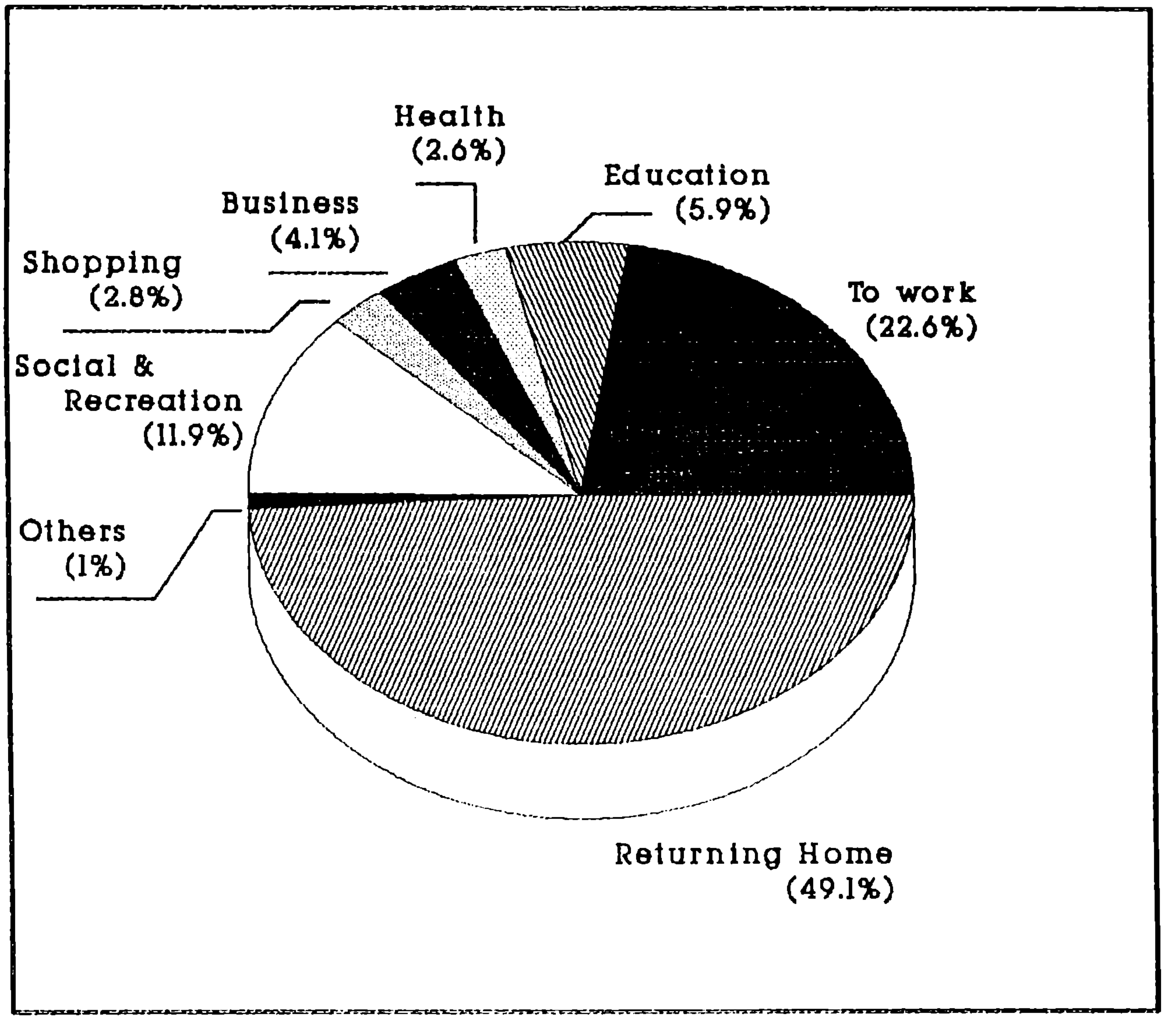
A traffic survey was conducted by the author in 1979 in Trivandrum City with the help of sixty student volunteers for the purpose of rescheduling the Trivandrum City services. Way bills of three days - a week day, a Saturday and a Sunday, were analysed. An O/D survey was conducted during peak hours viz. 8.00 A.M. to 10.30 A.M. and 3.30 P.M. to 6.00 P.M. for three days, in all important bus stops in the City. About 35,000 passengers were interviewed out of an

Fig 5.12 Waiting Time of Passengers



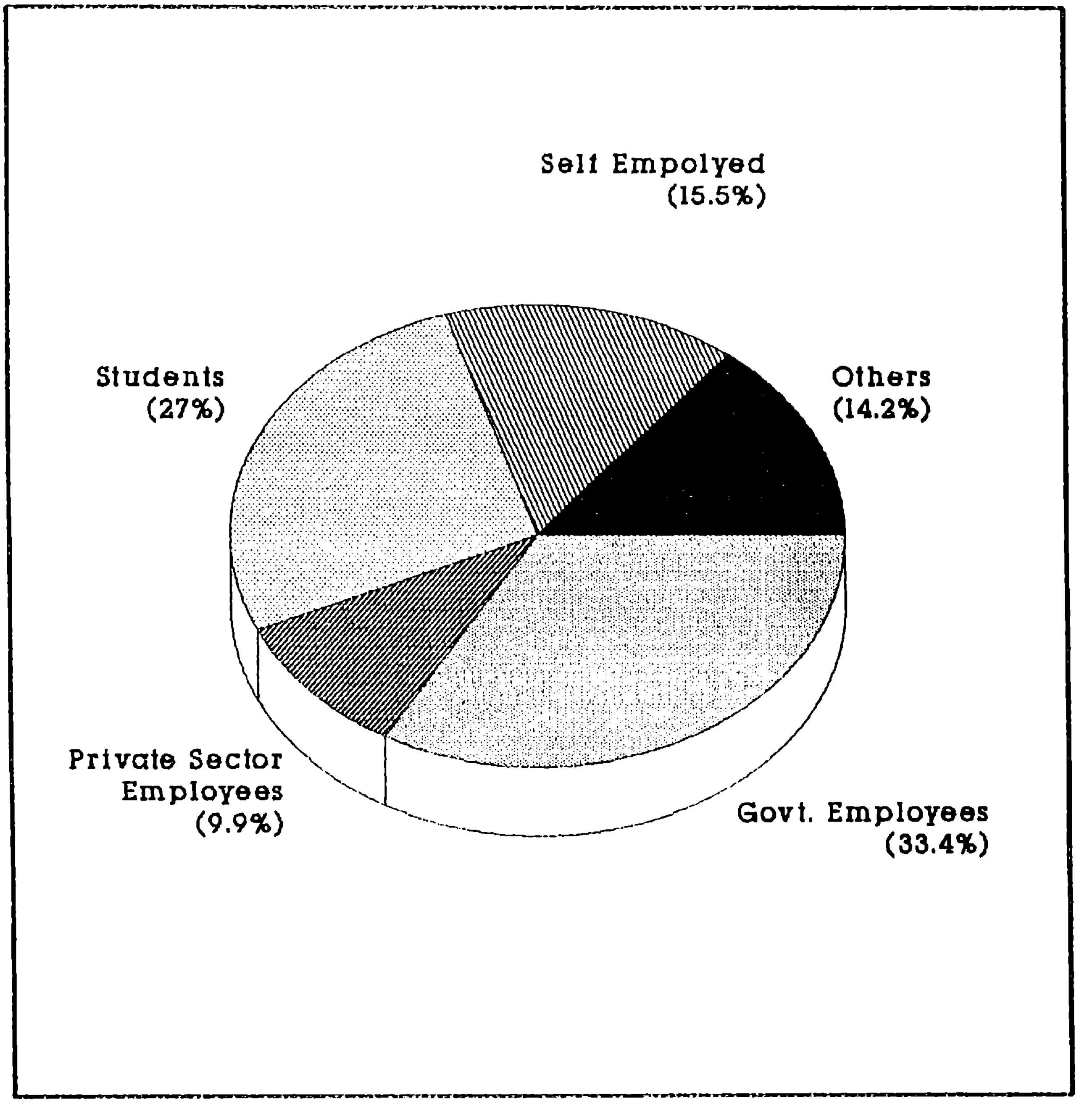
Source: Traffic Survey of Trivandrum City-National Traffic Planning & Automation Centre

Fig 5.13 Purpose of Trip of Passengers



Source: Traffic Survey of Trivandrum City-National Traffic Planning & Automation Centre

Fig 5.14 Activity Status of Commuters



(Source: Traffic Survey of Trivandrum City-National Traffic Planning & Automation Centre) average of 2.5 lakhs passengers travelling by the City Services every day. In addition, 'terminal surveys' were also conducted to estimate travel requirements of people in the outskirts of the City, living around terminal points of the bus routes. Data from this survey are made use of at several places in the present study.

Another traffic survey was conducted in Trivandrum City during 1979 by the National Traffic Planning and Automation Centre. This survey commissioned by the Government of Kerala was primarily meant to be used as a basis for town planning purposes. It was a more exhaustive survey comprising of O/D survey, traffic volume survey, cordon survey, socio-economic survey, etc. Data, Charts and Maps from this survey are also reproduced at several places in this thesis.

The data obtained from traffic surveys can be processed and the results thus obtained can be presented in various forms such as the following.

a) Maps : traffic volume diagram, traffic contours, traffic flow into cordons, etc.

b) Matrices (Origin/destination matrix, point to point travel matrix along a route, traffic matrix in a link etc.)

b) Graphs (Diurnal variation of traffic, seasonal variation of traffic, traffic growth over a period of time etc.)

c) Pie charts (Income pattern of population, pattern of vehicle ownership, social classification of commuters etc.)

e) Tables (Trip purpose Vs. Income level of commuters, waiting time at bus stops during different periods of the day, etc.)

As already mentioned, computers can be extensively used in the processing, analysis and presentation of these data. Graphs, pie-charts, matrices etc. given in this Chapter are typical examples of the presentation of the results of traffic survey.

CHAPTER - VI

OPERATING ASPECTS : HOW TO MEET CHANGING PATTERNS OF TRAFFIC DEMAND THROUGH TRAFFIC SURVEYS AND SCHEDULING

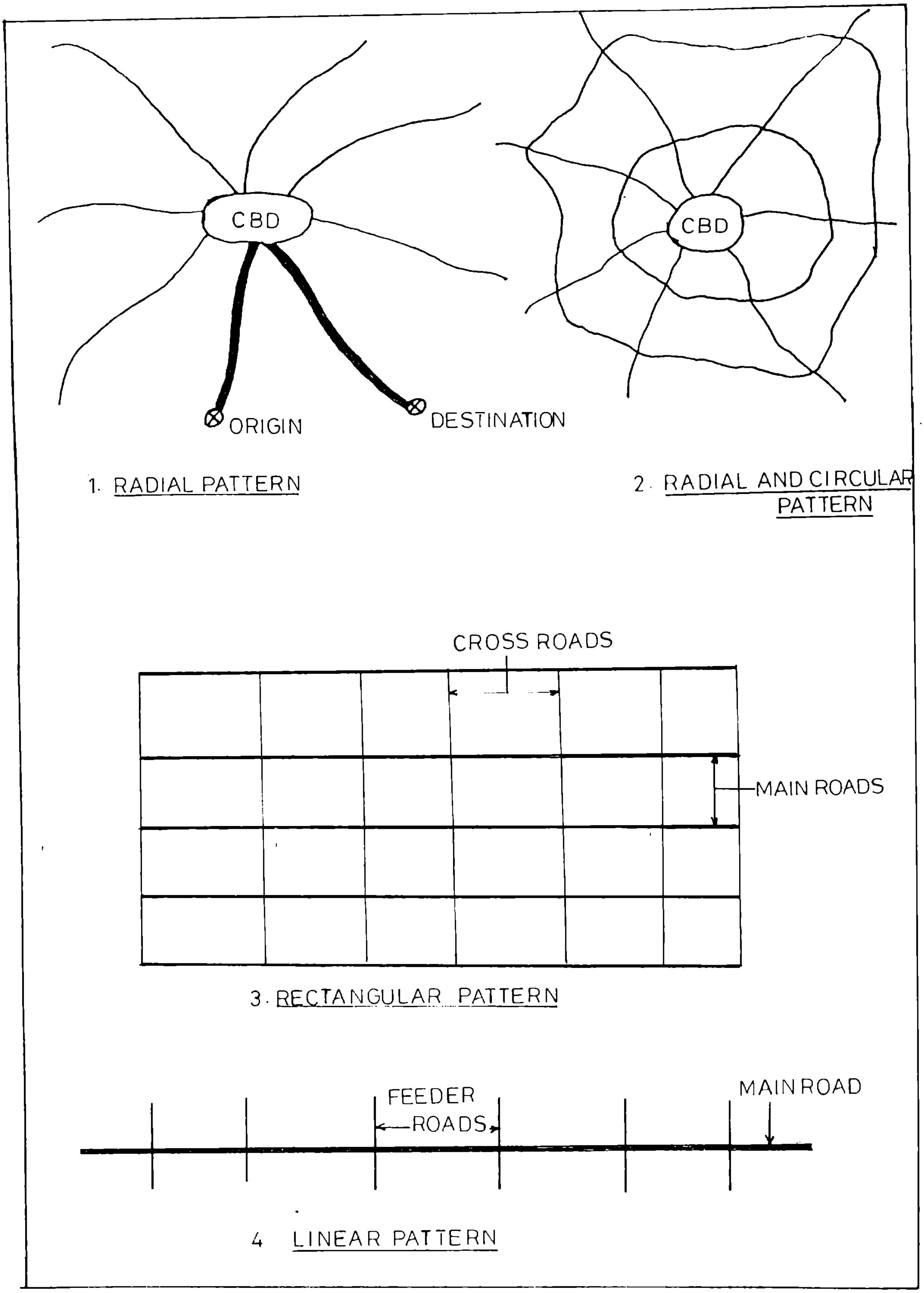
6.1 Geometrical Aspects of City Development

Once a proper assessment of the travel needs of the commuters is made, one can proceed to the scheduling of vehicles, which is the most important part in any public transport system management. This may be done in four steps, viz. (i).Depot location, (ii).Vehicle allocation to depots, (iii).Bus scheduling or the preparation of timetables; and (iv).Crew scheduling.

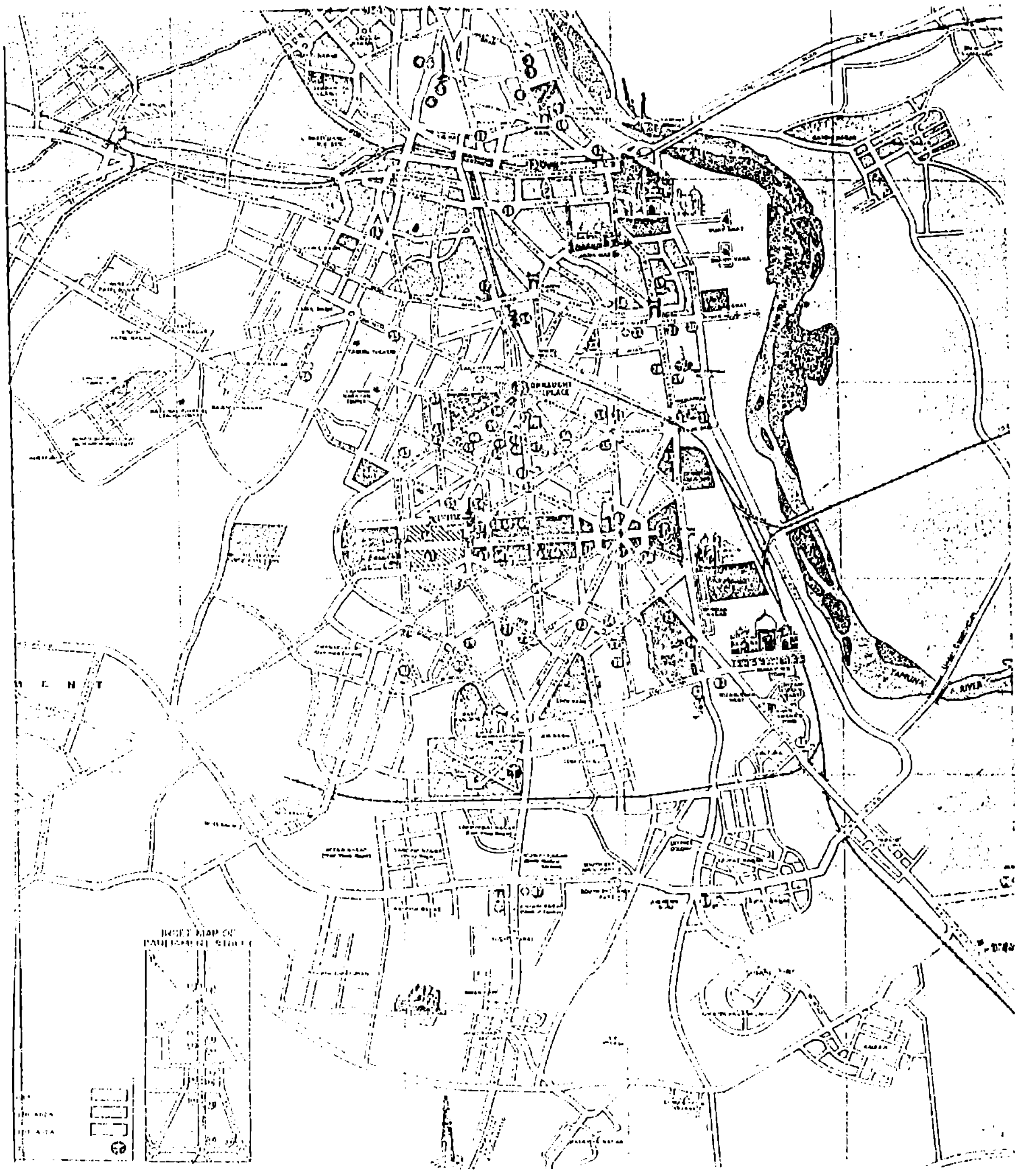
The geographical aspects of the city are to be considered in locating the bus depots. In small cities having a population of say, below 2 lakhs, there may be only one bus depot and this may be usually located in the 'heart' or CBD (Central Business District) of the city. However, in larger cities, there has to be a number of depots. For example, in a city like Delhi there are as many as 35 bus depots, operating a total number of 4400 buses. (142, p 17) Optimal location of depots plays a decisive role in the efficiency of bus operations.

The geometry of the roads is another important factor to be considered in locating depots. Fig:6.1 shows some typical road patterns. A city which grew outwards in all directions without any

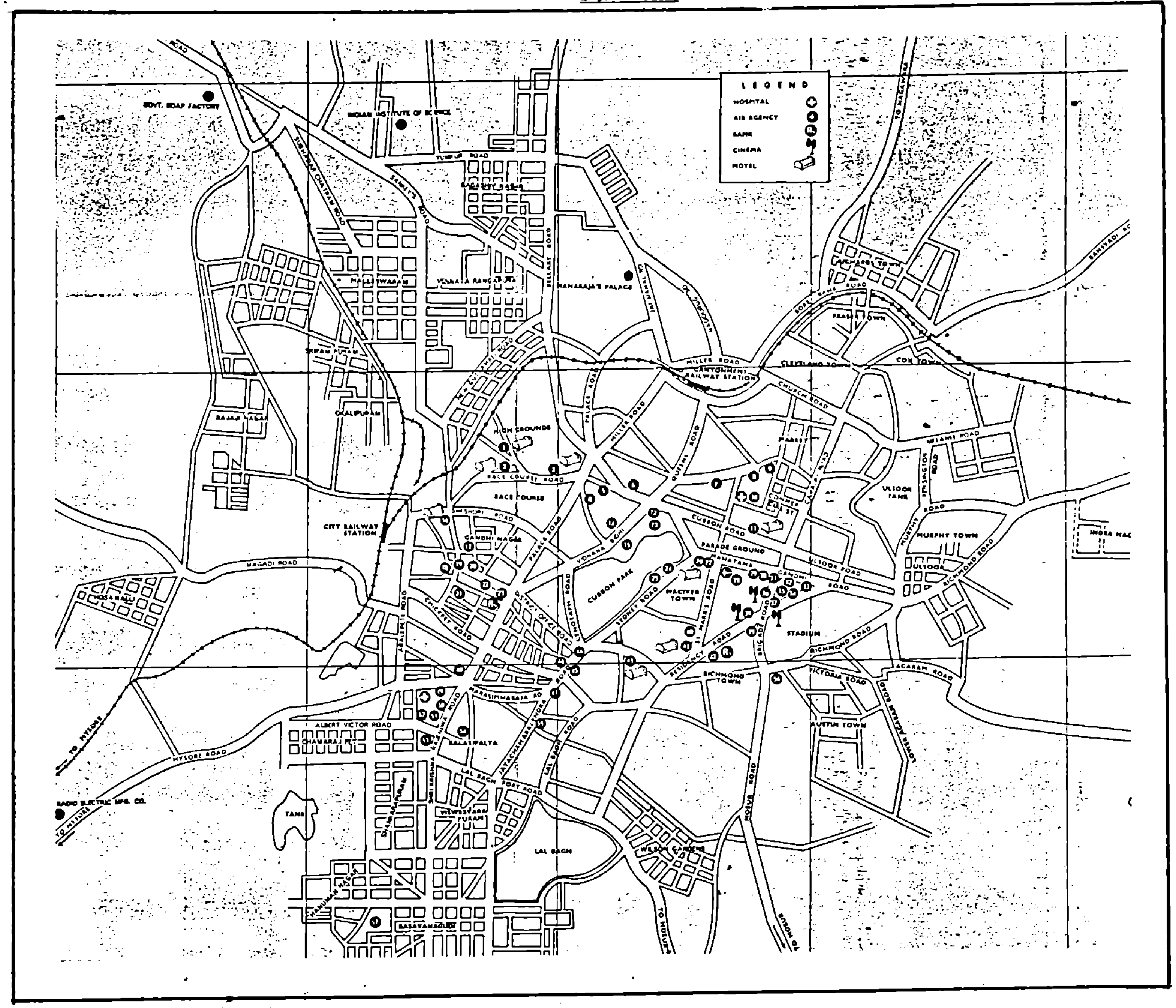
Fig 6.1 Different Types of Road Geometries



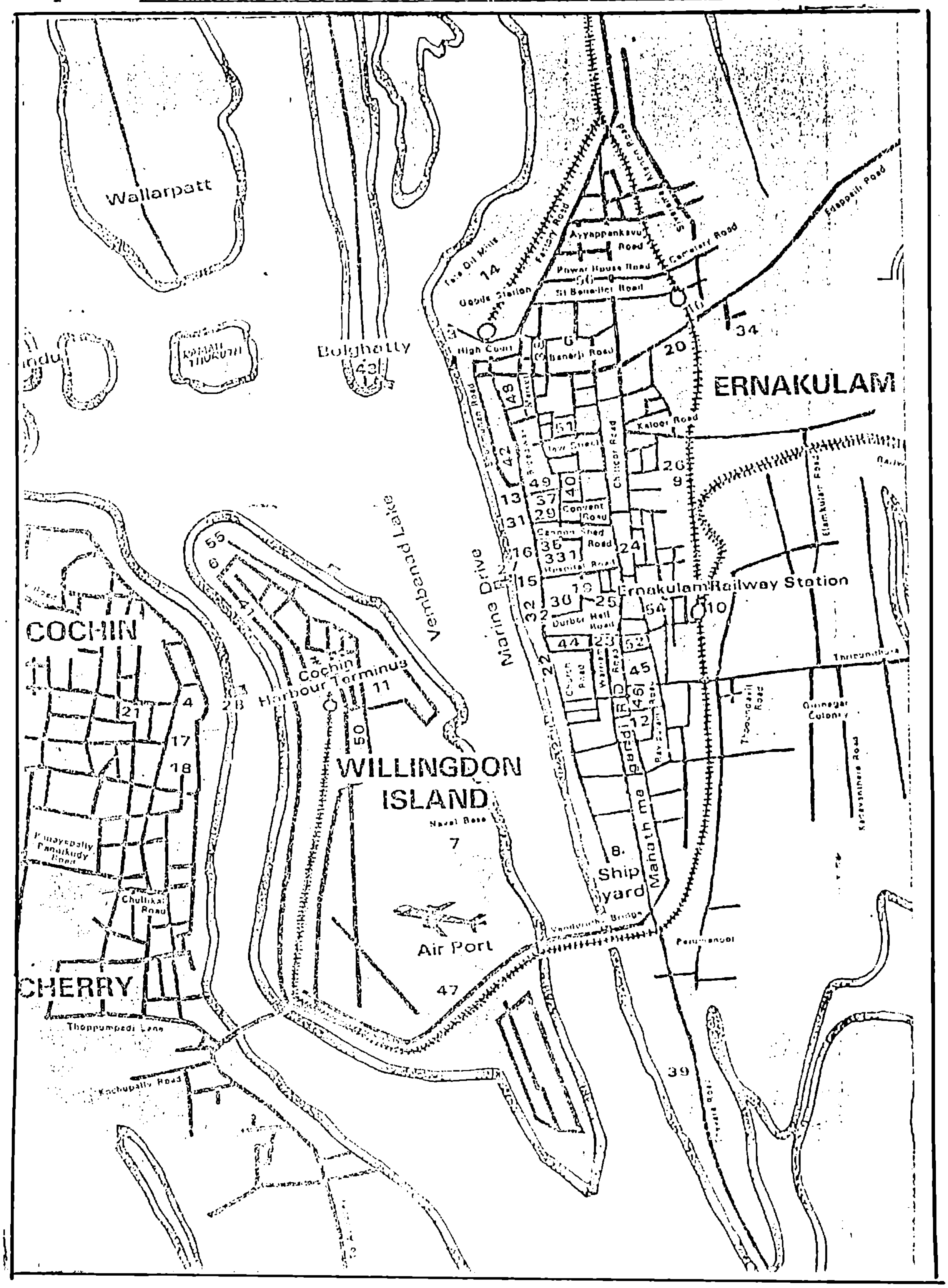
Map 6.1 Road Map of Delhi Showing Radial and Ring Raods



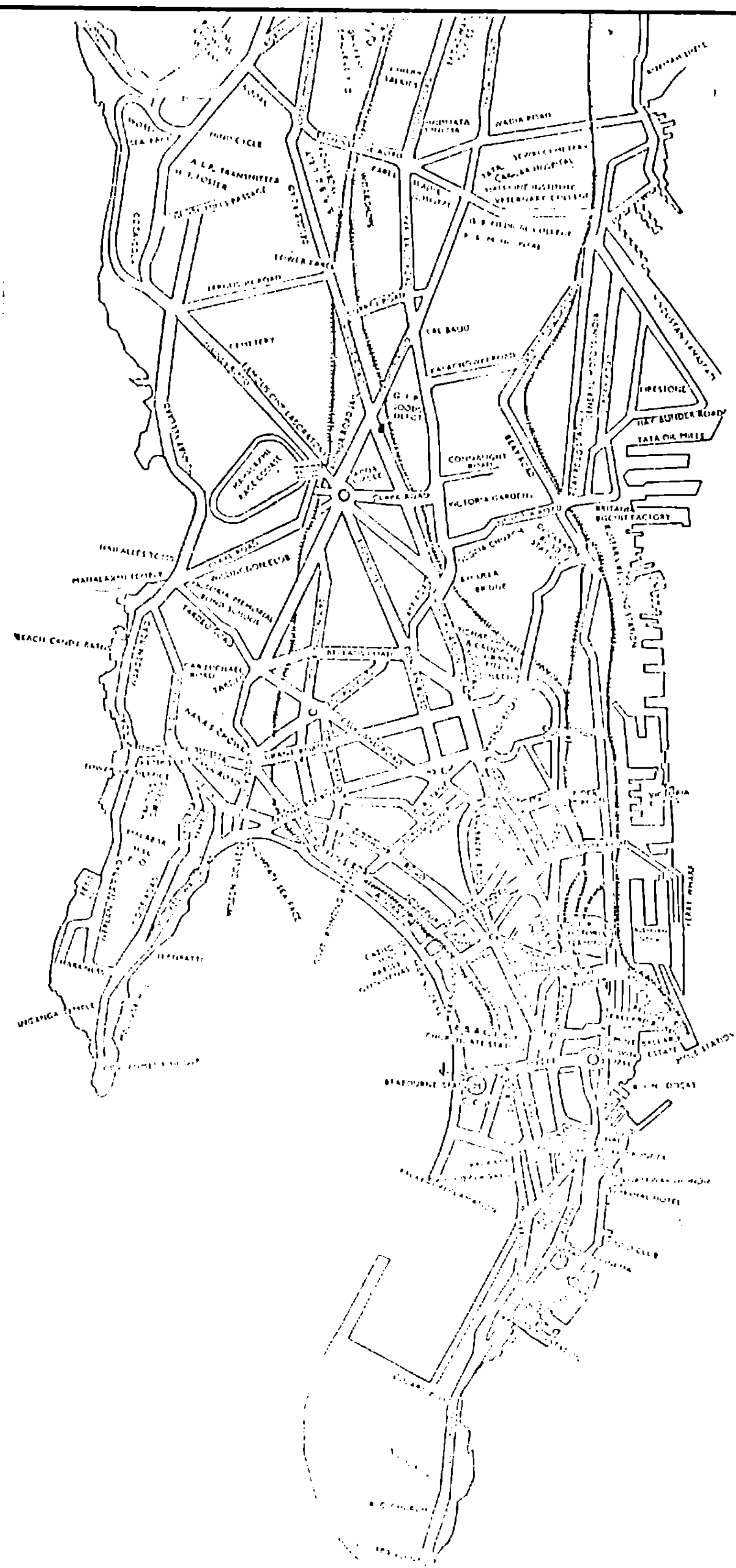
Map 6.2 Road Network of Bangalore City - An Example of Radial Pattern



Map 6.3 Road Network of Ernakulam Showing a Linear Pattern



Map 6.4 Road Network in South Bombay Showing Linear Pattern



restrictions, generally shows the radial pattern as shown in Fig. 6.1.1. Bangalore and Trivandrum can be considered to be in this category of cities having a radial road geometry. However, while radial roads may be there in many cities, the circular link roads connecting these radial roads may not be well developed. Due to this, passengers who have to travel from one place to another may have to come first to the central point and then travel to his destination. This 'hub and spokes' pattern naturally creates unnecessary inconvenience to travellers, causing an increase in their travel time and travel expenses. In such cases, it may be worthwhile to consider operating circular services, clockwise and anticlockwise.

There are also 'linear' patterns where the city grows lengthwise. This may happen when there are restrictions to growth on either side of the city due to the existence of sea, backwater, railway line, river, etc. Cochin is an example of this pattern. In old Bombay also, this linear pattern is prevalent - the traffic is mainly north-south in the heart of the city area. This may be noted from Maps 6.3 and 6.2.

In addition to these patterns, there can also be other patterns like the 'rectangular'pattern with main roads and cross roads. There are also the combination types. A combination type is one which does not conform strictly to the categories of 'linear' or 'radial' types. Their road geometry will be a mix of both of these types. In fact, if we consider many big cities, they will fall into this category, since some parts of the city may have a radial pattern and some other parts may have a linear pattern. A combination pattern is the consequence.

6.2 Depot Location

In a linear geometric pattern of road network with main road and perpendicular feeder roads, depots can be located at one end or at either ends, with buses plying regularly in both directions. Frequency of vehicles can be increased according to the volume of traffic flow. However, due to the fact that a large number of bus stops has to be provided along the bus route, effective passenger removal rate, which depends on vehicle speed, may be low, especially during peak periods.

The rectangular pattern is not very prevalent except in some planned cities. As already mentioned, a majority of cities and towns in India are in the category of radial pattern, as they have grown outwards from a central point. Many small towns operate with a single bus depot. In Trivandrum City, earlier there was only one depot at East Fort for city buses. Subsequently, in 1971 a second depot was established at Pappanamcode five kilometres away from the East Fort

Depot. Still later, two more depots were established at Vikas Bhavan and at Peroorkada in 1985.

Multi-depot operation can be of two types: (a) With a mother or main depot and satellite depots around it; or (b) with several depots, with more or less the same number of buses, each one operating independently. In the first type, the main depot operates from a central point to all places, and satellite depots take care of the travel needs of the local area assigned to it. In the second type, the traffic operation of the depots are more or less independent of each other each one handling the traffic in the region assigned to it. Further, these depots will handle a part of the total regional or interdepot traffic also. While the main depot has to be invariably in the heart of the city, the location of the satellite depots may be decided carefully, such that the satellite depots have a mutually complementary role. Study of traffic contours will help to identify the potential location of bus depots.

