ANALYSIS AND INTEGRATION OF MASS RAPID TRANSIT SYSTEM IN A METROPOLITAN CITY

A THESIS

submitted in fulfilment of the
requirements for the award of the degree
of
DOCTOR OF PHILOSOPHY
in
CIVIL ENGINEERING

By

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APRIL, 1997

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CANDIDATE'S DECLARATION

I hereby certify that the work which is being presented in the thesis entitled **"ANALYSIS AND INTEGRATION OF MASS RAPID TRANSIT SYSTEM IN A METROPOLITAN CITY"** in fulfilment of the requirement for the award of the *Degree of Doctor of Philosophy* and submitted in the Department of Civil Engineering of the University of Roorkee is an authentic record of my own work carried out during a period from August 1994 to April 1997 under the supervision of Prof. (Dr.) A.K. Gupta & Prof. (Dr.) S.S. Jain.

The matter presented in this thesis has not been submitted by me for the award of any other degree of this or any other University.

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This is to certify that the above statement made by the candidate is correct to the best of our knowledge.

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ABSTRACT

There have been rapid changes in the pattern of traffic in Indian cities in the recent past. The change in policy of the government towards manufacture of motorised two wheelers and introduction of fuel efficient cars in the market have caused flooding of more private vehicles on the roads. This has resulted in more congestion and air pollution. The travel cost and time of travel do not appear to be the only factors that now govern choice of mode. Users attitudes towards various travel attributes appear to play a major part in choosing the mode of travel.

It is evident that rail based mass rapid transit systems have a role to play in the urban transport system. In view of high investments, a realistic appraisal taking into consideration various costs involved, is necessary. The growth of registered motor vehicles in Delhi has been increased from 0.24 million in 1970 AD to around 2.5 million (July, 1996 AD). One can imagine as to how much would be the congestion level on roads, when there would be such a growth of vehicles.

It has been fully recognised by planners and engineers that solution lies in developing mass rapid transit facilities in the major cities. But the high initial costs involved in developing them and the difficulty in meeting the operation and renewal costs by fare box only has been the dividend in large for development of such facilities.

This calls for an in-depth study of alternative forms of mass transit systems, their capacities, costs and economics in the Indian context so that a proper mix can be arrived at for each city. Delhi, is the third largest metropolitan city in India proposed with three MRTS corridors. In this study these three proposed MRTS corridors of Delhi have been considered for detailed analysis.

Study of modal choice of urban commuters in depth has been receiving attention in developed countries since early sixties. They have been concentrating on development of disaggregate utility models and of late have been considering the need for study into the 'stated preference' of users. The study of attitude of commuters thus gains importance. No detailed studies in depth in this respect appears to have been done in Indian context. Different methodologies available for mode choice analysis have been tried in the context of Delhi city. The trend of change in mode choice in the city has been studied and the applicability of different methodologies have been analysed.

People's attitude towards choice of alternatives can be best studied using behavioural science techniques. Two methodologies have been tried viz., attitude survey and trade-off technique. A detailed attitude survey carried out amongst a sample of 605 commuters hailing from different areas in Delhi has brought out the following :

(i) Attitude of commuters towards travel attributes are not very much influenced by the characteristics of the places of residence. To some extent social status has a limited influence. To a larger extent, accessibility has a greater influence.

(ii) People attach different values of importance to various travel attributes depending on trip purpose. All commuter groups consider travel time as the most important for work trips, education and entertainment trips. Travel cost generally takes the second place and comfort or safety in travel the third place.

(iii) Attitude value being a stated preference, using it in conjunction with other variables would be a desirable approach to understand more logically the behaviour of commuters in selecting the mode.

The two approaches made use of, are : Multiple Linear Regression (MLR) and Multi-Nomial Logit (MNL) models. Out of the two, the MNL model is found to be more acceptable and considered as a better approach by many planners for mode choice analysis, since it accounts for the behaviour of users at individual's level.

As one of the main objective, development of models for mode choice analysis based on behavioural science technique has been undertaken and applied to examine their suitability to Indian conditions, for future estimations. It is in this context that the various models developed have been tested for a selected area (Shahdara) in Delhi City of India. Shahdara in Delhi has been chosen to study the applicability of the models derived.

The area selected has access to both road and rail facility. The proposed MRTS in Delhi will pass through this area by 2001 AD, and would link this area directly to CBD and number of important work centres.