As has already been mentioned in the earlier chapter, traffic contour is a line joining points of equal traffic volume in different roads of the city. Similar to survey contours, if properly drawn, we can see hills, valleys, and hillocks in the city, from the traffic point of view. The traffic intensity is maximum at hilltops and the crests of the hillocks. They would be the ideal choices for locating the bus depots. Unlike survey contours, traffic contours have no permanency. A new housing colony or a small township will create a small hillock which was not previously there in the map. Hence, traffic contours have to be updated every time when a fresh traffic survey is conducted. Fig: 6.2 shows the different types of traffic contours, while fig: 6.3 shows the traffic contours of Trivandrum City based on the traffic survey conducted by the author. Along each link in the traffic network, the total flow per day was marked. The links having a traffic volume just in excess of a given number, say 1000, are joined together. In the figure, four such contours are drawn, corresponding to a total traffic flow of 5000, 2000, 1000 and 500 passengers per day. If the traffic contours show only one hill with no separate hillocks around it or beside, a 'main and satellite' type depot location will be ideal. Just like rain water flows in all directions from the crest of a hill, traffic flow will also be in the same way, making crests of traffic hills, the most suitable choice for location of bus depots. The main depot, handling about 50% of the total traffic, can be located at the hill top and four or five satellite depots can be located around it. If clear hillock formations are available, naturally, their crests can be the ideal locations for satellite depots. If there are three or four hills of

Fig 6.2 Types of Traffic Contours

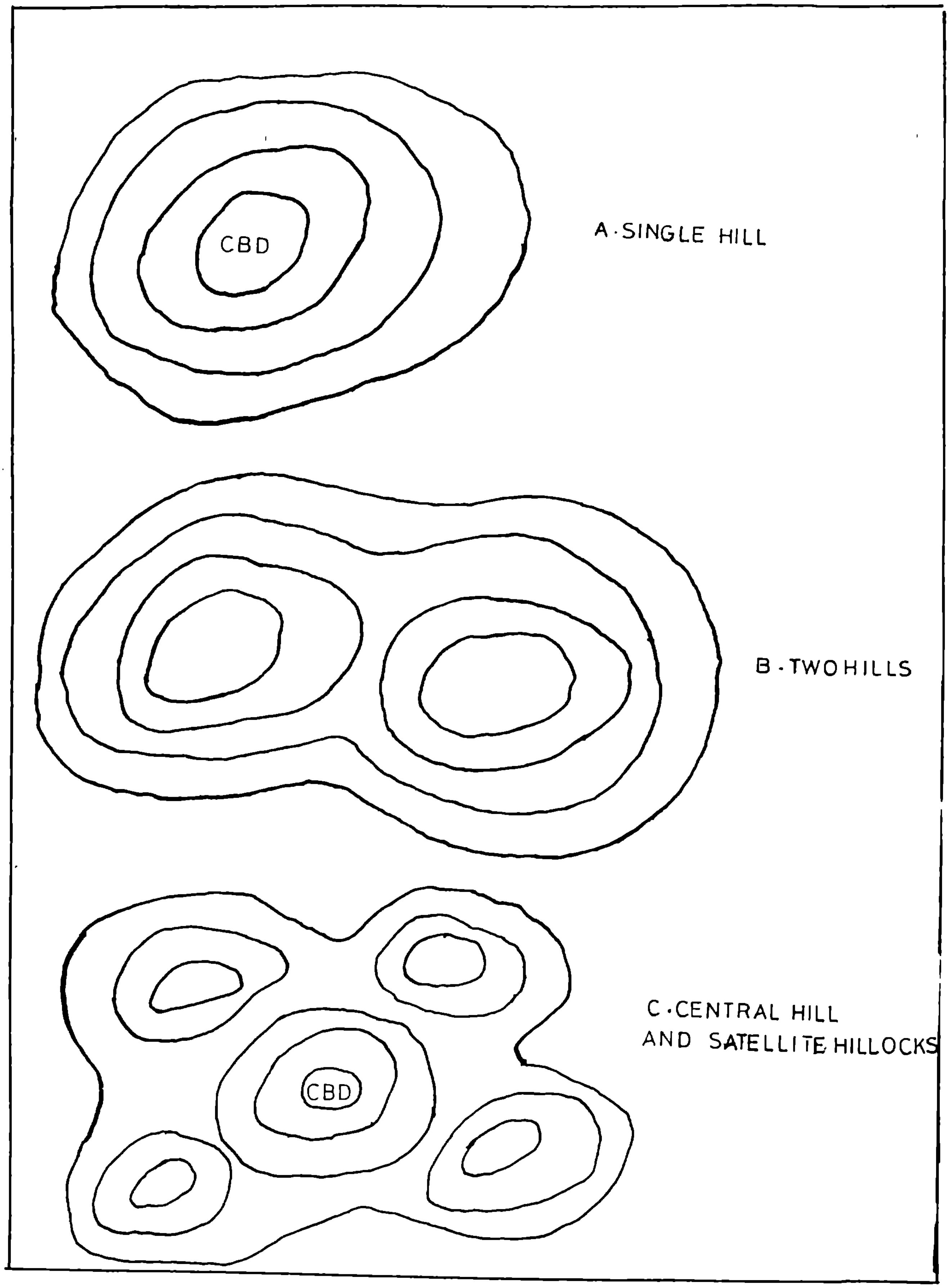
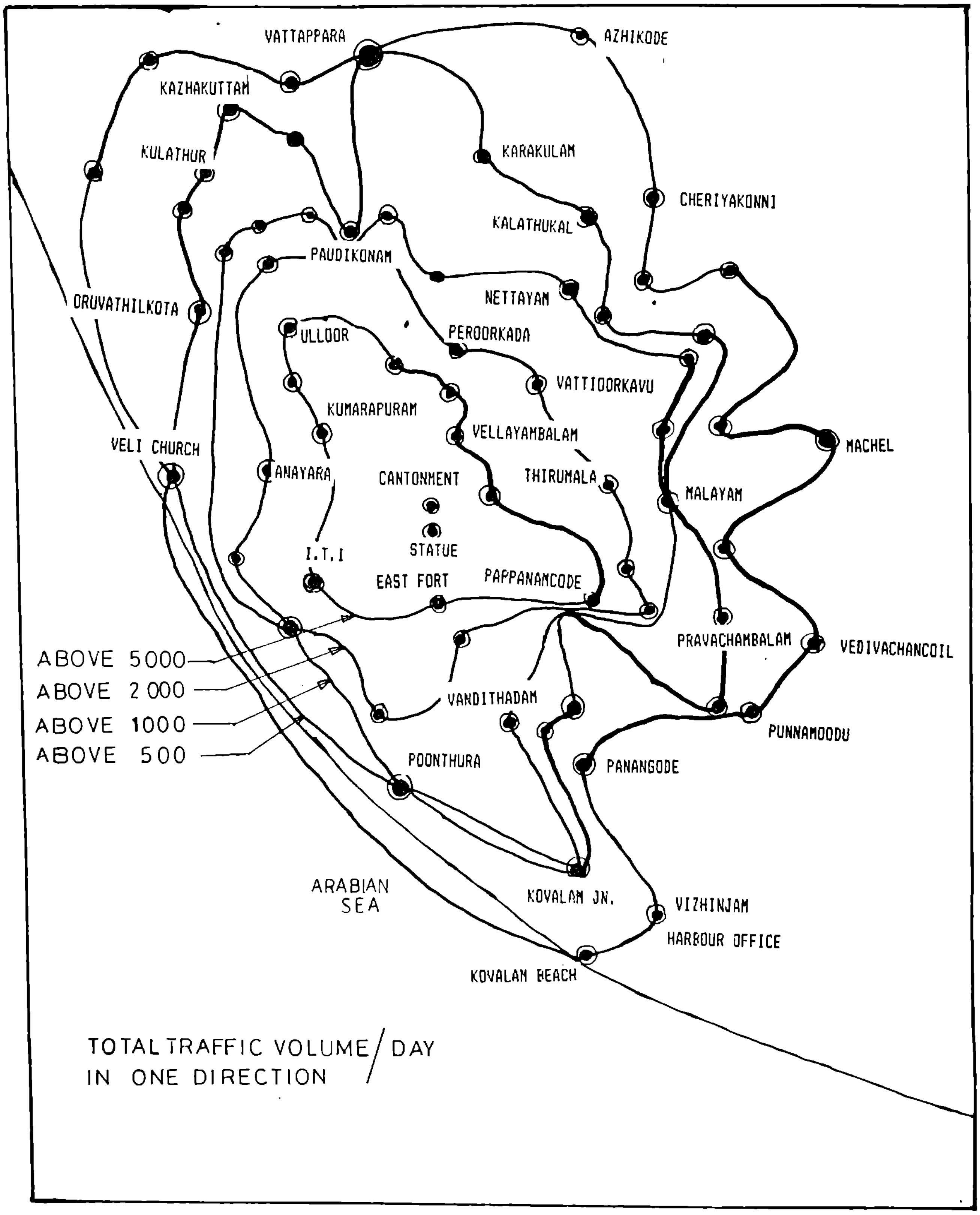


Fig 6.3 Traffic Contours of Trivandrum City



(SOURCE : TRAFFIC SURVEY CONDUCTED BY THE AUTHOR) more or less equal size, independent depot configuration may be considered.

Looking at the road network and traffic contours of Trivandrum City, it can be seen that the ideal location for the main depot is the Cantonment area, this being the centre of the innermost contour. However, since the main bus depot is already established at East Fort and another depot was established at the PMG Junction which is close to the Cantonment area, no decision was taken to locate a depot at Contonment. In addition, two more satellite depots are now located at Pappanamcode and Peroorkada. However, to complete the satellite depot system, in addition to these existing depots, four more satellite depots are proposed to be set up at Poojappura on the eastern side of the City, the Medical College on the northern side, Sreekaryam along the National Highway to Quilon on the northen side and at Ambalathara, on the southern side of the city.

Advantages of multi-depot operations are many. Firstly, these depots take care of the traffic needs of the short distance travellers in their respective regions who do not have to go to the city centre unnecessarily to go to their respective destinations. Secondly, smaller depots having a fleet size of, say upto 100, are easier to manage. Thirdly, short distance passengers will not board the long distance buses unnecessarily, so that the traffic density will be more evenly distributed. Any further, the incidence of one way empty services can be reduced. This will also help to improve the load factor of all the services.

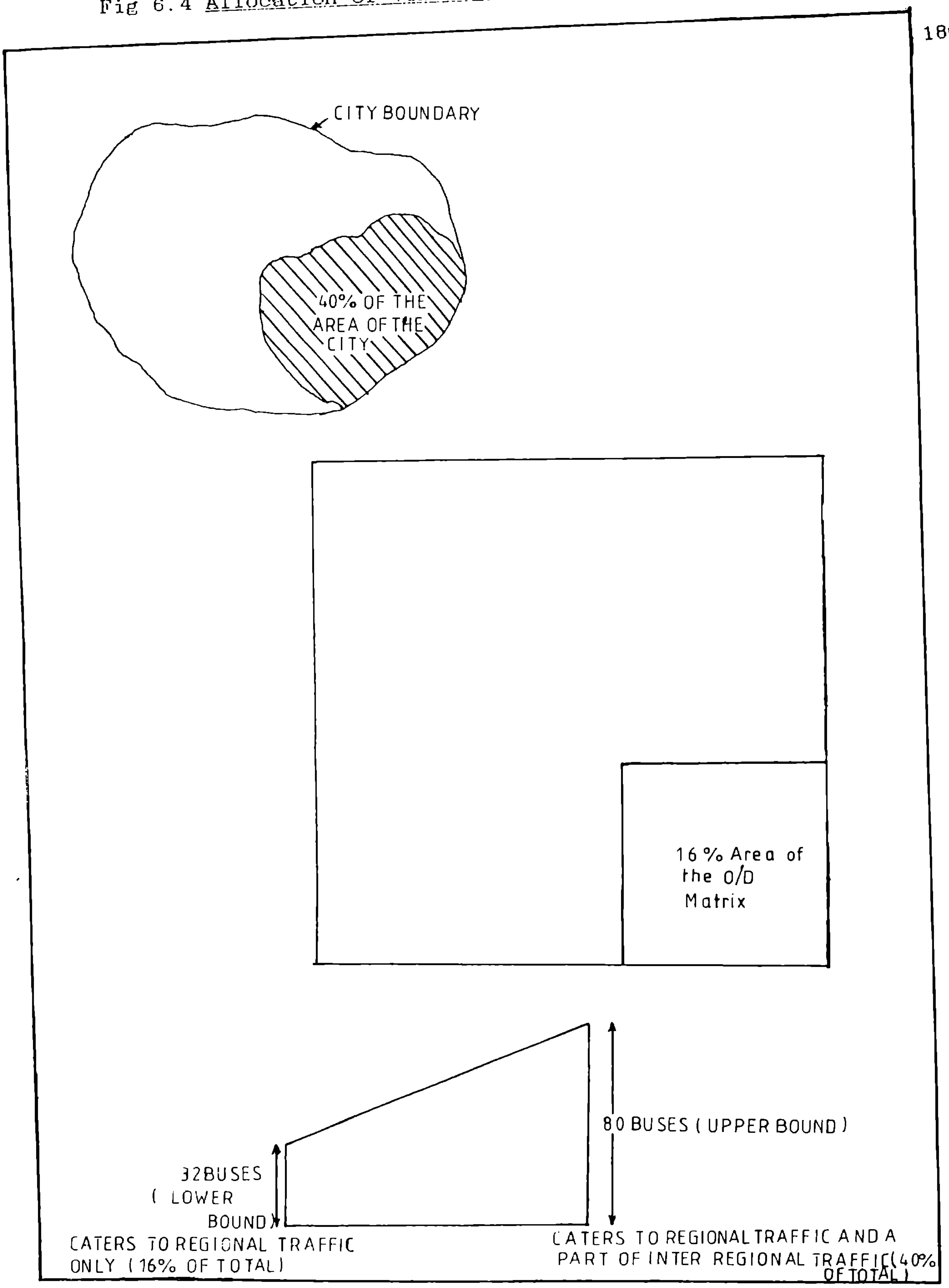
6.3 <u>Vehicle Allocation to Depots</u>

To decide upon the number of vehicles to be allotted to each depot, the basic factor to be taken into consideration is the volume of traffic to be shared by each depot. Naturally, if two depots are to share the traffic load equally, the total fleet will also have to be shared by these depots more or less equally. The traffic load in all cases can be measured in terms of passenger kilometres. Assuming that a city was served originally by 200 buses, all operated from a central depot, the whole city can then be divided into 50 sub regions and we will have a 50 x 50 O/D matrix.

As a hypothetical case, let the cell values in the matrix be equal. Let the area of operation assigned to the new depot be assumed to consist of 20 sub-divisions. If the complete internal traffic volume is to be handled by this depot, traffic demand corresponding to a 20 x 20 matrix, with 400 cells, will be handled by this depot. This submatrix with 400 cells forms only 16 percent of the whole 50 x 50 matrix, which will have 2500 cells. Hence 32 buses i.e., 16 percent of the fleet strength are to be allotted to this depot and the rest of 168 buses will remain with the main depot. The main depot will continue to cater to the travel demands of the people from this area to the other parts of the City. However, if this depot shares the inter-regional traffic also, the number of buses will increase and it can be upto 80 buses which is 40 percent of the fleet strength, proportional to the area of the region. Thirty two buses can be considered as the lower bound of the fleet strength to be allocated to the main and satellite depot concept while the upper bound will be applicable to the independent depot concept. This is elaborated in Fig: 6.4. Traffic contours thus come handy in deciding, upon the vehicles to be allocated to the depots. The volume of a 'hill' or 'hillock', measured in passenger kilometres of traffic flow in that area, can be used as a criterion to determine the number of vehicles to be allocated to each depot.

For cities like Trivandrum, which have grown outwards in all directions from a central point, Main and Satellite type depot arrangement is already there. The East Fort depot can be considered as the main depot. Pappanamcode, Vikas Bhavan and Perporkada depots as can be considered satellites. Presently, the fleet strength of these depots are that East Fort has 181 vehicles, Pappanamcode has 130, Vikas Bhavan has 90 and Peroorkada has 66. (190, 1990-91, p 52) It can be seen

Fig 6.4 Allocation of Vehicles to a Subdepot



that the main depot has about forty percent of the total fleet strength. It is adviseable to have three or four satellite depots also to be established in addition to existing ones. This is further discussed in Chapter 9.

6.4 Routing and Scheduling of Vehicles

Once the depot locations are decided, the bus routes to be operated can be decided. The route network will depend upon the road network available. In many cases, proper road links having sufficient width for bus operation may not be available between two places, even though there may be good travel demand existing between them. The origin-destination survey and traffic volume chart are the basis for deciding upon the routes to be operated. Since each route has also an origin and destination, there has to be compatibility between the origin-destination pattern of the routes and the O/D demand survey. Using the O/D survey, relative 'attractions' between different places can be ascertained and routes can be decided upon accordingly. In cities like Trivandrum, in addition to radial routes from depots, circular and lateral routes can also be operated, according to the O/D pattern. These trips will be beneficial to passengers as they may be able to provide direct or easier links between their origin and destination.

Table 6.1 shows a sample of 5 x 5 O/D matrix, obtained by interviewing a sample of passengers. Cell values indicate the number of passengers from one region who want to travel to another region. For example, the value of cell 4-3 is 42, which means that of the 147 people interviewed in region-4, 42 people wanted to travel to region-3. Similarly, of the total 707 people interviewed, 177 were from region-1, 102 were from region-2, 153 were from region-3, 147 were from region-4 and 123 were from region-5. Of these, a total of 84 wanted to go to region-1, 100 to region-2, 144 to region-3, 184 to region-4 and 183 to region-5.

The bus allocation which perfectly fits this O/D matrix is shown below that matrix. In this case, the ratio between the corresponding cell values is three and it is an example of a perfect fit. In the next example, where there is no perfect fit, the ratio of corresponding cell values are entered into the total matrix. The average of these ratios is 2.98. In the next deviation matrix, the variations of individual ratios to the average ratio is written. The average of the cell values of the deviation matrix works out to 1.145. The ideal value is one and when the value is more, it means that the compliance between O/D matrices is less. Hence while making schedules, it must be

Table 6.1

Analysis of O/D Matrix

O/D Matrix prepared from a sample of passengers interviewed.

		To 1	2	3	4	5	Total
From	1	9	21	30	51	66	177
	2	15	9	18	27	33	102
	3	27	33	12	57	24	153
	4	15	30	42	15	45	147
	5	18	15	42	33	15	123
	Total	84	108	144	184	183	702

A. Example of a perfectly fitting bus trip allocation

		To 1	2	3	4	5
From	1	3	7	10	17	22
	2	5	3	6	9	11
	3	9	11	4	19	8
	4	5	10	14	5	15
	5	6	5	14	11	5

Here, the ratio between corresponding cells is 3

B. Example of an allocation that does not fit perfectly

Bus trip allocation matrix

From \ To	1	2	3	4	5
1	4	8	9	17	21
2	5	4	5	8	10
3	10	12	4	20	9
4	6	9	13	5	14
5	7	5	15	10	4

Ratio Matrix

From \ To	1	2	3	4	5
1	2.25	2.65	3.33	3.00	3.14
2	3.00	2.27	3.60	3.37	3.30
3	2.70	2.75	3.00	2.85	2.60
4	2.50	3.33	3.23	3.00	3.21
5	2.57	3.00	2.80	3.30	3.75

Average cell value = 2.98

Deviation Matrix

To	1	2	3	4	5
1	1.320	1.135	1.118	1.006	1.0546
2	1.006	1.324	1.208	1.1325	1.117
3	1.103	1.0834	1.0067	1.0456	1.120
4	1.192	1.117	1.083	1.006	1.0872
5	1.160	1.006	1.0642	1.1074	1.258

Average cell value = 1.1145

strived at to bring this value as near to one as possible.

Once the routes to be operated are decided, the scheduling of vehicles can be done. This is basically a decision regarding the frequency of operation in each route and the timings of departure and arrival of vehicles. The usual pattern is to operate vehicles at constant frequencies, within a given time interval, say from morning till evening. For example, it can then be decided that the East Fort-Kovalam service may be operated every 30 minutes from 0600 hrs to 2100 hrs. Both the frequency of the buses and the period of operation can thus be arranged according to demand. Along the same route, shorter trips can also be operated, according to the travel pattern at different hours to and from different points or sections of the route.

6.5 An Algorithm for Vehicle Scheduling

The quarter-hourly or 15 minutes traffic flow through links in both directions can be used as a basis for vehicle scheduling. If we divide the total traffic volume by the passenger capacity of a bus, we can determine the minimum number of vehicles to be operated during the time interval under consideration. This is the minimum value, while the actual number of the buses operated can be more than this value.

Fig: 6.5 shows how the number of trips can be determined for two given types of traffic patterns. It is assumed that the passenger capacity of the bus, including standees can be taken as 75. In both these cases, short distance trips are to be operated first and long distance trips afterwards. Otherwise, due to overcrowding by short distance passengers, the long distance passengers in subsequent links may miss the bus. In this case, assuming that the demand pattern shown is for a period of 15 minutes, the maximum waiting time of the passenger will not be more than 15 minutes and the average waiting time will be 7.5 minutes. If this frequency is not possible in the other parts of the City, the time interval may be increased to 20 or 30 minutes, so that a certain degree of uniformity in the quality of service can be maintained for the City as a whole.

The data needed for scheduling are basically as follows:

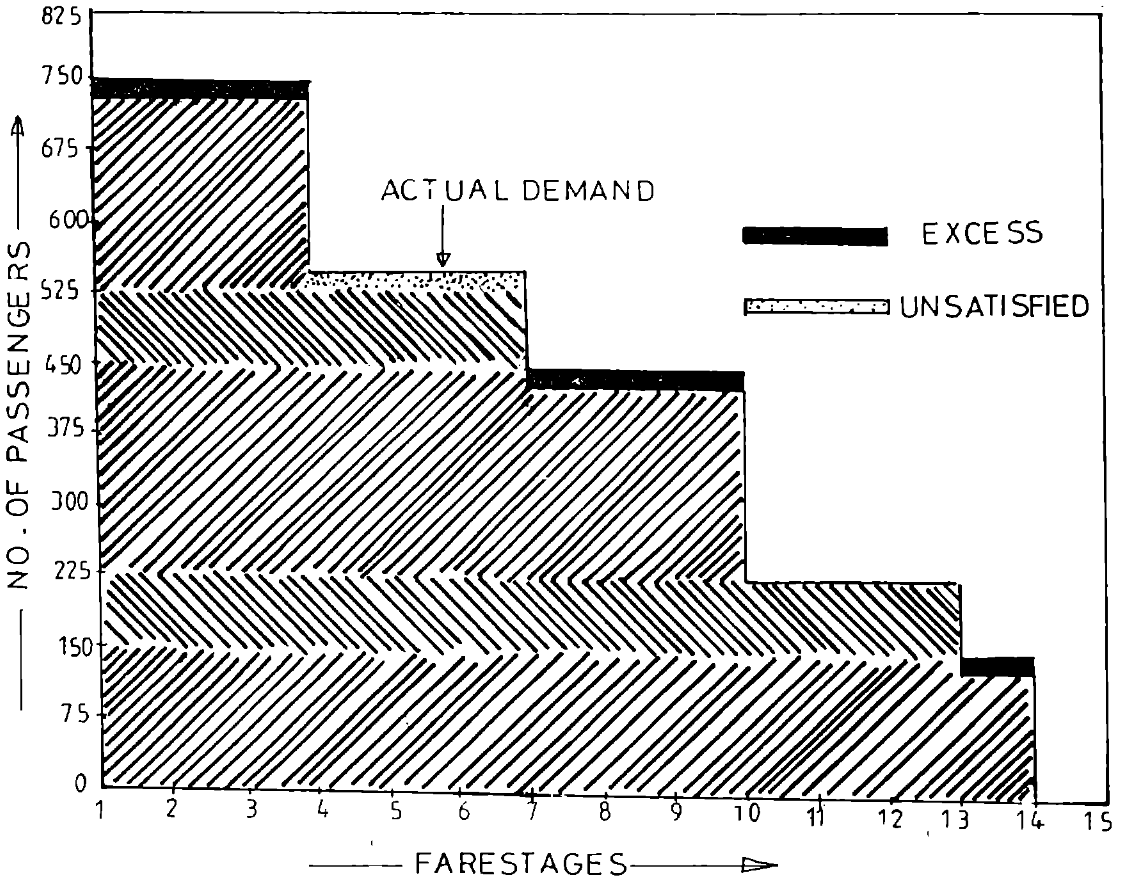
(i). Demand matrices,

(ii). Route network showing fare stages,

(iii). Traffic variation pattern (Diurnal);

and (iv). Passenger capacity and speed of the bus while normal capacity and normal speed are applicable during off-peak periods, higher capacities and slower speeds may be assumed during peak periods.

Fig 6.5A Trip Allocation - All Trips Starting From the Origin



Result:

3 trips of 3 links (interfarestages) in length.

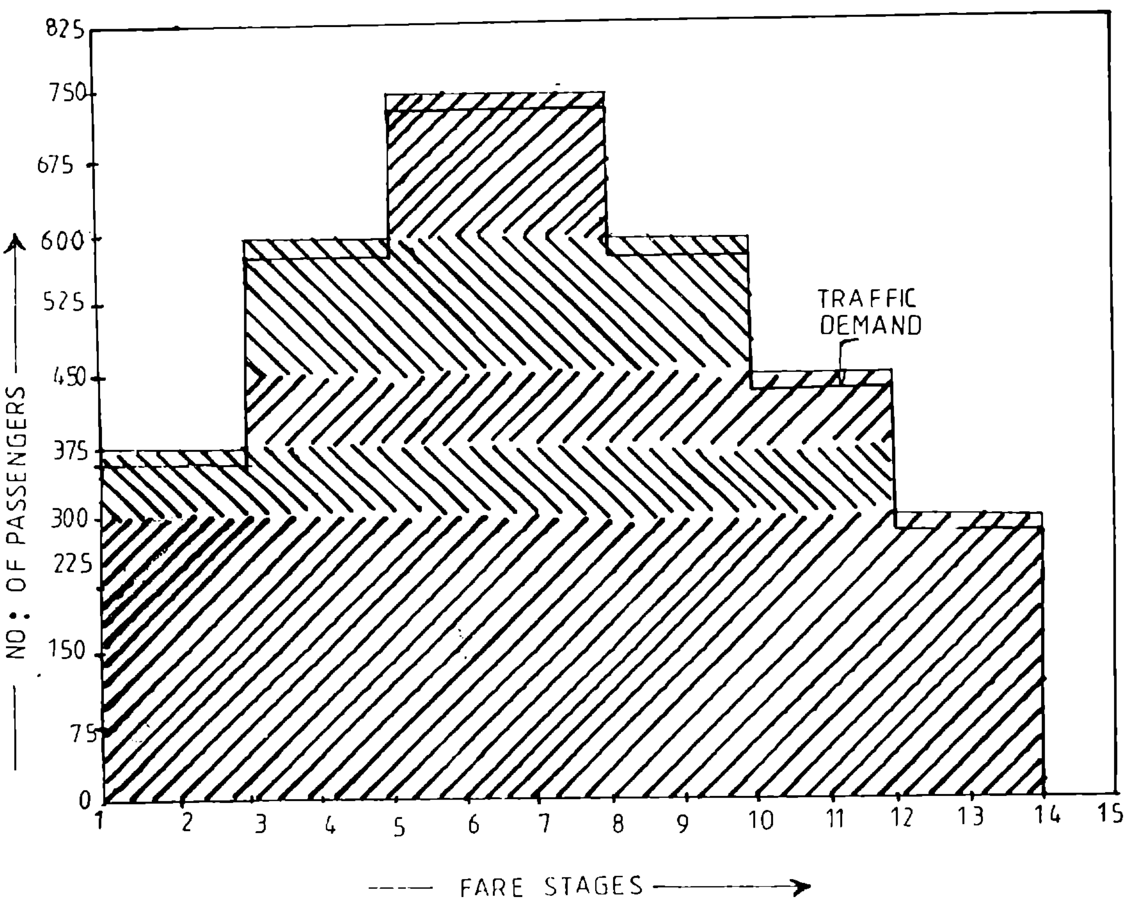
1 trip of 6 " " "

3 trips of 9 " " "

1 trips of 12 " " "

2 trips of 13 " " "

Fig 6.5B Trip Allocation - Trips Starting From Different Nodes



Results

4 trips of 13 links (interfare stages) in length from origin.

1 trips of 11 " " "

1 trips of 9 " " from node No. 3

2 trips of 7 " " "

2 trips of 3 " " from node No. 5

<u>Assumptions</u>

The following assumptions are to be made.

(i). Buses are run according to schedule,

(ii). Drivers stop vehicles at bus stops when there is passenger space available in the vehicle,

(iii). Passengers considered available within a given time interval are available at the bus stops at the beginning of the time interval,

(iv). People do not 'balk' from the bus stops during the stipulated waiting time,

(v). A traveller utilises his ticket to the maximum possible extent for the fare he has paid,

(vi). During the time interval considered, at least one bus is operated in all the routes; and

(vii). Traffic data obtained by journey bill analysis represent the actual traffic needs of the passengers.

<u>Algorithm</u>

<u>Step 1</u> Using the journey bills, make a quarter hourly traffic volume matrix for each link, in both directions. If there are 72 quarters in a day, corresponding to 18 hours of operation, there will be 72 cell values which can be conveniently arranged into a 4 x 18 matrix for a link in one direction. A similar matrix will be there for the reverse direction also. If a link is labelled as 3-4 in the forward directions, it will be labelled as 4-3 in the reverse direction.

Step 2 Take all the matrices of the links consisting of a route. If all routes have 10 links each, there will be 10 onward matrices and 10 reverse matrices.

Step 3 Provide a long distance bus, one each in the time interval decided upon. This will ensure that there will be one bus at every 15 minutes interval in both directions.

Step 4 Make reductions in the demand matrix corresponding to the trips assigned. This has to be done taking into account the passenger capacity and the speed of the bus.

Step 5 In the remainder matrix, assign more buses if required. In this case, sometimes full-length trips may not be necessary. Also, while operating buses, some demand may have to be left unsatisfied if it is less than a predetermined value, say, 10 passengers or so, depending upon a breakeven point of a schedule and other factors.

Step 6 When once the trips have been arranged like this to satisfy the optimum travel demand, arrangements can be made to operate the bus trips. In a quarter of 15 minutes duration, if there are three trips, they can be arranged at equal intervals of five minutes each. Similarly, if there are trips of different lengths in the same quarter, shorter trips may be put first, followed by longer trips subsequently.

Step 7 Convert the trips thus made into a complete route time table, showing the time of departure and time of arrival. Constraints in crew scheduling may also be taken into consideration while making the final time table.

This procedure may be followed for each route. When such scheduling has been made for all routes the time table for the depot will be complete.

While it may not be difficult to do the scheduling for small depots using this algorithm manually, it can be easily done using a computer, especially when the data is voluminous. An example of computerised scheduling has been worked out in Chapter 8.

6.6 Compliance With O/D Survey

The schedules prepared as described above will ensure that there are sufficient number of services to meet the traffic flow. In preparing the time table there is, however, one more dimension to be considered. This is the origin/destination pattern of the passengers. Let us assume that the City is divided into 20 subdivisions. Each trip, will have its origin in one subdivision and destination in another. The origins and destination of all routes can be entered into the corresponding cells, and their sum can be taken. In an ideal condition, the ratio between corresponding cells in the O/D matrix prepared on the basis of interviews with the travellers and the O/D matrix of the routes should be same. However, this is only an ideal hypothetical situation. But the degree of the approximation of the actual with the ideal can be measured by finding out the individual cell multiplier values and the deviation of each value from the average of all multiplier values.

6.7 Effect of Traffic Variation On Bus Utilisation

Another problem that the KSRTC faces in its operations pertains to changes in the volume of traffic at different times of a day. From the bus operater's point of view, the ideal condition would be to have a uniform traffic volume through out the day in both directions. For example, if the traffic volume during every quarter of an hour is 225 passengers in both directions, three buses will be operated at every 15 minute interval in both directions, assuming a bus capacity of 75. The time between successive trips can be five minutes. The maximum waiting time of a passenger will be 5 minutes and the average waiting time will be 2.5 minutes. Capacity utilisation of the bus will be 100 percent. There will be no overcrowding or under utilisation of buses.

But actual conditions are far from such ideal conditions. Table 6.2 shows the traffic flow through a particular link in Trivandrun City at 30 minute intervals from 5.00 A.M. to 11.00 P.M. Both for inward

Table 6.2 Traffic Flow Through a Link In Trivandrum City

No	Time	Inward	Outward	Total	Inward-Outward
1	0500-0530	62	35	97	+27
2	0530-0600	99	62	161	+37
3	0600-0630	143	99	242	+44
4	0630-0700	195	131	326	+64
5	0700-0730	308	173	481	+135
6	0730-0800	452	252	704	+200
7	0800-0830	601	364	945	+257
8	0830-0900	762	420	1182	+342
9	0900-0930	853	511	1164	+342
10	0930-1000	902	555	1457	+347
11	1000-1030	850	552	1402	+298
12	1030-1100	752	536	1288	+216
13	1100-1130	641	499	1140	+142
14	1130-1200	366	450	816	-84
15	1200-1230	249	421	670	-172
16	1230-1300	175	382	557	-207
17	1300-1330	145	351	496	-206
18	1330-1400	134	348	482	-214
19	1400-1430	136	353	489	-217
20	1430-1500	151	362	513	-261
21	1500-1530	180	401	581	-221
22	1530-1600	232	453	685	-221
23	1600-1630	281	522	803	-241
24	1630-1700	386	572	958	-186
25	1700-1730	441	648	1089	-207
26	1730-1800	503	673	1176	-170
27	1800-1830	540	701	1241	-161
28	1830-1900	542	685	1227	-143
29	1900-1930	506	662	1168	-156
30	1930-2000	452	610	1062	-158
31	2000-2030	353	522	875	-169
32	2030-2100	282	423	705	-141
33	2100-2130	201	332	533	-131
34	2130-2200	153	249	402	-96
35	2200-2230	99	161	260	-62
36	2230-2300	56	99	155	-43
	Total	13183	14549	27732	

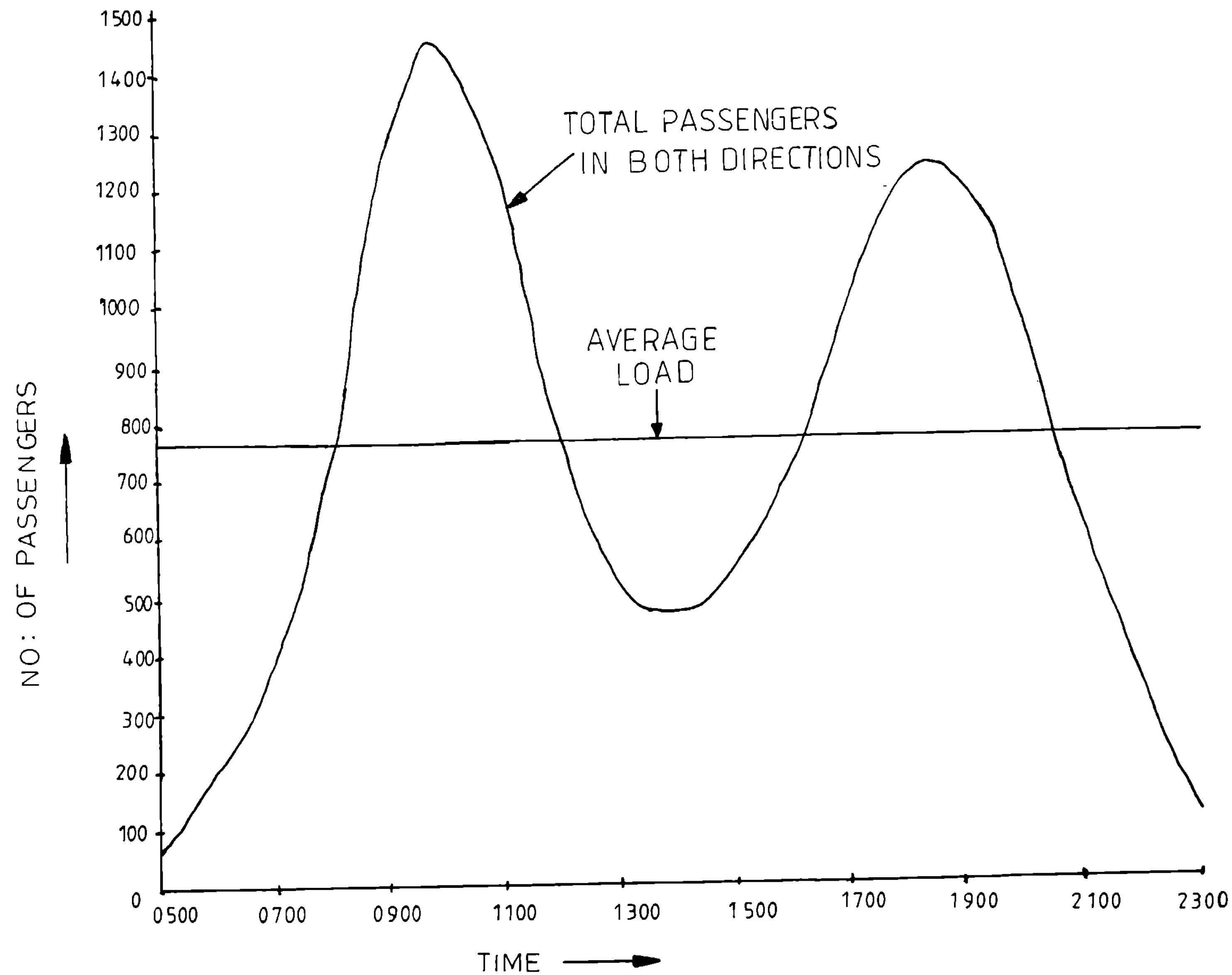
(Source: Data Collected by the Author)

traffic and outward traffic there are two distinct peaks, the morning and the evening peak. The morning peak is sharper for the inward traffic flow, since this is the period when people want to reach offices and other work places in the City on time. Evening peaks are not so sharp since people, except perhaps working women, can travel at a little more ease when compared to the journey during the morning hours. By comparing the hourly variation, it can be seen that in this particular case, outward traffic is marginally smoother than the inward traffic. If the traffic was completely uniform, about five buses each would have been sufficient for a period of 30 minutes in both directions. Buses can be operated at an equal interval of every six minutes, thereby reducing the average waiting time of passengers to just three minutes. However, this is only an ideal condition.

In actuality, when buses are operated like this, the occupancy ratio of the buses will be continuously varying. During peak hours, vehicle requirement will be more than twice their availability. There is overcrowding. Often, many people will not even be able to board the bus and reach their destinations on time. Similarly, during slack periods, the load factor is comparatively low. Even if a certain amount of overcrowding is allowed, say 33 percent during peak hours, thereby permitting 100 passengers to travel in a bus at a time, the number of passengers who will not be able to board a bus on time will be about 3200 or 11.5 percent of the total number of passengers. Among them, a majority of 63 percent will be during the morning peak and the remaining or 37 percent will be during the evening peak. This is shown in Fig 6.6 D.

One way to resolve this situation will be to operate more buses during peak hours. In addition to a base load of 10 buses per hour, if four more buses per hour are operated during the morning peak of 8.00 A.M. to 12.00 A.M. and the evening peak of 4.30 P.M to 8.30 P.M., the traffic demand will be more satisfactorily met. However, these buses will not have any alternate use during non-peak periods. This would, perhaps, then mean a case of uneconomic investment as vehicle utilisation would be marginal. Perhaps, a better alternative would be to stagger the office and school hours within about two or three hours. Thereby, the peaks can be levelled off to a great extent.

There is also another problem in the traffic pattern which is generally called as 'one way empty'. This is not unique to Trivandrum City. During morning hours there is more traffic towards the city. This situation continues until about 11.00 or 11.30 A.M. Thereafter, the outward traffic may be more than the inward traffic. This situation results in unequal load factors for incoming and outgoing buses at different



TOTAL PASSENGERS IN BOTH DIRECTIONS
AVERAGE LOAD
NO: OF PASSENGERS
TIME
1500
1400
1300
1200
1100
1000
900
800
700
600
500
400
300
200
100
0
0500
0700
0900
1100
1300
1500
1700
1900
2100
2300

Fig 6.6B Traffic Flow Through a Link - Variation of Outward Traffic

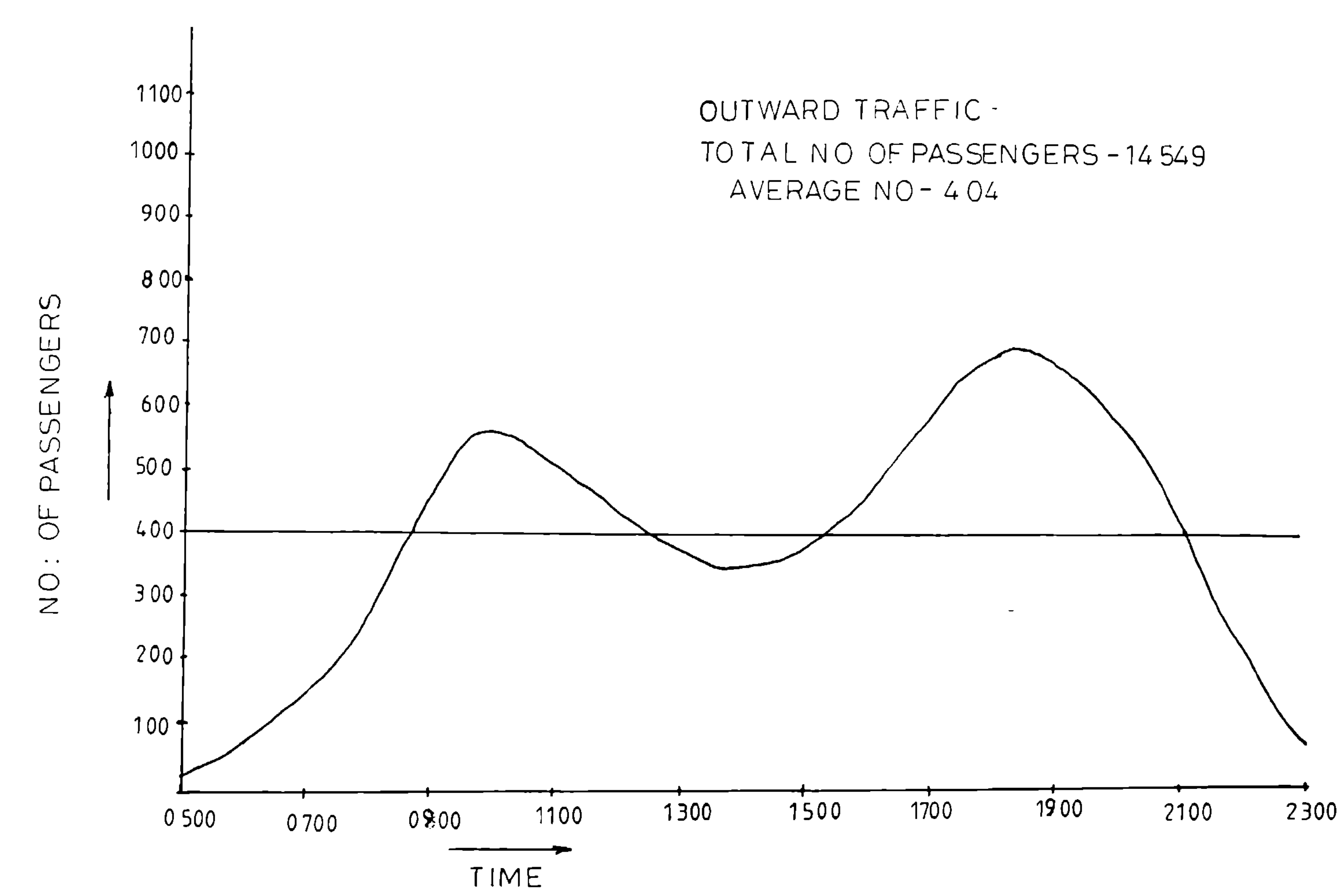


Fig 6.6C Traffic Flow Through a Link - Variation of Inward Traffic

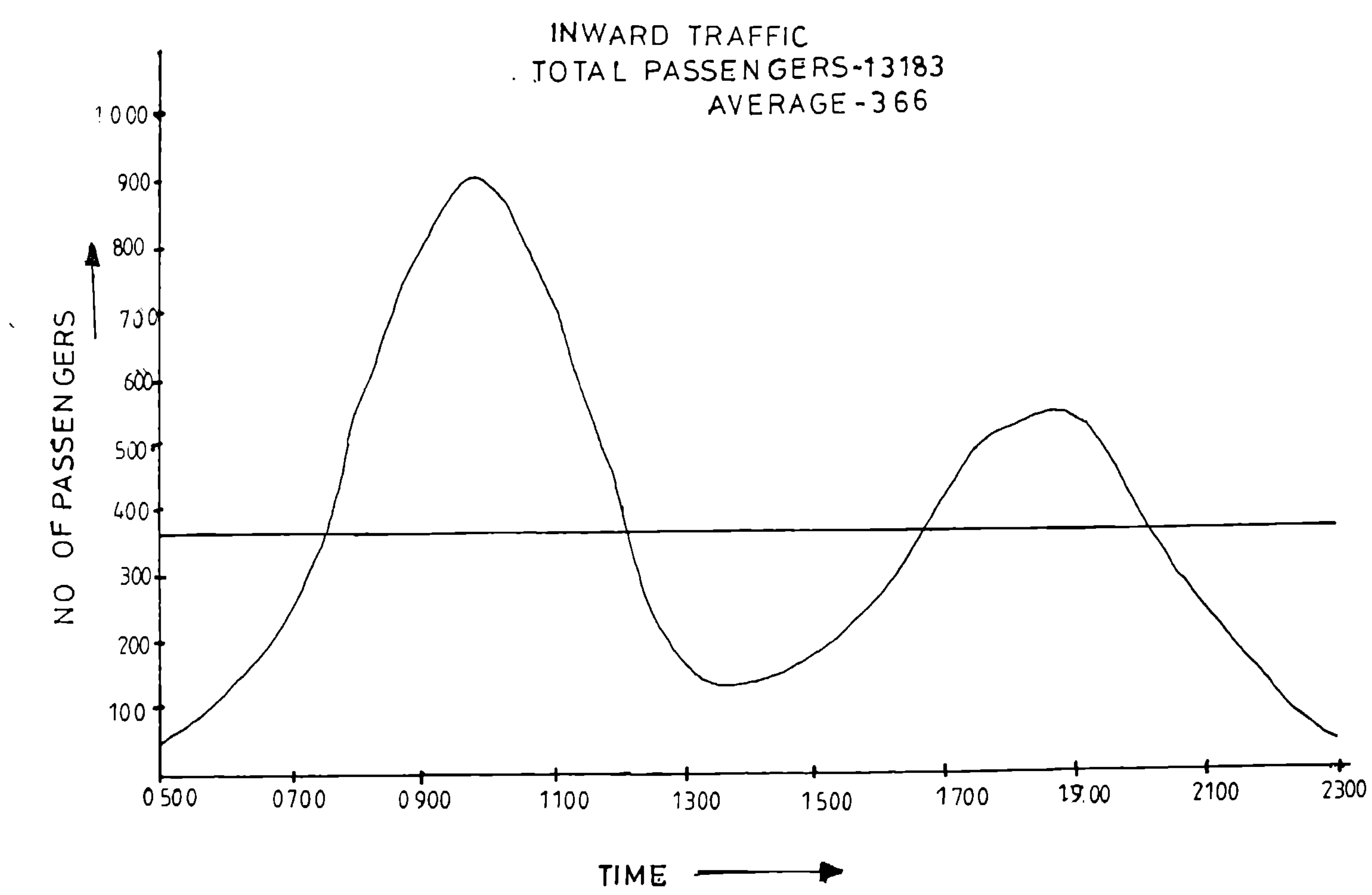


Fig 6.6D Traffic Through a Link - Peak Hour Operations

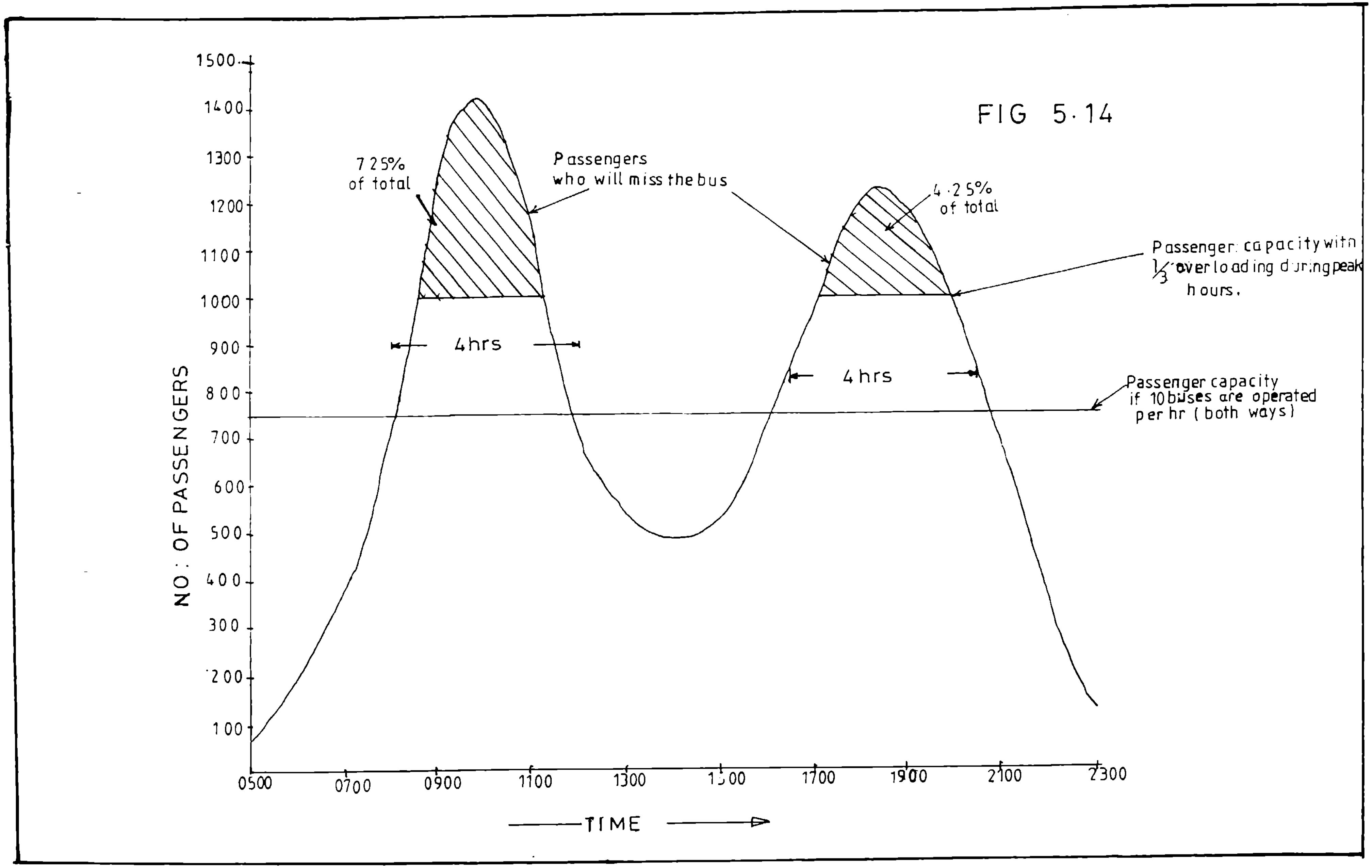
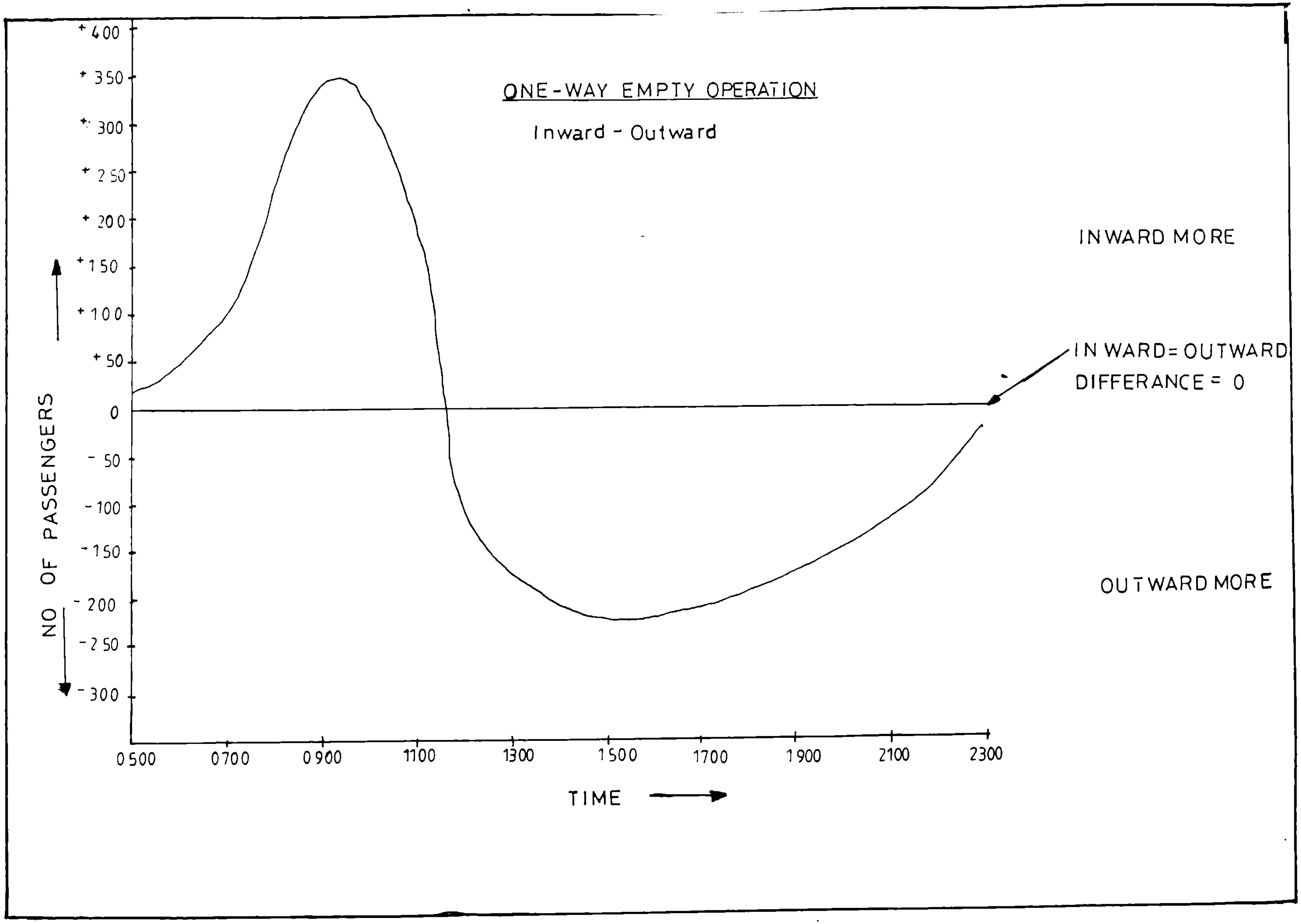


Fig 6.6E Traffic Flow Through a Link - 'Difference Curve'



times of the day. Buses may have to be operated to satisfy the demand for the incoming traffic during the first half of the day and, there after to satisfy the outward traffic.

Here again, the ideal situation would be to have both the inward and outward traffic more or less equal throughout the day. Fig:6.6.E attempts to provide an idea of the extent of the problem in Trivandrum City. As mentioned earlier, one-way-empty operation is illustrated by the difference curve, which measures the difference between the inward and outward flow. It can be seen from the figure referred to above that upto 11.30 A.M. the inward flow is more and thereafter the outward flow is more. This phenomenon is inevitable in any city which has a centre-to-outward growth pattern. Traffic contours for Trivandrum City, as seen in the previous Chapter, also justify the tidal flow in both directions, causing one-way-empty operation. Any improvement in this situation can be achieved only by avoiding concentration of offices, schools etc. in the centre of the city and locating as many as possible and especially the new ones, in the outskirts. But this can be achieved only through detailed town planning over a period of time.

6.8 <u>School Bus Scheduling</u>

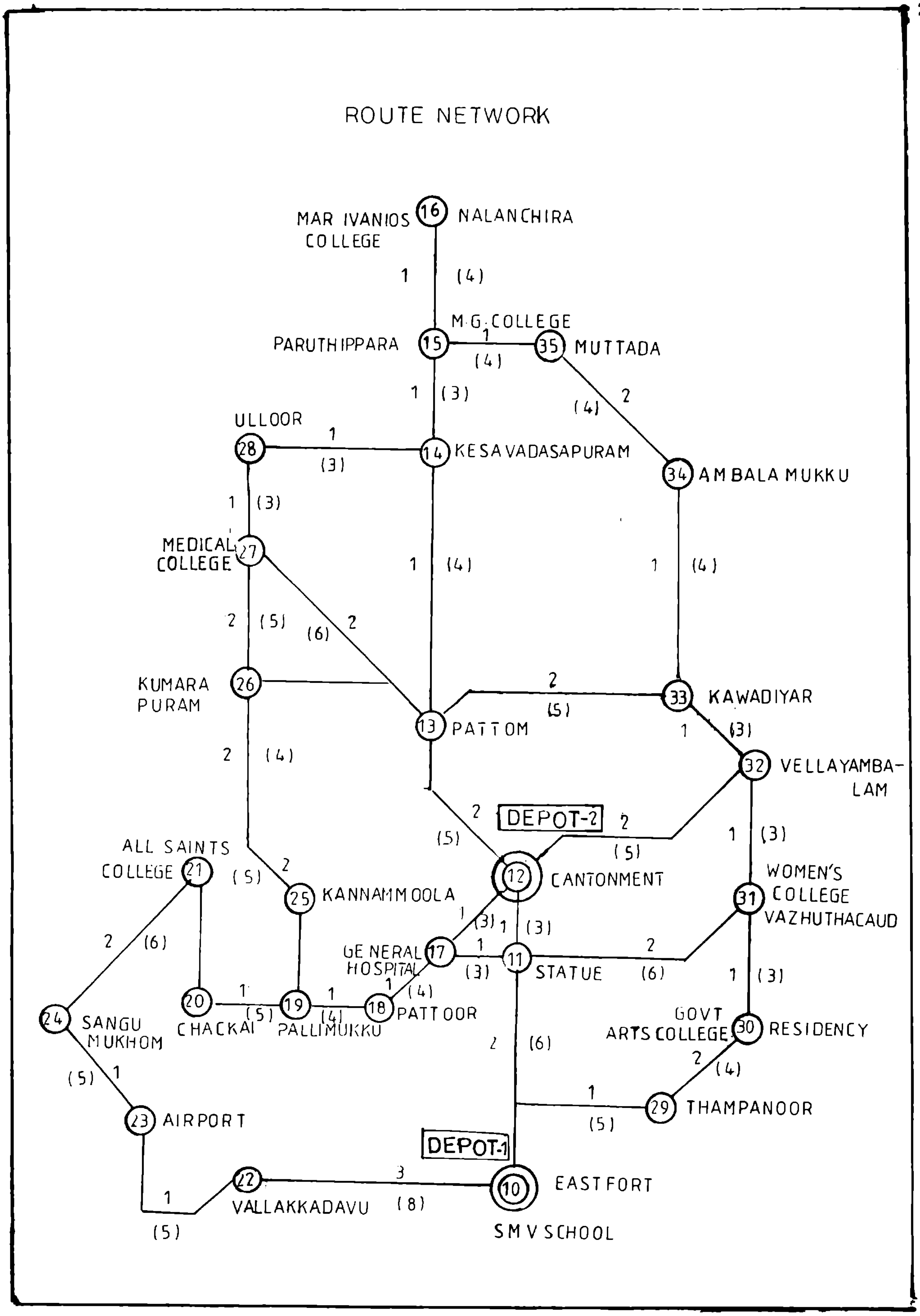
Trivandrum City, as has been mentioned above, has a sizeable student population. Since they are mostly monthly concession ticket holders for their journey to their educational institutions and back, their travel demand will not be reflected in the journey bills. However, an accurate assessment of their travel demand can be made, since their origins/ destinations can be correctly known. The main difficulty in Trivandrum city is that since the educational institutions start functioning at 9.30 A.M., the travel demand of the students adds to the pressure of the morning peak traffic. During the evening, this is less pronounced - since students may leave the institutions at 3.00 or 3.30 P.M. while offices continue to function upto 5 or 5.30 P.M.

In the Trivandrum City area, there are about 150 educational institutions. Nearly 38,000 students avail of concession tickets, including about 2000 students, studying in parallel colleges. As mentioned earlier, traffic congestion is very acute during morning hours, since education institutions start at 9.30 A.M. and offices also start at 9.30 A.M. or 10.00 A.M. This problem is less pronounced for students whose institutions are located in the outskirts of the city or in the suburban areas, while students studying in the institutions located in the heart of the city find their journeys very difficult. To avoid peak hour congestion, and to make sure that they can reach institutions, some students start their journey much earlier and reach their institutions about one hour earlier than the time the institutions start functioning. (185, p 52) Situations like having upto 120 passengers in a bus has been noted during morning peak hours. Operating more 'Students Only' trips during the peak hours can relieve this congestion to some extent, but sufficient vehicles must be available for this purpose. The problem of student trips can be reduced to a great extent, also if (i) more educational institutions operate their own buses; (ii) if at least some institutes are shifted from the heart of the city to the outskirts; (iii) school and office hours are staggered by at least one hour; and (iv) more students use their personal conveyance, or even walk down to their School/Colleges, if the distance is less than one or two kilometres.

The travel demand of students can be represented as an O/D matrix. For example, if there are 50 boarding points and 20 destinations, the size of the matrix will be 50 x 20. While this matrix represents the travel to the educational institutions, a 20 x 50 matrix can be drawn to represent the return trip. The travel load can be calculated in passenger kilometres, and the minimum number of buses required to satisfy the demand can also be calculated. Since the locations of the institutions in relation to the bus depots are at different places in the city, it may not, often be possible to give direct bus links to all the students from their boarding points to the institutions where they study. Due to this, the actual journey time will be greater than the minimum required journey time. Hence, in any school bus scheduling problem, we have to achieve two conflicting objectives: (i). to maximise the vehicle utilisation; and (ii). to minimise the additional journey time (actual-minimum required) of students. While many trips meant for students are operated as 'students only' buses, other trips are operated as ordinary trips which can be used by all passengers.

Fig: 6.7 shows a typical map with locations of institutions and boarding points of students. Distance of each link in kilometres and journey time, given in brackets in minutes are also shown. There are 26 boarding points, seven institutions and two depots. The approximate number of buses required can be found by dividing the total number of students by the average bus capacity. Since one bus caters to different institutions some students may reach their institutions earlier than required. Also, depending upon the location of the institutions, if all students are to be provided with proper transportation, some segment of the bus trip may have to be operated on a low load factor. This happens when a small number of students, say less than 10, is picked up from a

Fig 6.7 Route Map Showing Students Boarding Points and Bus Depots



comparatively far off point of origin. In any case, the efficiency of school bus scheduling can be measured by taking into account the following factors:

1. Number of vehicles used for school trips.
2. Overall load factor.
3. Overall bus kilometres operated.
4. Total additional journey time of students.

While factors 1, 3 and 4 are to minimised, factor 2 is to be maximised.

6.9 <u>Updating the Schedules</u>

As we have seen in Chapter-5, the travel demand is everchanging. Due to this, the schedules made today may become obsolete over a period of two or three years. Traffic surveys are to be conducted periodically and rescheduling is to be done based on the new traffic data. As for school bus scheduling, it is advisable that it is updated at the beginning of each academic year, after making an assessment of the student's travel requirements during that year. If standard computer programmes are made for this purpose, rescheduling can be done easily, once the travel demand data are assembled.

6.10 <u>Crew Scheduling and Vehicle Scheduling</u>

Once the time tables are prepared, crew scheduling and vehicle scheduling are easier tasks. In transport terminology, a 'schedule' also means the operation of a bus during a day. Usually, time-tables are prepared on a 'schedule' basis, so that a bus can be directly assigned to it. Crew schedules are to be prepared taking into account the prevailing duty norms. In Trivandrum City, usually two crew pairs can operate a schedule, and in this case, a vehicle will be engaged for a total time of sixteen hours. Since these two eight hours durations need not be continuous, the in-between gap can be suitably adjusted, according to the peak and off-peak periods. In any case, the aim of vehicle scheduling must be to maximise the vehicle utilisation-kilometres operated per bus per day.