Introduction of MRTS has been found to cause a shift of 11.5% from bus, 2.4% from motorised two wheelers, 3.5% from Car and 8% from bicycle trips to train and MRTS increasing its share by 25.4%. It has shown that the results obtained from the model are fairly close to the desires expressed by the people.

Trade-off game is considered as a better approach since it overcomes an inherent defect found in other types of opinion surveys which are conducted in a condition of 'no constraint'. A trade-off game has been conducted to assess the relative importance they attach to different travel attributes while choosing a mode for his travel. Scales of importance as expressed by them in both 'unconstrained' and 'constrained' conditions have been constructed.

The trade-off game results analysed can be used to work out the percentage of commuters using a particular mode that would shift to an improved or a new form of transport when levels-of-service of certain attributes are improved. The trade-off game study covers 12 travel attributes. These attributes have been studied under 5 to 7 levels-of-service. The results of the trade-off study have been used to estimate how the share of various modes would undergo changes when MRTS is introduced in a selected area.

The capital costs estimate of the mass rapid transit system projects are based on the unit rates for various elements of the project. These have been calculated on the basis of schedule of rates of Indian Railways, Calcutta Metro and Metropolitan Transport Project (Railways) Madras and is duly adjusted to the year 1996 AD, so as to represent cost of facilities if provided at respective percentage rates as adopted by the Indian Railways. The operating expenses estimate of the MRTS projects have been worked out using the data collected from various departments of Southern Railway and MTP (Railways) Madras in the year 1993 AD and using prevalent rates of payment. The operating expenses are duly adjusted in the year 1996 AD so as to represent cost of facilities if provided now.

Financial analysis by 'Annual Rate of Return' (ARR) method has been done for the year 2001 AD at three different scenarios of monthly season ticket fare and at projected daily ticket fare in the year 2001 AD. At the current projected fare structure in the scenario 1, the MRTS sections are not able to meet even, day-to-day expenditure. This indicates that metro section is not financially viable at three different scenarios of monthly season ticket fare and also at projected daily ticket fare. In the scenario 3, fare structure, the Metro section is able to meet its operating cost including depreciation.

The analysis indicates that a metro system which is fully used would be viable, if the cost of provision of initial infrastructure facilities are not considered, as in the case of a road transport facility where cost of provision and maintenance of road is borne by the state government, the other tangible benefits are saving in energy and less pollution. It is considered that the fare structure should be such that the fare box meets operational cost including replacement cost. It should be delinked from inter-city fare structure.

Economic analysis has been done separately for all the three MRTS corridors. Economic analysis indicates that the MRTS section will be economically viable if MRTS sections are at grade or an elevated. For the particular case of a Shahdara-Nangloi MRTS section, which is 17.7 km an elevated and 7.3 km at-grade has resulted in B:C ratio of 1.15 . Whereas Subzi Mandi-Holambi Kalan MRTS section which is 4.45 km an elevated and 14.85 km at-grade has resulted in B:C ratio of 1.23. Vishwavidyalaya-Central Secretariat Metro Section which is fully underground has resulted in B:C ratio of 0.63. The justification for urban railway projects should not be looked at merely on the grounds of commercial profitability. In such instances, it is very important to assess also the socio-economic implications of the projects. Urban railway projects have a significant impact on the society which would result the maximum possible benefit to the present and future generations, in the use of a particular case of fully utilised line the B:C radio exceeds 1.1 even without considering other benefits. The technique of cost-benefit analysis is an aid in assessing the desirability and viability of urban railway projects from the point of view of overall development of the society. It is therefore considered that, wherever possible, the MRTS should be at-grade or an elevated.

ACKNOWLEDGEMENT

I wish to express my sincerest appreciation and deepest sense of heartfelt gratitude and thanks to the research supervisor Prof.(Dr.) A.K.Gupta, Director Central Road Research Institute, New Delhi (currently on deputation from the former post of professor and Coordinator Centre of Transportation Engineering (COTE), Civil Engineering Department, University of Roorkee), for his very generous help, excellent guidance, lucid suggestions and encouragement throughout the course of this research work. Sparing his valuable time for useful long discussions, inspiring guidance, and painstaking efforts in thoroughly going through and improving the manuscript, inspite of his very demanding professional and administrative duties, extremely busy schedules, at national level, as Director, Advisor, and a number of professional obligations, are gratefully acknowledged.