6.11 Conclusion

As already seen, once an accurate assessment of the travel needs is made, the four major steps that follow in vehicle scheduling are as follows: (i) Depot location, (ii) Vehicle allocation to depots, (iii) Preparation of time tables; and (iv) Bus and crew scheduling. Among these, while existing depots can not be changed, new depots can be located after suitable analysis. Vehicle allocation to depots can also be changed, according to the changes in traffic demand. The next step —the most important step, is routing and scheduling. This has to be done taking into account the various objectives like passenger convenience, vehicle utilisation, etc. and contributes like depot location, routes available, and buses available. In Trivandrum City, school bus scheduling also requires special attention since one seventh of the total travellers in the City Services are students. Once the time tables and the schedules are prepared properly, allocation of vehicles becomes a comparatively easier task.

CHAPTER - VII

MAINTENANCE FACTORS

7.1 The Maintenance Function

If we consider vehicle scheduling and related functions as the 'software' in passenger transport management, the maintenance of vehicle can be considered as its 'hardware'. To keep all vehicle in 'roadworthy' condition is the function of the maintenance department. It includes all functions like purchase of vehicles and spares, maintenance, repair, overhauling and retirement of vehicles. Manpower, machinery and materials are involved in the maintenance function. The successful functioning of the transport organisation, to a great extent, will depend upon the efficiency of the fleet, which is the function of the maintenance department. Vehicles which are not in good condition, when pressed into service cause breakdowns, resulting in revenue loss and inconvenience to passengers. Moreover, it can cause accidents, cause damage to property and human beings. The efficiency of the maintenance department may be measured using a variety of parameters, such as follows:

1. Uptime ratio of vehicles.

$$\text{Uptime ratio (UTR)} = \frac{\text{Period during which the vehicle is in a running condition}}{\text{Total time}}$$

2. Meantime between failures (MTBF).

3. Meantime to repair (MTTR)
4. Failure rate (no.of failures/time span).
5. Accident rate of vehicles
6. Spare and consumable used per vehicle per year.
7. Fuel consumption of vehicles (kilometres/litre-KMPL)
8. Kilometre logged per vehicle per year.

While the first three parameters are mainly of academic interest, parameters 4 to 8 are of critical importance to any transport operator. Depot-wise data regarding accidents, breakdowns, fuel consumption and kilometres logged are available in KSRTC administration reports and were referred to in Chapter-4 earlier under Tables 4.9, 4.10, 4.18 and 4.19. As for the parameter of kilometres operated per vehicle, it may be noted that efficiency of maintenance is only just one of the several factors which affect it, while other factors like route length, location of the depot etc. may sometimes become more important.

Depot-wise data regarding spare parts consumption is not available since these items are centrally purchased. Moreover, maintenance and repair of vehicles are done at depots, as well as at divisional workshops.

Table 7.1 shows the material consumption of KSRTC vehicle, for the years 1989-90 and 90-91. Material consumption of buses depends upon a variety of

Table 7.1 Materials consumption of KSRTC Vehicles

Item	1989-90		1090-91	
	Amount in Rs lakhs	Paise per effective km	Amount in Rs lakhs	Paise per effective km
Fuel (Diesel)	3351.71	117.4	4046.00	144.9
Lubricants	249.00	8.7	263.00	10.1
Auto spares and parts	599.00	21.0	723.00	25.9
Tyres and tubes	1123.00	39.3	1126.00	40.3
Batteries	46.00	1.6	55.00	2.0
Other items	278.00	9.7	177.00	6.3
Total material cost	5646.71	197.71	6410.00	229.6
Total cost of operation	17548.78	614.4	20439.00	732.1

(Source: "Performance Statistics of State Transport Undertakings 1989-90 & 1990-91" page 42,54)

Table 7.2 Replacement Age Vehicles and Materials Consumption

Name of undertaking	Replacement Age		Materials consumption during the year 1990-91 (paise per effective km)
	Years	Lakh Kms	
BEST Undertaking	15	10.00	258.6
Maharashtra SRTC	10	7.00	205.6
Uttra Pradesh SRTC	8	5.25	194.6
Rajasthan SRTC	7	6.00	195.4
Nesamony TCL	6	6.00	186.1
Thiruvalluvoor TCL	3	5.51	180.7

(Source: "Performance Statistics of State Transport Undertakings 1989-90 and 90-92" pages 16,53,57,60,62) factors like the age of vehicles, load factor of vehicles, condition of roads etc. Keeping all the vehicles roadworthy all the time may be the ideal condition, but this is practically impossible and may even be nonproductive and self-defeating. If 100 buses are to be operated every day the depot should have at least 10 percent more buses or 110 buses, taking into account the number of vehicles which have to be docked for various maintenance and repair activities. The present administrative requirement is that there should be ten percent of spare vehicles over the number of schedules to be operated. The non-availability of sufficient number of vehicles leads to trip cancellations and a great deal of hardship to passengers. Well maintained vehicles are also more energy efficient and can save the fuel bill for the management considerably. While vehicle maintenance involves a variety of factors, only the more important among them are discussed in this Chapter.

7.2 <u>The Maintenance Organisation in KSRTC</u>

The Kerala State Road Transport Corporation has a four-level maintenance organisation with depots, divisional workshops, regional workshops and the Trivandrum Central Works. Presently there are five divisional workshops and three regional workshops - one for each region. In addition, the Central Works located at Pappanamcode, Trivandrum undertakes major repair works.

Depot workshops are mainly meant for routine maintenance works and repairs in connection with breakdowns and accidents of vehicles belonging to that depot. Routine maintenance consists of (i)daily maintenance, (ii)weekly maintenance; and (iii)monthly maintenance. There is a procedure prepared for each of these, with a check list of items to be attended to.

The organisation chart of the Vikas Bhavan Depot, shown in Figure 3.2, gives details of the various maintenance personnel. It can be seen that in this depot which has 90 vehicles, there are 92 maintenance personnel, making the ratio of depot maintenance staff to the number of vehicles held as almost 1:1. The different category of workers and their number is also shown in the figure. In the KSRTC, there are a total of 6820 maintenance personnel for a fleet strength of 3413, making the ratio of maintenance staff:buses held as 2:1.(199, p 80) Hence it can be seen that on the whole, half of the total maintenance staff are in the depots and the remaining half are in the divisional workshops, the regional workshops and the Central Works.

The Regional Workshops are mainly meant for repair maintenance works on buses to make them fit for the 'Certificate of Fitness' inspection, which is done by the State Motor Vehicles Department. This inspection is to be done every six months, except for new vehicles, for which this inspection is required only after a period of two years from the date of purchase.

Regional workshops undertake all reconditioning, body repairs and overhauling of vehicles; except engine overhauling. The Divisional workshops also undertake major accident repairs and other works upto engine replacement. The Pappanamcode Central Works undertakes engine overhauling also, in addition to other major repair and overhauling works.

Outturn is fixed for these workshops. Eight vehicles per month, are fixed for the divisional work shops. Twelve vehicles per month are fixed for the regional workshops. For the central works the outturn is fixed at 30 vehicles per month. These are only average figures. The actual monthly outturn may vary from these figures.

As was noted earlier, the Trivandrum City Services is operated through four depots located at East Fort, Pappanamcode, Vikas Bhavan and Peroorkada. While depot level maintenance is done in these places, major maintenance and repair works are undertaken to be done at the divisional workshops, regional workshops and the Central Works.

7.3 Replacement Age of Vehicles

The replacement age of vehicles is an important parameter which decides the 'roadworthy' condition of the fleet. If the replacement age is lower, the organisation will have a comparatively younger fleet and expenses towards breakdowns, repairs etc. will be lower. Generally, the average age of the fleet is taken as half of the replacement age. For example, if the replacement age is eight years, the average age of the fleet is taken as four years. This assumes that there are equal number of vehicles of all ages and the fleet size is fairly constant over a period of time. Most of the state transport undertakings have fixed a replacement age for their vehicle. Table 7.2 shows the replacement ages fixed by some of the state transport undertakings.

Tables 4.2 and 4.3 show the age pattern of KSRTC vehicles and that of the Trivandrum City Services fleet. KSRTC is not presently following any definite replacement age policy. It can be seen that it has an overaged fleet, when compared to other state transport undertakings. KSRTC's average age of vehicles is 6.25 years, while the normal value is around 3.5 years. It can also be seen that the effect of having an overaged fleet is reflected in the comparatively higher material consumption cost of the KSRTC fleet. This may be noted from Tables 7.1 and 7.2.

If the KSRTC fleet is comparatively old, the Trivandrum City Services fleet is still older, with an average age of 9.76 years. This fact about the older aged fleet of the KSRTC is also reflected in the breakdown rate of vehicles to a certain extent, as may be seen from Table 4.10. Needless to say, it will also mean higher material consumption costs for fuel, spares, etc.

Both technical and economic aspects influence the replacement age of vehicles. It is generally true of any equipment that its operating efficiency decreases as its age increases. The rate of deterioration will vary from item to item and will depend upon the extent of its utilisation. In this regard, there can be a broad classification of items into three categories:

1. Stationary items (Buildings, bridges, etc.).
2. Items which have both stationary and moving parts, such as the internal combustion engines, lathes, pumps, etc.
3. Items which have moving parts and are also mobile like car, scooter, bus, etc.

It is clear that functional deterioration will be maximum for the third category, since in addition to the movement of parts it is also subjected to vibration due to the uneven surface conditions of the roads, variations in humidity, temperature, dust content in the air, etc. Hence this category of equipments is likely to have the shortest useful or technical life.

However, the economic replacement age is different from technical age. The former is dependent on economic factors like bus fare, fuel prices, wages of employees etc.

Each transport undertaking should have a clear policy regarding the replacement age and economic age of vehicles. Moreover, each vehicle should be assessed separately before being replaced.The optimum replacement age suggested here should be therefore considered only as a general guideline.

In fact, chronological age of the vehicle is not the only measure for determining the replacement age of vehicles. Kilometres logged or hours of operation also require to be considered as a measure of the life of the vehicle. The technical condition of a vehicle will depend upon many factors like:

1. Kilometres operated and the average mileage the vehicle gives.
2. Pattern of load carried, eg: always heavily loaded or sparsely loaded etc.
3. Road conditions, viz. the gradient of the road, surface condition of the road, etc.
4. Type of maintenance provided to the vehicle.
5. Spares and replacements used etc.

It is generally true that for all passenger transport vehicles, their earnings per year progressively decreases, since the availability of the bus is less and operating expenses progressively increases as the age of the vehicle increases. There is also an operational derating done in practice. New vehicles are deployed for long distance routes and progressively their use will be changed into mofussil and later city services. This may adversely affect their utilisation and earnings.

Usually, the different levels of derating is done as follows.

1. Express or Limited Stop or Fast Passenger services (Interstate or long distance intercity services).
2. Intercity services within the State.
3. City services or mofussil services.
4. Stand-by buses or spare buses.

In any case, the profitability of operations, i.e., revenue earnings minus operating expenses over a given period of time progressively decreases as age increases. Also, there are other effects of aging of vehicles as follows.

1. Accident proneness of vehicles increases.
2. Exhaust pollution level increases.
3. Passenger comfort decreases.
4. Reliability of service decreases.

A study was conducted by the author in 1985 to evaluate the economic life of vehicles. Ten buses, each one year old to ten year old (all Tata make), were selected from Trivandrum City and nearby depots, making a total of 100 vehicles. Relevant data was collected. For each bus, data regarding monthly fuel consumption, monthly kilometres operated, spare parts used and maintenance work done were noted as may be seen from Tables 7.3 and 7.4. From this data, variation in kilometres operated, spare parts consumption, fuel consumption and running cost per kilometre were calculated. Based on the operating results of 1983-84 and 1984-85, the fixed cost per kilometre per bus and EPKM were calculated as Rs 2.63 and Rs 3.88 respectively. This means that only buses having an operating cost of Rs 1.125 per kilometre can earn a profit. The results of the study are shown in Table 7.5.

It can, therefore, be concluded that if it is desired that a bus is to be profit making or at least operate at the break-even levels the replacement age of vehicles has to be either 5.33 years or 5.6 lakhs kilometres. However, if the whole fleet needs only to operate on a break-even basis, with the losses made by the older fleet being compensated by newer fleet, the optimum economic age will be 7.6 years or 7.3 lakh kilometres. These findings may be seen from Fig: 7.5 and also from figures 7.1 to 7.4.

It may be mentioned here as a limitation of the quality of the findings of the study that this

Table 7.3 <u>Sample of Data Collected from a 1975 Make Vehicle</u>

Bus No. A 266
TATA 1210 E
Reg. No. KLX 2199
Chasis No. 34405047Ø4993
Engine No. 692DØ247Ø3Ø47
Date of Commissioning: 2-1-1975

Month		High speed diesel used in litres	Kilometer operated
January	1984	1505	7105
February	1984	1571	6960
March	1984	914	3933
April	1984	1508	6426
May	1984	1657	7551
June	1984	1598	7053
July	1984	1658	6754
August	1984	1984	7638
September	1984	1529	6849
October	1984	1604	7238
November	1984	1491	6543
December	1984	1514	6931
	Total	18243	80979

Engine oil changed	- 9 times
New tyres used	- 3 Nos.
Retread used	- 5 Nos.
Chasis repairs overhauled	- Once
Stearing box	- Twice
Engine R/C	- Twice
injection fuel pump R/C	- 3 times
Gear axle R/C	- Once
Gear box R/C	- 4 times
Front axle R/C	- once
Starter R/c	- Twice
Radiator R/C	- Once
Dynamo R/C	- Once

<u>SPARE PARTS USED</u>

Bulb head ligt	- 4 Nos.
Fan belts	- 3 Nos.
Bulb side and body	- 3 Nos.
Cup master cylinder	- 1 No.
Cup wheel cylinder	- 15 Nos.
Water pump	- 1 No.
Wiper motor	- 1 No.
Wiper arm	- 1 No.
Pressure plate	- 1 No.
Clutch disc	- 1 No.
Spring front	- 1 No.
Spring front rear	- 2 Nos.
Regulator	- 2 Nos.
Brake liner front	- 12 Nos.
Brake liner rear	- 14 Nos.

Table 7.4 Sample of Data Collected from a 1982 Make Vehicle

Bus No. N916
TATA LP 121 OE/52
REG: No.KLX 3417
Chasis No. 344050112250
Engine No. 692D03119039
Commissioned Date: 4-1-1982

Month		High Speed Diesel Used in liters	Kilometer Operated
January	1984	3086	13116
February	1948	1738	7387
March	1984	859	3651
April	1984	2655	11283
May	1984	2386	10140
June	1984	2893	12245
July	1984	3014	12809
August	1984	2589	11003
September	1984	2897	12312
October	1984	2731	11253
November	1984	1392	5897
December	1984	1415	5902
	Total	27655	117534

Engine Oil Changed	-	13 times
New tye used	-	4 Nos.
Retread tyres used	-	7 Nos.
Battery used	-	1 Nos.
Engine assembly R/C	-	Once
Injection fuel pump R/C	-	Three times
Gear box R/C	-	Once
Frontaxle R/C	-	Once
Water pump R/C	-	Twice

SPARE PARTS USED

Cup master cylinder used	-	3 Units
Cup wheel cylinder rear	-	12 Nos.
Cup wheel cylinder front	-	8 Nos.
Centre bearing	-	1 Nos.
Spring rear	-	1 Nos.
Break liner front	-	8 Nos.
Break linear rear	-	12 Nos.

Table 7.5 Variation of Operating Expenses vs Age of Vehicles

Age in years	Year of commissioning	Kms operated	Cum: Km	Running Cost Rs/Km	Total cost Rs/km	EPKM Ps/km	Profit/ loss Rs/km	Cum: profit/loss Rs/km
1	1983	130899	130899	1.158	3.788	3.88	0.092	0.092
2	1982	117534	248433	1.160	3.790	3.88	0.090	0.182
3	1981	100615	349048	1.167	3.797	3.88	0.083	0.265
4	1980	96458	445506	1.197	3.827	3.88	0.053	0.318
5	1979	88941	534447	1.232	3.862	3.88	0.026	0.344
6	1978	80799	615246	1.300	3.930	3.88	-0.050	0.294
7	1977	77999	693245	1.403	4.033	3.88	-0.153	0.141
8	1976	67418	760663	1.484	4.114	3.88	-0.234	-0.093
9	1975	63632	824295	1.500	4.130	3.88	-0.250	-0.343
10	1974	56243	880538	1.620	4.250	3.88	-0.370	-0.713

Fig 7.1 Pattern of Spare Consumption

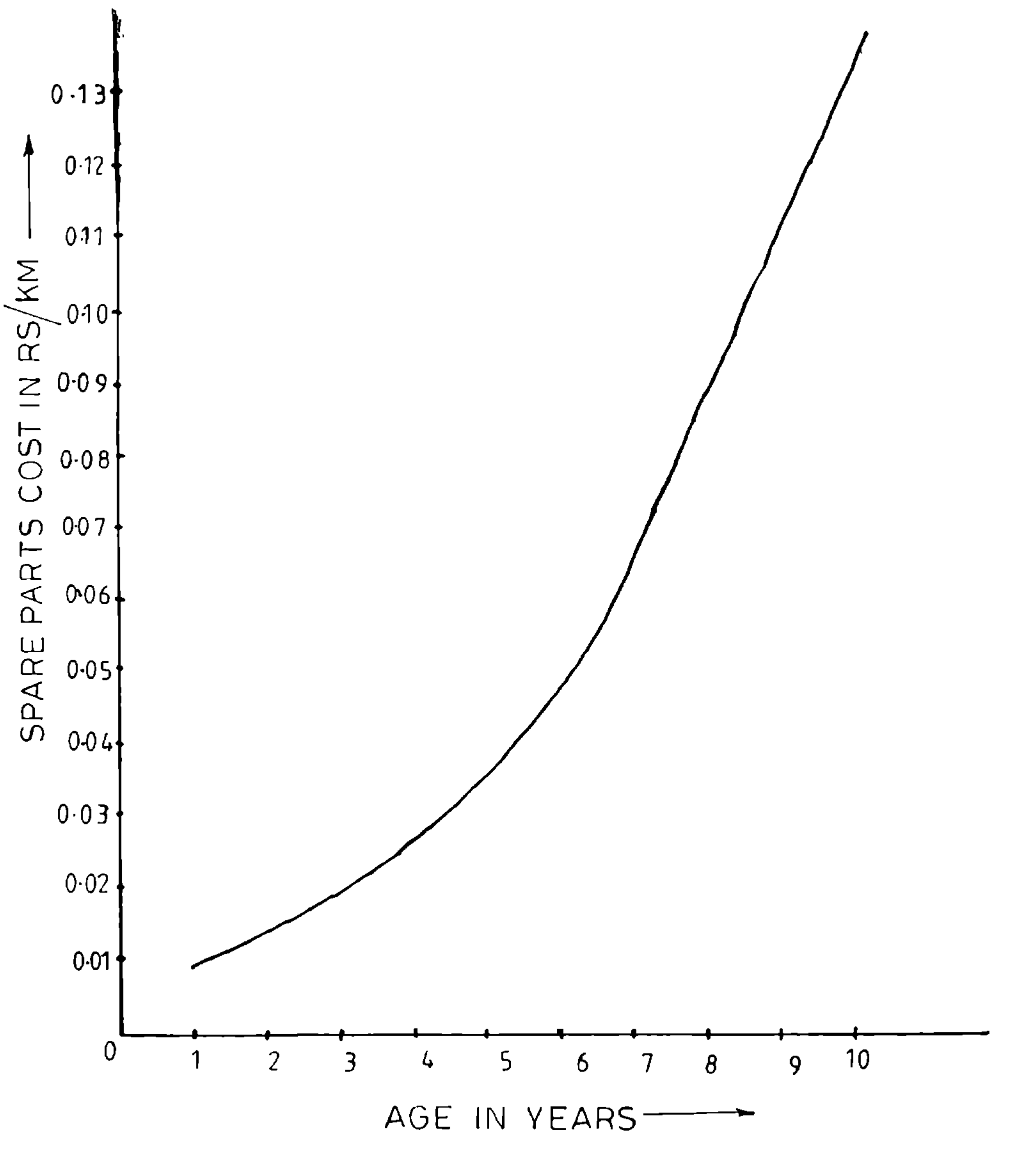


Fig 7.2 Variation of Fuel Consumption

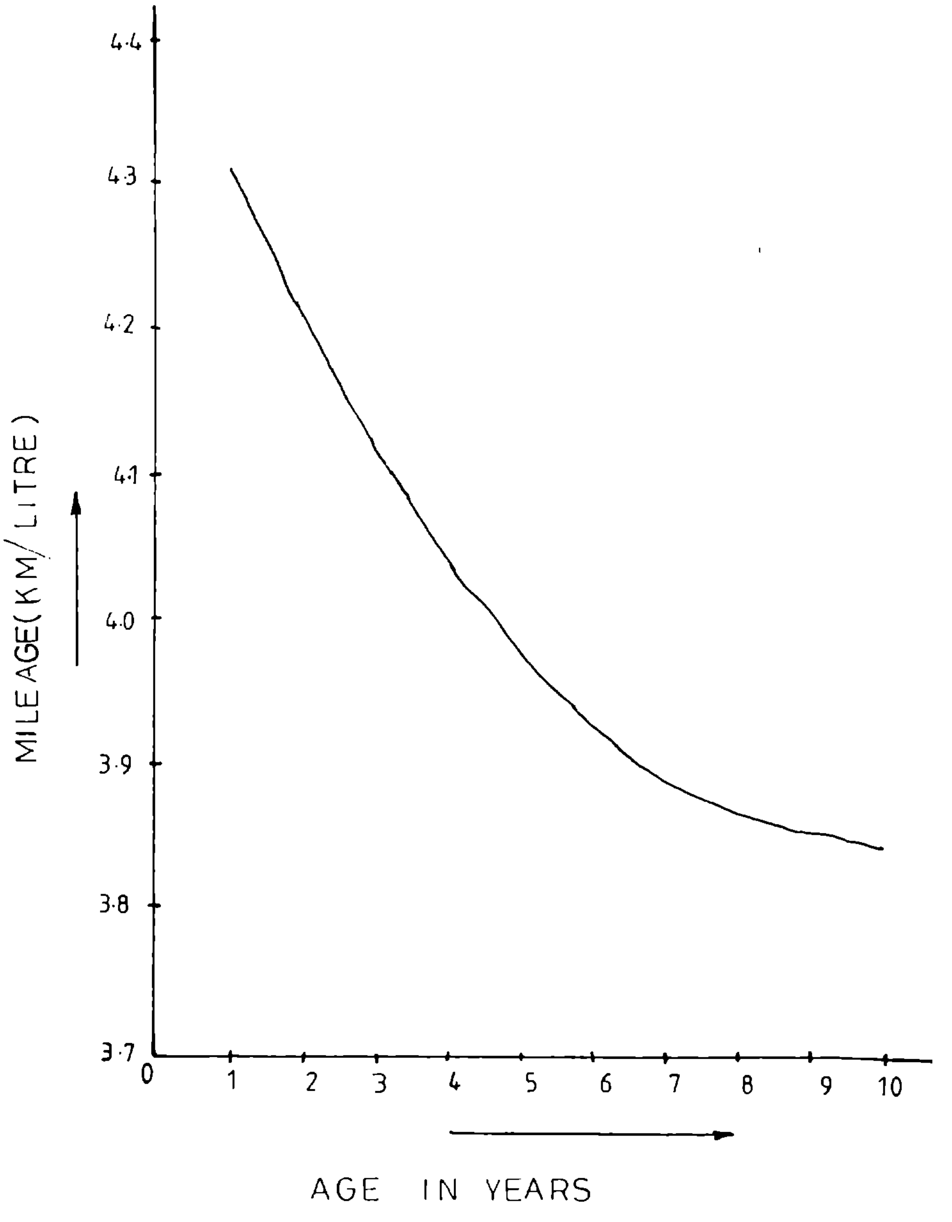


Fig 7.3 Variation of Kilometres Operated

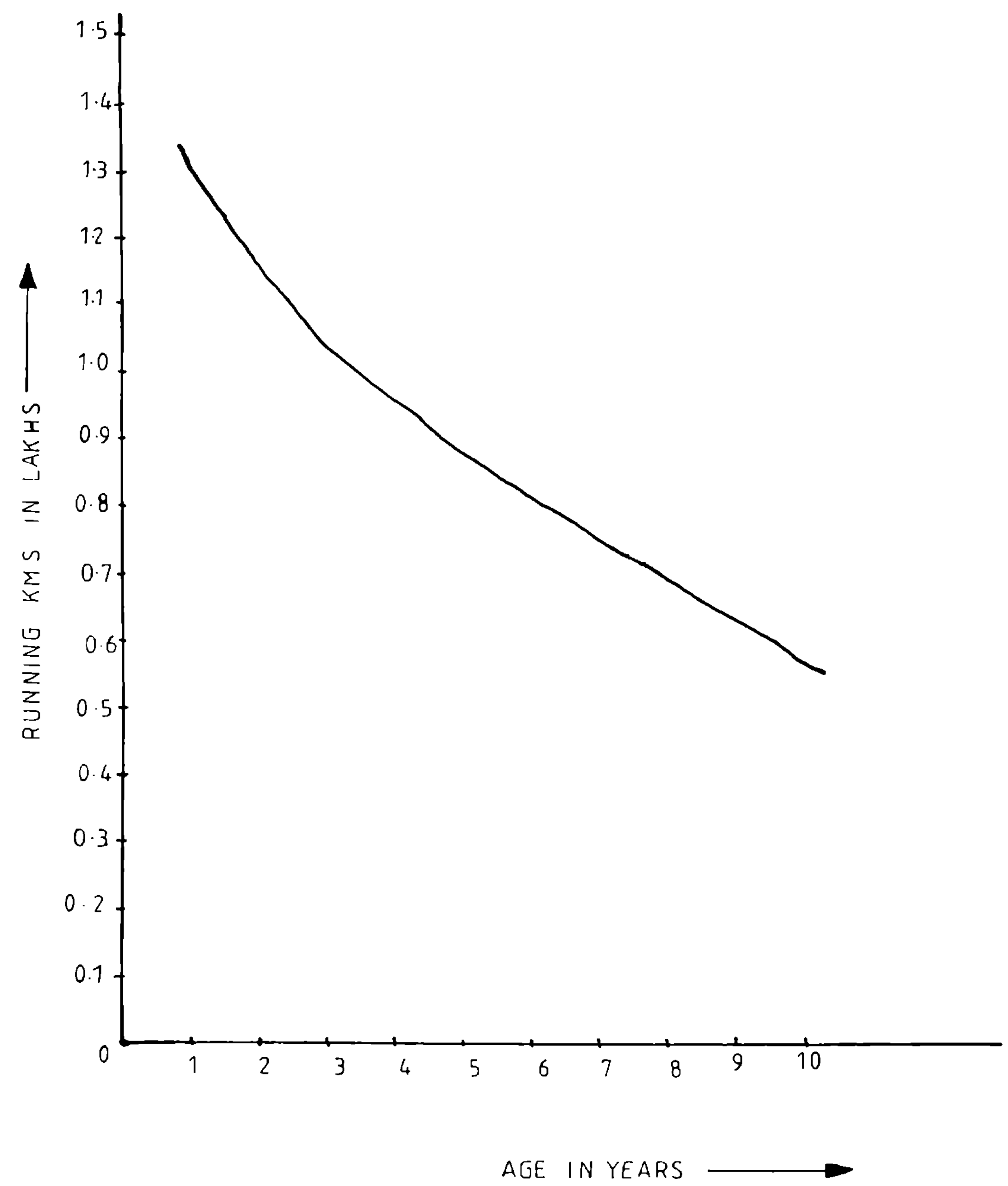


Fig 7.4 Variation of Operating Cost

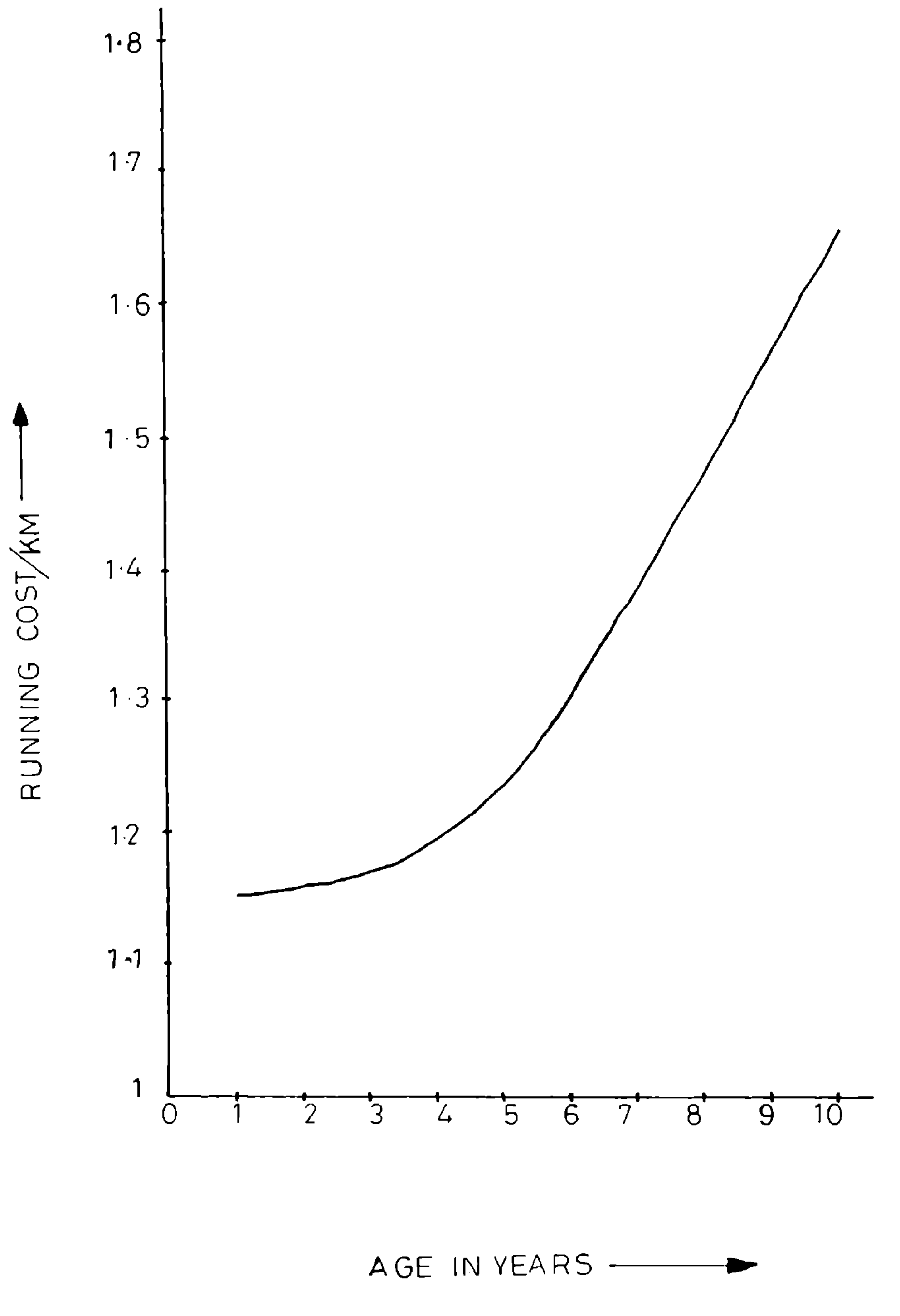
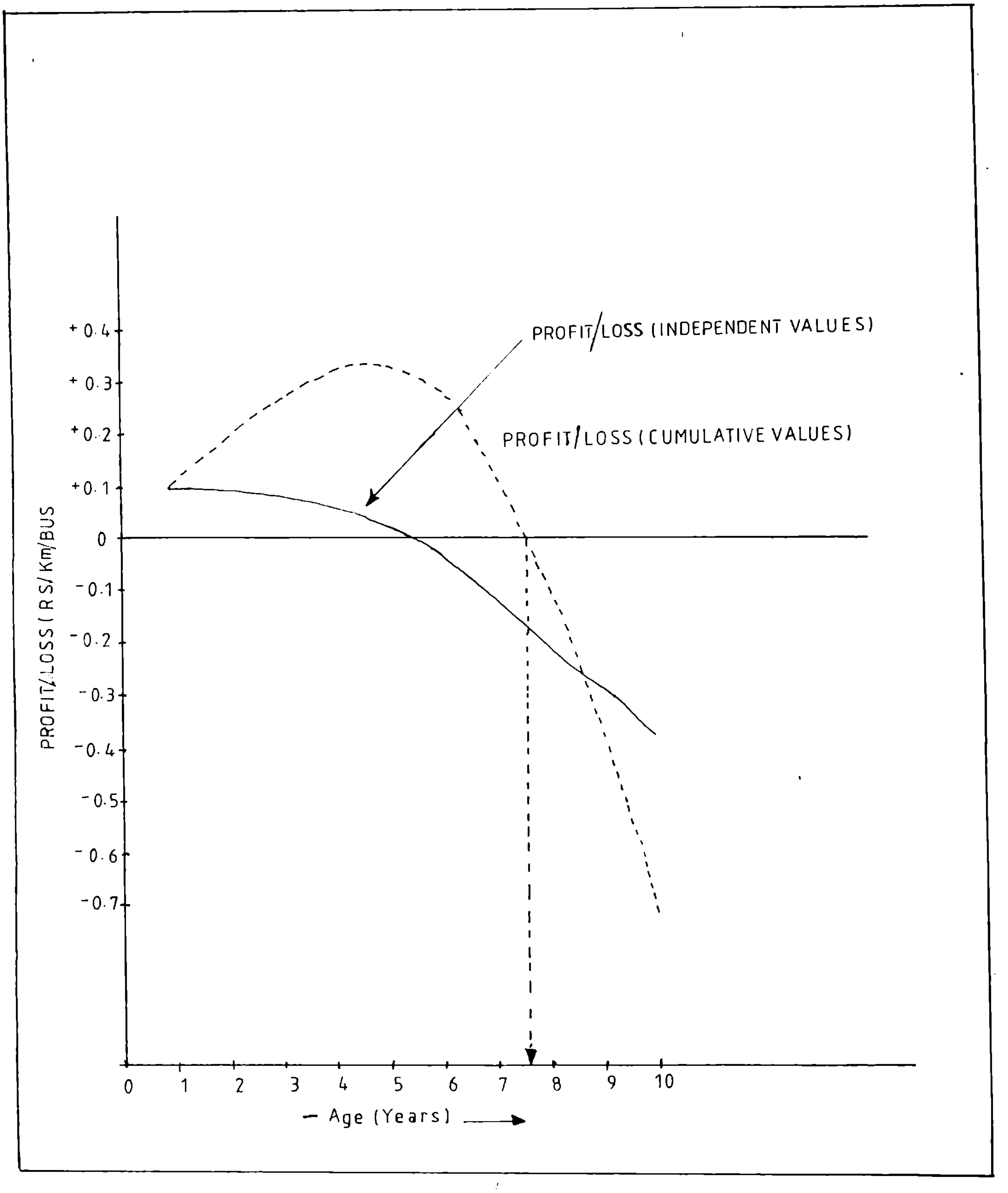


Fig 7.5 Determination of Economic Life



calculation of economic age depends upon the quality and selection of sample of buses considered and their operating parameters. Changes in the value of the economic age is possible if the criteria followed are changed, or if the sample parameters are changed.

The KSRTC has fixed the economic age of its buses as seven years. This was done based on a study made by the SQC unit of Indian Statistical Institute. (203 p 23) However, looking at the age pattern of KSRTC vehicles, as shown in Table 7.4, it can be seen that this norm is not really followed in practice. Nearly half of the KSRTC fleet is more than seven years old.

Comment on the results

As mentioned earlier the mention of 7.6 years as the optimum economic age is only to be used as a general guide line. Each bus should be separately assessed with respect to its technical conditions starting from say, four or five years of age, unless there are special reasons to stand even earlier. With computerisation, it should be possible to do this kind of analysis from the very first year of operation onwards. Due to this, some buses may have to be retired even before reaching this age, while it may be possible to keep some others for a longer period of time. It is due to this fact that some transport corporations determine the economic life in kilometres logged rather than by its chronological age. This system is better, but still not perfect enough. Another important aspect is the reconditioning or major repair done to various subassemblies incurring substantial expenses. This may be a general overhauling, overhauling of the engine, or even of changing the engine altogether. The economics of such major works should be calculated before they are undertaken. Such major overhauls naturally change the technical condition of the vehicle. In general, the ultimate criterion for determining the retirement age of a vehicle should necessarily take into account of its technical condition also.

7.4 Unit Replacement

Breakdowns and accidents are the main factors which affect the availability of buses in a depot. The efficiency of maintenance is the key factor which affects the occurrence of breakdowns and, to a certain extent, the occurrence of accidents. Needless to say, breakdowns and accidents of buses directly affect the regularity of operating services.

Table 7.6 shows these parameters in the City Services' depot, KSRTC as a whole and some other state transport undertakings. It can be seen that the breakdown rate and the accident rate are higher in KSRTC. It is only to be expected that irregularity of operation is also higher in the KSRTC.

It can also be seen that these factors are marginally higher for the Trivandrum City Services,

Table 7.6 Comparison of Breakdowns, Accidents and punctuality of service during the year 199Ø-91

Name of depots	Breakdown per 10,000 km	Accident per 1 lakh km	Irregularity of operation (%)	
			Departure	Arrival
East Fort	0.7	1.4	3.0	2.57
Pappanamcode	0.8	2.1	11.2	12.4
Vikas Bhavan	0.5	1.3	11.3	17.8
Peroorkada	0.9	1.9	6.9	7.4
KSRTC (as a whole)	0.8	1.8	10.3	11.5

Name of state transport undertaking	Breakdown per 10,000 km	Accident per one lakh km	Irregularity of operation (%)	
			Departure	Arrival
Maharashtra SRTC	0.49	0.27	4.95	5.03
Anna TCL	0.10	0.47	1.0	1.0
Gujarat SRTC	0.55	0.33	5.22	4.89
Karnataka SRTC	0.13	0.23	5.3	4.0

(Sources: 1. Kerala State Road Transport Corporation Administration Report 199Ø-91 pages 28, 3Ø, 32)
2. Performance Statistics of State Transport Undertakings 1989-9Ø and 199Ø-91 pages 122, 124)

when compared to KSRTC as a whole. Having more spare buses is one method by which the availability of buses for the operation can be improved. But this may not be possible due to financial constraints. A technique called 'Unit Replacement' or 'Floating Unit System' which can improve the availability of vehicles substantially, is described below.

Unit Replacement or floating unit system is a technique which makes a quantum jump in the operational availability of vehicles. Usually, when the breakdown of a vehicle occurs, it may be due to the malfunctioning of one or two components only. In the usual practice, after diagnosing the defect, the part is removed and/or repaired. If this repair takes a considerable amount of time, the vehicle will not be available for service during that entire time. Basically once the fault is diagnosed, the repair time consists of 1.Time required to remove the part; 2. Time required to repair that part; and 3. Time required to refit the part. In many cases, when the repair of the component cannot be done in the depot to which it belongs it has to be sent to another workshop which adds to the down time of the vehicle.

Under the unit replacement system, the critical components per subassemblies which frequently fail are identified; and their frequency of occurrence is noted. A suitable level of inventory of these 'critical' components is kept in the depot. When a vehicle is brought to the depot for repair, its fault is diagnosed and the malfunctioning part or subassembly is removed. Another such part or subassembly, new or reconditioned is fitted. The vehicle is thus made available for service in a much shorter time. The total down-time of the vehicle is kept to a bare minimum of removing and refitting the component. The removed part can be repaired in due course of time and can be kept in store for use later.

Failure Analysis

To make a decision as to which are the critical components to be kept for unit replacement, an analysis of the possible types of failure that occur to buses is to be done. This is called failure analysis. The whole vehicle can be divided into subsystems and components. The failure of the vehicle may be due to the failure of a particular component or a subsystem.

The main systems in a passenger bus are:

1. Engine.
2. Transmission system including tyres.
3. Electrical system.
4. Controls such as brakes, steering etc.
5. Suspension system.
6. Body and chasis.
7. Fuel and exhaust system.
8. Cooling system.

In this, a system like transmission system can be further divided into subsystems or components like the following.

1. Clutch.
2. Gear box.
3. Propeller shaft, including universal joints.
4. Differential.
5. Rear axle including wheels.

A subsystem like gear box again consists of various components. A gear wheel or lay shaft in the gear box may be considered as a component. By analysing the failure pattern of the vehicle, critical components can be identified. This is also sometimes called as Failure Modes and Criticality Analysis (FMCA). A particular type of failure itself may be due to one or more of several reasons. Various causes of engine failures obtained in an analytical study are shown in Table 7.7. Again, if any one of these causes is analysed it can be seen that the failure can be attributed to any one or more of several reasons.

For example, on an analysis of 89 bearing failures, the various reasons obtained were tabulated. They are shown in Table 7.8. The various reasons for bearing failures such as oil contamination, poor bearing setting etc. in that order of importance. Such an analysis will help to identify the potential causes of bearing failures and also to take suitable preventive measures in time.

Table 7.7 Types of Engine Failures

No.	Type	Frequency	%
1.	Bearing Failure	89	44.5
2.	High oil consumption	46	23.0
3.	Crankshaft failure	21	10.5
4.	Exploded Engine	18	9.0
5.	Value failure	11	5.5
6.	Cylinder head failure	4	2.0
7.	Other reasons	11	5.5
	Total	200	100.0

Table 7.8 Analysis of Bearing Failures

No.	Reason	Frequency	%
1.	Sudden oil starvation	28	31.46
2.	Contaminated oil	26	29.21
3.	Crank case dilution	14	15.73
4.	Poor bearing setting	10	11.24
5.	Over heated bearing	4	4.5
6.	Material failure	3	3.37
7.	Sabotage	3	3.37
8.	Accidental failure of oil pump	1	1.12
	Total	89	100.0

(Source for both tables: Engine Failure Analysis- Anil Dey, Journal of Transport Management January, 1985, p 15)

After conducting the failure analysis of the vehicle, we make out a list of critical components that fail frequently. To begin a replacement system, the critical items which are to be kept as inventory are decided upon. The quantity of inventory to be kept will depend upon the frequency of their failure. This researcher conducted a study of the unit replacement system followed in a depot near Trivandrum city having 125 buses and its analysis is given below.

Eighteen most critical items were identified by analysing past failure records. These items are listed in Table 7.9. Details regarding their price, time required for replacement etc. are shown in Table 7.10. The average inventory is calculated as the mean of the stock level at the beginning and end of each month. Inventory carrying cost is taken as 33 percent of the value of the average inventory carried. The study is based on data collected during January to April, 1984. Additional kilometres operated due to the implementation of the unit replacement system is shown in Table 7.11.

Savings The revenue earned per kilometre operated by the Corporation was Rs. 3.6 and 25 percent of this had been spent on the fuel bill.(196, p 61) Considering 75 percent as net earnings, due to additional kilometres operated, the increase in net revenue earned per annum can be calculated as Rs 5,00,580. The additional

Table 7.9 18 Critical Items and Their Failure Pattern

No.	Item	No. of failures in an year
1.	Injector	756
2.	Propeller shaft	198
3.	Gear box	156
4.	Starter motor	78
5.	Fuel injection pump	72
6.	Water pump	54
7.	Clutch assembly	48
8.	Steering assembly	36
9.	Engine assembly	30
10.	Rear spring	30
11.	Rear axle assembly	24
12.	Front assembly	12
13.	Air compressor	12
14.	Radiator assembly	12
15.	Drag link	12
16.	Tie rod	3
17.	Front spring assembly	2
18.	Cylinder head assembly	1
	Total	1536

Table 7.10 <u>Details Regarding 18 Most Critical Items</u>

No.	Item	Time requird for replacing (Hrs.)	Average Inventory kept	Price (Rs.)	Inventory carrying cost per year (Rs.)
1.	Engine assembly	54	4	57612	76048
2.	Steering assembly	13	4	2662	3514
3.	Front axle assembly	19	3	27609	27333
4.	Rear axle assembly	24	4	40004	5285
5.	Gear box	18	8	38205	85021
6.	Fuel injection pump	8	10	3867	12761
7.	Front spring assembly	6	2	888	586
8.	Rear spring	6	4	907	1197
9.	Propeller shaft	4	20	1530	10098
10.	Atomiser	7	80	181	4778
11.	Starter motor	2	7	2158	4984
12.	Tie rod	3	2	486	321
13.	Clutch assembly	21	6	2100	4158
14.	Drag link	1	3	300	297
15.	Cylinder head assembly	12	2	9302	6189
16.	Air compressor	19	2	1854	1227
17.	Radiator assembly	1	2	1854	1227
18.	Water pump	10	6	1000	1980
				Total	2,94,898

Table 7.11 <u>Additional Kilometres Operated</u>

Month		Additional Kilometers operated above last year's monthly average
January	1984	15342
February	1984	16284
March	1984	14928
April	1984	15246
	Total	61800

(Monthly average-15450 Km.)

Table 7.12 <u>Failure Patterns</u>

(a)

Life years	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Failure	3	3	3	3	3	3	3	3	3	3	5	15	20	20	10

(Total =100%)

(b)

Life years	1	2	3	4	5	6	7	8	9	10
Failure %	2	3	5	8	9	12	13	14	15	19

(Total =100%)

inventory carrying cost is about Rs. 3 lakhs per annum. The net gain thus works out to Rs. 2 lakhs per annum. If more components other than the 18 items kept for the study had been brought under the unit replacement system, there might have further increase in kilometres operated and, therefore of net profits. But what additional items should be brought under the unit replacement system can be decided only on the basis of adequate failure and economic analysis.

The unit replacement system improves the overall availability of buses, but it is not practised at present in any of the depots of the Trivandrum City Services. In fact it has been discontinued even in the one depot where it used to be practised earlier, due to financial reasons.

7. 5 Preventive Replacement

Preventive maintenance has to do with the necessary maintenance action at periodic intervals so that occurrence of breakdowns can be minimised. However, preventive maintenance cannot guarantee that a breakdown will not happen. Preventive replacement is a policy of replacing components which have completed a given period or extent of use, so as to preempt a possible failure during service. Such a replacement made before the actual failure occurs, is applicable only if the damage caused by a failure while working is more than the simple replacement cost of the equipment.

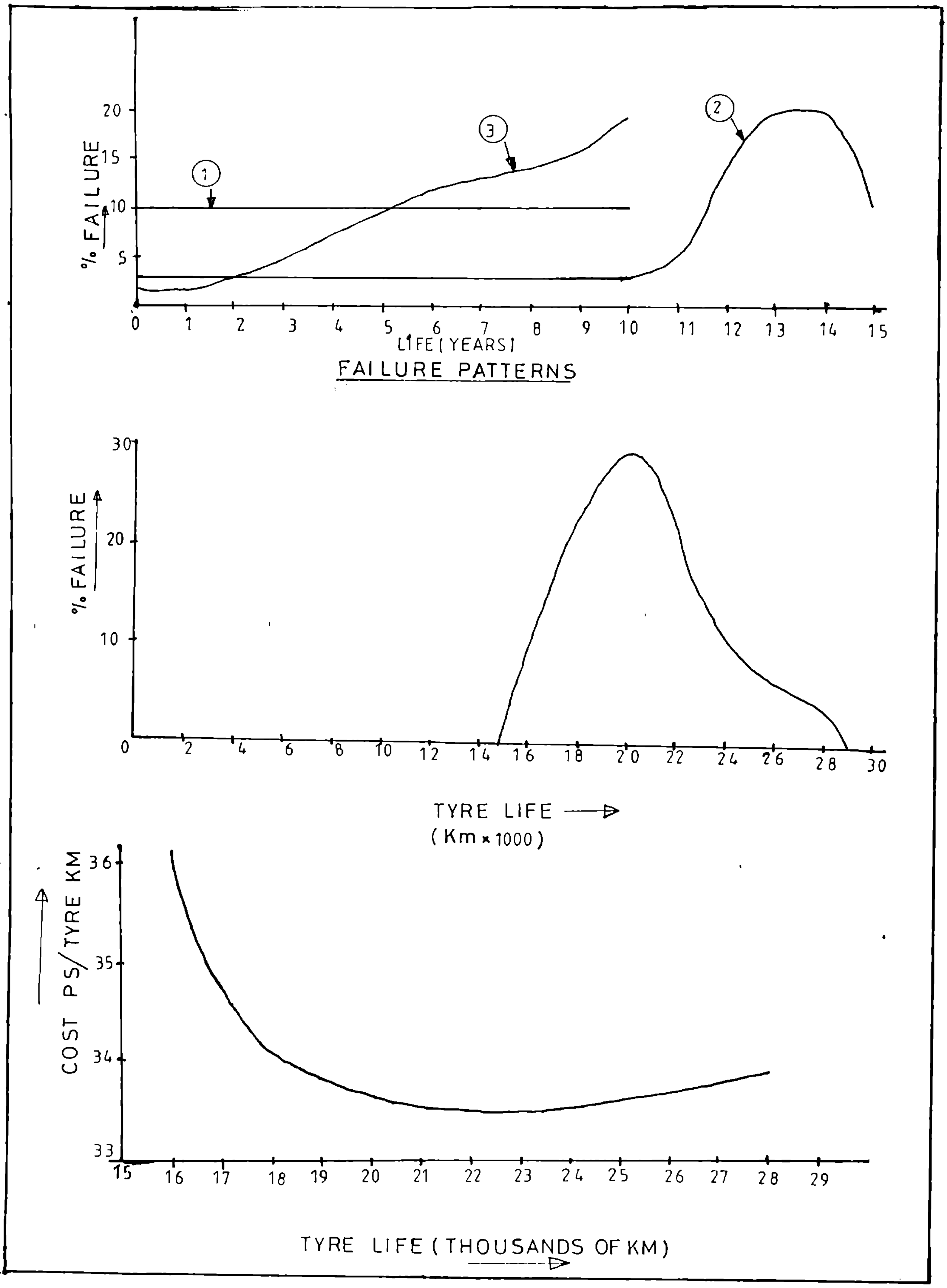
This is very much relevant in passenger bus operations since breakdowns during service causes loss of revenue and consumer goodwill and may, sometimes lead to costly accidents. A second factor to be considered in this context is that the expected remaining life of the component may be comparatively small. A much larger cost may be incurred due to failure during service, in addition to the cost of the component to be replaced. For such an analysis, the failure pattern of the equipment should has to be studied carefully.

Failure pattern

Any equipment has a failure pattern, within its maximum expected life. One extreme case is the uniform failure pattern during its expected life. For example, if the equipment has a maximum expected life of 10 years and 10 percent failures occur every year, it is an example of a uniform failure rate. Such a failure patten hardly exists.

For most of the equipments, there are two distinct periods within its useful life: (a). when the failure rate is low and fairly uniform; and (b). the subsequent wearout period when the failure rate is high. Table 7.12 gives examples of the two such failure patterns. In the second case, there is no clear demarcation between the above two periods since there is a uniform increase in failure rate. All the above mentioned failure patterns are shown in Fig: 7.6.

Fig 7.6 Preventive Repair



2

The preventive repair policy followed is as follows. Replace the component only on failure upto a certain pre-determined period of use or time, but once this period has been completed, replace the components even if they have not failed. We attribute different costs for replacement during failure while in use and simple replacement while not in use.

The preventive replacement policy can minimise the total cost in a number of instances. For example, suppose the failure pattern of bus tyres is as shown in Table 7.13. From the mortality tables it can be seen that tyre life can vary anywhere between 15,000 to 29,000 kilometres. If we assign a simple replacement cost of Rs 6000 per tyre and of Rs 7000 for replacement while in service, i.e. assuming Rs 1000 as the additional cost due to a tyre failure in service, the analysis of the associated costs are shown in Table 7.14. The mean life of the failed components are taken as the median value of kilometre interval where they have failed. In each row, the remaining tyres are assumed to be replaced at the end of the interval period. For example, in the second row, 10 + 20 = 30 tyres are replaced after completing 19,000 km. In each case, the total life is obtained as kilometres, associated costs are calculated and cost per tyre kilometre is calculated. In this example, the lowest value i.e. 33.65 Ps per kilometre comes within the

Table 7.13 Failure Pattern of Bus Tyres

Kilometers Run	% Failure
0-15,000	0
15,000-17,000	10
17,000-19,000	20
19,000-21,000	30
21,000-23,000	20
23,000-25,000	10
25,000-27,000	6
27,000-29,000	4
Total	100

Table 7.14 Calculation of Replacement Age

No	Km logged	% of failure	Mediam life of failed tyres (Km)
1	15000-17000	10	16000
2	17000-19000	20	18000
3	19000-21000	30	20000
4	21000-23000	20	22000
5	23000-25000	10	24000
6	25000-27000	6	26000
7	27000-29000	4	28000

No	Cumulative failure cost (Rs)	Replac-ment cost (Rs)	Total cost (Rs)	Total Km Operated	Cost\ tyre Km(Rs)
1	10000	600000	610000	1690000	36.10
2	30000	600000	630000	1850000	34.05
3	60000	600000	660000	1960000	33.67
4	80000	600000	680000	2020000	33.66
5	90000	600000	690000	2050000	33.65
6	96000	600000	696000	2064000	33.72
7	100000	600000	700000	2068000	33.85

range 23,000 to 25,000 km. Hence the policy may be to replace a tyre while in service upto 25,000 Km and once a tyre has logged 25,000 Km, it may be replaced in the depot, even without an actual tyre failure occurrence.

Table 7.14 shows the variation of cost per tyre kilometre, for various replacement intervals like 17,000 kms, 19,000 kms etc. The calculation is made assuming that there are 100 new tyres in the beginning. Fig 7.6 illustrates the variation of the cost per tyre kilometre in relation to kilometres logged. It is needless to say that the result thus obtained will mainly depend upon two factors; viz. a) the failure pattern of the equipment and; b) the associated costs.

Preventive replacement policy is not followed in Trivandrum City Services or in KSRTC. Moreover, if this policy is to be followed, log books of vehicles are to be kept properly and details regarding the fitment of major items are also to be entered in it properly.

7.6 Energy Conservation in the Road Transport Industry

In any passenger road transport undertaking, the fuel expenses constitute an important part in operating expenses. In the KSRTC, fuel expenses account for about twenty percent of the total operating expenses.(197, p 79) Any attempt toward energy conservation in passenger road transport undertakings will save money for the organisation and will save precious fuel for the nation. In one sense, the per capita energy consumption of a country can be taken as a yardstick of its trends in economic development.

In India, the main sources of energy are fire wood, agriculture wastes and cowdung-all non-commercial and coal, oil and electricity - all commercial. Sectorwise, agriculture, industry and transport are the main consumers of power. Within the transport sector, which uses commercial energy sources, 13.3 percent of the requirements are met by coal, 83.9 percent by petroleum based fuels and 2.8 percent by electricity.(12, p 7) Hence it can be seen that petroleum based fuels account for the most important source of energy requirement in transport. As per present estimates, even the limited fossil fuel sources of India from available reserves are expected to last only for the next 35 years.

The pattern of usage of different fossil fuels and their consumption in the road transport sector are shown in Table 7.15. The consumption of high speed diesel (HSD) in road transport is quite significant and is around 9.5 million tonnes per annum, which is more than 65 percent of the total diesel consumption in the country in an year. In India, since independence, there has been a spectacular increase in road length and vehicle population. The growth pattern of passenger traffic and goods traffic are shown in

Table 7.15 Pattern of Fossil Fuel Consumption

Product	Total consumption *	Consumption *
Gasolene	1.92	1.92
Diesel	14.12	9.45
Fuel oil	7.67	0.34
LPG	1.07	-
Jet oil	1.63	-
Kerosene	6.19	-

* 1985 figures

Table 7.16 Growth of Road Transport

Year	population	Passenger Traffic (Billions of passenger Km	Goods Traffic (Billions of Tonne Km)
1950-51	360.95	23.0	5.5
1960-61	439.07	57.0	35.0
1970-71	547.955	169.0	66.0
1980-81	685.18	521.9	158.8
1990-91	801.00	1028.9	305.8

(Source of both tables: Patankar, P.G. Energy Demand management in transport Sector Published by Central institute of Road Transport, Pune Pages 11, 12)

Table 7.16. The road network's share of total passenger traffic has steadily increased when compared to railways, the share of which has progressively decreased from 60 percent in 1950 to the present level of 20 percent of the total consumption. The growth in the requirement of HSD is presently at a rate of 12 percent per annum. The total HSD consumption in India now is more than twenty million tonnes. Estimated commercial vehicle (lorry) population in India in 1990 is 15.21 lakhs and of passenger road transport vehicle (buses) is 2.78 lakhs. Among these, more than a lakh of buses are owned by the public sector transport undertakings. (202, p 12) From these facts, it is clear that improvement in fuel efficiency of road transport vehicles will go a long way in saving the precious fossil fuel.

Present Status of Fuel Consumption

Fuel consumption in kilometres per litre varies from 3.0 to 5.0 in various public sector road transport undertakings. Some representative values are shown in Table 7.17. It can be seen that fuel consumption by city organisations is generally higher than that of mofussil organisation. The reasons for this phenomenon are discussed later in this Chapter. Table 4.18 shows the fuel consumption of buses in City Services' depots and that of KSRTC as a whole. Here also it can be seen that the fuel consumption rate in

Table 7.17 Fuel Consumption of Various Public Sector Road Transport Undertakings

Name of State Road Transport Undertaking	HSD consumption expressed in Kilometers/litre (as on June 1991)
Mofussil Organisations	
1. Gujarat SRTC	5.00
2. Andhra Pradesh SRTC	4.97
3. Kerala SRTC	3.64
4. Assam STC	4.11
5. Punjab State Transport	3.98
6. Thiru Valluvar TCL	4.48
7. Uttar Pradesh	4.59
8. Maharashtra SRTC	4.55
9. Orrissa SRTC	4.03
10. South Bengal STC	3.45
City Organisations	
1. Ahmedabad MTS	3.93
2. BEST Undertaking	2.99
3. Culcutta STC	3.35
4. Pallavam TCL	3.59
5. Pune Muncipal Transport	3.58
Organisations Operating in Hilly Areas	
1. Manipur SRTC	3.43
2. Meshalaya STC	3.28
3. Mizoram State Transport	3.00

(Source: Fuel cell Newsletter No.13, January 1992 Central Institute Of Road Transport, Pune pages 1,2)

City Services is marginally higher than that of KSRTC's services considered as a whole. Comparing these tables, it can be seen that a KMPL value of five for mofussil services and four for urban services can be set as targets to be attained. However, fuel consumption of buses depend upon the following factors, and all of them are not within the control of the transport operator.

1. Driver and his driving habits.
2. Engine.
3. Chasis and body design.
4. Road conditions.
5. Vehicle maintenance.

<u>Driver and his driving habits</u>

The following are the main factors in driving which affect the fuel consumption of the bus:

1. Running vehicle at an economic speed.
2. Uniform speed without frequent variations.
3. Proper use of brakes, anticipating stoppages in advance.
4. Use of proper gears.
5. Avoiding clutch riding.
6. Avoiding fanning or sudden acceleration.
7. Keeping tyres under proper inflation.

Proper training of drivers in these matters, and making energy saving a habit, or better a culture, will help to reduce fuel consumption. Petroleum

Conservation Research Association (PCRA) conducts training programmes for drivers in this area and they report that km per litre performance was improved from 3.75 to 4.15 i.e. an overall improvement of 12 percent, in one of their training sessions.

Engine Design

Automobile technology is improving steadily, India, has been a little slow in assimilating the latest advances. Some of the latest advances in engine technology are as follows:

1. Use of light alloy pistons.
2. Rotary valves.
3. Improved combustion chamber design.
4. Electronic control of air fuel mixture.
5. Super charging.
6. Use of hybrid fuels.

However, it should be admitted that initiative in these areas should have come from vehicle manufacturers. They were operating in an insulated, protected, sellers' market situation until now. It is only since the last five years that the automobile scene has undergone a sea-change and its ripples are reaching truck manufactures also.

Chasis and body design

Unlike engine design, transport undertakings can also play a role in this respect. Modern trends in this field are:

1. Aerodynamically designed body.
2. Weight reduction.
3. Reduction in rolling resistance.
4. Luggage hold under the floor of the bus.
5. Reduction in transmission losses.

The shape of the bus body decides the wind resistance to the vehicle. It is estimated that at a speed of 70 kms per hr, 20 percent of the power is spent in overcoming the wind drag. Taking this factor into account, conventional "flat-fronts" are being replaced by 'nose-type' design and also flat roof is giving way to 'arch roof'.

More spectacular changes are taking place in the area of material usage. Conventional steel components are giving way to light alloys and plastics. Plastics such as PVC (poly vinyl chlorides) and ABS (Acrylonitrile Butadiene Styrene) are being increasingly used for vehicle components. These have certain advantages, such as the following.

1. Light weight;
2. Less corrosion;
3. Better thermal and sound insulation;
4. Low coefficient of thermal expansion; and
5. Consequent dimensional stability.

Manufacturing techniques like screw injection technique, blow moulding technique, thermo forming, monomer casting, spin welding and sonic welding can be used in these cases. Weight reduction to the extent of a tonne in a truck chasis can be achieved using new materials. This will mean an additional pay load of a tonne or corresponding reduction in fuel consumption.

Rear engine vehicles have already been developed, which have less transmission losses and less noise to passengers.

Road conditions

Needless to say, road conditions influence fuel consumption of the vehicle. Smooth well-surfaced level roads are the best fuel savers. Apart from higher fuel consumption, rough roads also cause damage to vehicle parts due to shock and vibration. Other than surface conditions, gradient and curvature of the road are also important factors. Roads having several lanes enable smoother flow of traffic and add to fuel efficiency.

Vehicle maintenance

Last but not the least, proper maintenance of the vehicle plays a good part in improving fuel efficiency. Some factors related to maintenance are as follows.

1. Preventing leakages of fuel lines.
2. Avoiding spillage in fuel tank.
3. Using correct grade lubricants.
4. Maintaining correct tyre pressure.
5. Maintaining air cleaner in proper

condition.

6. Use of good fuel fitters and changing them at correct periods.
7. Setting tappet clearance correctly.
8. Keeping injectors in correct condition.
9. Avoiding brake drag.
10. Maintaining correct wheel alignment.
11. Preventing clutch slippage.
12. Keeping the silencer clean.
13. Preventing black smoke.
14. Setting fuel injection timings correctly.

Added problems of fuel efficiency for buses operating in urban areas

Buses operating in cities and urban areas have particular problems which decrease their fuel efficiency.

1. Low operating speeds.
2. Overcrowding of passengers.
3. Frequent stoppages, due to more bus stops.
4. Idling at traffic junctions and traffic lights.
5. Stop and go journey due to traffic congestion.

Hence, as was already mentioned, even a performance of 4 kilometres per litre itself can be considered as a good achievement for an urban bus fleet regarding fuel efficiency. It may also be mentioned that some of the factors above like road conditions, innovations in engine design etc. are not under the control of the bus operator. However, other factors like driver training, body design and maintenance of vehicles are under their reach. In KSRTC there are no regular training programmes for drivers to develop fuel saving driving habits. Similarly, only some marginal changes have been made in body design during the past several years, from the aerodynamic point of view. Kerala's terrain is not level, when compared to some of the other states. Hence, most of the roads, except those in the coastal areas, are not level. Heavy rains during the two monsoons make the condition of the roads worse. Even though Trivandrum is a coastal city, its roads are not level. Yet, KSRTC's present KMPL value of 3.65 has sufficient room for improvement.