I also wish to extend my appreciation and profound sense of heartfelt gratitude and thanks to the research supervisor Prof.(Dr.) S.S.Jain, Professor and Coordinator, Centre of Transportation Engineering (COTE), Civil Engineering Department, University of Roorkee, for having rendered excellent guidance, lucid suggestions and encouragement from very inception to the successful completion of the work. Sparing his valuable time for useful long discussions, dynamic guidance, and painstaking efforts in thoroughly going through and improving the manuscript, inspite of his extremely busy schedules. His concrete directions during the initial planning of the work have been the basic back-bone for the success of this work, are gratefully acknowledged.

I am thankful to the Vice Chancellor, University of Roorkee and the authorities of the University of Roorkee for having provided necessary facilities for carrying out this research work.

I wish to express my thanks and appreciation to Dr.P.K.Pande, Dr. Gopal Ranjan both former Professors and Head of Civil Engineering Department and to Dr. K.G. Rangaraju, Professor and Head, Department of Civil Engineering, University. of Roorkee, for their help and support and encouragement during the period for the successful completion of this research work.

I acknowledge with thanks the assistance and encouragement given by all the teaching, non-teaching staff and students of the Division of Transportation Engineering Section, Deptt. of Civil Engg., University of Roorkee.

I am thankful to Prof L.C.Wadhwa, James Cook University, Australia, Dr. Stephen Samuels the University of New South Wales, Sydney, Australia, Prof.(Dr.) Huw C.L. Williams, Department of City and Regional Planning, University of Wales, College of Cardiff, U.K., for discussion during their visits to COTE, Department of Civil Engg. University of Roorkee,Roorkee. The work of Dr. Criss Abbess, Middlesex University, U.K., Prof. William C.Taylor, Department of Civil and Environmental Engineering, College of Engineering, Michigan State University, U.S.A., Prof. Paul Hooper, the University of Sydney, Australia, gave me a source of inspiration in completing this work. The enormous wealth of literature made available to me through many visits made to abroad by my supervisors have been very helpful. The useful discussion with Prof.(Dr.) B.R.Marwah, IIT Kanpur, Dr. L.R. Kadiyali, New Delhi, Er. D.P. Gupta, New Delhi, Dr. P.S. Rana, HUDCO, New Delhi, Prof. (Dr.) D.V.Singh, Vice Chairman, AICTE,New Delhi, Prof (Dr.) H.K.Sinha, Patna University, Prof(Dr.) S.P.Palaniswami IIT Kanpur and Prof (Dr.) P.K.Sikdar IIT, Bombay and Prof. (Dr.) S.K.Khanna (formerly Chairman, AICTE, New Delhi) are gratefully acknowledged.

I express my sincere thanks to Prof S.Raghavachari, R.E.C. Warangal for his encouragement during the course of this research work. Sincere thanks are due to Dr. N.S.Srinivasan, Chairman Transport Advisory Forum Chennai (Madras), and Dr. S.Ponnuswami (Formerly Additional General Manager, Southern Railway Madras), Chennai (Madras), for having useful personal discussion at Madras (Chennai) and at Delhi.

The financial support of University Grants Commission, New Delhi, in the form of Senior Research Fellowship provided to me, is gratefully acknowledged, The help received in data collection from Mr. R.P.Singh, SLT, Mr. K.A. Siddiqui, RT (Rtd.), Mr. Pradeep Singh L.T., Mr. Y.S.Pundir L.T., Mr. Ramkumar T.A.-C, Mr. M.P.Gupta, APO, Mr. N.K.Verma S.P.A., Mr. Mahesh Verma, Mr. Jogender Saini, Mrs Anita, Mr. Bophal singh, Mr. Rakesh, Mr. B.S.Karki, Mr. Surender Kumar, Mr. Shyam Sunder, Mr. Vinod Kumar, Mr. Kunwar Singh and Mr. Rajendra and all other staff members of the Centre of Transportation Engineering and Project cell are gratefully acknowledged. My Fellow Research Scholars and friends, Mr. M.P.S.Chauhan, Mrs. Tripta Goel, Mr. Devesh Tiwari and Mr.Praveen Kumar, deserve a lot of thanks for their help and cooperation, especially during data handling work. Their help came spontaneously and continuously and is thankfully acknowledged.

I am deeply grateful to Mr. Rajeev Verma and Mr.Sanjeev Kumar who assisted me in the work of data processing and typing the draft of the thesis.