7.7 Maintenance Priorities

In any bus garage which undertakes maintenance and repair, there should be some norms under which vehicles are taken for maintenance or repair. The simple rule of first come first served is not applicable here, since it has no relevance in this context. One factor which can be used for determining priority is the repair time. Vehicles which require the least repair time are to be serviced first. However, logical this may appear to be at first, this method may create problems for vehicles requiring longer repair time, since they may get never attended to. Another factor which is also to be taken into consideration is the availability of necessary spares and components. In this regard, the vehicle which has all the necessary spares must be given priority. A priority model is proposed taking into consideration of the following three factors:

1. Arrival time.
2. Repair time
3. Availability of spares.

Each factor is given a rating on a 1 to 10 point scale, with the least preferred given one point and the most preferred given a point of 10. In between, variation is assumed to be linear. Table 7.18 gives the data regarding seven vehicles in a depot which are waiting to be repaired. Each factor is converted into a 10 point priority scale. For example, in repair time, bus 'D' which requires the least repair time, of say 2 hours is given a priority of 10 and the bus'G' which requires the maximum repair time of say 14 hours is given a priority of only one. The priority values in all the three factors are added up to get a rank. The vehicle which gets maximum points is ranked first and so on. The final priority arrived at in this example is D-C-A-E-B-F-G, as is shown in Table 7.19. This procedure can provide a more rational way for

Table 7.18 Data Regarding 7 Vehicles Waiting for Repair

Vehicle	Arrival priority	Repair time	Availability of spares (%)
A	1	5	70
B	2	8	60
C	3	3	85
D	4	2	100
E	5	7	80
F	6	12	85
G	7	14	90

Table 7.19 Priority Points (1-10 Sacle)

Vehicl	Arrival Prior-ity	Repair time	spare availa-bility	Total points	Rank
A	10	7.75	3.25	21	3
B	8.5	5.5	1	15	5
C	7.0	9.2	6.125	22.35	2
D	5.5	10	10	25.5	1
E	4.0	6.25	5.5	15.75	4
F	2.5	2.5	6.625	11.625	6
G	1	1	7.75	9.75	7

determining maintenance priorities than say, the first come first served principle.

7.8 Use of Control Chart Techniques in Passenger Road Transport Management

Control chart techniques, being a part of quality control procedures, is widely made use of in production-related functions. However, over the years, this technique is being gainfully used in other areas also. Wherever there is a variable characteristic, which is to be kept under control within specified limits, this technique will be useful. The variable characteristic can be anything like:

1. Diameter of a shaft.
2. Horse power developed by an engine.
3. Monthly expenditure in rupees in a company.
4. Percentage of students passing an examination over the years.
5. Number of vehicle accidents in a transport corporation.
6 Quantity of fertilisers used by farmers in an area every year.
7. Cost of production of a component in rupees.

In short, when there is a variation to be controlled, control chart technique can be applied. The originator of these charts is Dr. A.W. Shewhart who worked out the chart during the early part of this century. This technique involves setting performance objectives, sensing any possible variation through control charts, diagnosis of the possible causes, preventive measures and remedial actions.

Theory of Control Charts

When a set of variable values (representing any characteristic) numbering at least forty or fifty is given, control charts can be drawn. These values will be grouped in subgroups. If there are 50 values, it can be divided in to 10 subgroups of size five. Ten points will be plotted in the control charts (there will be two control charts- one for the 'centring' and the other for the 'dispersion') and if all these ten points are within the control limits, the process is considered to be in control, otherwise not. Basically what is checked is whether all the values are belonging to the group or not and to identify the 'odd man out', if any. Strange, it may seem, that in a group of fifty students who have performed poorly, a good student will stand out as the 'odd man out'. However, in most cases, the control charts identify the non-conformities, so that action can be initiated. The basis of control charts is the 'Central Limit Theorem' which states that whatever be the shape (of the frequency distribution) of the parent distribution, the distribution of their averages will always have the shape of a normal (bell shaped) distribution curve. Based on this theorem, 3-sigma control limits are calculated, both for average and range of the sub group values. An $\overline{X}$ chart is plotted which controls the centring, while R chart controls the dispersion. 3-sigma control limits are generally used, which covers 99.73% of the population. However, control limits can be calculated for other sigma values also. Quality control tables are available, which can be used for calculating control limits (see Table 7.2Ø).

Procedure

To illustrate the control chart technique,

the data given in table 7.21. can be considered. Fifty individual values correspond to a variable quality characteristic which is to be maintained between two specified limits. They are grouped into 1Ø subgroups of size 5, and their sub group average and ranges (difference between the highest and smallest value in the sub group) are calculated. Using the tables 7.18, 3-sigma control limits are evaluated. Comparing the $\overline{X}$ and R values with the control limits thus obtained, it can be seen that the process is in control (see Fig: 7.7). However, if a value is excessively high (say 25Ø), it will be seen in the control chart as 'plot' which is out of control.

While 'in control' condition shows that the parameter considered is within our specified limits, if

Number of bservations in sub groups n	Factors for X chart A_2	Factors for R chart D_3	D_4
2	1.88	0.00	3.27
3	1.02	0.00	2.57
4	0.73	0.00	2.28
5	0.058	0.00	2.11
6	0.48	0.00	2.00
7	0.42	0.08	1.92
8	0.37	0.14	1.86
9	0.34	0.18	1.82
10	0.31	0.22	1.78
11	0.29	0.26	1.74
12	0.27	0.28	1.72
13	0.25	0.31	1.69
14	0.24	0.33	1.67
15	0.22	0.35	1.65
16	0.21	0.36	1.64
17	0.20	0.38	1.62
18	0.19	0.39	1.61
19	0.19	0.40	1.60
20	0.18	0.41	1.59

Upper control limit for $\bar{X}$ = UCL $\bar{X} = \bar{X} + A_2 \bar{R}$

Lower control limit for $\bar{X}$ = LCL $\bar{X} = \bar{X} - A_2 \bar{R}$

Upper control limit for R = $UCL_R = D_4 \bar{R}$

Lower control limit for R = $LCL_R = D_3$

Table 7.20 <u>Factor for Determining $\bar{R}$ the 3-Sigma Control Limits for $\bar{X}$ and R Charts</u>

(Source, Grant of Levenworth: <u>Statistical Quality Control</u> (sixth edition) Mc Graw Hill Book Company (1988) page 670)

Fig 7.7 Control Charts

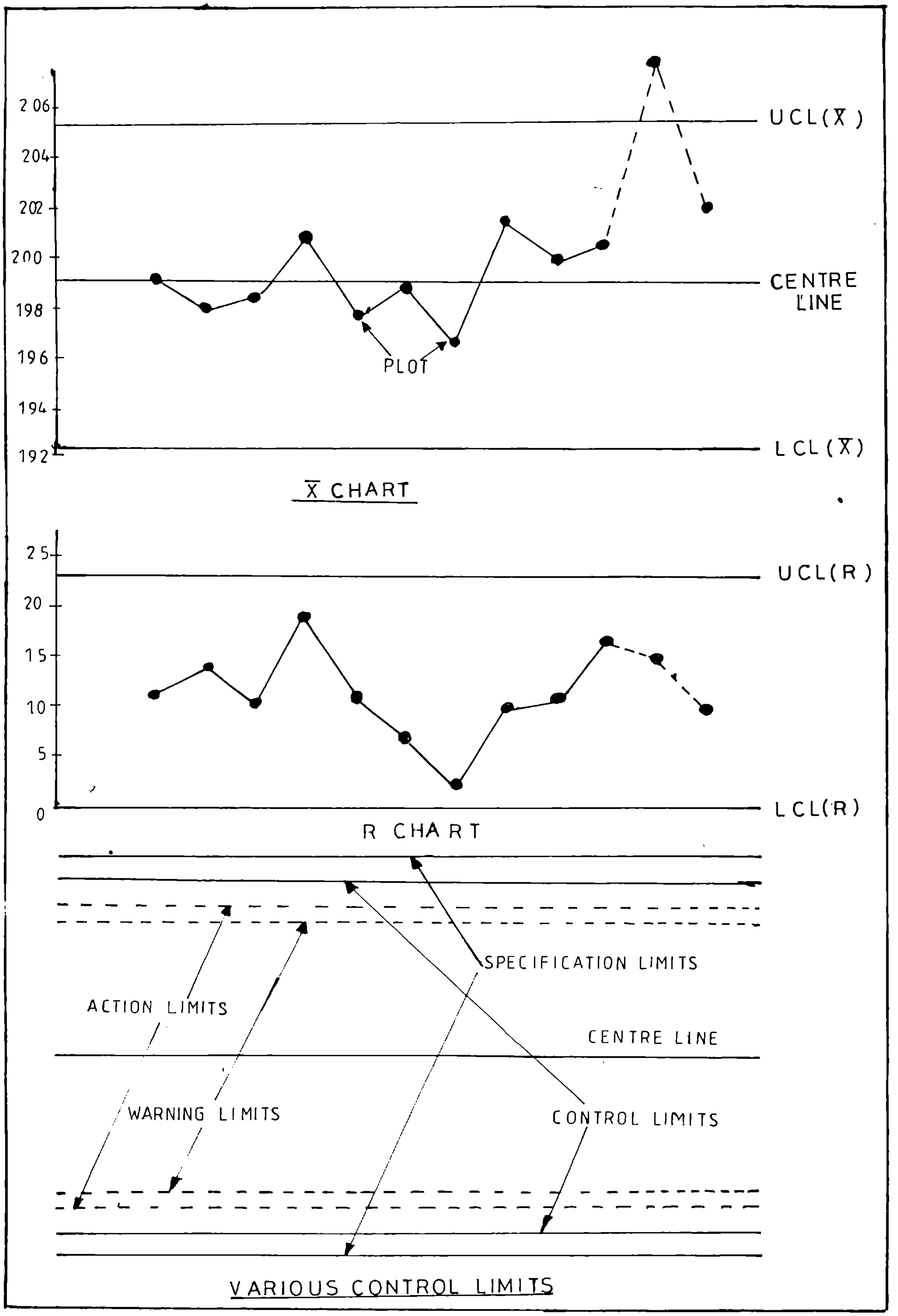


Table 7.21 Example Showing the Calculation of Control Limits

Sub group Number	Measured value of a Critical parameter					Sub group Average	Range
1	195	201	194	201	205	199.2	11
2	204	190	199	195	202	198.0	14
3	195	197	205	201	195	198.6	10
4	211	198	193	199	204	201.0	18
5	204	193	197	200	197	197.6	11
6	200	202	195	200	197	198.8	7
7	196	198	197	196	196	196.6	2
8	201	197	206	207	197	201.6	10
9	200	202	204	192	201	199.8	12
10	203	201	209	192	198	200.6	17

Average of $\overline{X}$ values $= \dfrac{1991.8}{10} = 199.18$ $(\overline{\overline{X}})$

Average of R values $= \dfrac{112}{10} = 11.2$ $(\overline{R})$

From Quality control tables (see table 7.18) for a sub group size of 5,

$$A_2 = 0.58$$

$$D_3 = 0$$

$$D_4 = 2.11$$

Here control limits for average $(\overline{X})$

$$UCL\ \overline{X} = \overline{X} + A_2\ \overline{R} = 1991.18 + 6.496 = 205.676$$

$$LCL\ \overline{X} = \overline{X} - A_2\ \overline{R} = 199.18 - 6.496 = 192.684$$

Control limits for range (R chart)

$$UCL_R = D_4\ \overline{R} = 2.11 \times 11.2 = 23.632$$

$$LCL_R = D_3\ \overline{R} = 0 \times 11.2 = 0$$

(Both $\overline{X}$ and R values are within control limits) a plot goes out of control, we have to take remedial actions. For this, a diagnostic study is to be conducted. One or more factors may be contributing to this deviation. Corrective action is to be initiated, and the characteristic can be brought under control. However, we can take preventive measures also, so that points do not go out of control. 'Warning limits' and 'action limits' are also drawn in control charts so that any deviation when it occurs can be detected in advance and preventive measures can be taken, ensuring that the quality characteristic is kept within specified limits.

Application in Passenger Road Transport Industry

While control chart techniques have found wide-spread use in production oriented industries, it is yet to take its roots in the management of passenger road transport industry. Many areas of operation and maintenance of vehicles will benefit from control chart techniques. Some of the parameters which can be monitored using control charts include the following.

1. Absenteeism of operating crew
2. Schedule cancellations.
3. Number of complaints received from public during every month.
4. Spare consumption in rupees in a depot every month.
5. Occurrence of accidents/10000 Km.operated.

6. Breakdown rate of vehicles.

The management can identify the critical parameters, and fix some desired or 'specified' values for them. Monitoring can be done on a weekly or monthly basis. The various factors contributing to a possible variation can be identified, and remedial action can be taken. In fact, the whole philosophy of control charts is prevention, rather than that of taking action once the damage has already been done. Performance objectives can be reviewed periodically and standards may be modified, so that the system works even better in the days to come.

7.9 Conclusion

Summing up, in this chapter on maintenance aspects, some of the important factors which can influence the efficiency of maintenance were discussed. These were (i) Replacement age of vehicles, (ii) Unit replacement, (iii) Preventive replacement, (iv) Energy conservation, (v) Maintenance priorities and (vi) Use of the control charts technique. Application of these techniques has their cost-benefit implications. A judicious use of these techniques will go a long way in improving the efficiency of the maintenance function in a passenger bus transport undertaking.

CHAPTER - VIII

PLANNING FOR FUTURE

8.1 Importance of an Efficient Passenger Bus Service System in the Days to Come

Looking at the travel scenario of Trivandrum City and its adjoining areas, it can be easily seen from past trends that there will be a steady increase in travel demand in the days to come due to the following factors: 1. Increase of population in Trivandrum City and adjoining areas

2. General economic development, as reflected in the income level of the people and greater disposable income in consequence

3. Increase in travel length due to dispersion of housing colonies, offices, institutions, etc. in a wider area.

Unless the public transport system is able to meet this growing demand, passengers will be put to great difficulties and this is likely to be reflected in other walks of life such as work culture, education, family life, etc. A part of the population which is comparatively better off may be able afford to use their own conveyance, such as a two wheeler, an automobile, etc. But increase in motor vehicle population will add to the congestion on the roads, in addition to causing excessive energy (fuel) consumption and atmospheric pollution. An efficient public transportation system will go a long way in saving precious fossil fuels. If adequate bus services are provided to the outskirts of the City from the central area, it will also help to disperse the residential pattern of the population. This will help to reduce congestion in the heart of the city.

8.2 Tomorrow's Requirements

The population growth of Trivandrum City since 1961 is shown in Table 3.1 and the projected population for 2001 AD is about 6.5 lakhs. However, this projection is based on a decadal growth rate of 17.93% based on the 1971 and 1981 census. The actual growth of population in Trivandrum city during the last decade (1981-1991) was only 8.42%. Hence a more likely population figure for the city by the year 2001 can be estimated to be around 6 lakhs. By the year 2011 AD this is likely to be around seven lakhs. While this shows that Trivandrum is only a slow growing city the projected population for Trivandrum city region metropolitan area, including the 15 panchayats adjoining it for the year 2001 is likely to be about 13 lakhs. (195, p 99) The population of this area in 1981 was about nine lakhs and assuming a growth rate, two lakhs per decade, the population of Trivandrum metropolitan area in 2011 AD would be around 15 lakhs. Trivandrum City services will be required to serve this growing metropolitan area and its population and any planning done now should take into account these requirements.

As has already been mentioned, population should not be the only criterion to decide the extent of bus services to be provided. (10, p 419) The annual increase in the income level of the people of Kerala is presently in the order of five percent.(199, p 8) This will mean a decadal increase of about sixty percent. There have been marginal increases in the travel lengths of people also. The average travel length of passengers in Trivandrum City Services, which was 7.5 kilometres in 1985-86 has increased to about eight kilometres in 1990-91. (190, 1990-91, p 74)

Considering these factors also, the fleet size of city services may have to be augmented to be around 750 buses during the year 2001 (from the present size of 467) and 1000 buses during the year 2011. These increases would be just sufficient to maintain the existing quality of services, which is already very poor.

The above projections are based on three factors: (i) A decadal growth rate of about twenty percent in the Trivandrum Metropolitan Area as projected by the Department of Town Planning (ii) A decadal growth rate of sixty percent in the income level of the population and (iii) A decadal growth rate of ten percent in the average route lengths of passengers. However, these values are only modest estimates and if more buses are available, the quality of the operation of the services can be enhanced.

8.3 Town Planning and Infrastructural Facilities

Traffic needs in the years to come will greatly depend upon the type of development that is planned for the City. In Trivandrum City, the Department of Town Planning proposes three alternate ideas for development.

1. Development of the core (central) area. All future developments proposed to be concentrated within the central core, will lead to a 'compact city' with high intensity of development.

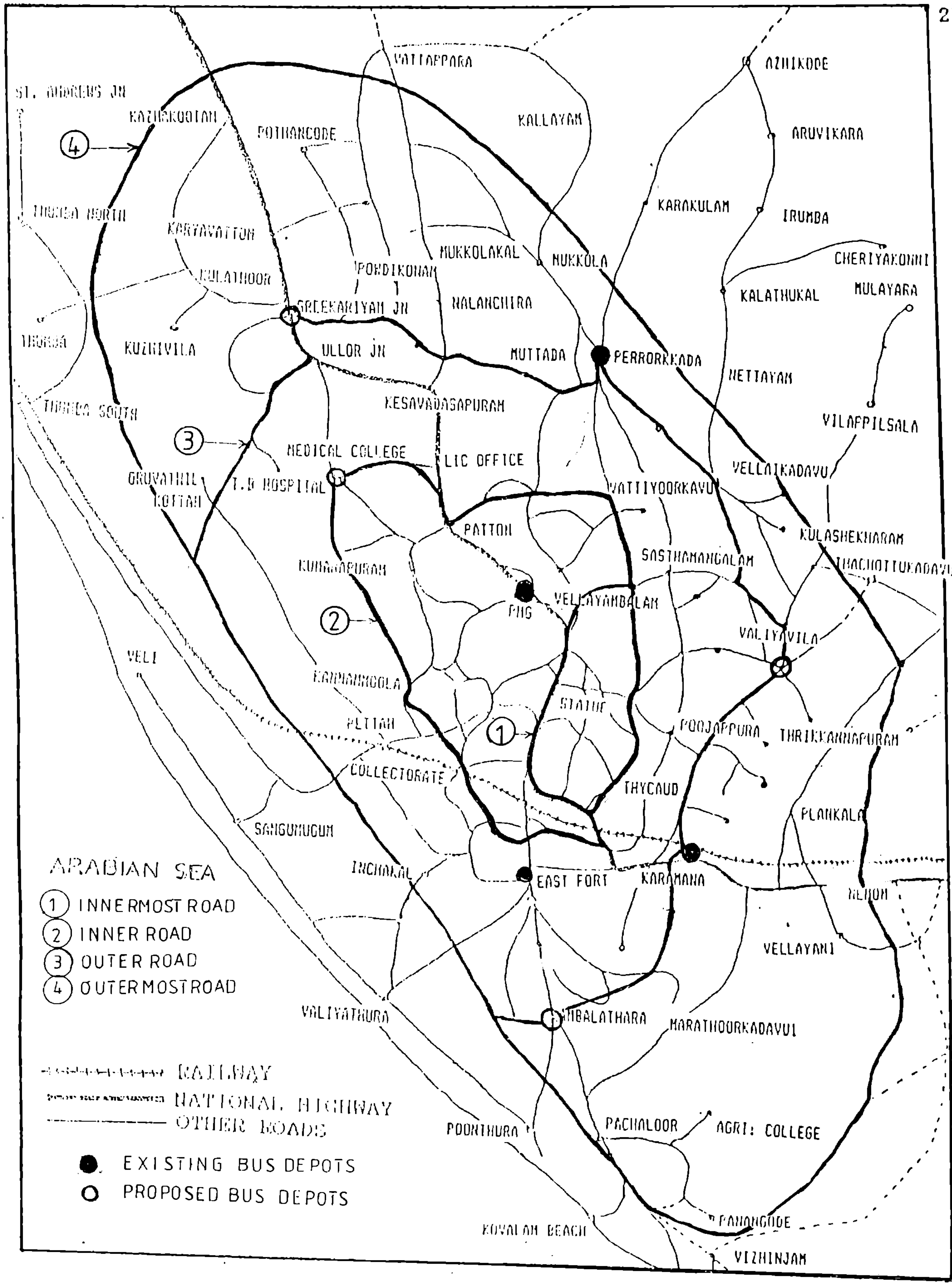
2. In future developments the present trends of spread out to the peripheral areas will be encouraged to continue, leading to urban sprawl and higher investment in infrastructural development. The core area will be left as it is and the development will be in the annular area around the core area.

3. This is a combination of alternatives 1 and 2. Future developments will be suitably directed in such a way as to identify priority development zones where the present infrastructure can absorb more activities and where infrastructure development may need comparatively less investment. This may be a compact city spreading out in the desired directions with incremental investment. (195, p 95)

From the point of view of providing transportation, alternative (2) is, perhaps, the best choice since any type of concentration of facilities will only add to the existing strain on the public transport system. Perhaps a rail system or an underground rail system would be ideal, but this would be quite capital intensive.

Providing a better road network is the next important priority. The existing roads are to be widened. A radial and circular road pattern can possibly be developed, as may be seen from Map 8.1. Four circular roads - the innermost circle, inner circle, outer circle and outermost circle - are to be developed. The suggested pattern of these roads, in the form of concentric circles is based on the 'centre to outwards' growth pattern of Trivandrum City, as may be seen in the traffic contours in Fig 5.3. The outermost circle is drawn, based on the alignment of a circular link road as proposed by the Town Planning Department in the development plan for Trivandrum Metropolitan Area. The redeeming feature of this plan, apart from cost, is that radial roads are already in existence, but then, they will also have to be widened suitably. If this road network system is suitably developed and maintained, it will go a long way in solving the transportation problems of the Trivandrum Metropolitan Area.

Map 8.1 Trivandrum City - Circular Roads



8.4 Operational Aspects

From the point of view of bus operation, location of new depots is another important criterion. In addition to the existing four depots, four new depots each of which will carry a fleet size of about 125 buses are proposed to be established, when the total number of buses operated in the city will increase from 467 to 1000. The location of these depots are at present proposed as follows:

1. Medical College.
2. Sreekaryam.
3. Poojappura / Thirumala.
4. Ambalathara.

The location of these new bus depots is suggested by taking into consideration a 'main and satellite' pattern of depot configuration, which is most suitable for Trivandrum City. A time frame is to be deciphered for the establishment of these depots. When a new depot is commissioned, fleet allocation in all the depots is to be made suitably. When all the eight depots are in operation, it may be advisable that the mother depot status is equally shared by the East Fort and PMG depots, since they are located in the inner circle of the road network. Circular services, connecting these depots may also be operated so that passengers do not have to come to the centre of the city every time for going from one place to another.

Traffic surveys are to be conducted every two or three years to assess the changes happening in the travel pattern and travel demand. Based on this survey, bus allocation to depots can be changed and rescheduling can be done. A system of inviting suggestions and opinions from the travelling public during rescheduling may help in incorporating changes beneficial to them. A suitable computer software may also be developed, which can be used to draw up the revised time tables, once the changes in the travel demand data are collected.

A close interaction of the transport authorities with the town planning authorities and the local bodies is also required. This is lacking now. The city goes on growing under different schemes and the city transportation system is required to provide somehow or other the transportation facilities arising on account of establishment of new offices, shopping centres, residential, commercial or industrial complexes etc. A co-ordinated effort of all agencies involved in the process, such as of town planning, civic authorities, public works, transport corporation etc., may be able to solve the numerous transportation problems that may arise out of development.

8.5 Maintenance and House keeping

While considering the maintenance aspects of vehicles for the coming decades, the changes and improvements that are happening around the world in vehicle technology and transportation management may also have to be taken into account. These include such items as the following.

1. Fuel efficient engines.
2. Lighter chasis and busbody.
3. Aerodynamic body design.
4. Use of nonmetallic components.
5. Availability of technologically improved components and subassemblies, etc.

Unless a time bound plan for modernisation, acquisition of new generation vehicles and assimilation of new technology is made, the Trivandrum City Services will be left behind others with an obsolete fleet and other operational problems. Suddenly, privatisation has become the policy of the day. The average age of vehicles has to be brought down to a respectable figure of three or four years with the replacement age around seven years, as was pointed out in the previous chapter. This will go a long way in increasing the availability of vehicles, reducing maintenance effort and subsequently spare parts consumption. Reliability of the services from the consumer point of view will also greatly improve.

In the area of maintenance management, new techniques like unit replacement or floating unit system, preventive repair etc. may also be required are to be adopted. Computerised log books are to be kept, and centralised monitoring may have to be done, for each vehicle. A time schedule may have to be prepared in advance for the major repairs and overhauls to be done for each vehicle. When advanced planning is done for docking the vehicles for repairs, it may be necessary to have a clear idea regarding the availability of vehicles for operation and otherwise from time to time. Allowance may have to be given to take into account breakdowns, accidents and other unanticipated events.

8.6 Computerisation

The first computers came into use during the early fifties, but it was during the early seventies that their use became widespread. Since then, with the advent of microprocessors, there had been spectacular changes in the capabilities of computers. What mainframe computer did during early seventies, can now be done with a personal computer. Variety and versatility of the software has increased. Techniques like laser printing, colour drafting, networking etc. have come into existence. The cost of the computers has also progressively come down, so that it has become affordable to larger segments of the population. The nineties will undoubtedly see further improvement in the capabilities of computers and widespread increase in computer usage. In long range planning for transportation, the application of computers for planning and operation will be a major factor for improvement in performance of the Trivandrum City Services, if it proposes to manage its activities in a more systematic manner.

Computerisation can be effectively utilised in passenger road transport management in many critical areas like the following.

1. Pay roll accounting.
2. Provident fund accounting.
3. Financial accounting.
4. Purchasing.
5. Materials management and stock keeping.
6. Ticketing and accounting of revenue.
7. Passenger ticket reservation.
8. Performance reports.
9. Traffic surveys and analysis of traffic data.
10. Routing and scheduling of vehicles.
11. Maintenance.
12. Management and analysis of vehicle log books.

<u>The need for Computerisation</u>

The KSRTC operation, even within Trivandrum City, involves tens of thousands of passengers, a large operating crew and hundreds of vehicles every day. Enormous data is generated like details of tickets sold, bus schedules operated, breakdowns, accidents, crew employed, consumption of materials, etc. In small undertakings, it may be possible to process this data manually for more efficient operation. But larger transport undertakings having more than say 100 buses may find it difficult and time consuming to process such data manually and obtain the results in different desired formats. Manual data processing is also likely to be tedious, time consuming and error prone. Details of daily collection, EPKM (earnings per kilometre), load factor etc. can be maintained every day on the computer. Online inventory management systems can keep track of the inventory on a daily basis and make the large exercise of annual stock taking quite unnecessary. Computerised passenger ticket reservation facility, now available with some transport corporations, is also likely to add to the convenience of the travelling public. Computerisation can also help in rescheduling vehicles according to the changes in travel demand. It can also be gainfully used in maintenance, replacement decisions and fault diagnosis.

8.7 Status of Computerisation in State Road Transport Undertakings in India

In India, there are about 60 public sector passenger road transport undertakings, having a total fleet strength of more than one lakh vehicles. While two of them, viz., the Maharashtra State Road Transport Corporation and the Andhra Pradesh Road

Transport Corporation, have a fleet strength of more than 10,000 vehicles each, a vast majority of the state transport undertakings have fleet strengths varying between 500 to 10,000. Among them, 25 state transport undertakings have computerised their operations, to varying extent. (60, p 26) The Andhra Pradesh Road Transport Corporation has a separate department of computerisation and has computerised its depot level operation also. While about 15 undertakings are using computers in both headquarters and depots, the remaining have computers only in their headquarters. Two undertakings, viz. BEST and MSRTC have main frame computers, while others have mini computers and personal computers of different varieties. The broad areas which have been computerised at present are the following.

1. Pay bill accounting.
2. Provident fund accounting.
3. Inventory and materials management.
4. Financial accounting.
5. Ticketing and revenue.
6. Maintenance management.
7. Personnel management.
8. Route rationalisation.
9. performance reports.
10. Accident analysis.
11. Fuel consumption.

12. Tyre performance analysis.

13. Battery performance analysis.

The software required for these have been mostly prepared by consultants like Computer Maintenance Corporation, Tata Consultancy Services, National Informatics Centre etc. A few undertakings have developed their own software. All state transport undertakings find it difficult to attract and retain qualified computer professionals since they are offered much higher salaries in many other public and private sector units.

8.8 Computerisation in KSRTC - The State of the Art

The Kerala State Road Transport Corporation has a full-fledged computer centre, working under the Manager Management Information Systems as a part of its statistical section. It has one PC-AT, one PC-XT and ten PCs. For getting the output of the data, there is a dot-matrix printer and a line printer having a capacity of 300 lines per minute. The total investment in the hardware will be in the order of ten lakhs rupees. On the personnel side, there are two programmers and twenty data entry assistants. All the personnel have been selected from KSRTC itself and were given suitable training. The computer centre presently works on a two shift basis.

The main areas which are presently computerised are as follows.

a. Inventory : Mainly record keeping like Goods Received, Issue Notes, Local Purchase, Stock of Items etc., including inventory data processing. Inventory control is yet to be computerised.

b. Personnel management : A complete data bank of all employees is kept, which is useful for transfers, posting, promotions, training programmes, etc.

c. Provident fund accounting : The provident fund accounts of the employees were not at all upto date as there was a backlog of about five years, which is presently being updated. One shift of the computer centre is at present entirely engaged in provident fund accounting work.

d. Maintenance : Important maintenance works done on vehicles are now logged in the computer.

e. Operational and financial information : Daily collection data, kilometres operated, breakdowns, etc. There is also a daily ranking of ten 'top' depots and ten 'lowest' depots, taking into account various factors like collection, kilometres operated, breakdowns, accidents, schedule cancellations, etc.

The computer centre is a common facility, located at the head office of KSRTC. It can be seen that there are many more areas of operation which can be computerised. Since there are no depot-level computers, there is no exclusive computer facility for Trivandrum City Services.

8.9 New Avenues for Computerisation

While computerisation has made a good start in many of the state road transport undertakings, much remains to be done. There are many more areas which can be computerised, such as the following:

1. Traffic surveys and analysis of travel demand.
2. Routing and scheduling of vehicles.
3. Crew scheduling.
4. Scheduling trips for educational institutions, including 'students only' trips.
5. Computerised log books for vehicles.
6. Maintenance scheduling.
7. Expert system for fault diagnosis.
9. Networking of depots, using computers etc.

In urban transport operation, where travel demand and traffic pattern are susceptible to constant changes, immediate changes in schedules can be made in response to the changing requirements. It may be a few additional services required for a public event in some part of the city, some extra buses required for an annual festival lasting a few days or catering to the travel demand of a new housing colony which has come up in the outskirts of the city etc. Time tables may be modified easily as per changing demand using the computer, every six months or every year.

8.10 Computerised scheduling of Vehicles in a Route

To demonstrate the usefulness of computerised vehicle scheduling, consider a route of length 13.5 kilometres, divided into nine links or interfare-stages. Let the bus operation be from 5.ØØ A.M. till 11.ØØ P.M. Demand matrices of size 1Ø x 1Ø are prepared from way bill analysis, at an interval of 15 minutes. That is to say, there will be 36 demand matrices corresponding to the timings Ø5ØØ Hrs, Ø515 Hrs,..... up to 2245 Hrs. A sample matrix of this type is shown in Table 8.1. The half matrix on the upper right hand side shows the details of outward passengers and the half matrix on the lower left hand side shows the details of inward passengers. In this example, the total number of passengers is 8995 for the whole day. Fig 8.1 shows the pattern of traffic variation during the day, considering the total number of passengers. Using this data contained in the 36 demand matrices which is based on the bus operation, other details like the following can be obtained:

1. Number of passengers travelling from a node during each time of the day.
2. Number of passengers travelling to a node during each time of the day.
3. Number of inward passengers during each time of the day.
4. Number of outward passengers during each time of the day etc.

Fig 8.1 Diurnal Variation of Passenger Traffic in a Route

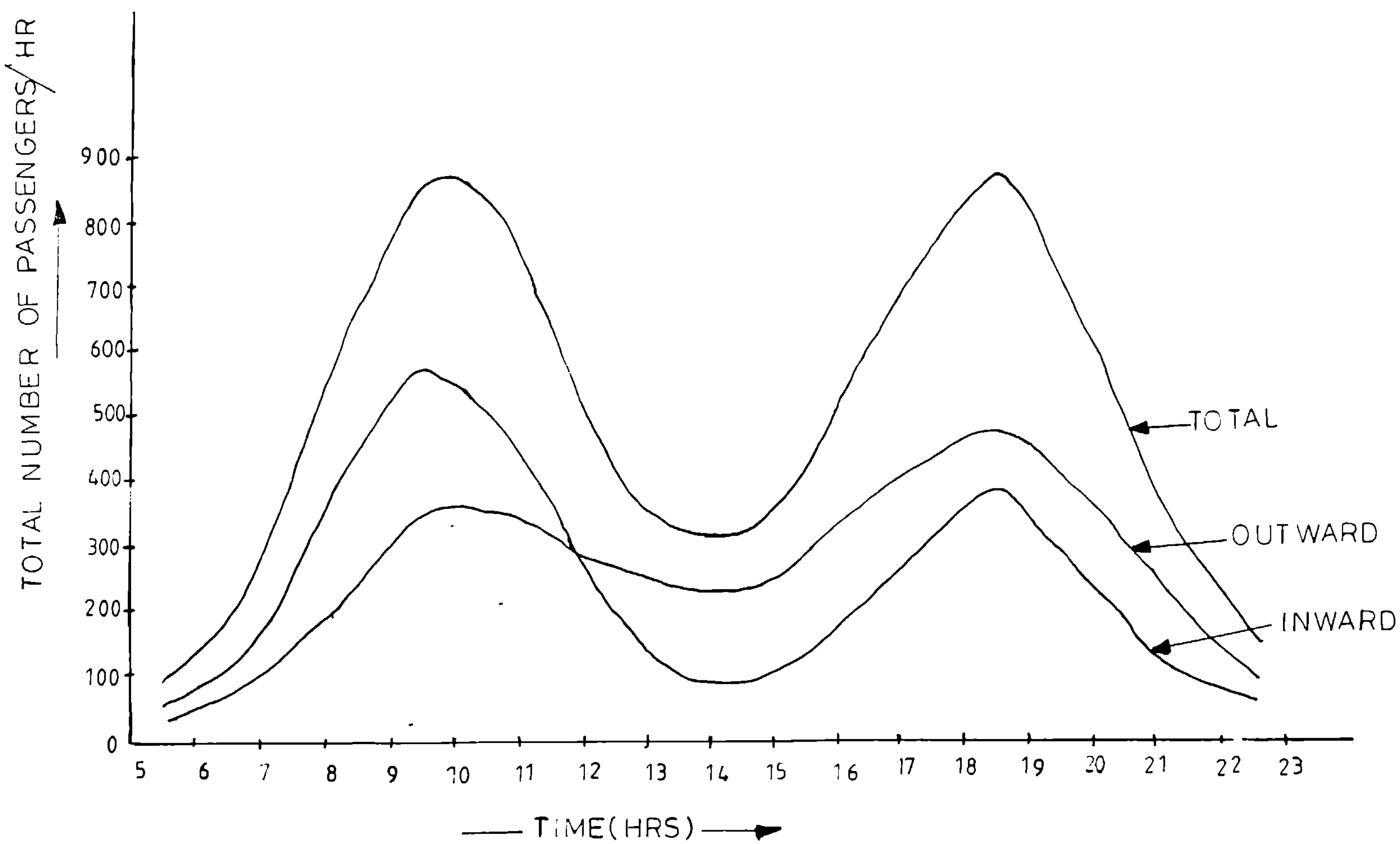
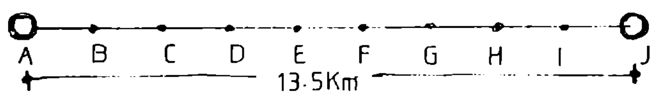


Table 8.1 A Typical Demand Matrix

TIME 0500 HRS

ORIGIN 

DESTINATION

Route length - 13·5 Km   length of a link - 1·5 Km

Number of links - 9

Speed of the bus   3 links in 15mts or 12 links/hr or 18 Km/hr

FROM \ TO

	A	B	C	D	E	F	G	H	I	J	TOTAL
A	-	1	1					1			3
B		-	1		1						2
C	1		-		2		2				4
D	1	1		-				1			1
E			2		-						-
F		1				-					-
G			2				-				-
H	1		1					-			-
I									-		-
J										-	-
TOTAL	3	2	5	-	-	-	-	-	-	-	20

Also a graphic display is shown regarding the details of passengers corresponding to a demand matrix.

Buses can be scheduled for departure from the origin at fixed intervals. The total running time to cover the route length of 13.5 km is taken as 45 minutes. The return trip starts after five minutes intervals and hence the total time taken for an onward and return journey is 95 (45+5+45) minutes. The bus again waits for five minutes in the depot, before going for the next trip. The normal bus capacity is taken as 60 passengers (including standees). During peak hours, which can be specified, the bus capacity and operational frequency can be increased, if required. Bus trips will be listed, showing its departure and arrival timings and details like the total number of passengers carried, the total collection, the load factor and the EPKM for each trip can also be shown. After operating the trips, it can be verified whether any residual passengers, i.e. passengers who missed the bus are left. The average waiting time of the passengers can be calculated, once the bus frequencies are known. An Appendix showing the computer program and related data are given at the end. (Appendix - 1)

The greatest advantage of computerised scheduling is its flexibility. Changes can be made in the various parameters like passenger carrying capacity, speed of the bus, length of the trip, frequency of operation, fare structure etc. Once a software for scheduling is made, it is easy to reschedule the vehicles when a change occurs in any of the controlling parameters.

8.11 Computerised log books

Log books are registers kept for each vehicle to record the details regarding maintenance, replacement of parts, overhaul etc. A log book is to be opened when a vehicle is commissioned for service and should be kept till it is condemned or sold. The usual practice is to keep a separate log book for each vehicle. It is kept in the depot to which the vehicle belongs. When an ordinary log book like a note book, is kept it is difficult to get information like the following.

1. Number and identity of vehicles which have logged more than 2 lakh kilometres.
2. Vehicles which are fitted with a particular brand of starter motor.
3. Number of breakdowns due to brake failure in any given year
4. Vehicles which are giving a mileage of less than the accepted or acceptable mileage rate.

The above listing is not exhaustive, but has been for illustrative purposes.

When vehicle log books are kept in a computer, it is in a centralised place and the type of data mentioned above can be processed and obtained easily. However, in a transport corporation which has several depots, log book data from depots should be fed into the main computer every week, fortnight, or at least once in a month depending on the use to which they are put. Computerised log book can also be made to remind the management to do the necessary maintenance or replacement to be done to the vehicle from time to time. For example, it can be programmed to inform the management when the different activities like the following are to be done.

1. Engine of a bus has completed three lakh kilometres and has, therefore, to be sent for overhauling.
2. A new bus has completed 10,000 Km and this has to be sent for its third service.
3. Fuel injection pumps in the following vehicles have completed 50,000 Km and are to be reconditioned.

In any case, computerised log books will go long way in improving the maintenance and thereby the reliability, availability or dependability of vehicles.

8.12 Cost of Computerisation

The cost of computerisation will depend upon mainly three factors: 1. Cost of the hardware, i.e. the computer and related accessories, air conditioning units, uninterrupted power supply (UPS) etc. 2.

Operating expenses of the computer and 3. Salary of computer personnel. While a simple personal computer and accessories may cost, in most cases, less than Rs 50,000, the cost of a good main frame computer with a large number of terminals may go upto a crore of rupees or more. While deciding upon the computers to be purchased, factors like the following may have to be examined.

1. Areas of operation which are to be computerised, such as wages, purchase, cash collection, etc.
2. Volume of the data involved; and
3. Type of processing to be done with the data, and the details of outputs required.

While most of the public sector transport undertakings in India have installed only several personal computers like simple PCs, XTs or ATs some undertakings have gone for minicomputers and even main frame computers. In any case, in the years to come, computers and computerisation will play a significant role in passenger road transport management.

In conclusion, planning for future involves several steps. The first one is the assessment of the growth pattern of the city. Development of infrastructural facilities is to be based on this. Travel needs of the people are to be assessed, and new bus depots are to be located. Fleet allotment to these new depots and to the existing depots is to be based on travel demand data. In maintenance and house keeping techniques like economic replacement age, preventive repair etc. will greatly improve the availability of vehicles. Computerisation can be gainfully made use of in bus scheduling and other areas of bus transport operation, like maintenance, purchasing, accounting, etc. Proper forward planning, both long range and short range, will go a long way in improving the efficiency of any passenger road transport system.

CHAPTER - IX

CONCLUSIONS AND RECOMMENDATIONS

9.1 Conclusions of this study

Successful management of an urban passenger road transport system is possible only through a collective effort by the bus operator, the town planning authorities, local bodies, the government and the travelling public. An efficient transportation system is a boon to society and an inefficient one its bane. The transportation system of any city will be positioned somewhere in between these two extreme conditions. Moving backwards is easy, while moving forwards to a more efficient system requires a concerted effort from all those who are concerned with it.

The aim of this study was primarily to explore a few avenues, or areas of action which can make the public transportation system of Trivandrum a little more efficient than what it is now. Trivandrum is a typical 'second order city' which has urban transportation problems like any other city in India and other developing countries. Therefore, a study of its problems and the methods of their solutions have applicability to other similar cities.

Trivandrum, at present is a medium sized city with a population of about 5.25 lakhs. Even if the seven adjoining panchayats are also taken into account, its population is only seven lakhs. The urbanisation rate is also comparatively low. This means that there is still time left, before its condition deteriorates to an incorrigible stage.

The most basic requirement in attempting to design a proper transportation system is that a systematic and rational approach is adopted, instead of depending on adhoc solutions. This includes all areas; such as town planning, assessment of travel needs, depot location, fleet allocation to depots, vehicle scheduling, maintenance of the fleet etc. Many of these aspects have already been discussed in earlier chapters.

9.2 Recommendations for the Improvement of Trivandrum city bus services

The following are some recommendations made by the researcher for the improvement of Trivandrum City services.

A. Staggering of office and school hours

Meeting the traffic requirements during the peak periods is one of most difficult problems presently faced by the bus operator in Trivandrum City. This problem is more acute during morning hours than in the evening. At present all educational institutions start working at 9.30 A.M. It may be recalled that previously both schools and offices used to start working at 10.00 A.M. Timings of schools and colleges were 10.00 A.M. to 4.00 P.M. and that of the offices were 10.00 A.M. to 5 P.M. It was during the sixties that a slight advancement by 30 minutes was effected for educational institutions, making its timings as 9.30 A.M. to 3.30 P.M. This benefit is already neutralised to a certain extent since in many central government offices and public sector undertakings which are working on a 5 day week basis, the office hours have been changed as to start at 9.30 A.M. Hence, if any levelling is to be obtained in the morning peak, the timings of educational institutions should be advanced by at least one hour, that is, they should function from 8.00 or 8.30 A.M to and may go upto 2.00 P.M. or 2.30 P.M. Institutions functioning in the outskirts of the city may perhaps have a different timing, such as from 9.00-3.00 P.M., since they do not contribute to the traffic congestion as much as those located in the centre of the city. The evening peak will also be smoothened further due to this change. One important step to be undertaken before implementing this is an assessment of the traffic demand of students using the city services. This can be easily done using the register of concession tickets. Scheduling of services to meet the student demand can then be undertaken.

B. Encouraging Educational Institutions and Other Organisations to Operate Their Own Buses

Already many educational institutions, both government and private and other organisations like ISRO are operating their own vehicles. If more institutions and organisations join this fold, that much traffic load will be taken off the public transport system. The operating expenses of these buses are usually met from the fees that are collected from the students who use these services. These fees are invariably much higher than what they pay for the KSRTC services. KSRTC already has a scheme of selling their old buses to educational institutions at concessional prices, but this scheme has not been taken full advantage of by the educational institutions. Since an efficiently operated bus service handled by a company may tend to attract many of those who are otherwise using their own conveyance, it may help to save a considerable amount of fuel and reduce air pollution within the City. Another advantage is that it relieves the public transport system of some peak load traffic, which is the time when the public transportation system is put to maximum strain.

C. Circular and Through Services

The present pattern of operation of bus services in Trivandrum city is radial services, with the bus depot as the centre. That is to say, the origin of the trips is from the bus depot and the destinations are places in the outskirts of the City. In addition to this pattern, two types of services viz. the circular and through services can be thought of. Through service would be like the diameter of a circle - from one point in the circumference to another point in the circumference which will be highly beneficial to the travelling public. It will be advantageous to the traveller and the management since it saves unnecessary travel by passengers to the centre of the city every time to get a connecting service. The extent of such services to be provided can be ascertained from the O/D survey. Circular trips can be operated at a given frequency in both directions along the circular roads. Frequency of operation can be more in the inner circles when compared to the outer ones.

D. Conduct of Traffic Surveys

As we have already seen, assessment of travel requirements may be made the basis for vehicle scheduling. Since the travel demand pattern is ever changing, due to the establishment of new housing colonies, shopping centres etc., the traffic surveys (both volume survey and O/D survey) are to be conducted once every two or three years if not more frequently. It can be conducted directly by the KSRTC or through any other agency. Expenditure for the same, which will amount to a few lakhs of rupees, will be easily realised due to additional earnings through better scheduling. Moreover, it will add to the convenience of the passengers. Processing of the data collected during traffic survey can easily be done using a computer.

E. Separate Schedules for Week Days, Saturdays and Public Holidays

The Travel requirements in a city on the several days within a week is different. Separate schedules are required for week days (Monday through Fridays) when both educational institutions and others like factories, offices are etc. working. Saturdays which are holidays for educational institutions, but a working day for most of the offices and Sundays and other public holidays may have different traffic demand. The pattern of travel demand during holidays will be altogether different from other days. More buses are to be provided for leisure travellers, who may probably want to go to places like the museum, beach or Kovalam. Needless to say, the time-tables of the city services should be published regularly so that the travelling public are made aware of these changes within the week.

F Rail-Road Co-ordination

There are three railway stations in Trivandrum City, viz. the Trivandrum Central, Trivandrum Pettah and Kochuveli. Among these, the Trivandrum Central is by far the most important railway station. It is located opposite the Thampanoor KSRTC bus depot which operates the mofussil and long distance services. The City Bus Depot at East Fort is less than one kilometre away. It is estimated that about 10,000 passengers arrive at the Trivandrum Central station every day, while the corresponding figure for Trivandrum Pettah is about 2000. A vast majority of these passengers depend on city bus services for coming to these stations and also for going to various places in the city. If bus services can be dovetailed to the demand of rail passengers, it will be a great boon to the travelling public. Already some early morning trips are operated for the benefit of passengers to reach Trivandrum Central station to catch trains like the Venad Express, Parasuram Express etc. However, no suitable bus services are provided to office goers and others arriving at the Trivandrum Central railway station during morning hours. Bus services complementary to the rail services will be of great help to passengers who make use of both modes of conveyances.

G. <u>Town Planning and Road Development</u>

A more detailed discussion about the importance of linking town planning and road development has already been done in the previous chapter. By providing facilities like schools, shopping centres etc. near housing colonies and satellite townships, travel demand can be effectively reduced. Also, wider roads, especially radial and ring roads, may help the smooth operation of bus services. Moreover, the involvement of the public transport authorities also in the process of town planning will go a long way for the co-ordinated development of the city.

H. Satellite Depots

The advantages of multidepot operation have already been discussed. In addition to the existing depots, new depots may have to be established, as the fleet strength of the city bus services grows. The suggested locations are at Medical College, Sreekaryam, Ambalathara and Poojappura. An equitable fleet allocation to these depots is also to be made, taking into account the traffic load these depots have to share.

I. Variable Running Times

The running time between any two places is now treated as of a fixed duration. This is not realistic in city services, since more time is required during peak periods due to traffic congestion and other problems. This is especially true of buses operating in the heart of the City. A variable running time pattern can be adopted, taking into account the two factors: 1. Period of operation during the day and 2. The area of operation, i.e. whether it is in the centre of the

City or in the outskirts. This will be more realistic and pragmatic. Such changes can be easily incorporated while computerised scheduling is done.

J. Point to Point Mini Bus Service

Mini bus services, having a seating capacity of 20-25 passengers can be operated by KSRTC or some other agency with a slightly higher fare structure, operating between fixed places, at fixed intervals. These places can be important passenger destinations in the city like the Medical College, Cantonment, Thampanoor, etc. The advantage is that if at least 50,000 passengers can make use of this parallel transport system every day, the city services will be relieved of that much passengers load. A small portion of the passengers may also be attracted by this service who may otherwise be travelling by autorikshaws or their personal conveyance. Needless to say, these services should not allow standee passengers and should provide more comfortable and punctual services than what is presently offered by city bus services.

K. Replacement Age of Vehicles and adequate maintenance

The necessity of replacing vehicles at an optimal replacement age has already been discussed in Chapter-7. It is essential that the vehicles are to be replaced at least during the eighth year, keeping the average age of the fleet at around 3.8 years. Also, proper maintenance methods can give longer useful life to the vehicles and reduce operating expenses. Both economical and technical factors are to be taken into account in determining the replacement age of vehicles. In any case, a time bound plan for the retirement of old vehicles and purchase of new vehicles is required, to keep the fleet in road worthy condition.

L. Techniques to Improve the Availability of Vehicles

Improved maintenance techniques like preventive repair, unit replacement system etc. have already been discussed in chapter-7. These techniques, when implemented properly, will increase the overall availability of vehicles, by reducing their down time. Needless to say, proper maintenance of vehicles will also make them more fuel efficient, thereby making a savings in the fuel bill also. It will also increase the revenue earnings since effective kilometres operated per bus will show a significant improvement.

APPENDIX - 1

COMPUTER PROGRAMME

```
10      KEY     5,"8Ø"+CHR$(13)+"1Ø"+CHR$(13)+"8ØØ,1ØØØ"+
CHR$(13)
2Ø      KEY     6,"9Ø"+CHR$(13)+"5"+CHR$(13)+"16ØØ,18ØØ"+
CHR$(13)
3Ø KEY 7,"1ØØ"+CHR$(13)+"4"+CHR$(13)
4Ø  CLS:KEY  OFF:COLOR  15,Ø:PRINT  TAB(26);"TRANSPORT
MANAGEMEMT SYSTEM":COLOR 7,Ø:PRINT STRING$(8Ø,"_")
45 LOCATE  22,1:PRINT STRING$(8Ø,"_"):LOCATE 7,28:PRINT
"M A I N  M E N U":PRINT TAB(28);STRING$(16,2Ø5)
5Ø LOCATE 1Ø,3Ø:PRINT "1. INPUT DATA":PRINT TAB(3Ø);"2.
CHANGE   DATA   ":PRINT   TAB(3Ø);"3.  RUN   BUS":PRINT
TAB(3Ø);"4. SEE MATRIX";TAB(3Ø);"5. QUIT"
55 PRINT  :LOCATE 16,3Ø:PRINT "YOUR CHOICE    :";:COLOR
15,Ø:INPUT      "",A:COLOR      7,Ø:ON     A      GOSUB
8Ø,2ØØ,25Ø,1ØØØ,9ØØ
7Ø GOTO 4Ø
8Ø  C1=1:CLS:LOCATE  12,25:PRINT  "Computer reading  in
matrix...":DIM MM(72,1Ø,1Ø)
9Ø FOR I=1 TO 72:LOCATE  15,3Ø:PRINT "MATRIX NO:";I:FOR
J=1 TO 1Ø:FOR K=1 TO 1Ø:READ MM(I,J,K)
1ØØ NEXT K,J,I
11Ø  CLS:PRINT TAB(2Ø);"PLEASE  INPUT   THE  FOLLOWING
DETAILS:":PRINT :PRINT
12Ø  INPUT "NORMAL  BUS  CAPACITY (Passengers  per bus)
";NCP:INPUT "NORMAL FREQUENCY OF BUS (Time  between bus
departure in minutes)";NF
13Ø  INPUT  "TIME  OF  MORNING  PEAK  HOUR  (start,end)
:",PS1,PE1
14Ø INPUT  "CAPACITY IN  MORNIMG PEAK HOUR  (passengers
per bus) :",CP1
141 INPUT "FREQUENCY IN MORNIMG PEAK HOUR (time between
bus departure in minutes) :",F1
15Ø  INPUT  "TIME  OF  EVENING  PEAK  HOUR  (start,end)
:",PS2,PE2
16Ø INPUT  "CAPACITY IN  EVENIMG PEAK  HOUR (passengers
per bus) :",CP2
```

```
165 INPUT "FREQUENCY IN EVENIMG PEAK HOUR (time between
bus departure in minutes) :",F2
170 PRINT  : INPUT "ANY FLAW  IN DATA(Y/N)" ; YN$  : IF
YN$="Y" OR YN$="y" THEN 110
199 F=NF:CP=NCP:C1=1:RETURN
200 CLS:IF C1<>1 THEN 203 ELSE 205
203  CLS:LOCATE 12,30:PRINT  "ERROR :  DATA MATRIX  NOT
INPUT!"
204  PRINT : PRINT TAB(30) ; "Press any key to continue
..." : AN$ = INPUT$(1) : RETURN
205 PRINT TAB(20);" PLEASE RE-INPUT DETAILS AS NEEDED "
: PRINT
210 GOTO 120
250 CLS : PRINT TAB(20);"SECTION FOR ACTUAL RUNNING  OF
BUS ":PRINT STRING$(80,"_")
260 PRINT :PRINT :IF C1=O THEN PRINT "ERROR:MATRIX DATA
NOT  INPUT.INPUT DATA ON RETURN TO MAIN  MENU " : YN$ =
INPUT$(1) : RETURN
261 LOCATE  5,15:PRINT "NOTE : EPKM  shows EARNINGS PER
KILOMETRE"
264  PRINT :PRINT  TAB(20);"PRESS ANY  KEY TO  CONTINUE
..." : Y$ =  INPUT$(1) : CLS : ST  = 500 : D=1 :  X=0 :
RS=0 : RST=0 : GOSUB 700
280 PK=0 : LF=0 : EPKM=0 : PU=0 : TB =0 : TU=0 : TC = 0
: X=X+1 : DIM GD(10)
290 IF D=1 THEN A=1:B=9 ELSE A=10:B=2
300 FOR I=A TO B STEP D
310 TS=INT(RS/15)+1:TB=TB-GD(I)
311 IF D=1 THEN C=10:E=I+1 ELSE C=1:E=I-1
321 FOR J=C TO E STEP -D:K=MM(TS,I,J):IF TB+K>=CP  THEN
PA=CP-TB ELSE PA=K
340 MM(TS,I,J)=MM(TS,I,J)-PA:GD(J)=GD(J)+PA
360 TB=TB+PA:PU=PU+PA:PK=PK+PA*1.5*(ABS(I-J))
:TC=TC+(PA*(50+20*(ABS(I-J)))/100)
380 NEXT J:RS=RS+5:NEXT I:ERASE GD
400     ET=500+100*(INT(RS/60))+INT(RS-60*(INT(RS/60)))
```

```
:LF=PK/(CP*13.5):EPKM=TC/13.5
405 IF CSRLIN=22 THEN COLOR 6,0:PRINT STRING$(79,"_")
:PRINT TAB(20);"Press S to stop ,any other key to
continue...":YN$=INPUT$(1):IF YN$="S" OR YN$="s" THEN
RETURN ELSE CLS:GOSUB 700
407 A$=STR$(X)+"."+"("+STR$(ST)+"-"+STR$(ET)+")"
410 PRINT TAB(1);A$;TAB(21);"Rs.";:PRINT USING
"#####.##";TC;:PRINT TAB(37);PU;TAB(55);:PRINT USING
"#.###";LF;:PRINT TAB(70);:PRINT
USING"####.##";EPKM:TEPKM=TEPKM+EPKM
420 IF D=1 THEN
RS=RS+5:ST=500+100*(INT(RS/60))+INT(RS-60*(INT(RS/60)))
:D=-1:GOTO 280
430 RS=RST+F:RST=RS:ST=500+100*(INT(RS/60))
+INT(RS-60*(INT(RS/60))):D=1
440 IF ST>=PS1 AND ST<=PE1 THEN F=F1:CP=CP1:GOTO 460
450 IF ST>=PS2 AND ST<=PE2 THEN F=F2:CP=CP2:GOTO 460
455 F=NF:CP=NCP
460 IF ST>=2045 THEN 600
470 GOTO 280
600 AEPKM=TEPKM/X:PRINT :PRINT "AVERAGE EARNINGS PER
KILOMETRE :";AEPKM
610 RETURN
700 COLOR 6,0:PRINT TAB(30); "INFORMATION CHART":PRINT
STRING$(80,"_")
710 PRINT TAB(3); "TRIP NUMBER"; TAB(20); "COLLECTION";
TAB(35); "TICKETS SOLD"; TAB(53);"LOAD FACTOR";TAB(72);
"EPKM" :PRINT STRING$(80,"_") :COLOR 7,0 :RETURN
900 CLS: LOCATE 12,20 :INPUT "ARE YOU SURE YOU WANT TO
QUIT(Y/N)"; YN$
910 IF YN$ = "N" OR YN$ = "n" THEN RETURN
920 END
1000 IF C1<>1 THEN 203 ELSE CLS :PRINT TAB(25);
"LISTING OF MATRIXES"
1010 LOCATE 10,1 :INPUT "TIME OF MATRIX TO VIEW(Input
500 for matrix no.1 )" ;AN$
```

```
1Ø2Ø IF AN$="A"  OR AN$="a"  THEN  RV=5ØØ  : GOTO  1Ø4Ø
ELSE V=VAL(AN$):IF V<5ØØ THEN 1ØØØ
1Ø23 IF VAL(AN$)>999 THEN C=2 ELSE C=1
1Ø24 RV=(VAL(LEFT$(AN$,C))-5)*6Ø+(VAL(RIGHT$(AN$,2)))
1Ø25 V=(RV/15)+1
1Ø3Ø GOTO 1Ø41
1Ø4Ø FOR V=1 TO 72
1Ø41 CLS:COLOR 6,Ø:LOCATE 4,1Ø
1050 PRINT "        ╔════╤═════════════════════════════════════════╗"
1060 PRINT "        ║    │ A  B  C  D  E  F  G  H  I  J     TOTAL  ║"
1070 PRINT "        ╟════╪═════════════════════════════════════════╢"
1080 PRINT "        ║ A  │                                         ║"
1090 PRINT "        ║ B  │                                         ║"
1100 PRINT "        ║ C  │                                         ║"
1110 PRINT "        ║ D  │                                         ║"
1120 PRINT "        ║ E  │                                         ║"
1130 PRINT "        ║ F  │                                         ║"
1140 PRINT "        ║ G  │                                         ║"
1150 PRINT "        ║ H  │                                         ║"
1160 PRINT "        ║ I  │                                         ║"
1170 PRINT "        ║ J  │                                         ║"
1180 PRINT "        ║    ├═════════════════════════════════════════╢"
1190 PRINT "        ║    │                                         ║"
2000 T1=0:T2=0:PRINT "  ╚════╧═════════════════════════════════════════╝"
2ØØ5  LOCATE 5,15:COLOR 15,Ø:PRINT INT(V):LOCATE 2,37 :
PRINT "TIME :  "; :A=5ØØ+1ØØ*(INT(RV/6Ø)) +INT  (RV-6Ø*
(INT (RV/6Ø)))
2ØØ7 IF A >= 1ØØØ  THEN AX$ = AN$ ELSE AX$ = "Ø" + MID$
(STR$ (A),2,3)
2ØØ9 PRINT AX$;" ";"HRS"
2Ø1Ø COLOR 7,Ø  : DIM TD(1Ø) :  FOR J=1 TO 1Ø :  LT=Ø :
FOR K=1 TO 1Ø
2Ø2Ø LOCATE (6+J), (21  + ((K-1)*4)) : O = MM (V,J,K) :
IF O < 1Ø  THEN O$ = "Ø" +RIGHT$ (STR$ (O), 1)  ELSE O$
= RIGHT$ (STR$(O),2)
2Ø3Ø PRINT O$:AT=AT+MM(V,J,K):TD(K)=TD(K)+MM(V,J,K)
2Ø31 IF J<K THEN T1=T1+MM(V,J,K) ELSE T2=T2+MM(V,J,K)
2Ø33 NEXT K:LOCATE (6+J),64
2Ø34 IF T1<1Ø  THEN T1$  = " Ø"  + RIGHT$  (STR$(T1),1)
ELSE T1$=STR$(T1)
```

```
2Ø35 IF T2 <  1Ø THEN T2$  = "Ø" + RIGHT$(STR$  (T2),1)
ELSE T2$ = STR$(T2)
2Ø36 PRINT T2$ + "," + RIGHT$(T1$,3) : AT1 = AT1 + T1 :
AT2=AT2 +T2 : T1 = Ø : T2 = Ø : NEXT J
2Ø4Ø  FOR B=1  TO 1Ø  : LOCATE 18,(2Ø  + ((B-1)*  4)) :
PRINT TD(B) : NEXT B : ERASE TD
2Ø45  LOCATE  18 , 63 :  PRINT STR$(AT2) + "," + RIGHT$
(STR$ (AT1) ,3) : AT1 = Ø : AT2 = Ø
2Ø5Ø LOCATE 2Ø,3Ø:PRINT "MATRIX TOTAL : ";AT:AT=Ø
2Ø51 LOCATE 23,3Ø  : PRINT "Press  any key to  continue
..." : AH$ = INPUT$(1)
3ØØØ CLS  : LOCATE  2,15 : PRINT  "LISTING OF  NO :  OF
PASSENGERS PASSING BETWEEN LINKS"
3Ø1Ø COLOR 6,Ø:LOCATE 4,1Ø
3040 COLOR 7,0:PRINT "╔════════════════════════╦═════════════════════╗"
3050 PRINT "║       F O R W A R D    ║    B A C K W A R D      ║"
3060 PRINT "╠════╦═══════════════════╬════╦════════════════════╣"
3070 PRINT "P.AB ║                   P.BA ║                    ║"
3080 PRINT "P.BC ║                   P.CB ║                    ║"
3090 PRINT "P.CD ║                   P.DC ║                    ║"
3100 PRINT "P.DE ║                   P.ED ║                    ║"
3110 PRINT "P.EF ║                   P.FE ║                    ║"
3115 PRINT "P.FG ║                   P.GF ║                    ║"
3120 PRINT "P.GH ║                   P.HG ║                    ║"
3130 PRINT "P.HI ║                   P.IH ║                    ║"
3140 PRINT "P.IJ ║                   P.JI ║                    ║"
3150 PRINT "╚════╩═══════════════════╩════╩════════════════════╝"
316Ø DIM LT(1Ø):FOR I=1 TO 9 :X=Ø
317Ø X=X+1:FOR K=I+1 TO 1Ø:LT(I)=LT(I)+MM(V,X,K)
318Ø NEXT K:IF X=I THEN 319Ø ELSE 317Ø
319Ø NEXT I
32ØØ FOR I=1  TO 9  : LOCATE (7+I),2Ø  : PRINT LT(I)  :
NEXT I:LP=25:G=Ø:GOSUB 329Ø
321Ø ERASE LT:DIM LT(1Ø):FOR I=1Ø TO 2 STEP -1:X=11
322Ø X=X-1:FOR K=I-1 TO 1 STEP -1 : LT(I-1) = LT(I-1) +
MM(V,X,K)
323Ø NEXT K:IF X=I THEN 324Ø ELSE 322Ø
324Ø NEXT I
325Ø  FOR I=1  TO  9:LOCATE  (7+I),48:PRINT  LT(I):NEXT
I:LP=53:G=Ø:GOSUB 329Ø
```

```
326Ø ERASE LT : IF AN$ <> "A" AND AN$ <> "a" THEN
LOCATE 23,2Ø:PRINT "Press any key to return to main
menu....":AN$=INPUT$(1):RETURN
327Ø LOCATE 23,2Ø : PRINT "Input S to stop,any other
key to continue...":AS$=INPUT$(1):IF AS$="S" OR AS$="s"
THEN RETURN
328Ø RV=RV+15:NEXT V:RETURN
329Ø FOR FG=1 TO 9:IF LT(FG)>G THEN G=LT(FG)
33Ø5 NEXT FG:DI=INT(G/15)+1+(2*(LB=53))
331Ø FOR I = 1 TO 9 : LOCATE (7+I) , LP : PRINT "█" :
LH = INT(LT(I)/DI):IF LH=Ø THEN 332Ø ELSE FOR B=1 TO LH
: LOCATE (7+I),(LP+B):PRINT "▄":NEXT B
332Ø NEXT I:RETURN
4ØØØ DATA Ø, 1, 1, Ø, Ø, Ø, Ø, 1, Ø, Ø, Ø, Ø, 1, Ø, 1,
Ø, Ø, Ø, Ø, Ø, 1, Ø, Ø, Ø, 2, Ø, 2, Ø, Ø, Ø, 1, 1, Ø,
Ø, Ø, Ø, Ø, 1, Ø, Ø, Ø, Ø, 2, , , , , , , , Ø, 1, , , ,
, , , , , , , 2, , , , , , , , 1, , 1, , , , , , , , ,
, , , , , , , , , , , , , , , , , ,
4Ø1Ø DATA Ø, 1, 1, Ø, Ø, Ø, Ø, 1, Ø, Ø, Ø, Ø, 1, Ø, 1,
Ø, Ø, Ø, Ø, Ø, 1, Ø, Ø, Ø, 2, Ø, 2, Ø, Ø, Ø, 1, 1, Ø,
Ø, Ø, Ø, Ø, 1, Ø, Ø, Ø, Ø, 2, , , , , , , , Ø, 1, , , ,
, , , , , , , 2, , , , , , , , 1, , 1, , , , , , , , ,
, , , , , , , , , , , , , , , , , ,
4Ø2Ø DATA Ø, 1, 1, Ø, Ø, Ø, Ø, 1, Ø, Ø, Ø, Ø, Ø, 1, Ø,
1, Ø, Ø, Ø, Ø, 2, Ø, Ø, Ø, 2, Ø, 2, Ø, Ø, Ø, Ø, 1, Ø,
Ø, Ø, Ø, Ø, 1, Ø, Ø, 1, 1, Ø, Ø, Ø, Ø, Ø, Ø, Ø, Ø, 1,
Ø, Ø, Ø, Ø, Ø, Ø, Ø, Ø, Ø, Ø, Ø, Ø, 2, Ø, Ø, Ø, Ø, Ø,
Ø, Ø, Ø, Ø, Ø, 1, Ø, Ø, Ø, Ø, Ø, Ø, 2, Ø, Ø, 1, 1, 1,
1, Ø, Ø, Ø, Ø, Ø, Ø, Ø, Ø, Ø, 1, 1, Ø
4Ø3Ø DATA Ø, 1, 1, Ø, Ø, Ø, Ø, 1, Ø, Ø, Ø, Ø, Ø, 1, Ø,
1, Ø, Ø, Ø, Ø, 2, Ø, Ø, Ø, 2, Ø, 2, Ø, Ø, Ø, Ø, 1, Ø,
Ø, Ø, Ø, Ø, 1, Ø, Ø, 1, 1, Ø, Ø, Ø, Ø, Ø, Ø, Ø, Ø, 1,
Ø, Ø, Ø, Ø, Ø, Ø, Ø, Ø, Ø, Ø, Ø, Ø, 2, Ø, Ø, Ø, Ø, Ø,
Ø, Ø, Ø, Ø, Ø, 1, Ø, Ø, Ø, Ø, Ø, Ø, 2, Ø, Ø, 1, 1, 1,
1, Ø, Ø, Ø, Ø, Ø, Ø, Ø, Ø, Ø, 1, 1, Ø
```

M A I N   M E N U

1. INPUT DATA
2. CHANGE DATA
3. RUN BUS
4. SEE MATRIX
5. QUIT

YOUR CHOICE   :1

INPUTING VARIABLE DATA

PLEASE INPUT THE FOLLOWING DETAILS:

NORMAL BUS CAPACITY (Passengers per bus) ? 6Ø
NORMAL FREQUENCY OF BUS (Time between bus departure in minutes)? 1Ø
TIME OF MORNING PEAK HOUR (start,end) :8ØØ,1Ø3Ø
CAPACITY IN MORNIMG PEAK HOUR (passengers per bus) :8Ø
FREQUENCY IN MORNIMG PEAK HOUR (time between bus departure in minutes) :5
TIME OF EVENING PEAK HOUR (start,end) :153Ø,183Ø
CAPACITY IN EVENIMG PEAK HOUR (passengers per bus) :8Ø
FREQUENCY IN EVENIMG PEAK HOUR (time between bus departure in minutes) :5

ANY FLAW IN DATA(Y/N)? N

SAMPLE MATRIX DATA

TIME : Ø5ØØ HRS

1	A	B	C	D	E	F	G	H	I	J	TOTAL
A	ØØ	Ø1	Ø1	ØØ	ØØ	ØØ	ØØ	Ø1	ØØ	ØØ	ØØ, Ø3
B	ØØ	ØØ	Ø1	ØØ	Ø1	ØØ	ØØ	ØØ	ØØ	ØØ	ØØ, Ø2
C	Ø1	ØØ	ØØ	ØØ	Ø2	ØØ	Ø2	ØØ	ØØ	ØØ	Ø1, Ø4
D	Ø1	Ø1	ØØ	ØØ	ØØ	ØØ	ØØ	Ø1	ØØ	ØØ	Ø2, Ø1
E	ØØ	ØØ	Ø2	ØØ	ØØ	ØØ	ØØ	ØØ	ØØ	ØØ	Ø2, ØØ
F	ØØ	Ø1	ØØ	ØØ	ØØ	ØØ	ØØ	ØØ	ØØ	ØØ	Ø1, ØØ
G	ØØ	ØØ	Ø2	ØØ	ØØ	ØØ	ØØ	ØØ	ØØ	ØØ	Ø2, ØØ
H	Ø1	ØØ	Ø1	ØØ	ØØ	ØØ	ØØ	ØØ	ØØ	ØØ	Ø2, ØØ
I	ØØ	ØØ	ØØ	ØØ	ØØ	ØØ	ØØ	ØØ	ØØ	ØØ	ØØ, ØØ
J	ØØ	ØØ	ØØ	ØØ	ØØ	ØØ	ØØ	ØØ	ØØ	ØØ	ØØ, ØØ
	3	3	7	Ø	3	Ø	2	2	Ø	Ø	1Ø, 1Ø

MATRIX TOTAL : 2Ø

LISTING OF NO: OF PASSENGERS PASSING BETWEEN LINKS

FORWARD		BACKWARD	
P.AB	3	P.BA	3
P.BC	4	P.CB	5
P.CD	6	P.DC	9
P.DE	7	P.ED	7
P.EF	4	P.FE	5
P.FG	4	P.GF	4
P.GH	2	P.HG	2
P.HI	Ø	P.IH	Ø
P.IJ	Ø	P.JI	Ø

TWO RESIDUAL MATRICES

TIME : Ø5ØØ HRS

1	A	B	C	D	E	F	G	H	I	J	TOTAL
A	ØØ	ØØ	ØØ	ØØ	ØØ	ØØ	ØØ	ØØ	ØØ	ØØ	ØØ, ØØ
B	ØØ	ØØ	ØØ	ØØ	ØØ	ØØ	ØØ	ØØ	ØØ	ØØ	ØØ, ØØ
C	Ø1	ØØ	ØØ	ØØ	ØØ	ØØ	ØØ	ØØ	ØØ	ØØ	Ø1, ØØ
D	Ø1	Ø1	ØØ	ØØ	ØØ	ØØ	ØØ	Ø1	ØØ	ØØ	Ø2, Ø1
E	ØØ	ØØ	Ø2	ØØ	ØØ	ØØ	ØØ	ØØ	ØØ	ØØ	Ø2, ØØ
F	ØØ	Ø1	ØØ	ØØ	ØØ	ØØ	ØØ	ØØ	ØØ	ØØ	Ø1, ØØ
G	ØØ	ØØ	Ø2	ØØ	ØØ	ØØ	ØØ	ØØ	ØØ	ØØ	Ø2, ØØ
H	Ø1	ØØ	Ø1	ØØ	ØØ	ØØ	ØØ	ØØ	ØØ	ØØ	Ø2, ØØ
I	ØØ	ØØ	ØØ	ØØ	ØØ	ØØ	ØØ	ØØ	ØØ	ØØ	ØØ, ØØ
J	ØØ	ØØ	ØØ	ØØ	ØØ	ØØ	ØØ	ØØ	ØØ	ØØ	ØØ, ØØ
	3	2	5	Ø	Ø	Ø	Ø	1	Ø	Ø	1Ø, 1

MATRIX TOTAL : 11

TIME : Ø8ØØ HRS

13	A	B	C	D	E	F	G	H	I	J	TOTAL
A	ØØ	ØØ	ØØ	ØØ	ØØ	ØØ	ØØ	ØØ	ØØ	ØØ	ØØ, ØØ
B	ØØ	ØØ	ØØ	ØØ	ØØ	ØØ	ØØ	ØØ	ØØ	ØØ	ØØ, ØØ
C	ØØ	ØØ	ØØ	ØØ	ØØ	ØØ	ØØ	ØØ	ØØ	ØØ	ØØ, ØØ
D	ØØ	ØØ	ØØ	ØØ	ØØ	ØØ	ØØ	ØØ	ØØ	ØØ	ØØ, ØØ
E	ØØ	ØØ	ØØ	ØØ	ØØ	ØØ	ØØ	ØØ	ØØ	ØØ	ØØ, ØØ
F	ØØ	ØØ	ØØ	ØØ	ØØ	ØØ	ØØ	ØØ	ØØ	ØØ	ØØ, ØØ
G	ØØ	ØØ	ØØ	ØØ	ØØ	ØØ	ØØ	ØØ	ØØ	ØØ	ØØ, ØØ
H	ØØ	ØØ	ØØ	ØØ	ØØ	ØØ	ØØ	ØØ	ØØ	ØØ	ØØ, ØØ
I	ØØ	ØØ	ØØ	ØØ	ØØ	ØØ	ØØ	ØØ	ØØ	ØØ	ØØ, ØØ
J	ØØ	ØØ	ØØ	ØØ	ØØ	ØØ	ØØ	ØØ	ØØ	ØØ	ØØ, ØØ
	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø, Ø

MATRIX TOTAL : Ø

DETAILS OF TRIPS GENERATED

INFORMATION CHART

TRIP NUMBER	COLLECTION	TICKETS SOLD	LOAD FACTOR	EPKM
16.(7ØØ- 745)	Rs. 44.4Ø	38	Ø.235	3.29
17.(62Ø- 7Ø5)	Rs. 14.3Ø	13	Ø.Ø72	1.Ø6
18.(71Ø- 755)	Rs. 43.7Ø	43	Ø.2Ø6	3.24
19.(63Ø- 715)	Rs. 18.ØØ	16	Ø.Ø93	1.33
2Ø.(72Ø- 8Ø5)	Rs. 57.1Ø	51	Ø.293	4.23
21.(64Ø- 725)	Rs. 17.8Ø	16	Ø.Ø91	1.32
22.(73Ø- 815)	Rs. 71.4Ø	6Ø	Ø.383	5.29
23.(65Ø- 735)	Rs. 16.2Ø	16	Ø.Ø76	1.2Ø
24.(74Ø- 825)	Rs. 71.1Ø	65	Ø.357	5.27
25.(7ØØ- 745)	Rs. 18.6Ø	18	Ø.Ø89	1.38
26.(75Ø- 835)	Rs. 7Ø.2Ø	64	Ø.354	5.2Ø
27.(71Ø- 755)	Rs. 18.3Ø	17	Ø.Ø91	1.36
28.(8ØØ- 845)	Rs. 82.8Ø	72	Ø.433	6.13
29.(72Ø- 8Ø5)	Rs. 27.8Ø	24	Ø.146	2.Ø6
3Ø.(81Ø- 855)	Rs. 84.7Ø	81	Ø.4Ø9	6.27

Press S to stop ,any other key to continue...

Analysis of data

Basic data

Total number passengers	- 8995
Average number of passenger/Hr	- 500
Duration of operarion	- 0500 Hrs to 2300
Length of route	- 13.5 Km (9 links)
Length of a link	- 1.5 Km
Speed of the bus	- 18 Km/hr(5mts/link)
Fare structure	- Basic fare 50 Ps + 14 Ps per kilometer

Variable data

Normal bus capacity	- 60 passengers
Bus capacity during peak periods	- 80 passengers
Morning peak period	- 0800 Hrs to 1030 Hrs
Evening peak period	- 1530 Hrs to 1830 Hrs
Bus frequency during normal period	- 10 mts (either direction)
Bus frequency during peak period	- 5 mts (either direction)

Results

Number of trips	- 256
Total kilometers operated	- 256 x 13.5 = 3456 Km
Total tickets sold	- 8661
Residual passengers (those who could not be provided with bus service)	- 8995 -8611 = 384
Total fare collected	- Rs 9817.50
Average collection/passenger	- Rs 1.14
Average EPKM	- Rs 2.84
Average waiting time of passengers during off peak period	- 5 mts
Average waiting time of passengers during peak period	- 2.5 mts

PASSENGER ROAD TRANSPORT TERMINOLOGY

1. Accessibility (for passengers)

   a) A measure of the ability of all persons to travel between various origins and destinations.

   b) The sum of travel times from one zone to all other zones in a region, weighted by the relative attractiveness of the destination zones involved.

2. Accessibility (in vehicle maintenance)

   The ease at which a part is removed and refitted - usually measured by the time taken to do so.

3. Area Coverage

   The geographical area that a transport system is considered to serve, normally including an acceptable walking distance of Ø.4 Km. from terminus points also.

4. Area Sampling

   A statistical technique that divides a geographical region in to smaller areas and uses random selection to determine specific area or respondents to be interviewed.

5. Attendance Ratio

$$\text{Attendance ratio} = \frac{\text{Available man-days}}{\text{Expected man-days}}$$

6. Attributes of Service

Those aspects of a transportation system that affect travel decisions regarding its use such as travel time, cost, reliability and safety.

7. Average Age of Buses (Year or Km.)

The total period from the date of commissioning to present date can be measured as chronological age (years) or kilometres logged (Km.).

8. Average Carrying Capacity

$$\text{Average carrying capacity} = \frac{\text{Total seating capacity of all buses in the fleet}}{\text{Number of buses in the fleet}}$$

9. Average Earnings per Passenger

$$\text{Average earnings per passenger} = \frac{\text{Total earnings from passengers}}{\text{Total number of passengers}}$$

10. Average Number of Buses

a) $$\text{Average number of buses on road} = \frac{\text{Total number of bus-days on road in period}}{\text{No. of days of the period}}$$

b) Average number of buses in workshops $= \dfrac{\text{Total number of bus days spent in workshops in a period}}{\text{No. of days of the period}}$

11. Average Number of Schedules

Average number of Schedules during any specific period is arrived at by adding the number of schedules to be operated from day to day during the period (week, month, year) and dividing the sum total by the number of days in the period.

12. Average Route Distance

$$\text{Average route distance} = \frac{\text{Total route Km. of all routes}}{\text{Total number of routes}}$$

13. Average Seating Capacity

$$\text{Average seating capacity} = \frac{\text{Total seating capacity of all the buses in the fleet held}}{\text{Number of buses in the fleet}}$$

14. Average Scheduled Kilometres

Average scheduled kilometres during any specific period (viz, week, month, year etc.) is obtained by dividing the total scheduled kilometres fixed for the schedules actually to be operated day to day during the period by the number of days in the period.

15. Average Daily Effective Kilometres

This is obtained by dividing the total effective kilometres operated during any specified period by the number of days in the period.

16. Axle Weight

Axle weight means in respect of the axle of any vehicle, the axle weight certified and registered by the registering authority as permissible for the axle.

17. Break-Down

A break down is defined as a stoppage of bus on road due to mechanical defects or other failures rendering the bus immobile irrespective of the time involved.

18. Break-Even Point

Break-Even point is that point at which the total operating revenue is equal to the total operating cost.

19. Bunching

Too many buses co m ing together in one direction.

20. Bus Days Lost

This is the sum total of days each bus has remained in workshop, reckoned over a period of time.

21. Bus Depot

A place where garage facilities are provided for the buses.

22. Buses in Workshop

Buses in depot workshops, divisional workshops and Regional/Central workshops as at a particular point of time under the following conditions are considered as buses in workshops.

a. Buses under routine inspection

b. Buses off-road for repairs, reconditioning etc

c. Buses withdrawn for scrapping

d. Buses awaiting spares, assemblies, labour and equipment

e. Buses awaiting evacuation to other workshops.

23. Buses off-Road

Buses are considered to be off-road when they are not in road worthy condition.

24. Buses on Road

A bus which performs effective kilometres, is a bus on road.

25. Buses Under Repair

Buses which are receiving attention in workshop other than routine inspection, and which are not waiting for spare parts, labour and equipment.

26. Buses Under Routine Inspection

Buses which are taken into depot and divisional workshops for routine inspection according to a pre-planned scheme of periodical maintenance or docking including RTO passing (Certificate of Fitness inspection) are considered to be under routine inspection

27. Bus Schedule

A bus schedule is a programme of operation of a bus on one or more routes operating one or more trips within 24 hours. Also simply called a 'schedule'.

28. Bus Stop

A waiting, boarding and alighting area, usually designated by distinctive signs and by curbs or by pavement markings.

29. Bus Way

A special road way designed for exclusive or predominant use of buses in order to improve the bus movement and bus passenger travel times.

3Ø. Cancelled Kilometres

Scheduled kilometres not operated are called cancelled kilometers.

31. Capital Employed

This is defined as net fixed assets + current Assets - Current liabilities.

32. Capital Expenditure

Capital expenditure represents all expenditure incurred in the acquisition of permanent assets which are intented to be continuously used in the business of the undertaking for purposes of earning revenue.

33. Capital Invested

This is defined as capital contributions from Government + long term loans including fixed deposits from public + free reserves including accumulated profits less accumulated losses to the extent these are applicable.

34. Capital Receipts

Capital receipts represent the money received from the participating Governments as contribution towards the capital investment in the undertaking for utilisation for acquisition permanent assets to run the business.

35. Carrying Capacity

Carrying capacity means the number of seats offered in a bus plus the standees authorised as a part of carrying capacity and excluding the seats alloted to operating crew.

36. Carrying Capacity Kilometres

The average carrying capacity multiplied by the effective kilometres operated given the carrying capacity kilometres.

37. C.B.D.

Central Business District - Area mostly at the centre of the city where major activities are concentrated.

38. Cordon

An area enclosed by a closed loop.

39. Cost of Operation

The total working cost incurred in connection with the business of transportation of passengers is termed as cost of operations.

40. Cost per Kilometre (CPKM)

The cost per kilometre (CPKM) is computed by dividing the total cost of operations by the total effective kilometres.

41. Day

'Day' means a period of twenty four hours beginning at mid-night.

42. Dead Kilometres

Kilometres covered by public service buses in following circumstances will be considered as, dead kilometres.

a) Movement between bus stand and depot and vice versa

b) Movement from stand and/or depot to fuelling point and back

c) Movement of buses sent to continue the operation of break down or accident bus upto the point of break down/accident

d) Movement of buses sent to start operations from some other depot/operating point

e) Movement of buses sent to the point of docking, repairing, reconditioning etc.

f) Movement of buses for testing purposes.

43. Delays

Running of buses behind the schedule time at the starting point and/or at the destination is a delay.

44. Demand Matrix

The matrix showing traffic demand between all nodes in a route.

45. Depot

The organisational unit of a transport undertaking directly responsible for the operation of the bus service.

46. Destination

The place where the journey ends or the place where the traveller wants to go

47. Double Duty

A bus being operated for two duties (of the crew).

48. Double Spell

A bus being operated for one duty only, split up during the morning and evening peak periods

49. Earnings per Bus (EPB)

$$\text{Earnings per bus} = \frac{\text{Total earnings during the period}}{\text{Average number of buses held during the period}}$$

(This can also be calculated for each bus, separately).

50. Earnings per Kilometre (EPKM)

$$\text{EPKM} = \frac{\text{Total earnings}}{\text{Total effective kilometres}}$$

EPKM is expressed as Rupees / Km.

51. Earnings per Passenger Kilometre (EPKM)

$$\text{Earnings per passenger kilometre} = \frac{\text{Total revenue}}{\text{Total passenger Km.}}$$

52. Earnings per Seat Kilometres Offered

This is obtained by dividing total traffic revenue by the product of total effective kilometres and average carrying capacity of the buses.

53. Economic Life

The period during which a bus is economical to operate, for its owner ; usually measured in years. (It can also be calculated in kilometres logged).

54. Engine Oil Consumption

The total quantity of engine oil consumed by a bus during a given period represents the engine oil consumption for the period.

55. Extra Trips

Trips operated for the clearance of additional traffic, on regular routes, when the regular scheduled trips are not adequate to clear the rush or to cater to special and religious celebrations etc. on account of casual contracts are termed as extra trips.

56. Fare

The authorised payment for a ride on a passenger bus whether cash, token, or pass.

57. Fare Stage (Node)

A point at which the fare changes; or the end point of a route.

58. Fare Structure

A fare structure lays down different fares charged, based on:

a) Length of journeys

b) Types of routes like metalled, non-metalled or hilly routes

c) Types of service - ordinary, express etc.

d) Time and day of operation - night services, holiday specials etc.

59. Feeder Services

A service which takes passengers to a point where buses are available more frequently.

60. Fuel Consumption

The total quantity of fuel consumed by buses for performance of kilometres of run. Conversly 'mileage' is the kilometres run by a bus using a given quantity of fuel (usually, 1 litre).

61. Gross Kilometre

The total kilometres covered by public service buses for earning revenue and for other purposes is known as gross kilometres.

62. Gross Profit

The excess of the total gross revenue over the revenue expenditure (ie., the cost of operations excluding the cost on depreciation and interest charges)

63. Gross Revenue

The total revenue dervied from all sources constitute "Gross Revenue".

64. Hours of Work

Hours of work means the time during which the motor transport worker is at the disposal of the employer or any other person entitled to claim his services.

65. Inventory

The materials held in a stock point (fuel, oil, auto spares, tyres, tubes batteries etc) on a particular day indicating the volume and value of inventory held on that day.

66. Inventory Carrying Cost

It is the cost of carrying inventory per item per year, expressed in terms of percentage of the inventory value.(Mainly this consists of interest charges and expenses for physical storage).

67. Inventory Held per Bus

$$\text{Inventory held per bus} = \frac{\text{Inventory held}}{\text{No. of buses held on that day}}$$

68. Kilometre Efficiency

It is the ratio of effective kilometres (excluding Km. operated through extra trips) to scheduled Km. planned for operation.

69. Late Arrivals

Arrival of bus on scheduled trip (including scheduled extra trips) behind scheduled arrival at the destination is known as late arrival.

70. Late Departures

Departure of buses on scheduled trips (including scheduled extra trips) behind scheduled time at the starting point are known as late departures.

71. Lead Time

The time interval between raising an intend and actual receipt of the purchased item is called lead time.

72. Life of Batteries

Life of batteries can be expressed as the total kilometres given by it or the total days of service it gave.

73. Life of Engines

This represents the total kilometres given by the engines, new or reconditioned, from the date of their fitment on the bus, upto the date of their removal for scrapping or reconditioning, as the case may be.

74. Life of Fuel Injection Pumps

This represents the total kilometres given by the fuel injection pumps, new or reconditioned, from the date of their fitment on the buses upto the date of their removal, for reconditioning or scrapping, as the case may be.

75. Link (Inter - fare stage)

The route between two fare stages.

76. Load Factor (%)

Ratio of total passenger kilometres to capacity Kilometres expressed as a percentage.

77. Log Book

A book kept for a vehicle to register all the important operational and maintenance data pertaining to that vehicle.

78. Megapolis

A heavily populated region centering on a metropolis or embracing several metropolises.

79. Mixed Traffic

Traffic of all types, buses, cycles, pedestrians, autorikshaws, cars, etc. plying through the same road.

80. Mobility of Population

It is measured by the following indices:

a) Road length Sq.Km. of area served

b) Road length per 10,000 population

c) Buses per 10,000 population

81. Modular Design

A design where sub - assemblies are in easily remov able modules.

82. Net Profit

The excess of total (gross) revenue over the total cost of operation (including depreciation and interest) in the net profit.

83. Network (of routes)

Combination of all connected nodes and links.

84. Node (Fare - stage)

A point at which the fare changes; or the end point of the route.

85. Noon Gap

The off peak period during noon.

86. OBD

Outlying Business District - area surrounding CBD.

87. Occupancy Ratio (%)

$$\text{Occupany ratio} = \frac{\text{Passenger kilometres} \times 100}{\text{Seat Km offered}}$$

88. O / D Survey

Origin / Destination survey regarding the boarding point and destination of passengers.

89. Off - peak Period

Period during which traffic volume is comparatively less. (Some times called slack period also).

90. Operating Profit

The excess of total traffic or operating revenue over the total cost of operation is the operating profit.

91. Operating Ratio (%)

$$\text{Operating ratio} = \frac{\text{Operating cost}}{\text{Traffic/operating revenue}} \times 100$$

92. Ordering Cost

It is the cost of placing a purchase order and includes the costs related to clerical work involved, receiving, reception, inspection, stocking and distribution of the materials.

93. Origin

The starting place of the journey.

94. Over Serviced (Route, Area)

A route or area where service provided is more than what is sufficient.

95. Passenger Kilometres

This is the total of kilometres all the passengers have travelled over a period of time. it is conveniently calculated as $= \dfrac{\text{Traffic revenue}}{\text{Fare per Km.}}$

96. Passenger km. per Litre

$$\text{Passenger Km/litre} = \frac{\text{Total passenger Km.}}{\text{Total fuel consumption}}$$

97. Peak, Slack and Normal Periods

Peak Period: Peak period is a period having high traffic activity indicating maximum traffic demand.

Slack Period: Slack period is a period having low traffic activity indicating minimum traffic demand.

Normal Period: Normal period is a period having average traffic demand in magnitude which is between peak and slack periods.

98. Percentage Turnover of Staff

$$\text{Percentage turnover of staff} = \frac{\text{No. of persons joining} + \text{No. of persons leaving}}{\text{Average number of employees during the period}} \times 100$$

99. Priority Discipline (in Maintenance)

The preferential treatment given in maintenance or repair for a vehicle according to a pre-determined norm.

100. Productivity of Buses

This parameter computed as the kilometres kilometres operated per bus held/day.

$$\text{ie} = \frac{\text{Average effective Km. done/day}}{\text{Average number of buses held/day}}$$

101. Productivity of of Employees

It is the total effective Km. operated for a period divided by total man days paid for during the period.

102. Public Place

'Public Place' means a road, street, way or other place whether a thorough fare or not, to which the public have a right to access and includes any place/ stand at which passengers are picked or set down by a stage carriage.

103. Public Service Vehicle

This means any motor vehicle used or adapted to be used for the carriage of passengers for hire or reward and includes a maxi-cab, a motor-cab contract carriage or stage carriage.

104. Quality of Service Index

Quality of service index is designed to enable effective measure of service quality. It is computed as follows.

$$QSI = \frac{W_1A + W_2B + W_3C + W_4D + W_5E}{W_1 + W_2 + W_3 + W_4 + W_5}$$

$W_1 = 60 \quad W_2 = 20 \quad W_3 = 10 \quad W_4 = 5 \quad W_5 = 5$

$$A = \frac{a \times 100}{T}$$ (a = no. of accidents)

$$B = \frac{b \times 100}{T}$$ (b = no. of break downs)

$$C = \frac{c \times 100}{ST}$$ (c = no. of trips cancelled)

$$D = \frac{d \times 100}{T}$$ (d = no. of late departures)

$$E = \frac{e \times 100}{T}$$ (e = no. of late arrivals)

ST - Scheduled Trips T - Trips Operated

105. Rate of Breakdown

These are relative measures of the incidence of break downs.

a) Rate per 10,000 effective Km. $= \frac{\text{Total number of break downs}}{\text{Total effective Km.}} \times 100$

$$\text{b) Rate per bus on road} = \frac{\text{Total no. of break downs (over a period)}}{\text{Average no. of buses on road}}$$

106. Rate of Consumption of Spare Parts

$$\left.\begin{array}{r}\text{Spare Consumption}\\ \text{per 10 buses on}\\ \text{road}\end{array}\right\} = \frac{\text{Consumption of a particular part during a period} \times 10}{\text{Average no. of buses during the period}}$$

Spare consumption is also expressed as Rupee value of all spares consumed during a period (usually an year) per bus.

107. Registered Axle Weight

Registered axle weight means in respect of the axle of any vehicle, the axle weight certified and registered by the registering authority as permissible in the axle.

108. Registered Laden Weight

Registered Laden weight means in respect of any vehicle, the toal weight of the vehicle and load certified and registered by the registering authority as permissible for that vehicle.

109. Regularity of Operation

Regularity of operation is the percentage of scheduled trips actually operated to the total scheduled trips as per time table.

110. <u>Reliability of a Service</u>

Proba bility that a scheduled trip is operated.

111. <u>Removal Rate</u>

The speed at which passengers are moved expressed in Km / hr.

112. <u>Re-order level and Re-order Point</u>

The level at stock of any item at which an order is initiated for more supplies of that item, when the total stock on hand plus on order falls below the level point.

113. <u>Resource Utilisation Coefficient</u>

This is the product of occupancy ratio, fleet utilisation and Km. efficiency.

114. <u>Retained Profit</u>

The profit or surplus remaining after charging income tax and net appropriations is the retained profit.

115. <u>Return on Capital Employed</u>

It is defined as: (Net profit + interest paid on capital + Interest paid on short and long term loans - interest earned on investment) ÷ Capital employed.

116. <u>Return on Capital Invested</u>

This is defined as: (Net profit + Interest paid on capital and long term loans) ÷ Capital invested.

117. Road Capacity

The capacity of any road section or network may be defined as the number of vehicles that can be cleared subject to a given minimum average speed of motorised vehicles (say 40 Km. per hour).

118. Road kilometres

This is the actual length of the road covered by the route in operation.

119. Route

'Route' means a line of travel which specifies the highway which may be traversed by a bus between one terminus and other.

120. Running Time

This is the total time provided for operation of a single journey between the terminals.

121. Schedule

The operation of a bus during one day (24 hrs).

122. Scheduled Kilometers

The effective kilometres planned to be operated on a given day by a depot/division/undertaking as per the bus schedules of the unit as per the scheduled kilometres on that day.

123. Scheduled Trips

All trips planned as per the approved bus schedule are known as Scheduled Trips.

124. Seating Capacity

Seating Capacity means the number of seats offered in a bus excluding the seats alloted to the operating crew.

125. Seat Km. Offered

The weighted average seating capacity multiplied by the effective kilometres operated gives the seat kilometres offered.

126. Service Level (for Inventory)

$$\text{Service level} = \frac{\text{No. of items supplied in full}}{\text{No. of items intended}} \times 100$$

127. Spare Buses

Buses which are in fit condition and are available for being put on road at any time required are termed as spare buses.

128. Spread Over

Spread over means the period between the commencement of duty on any day and the termination of duty on that day.

129. Stage Carriage

Stage Carriage means a motor vehicle constructed or adapted to carry more than six persons excluding the driver which carries passengers for hire or reward at separate fares paid by or for individual passengers, either for the whole journey or for stages of the journey.

130. Standing Time

Time Scheduled at the terminals to ensure regularity of service and allowing alighting and boarding of passengers.

131. Stay Bus

A bus which remains in a terminal point during night and comes back to depot during next morning.

132. Steering Duty Hours

It is the time spent on active duty at the wheel plus any terminal lay over time.

133. Stock Out Cost

It is the loss of income that may follow if any item is out of stock in store.

134. Technical Life (or useful life)

The period of life during which the equipment is utilised for its intended purpose.

135. Terminus

Place where the bus service terminates.

136. Total Cost per Bus

$$\text{Total cost per bus (on road/held)} = \frac{\text{Total cost during the period}}{\text{Average number of buses (on road/held) during the period}}$$

137. Trailer

'Trailer' means any vehicle other than a side car drawn or intended to be drawn by a motor vehicle.

138. Traffic Contour

A line joining different points having the same traffic volume.

139. Traffic Revenue

Income realised from transportation of passengers and incidental sources related transportation of passengers constitutes traffic revenue.

140. Trip

Trip means a single journey from one point to another, and every return journey shall be deemed as a separatè trips.

141. Trips Operated

Trips operated differ from scheduled number of trips to be operated to the extent of

(a) cancellations in scheduled operations and

(b) extra trips operated during the period.

142. Turnover of Workshops (%)

$$\text{Turn over of workshops (\%)} = \frac{\text{No. of buses turned out}}{\text{No. of buses received}} \times 100$$

143. Tyre Kilometre

This represents the total gross kilometres covered by the tyre from the date of its fitment on the bus up to the time of its removal either for scrapping or for retreading.

144. Unit Replacement

Method of quick repair work by removing and refitting the unit which contains the malfunctioning component.

145. Unladen Weight

Unladen weight means the weight of a vehicle including all equipment ordinarily used with the vehicle or trailer when working, but excluding the weight of a driver or attendant.

146. Under Serviced (Route , Area)

A route or area where the bus service provided is less than what is required.

147. Utilisation of Fleet

$$\text{Percentage of fleet utilisation} = \frac{\text{No. of buses on road}}{\text{No. of fleet held}} \times 100$$

148. Vehicle Utilisation (Km)

Kilometres operated by a vehicle measured over a period of time (day, month, or year)

APPENDIX - 3

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