I can not forget to recall with my heartiest regards, the never extending heartfelt stream of caring and blessing of my parents and brothers who gave me courage and confidence to complete this work.

Finally, it is a distinct pleasure for me to acknowledge the heartfelt gratitude to my wife Dr.Bharti Singh for her help, moral support and encouragement, throughout the period of this research study. Lastly, but never the least, I can not forget the little helping hands to me from my lovely small daughter Isha Singh, for her patience during the completion of this research work.

Indrasen Singh

Date : April, 8- 1997 (INDRASEN SINGH)

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LIST OF ABBREVIATIONS AND SYMBOLS

$A_j^i(k)$	Perceptive score of level of satisfaction from mode k in respect of attribute j for individual i.
ATP	Automatic Train Protection.
ATO	Automatic Train operation.
ATS	Automatic Train Supervision.
AIPT	Attitude value for Intermediate public Transport.
ACR	Attitude value for Car.
ATW	Attitude value for Motorised Two Wheeler.
ABS	Attitude value for Bus.
ATR	Attitude value for Train.
ACY	Attitude value for Bicycle.
AC	Alternate Current.
BG	Broad Gauge.
BS	Bus (mode).
BCR	Benefit Cost Ratio.
C_k^i	Overall Attitude value on mode k for individual i from a chosen trip purpose (In this study only work trips are considered).
CATC	Continuous Automatic Train Control.
CF	Comfort Factor.
CN	Convenience Factor.
COP	Car Owning People.
CR	Car (mode).
CY	Bicycle (mode).
CYP	Bicycle Owning people.
DDA	Delhi Development Authority.

DTC	Delhi Transport Corporation.
DT	Distance of Travel in Kilometer.
DTBS	Distance of Bus Stop in Kilometer.
DTRS	Distance of Railway Station in Kilometer.
EMU	Electric Multiple Unit.
EWS	Economically Weaker Section.
FQBS	Frequency of Arrival of Bus in Minutes.
FQRT	Frequency of Arrival of Train in Minutes.
FI	Family size Index.
HIG	High Income Group.
IPT	Intermediate Public Transport (Taxi, Autorickshaw, Cycle-Rickshaw).
IRR	Internal Rate of Return.
ISBT	Inter State Bus Terminus.
Km	Kilometer
KV	Kilo Volt
$L(\theta)$	Log Likelihood value for Final Coefficient Value θ.
L(o)	Log Likelihood value for Coefficient Value o.
LOS	Level of Service.
LRT	Light Rail Transit.
LST	Level of Satisfaction.
LIG	Low Income Group.
MRTS	Mass Rapid Transit System (Rail).
MTPR	Metropolitan Transport Project (Railways).
MIG	Middle Income Group.
MLR	Multiple Linear Regression.
MNL	Multi-Nomial Logit.
MLS	Mean Level of Satisfaction for the Mode .

NPV	Net Present Value.
NVP	Non Vehicle owning People.
OHE	Over Head Equipment.
P_j^i	Feeling of Importance of Travel Attribute j for Individual i.
PM	Primary Mode.
PT	Public Transport.
r	Coefficient of Correlation.
R^2	Coefficient of Determination.
ρ^2	Pseudo R Square Value.
RL	Reliability Factor.
Rs.	Rupees.
RRT	Rail Rapid Transit.
RGR	Regional Rail.
SD	Standard Deviation.
SF	Safety Factor.
SR	Southern Railway (of India).
S	Sample Size.
SCADA	Supervisory Control and Data Acquisition.
SCR	Streetcars
TM	Time of Travel in Minutes.
TR	Train (mode).
TW	Motorised Two Wheeler (mode).
TWP	Motorised Two Wheeler owning people.
WK	Walk (mode).

CHAPTER 1
INTRODUCTION

1.1 Background

Major Metropolitan cities have always been centres of human activities. In addition to being seats of various levels of government, they have been generally industrial, educational, cultural and trade centres. However, before the large scale industrialization in India, the most predominant activity was agricultural sector of the economy. This pattern was completely changed by the industrial revolution, which was initiated and sustained by many institutional, economic, and technological developments in the course of the eighteenth and nineteenth centuries.

Urbanisation in India has become more marked only in the current century. The percentage of urban population in 1921 AD was 78 in U.K., 51.2 in USA, 46.4 in France while that of Japan was 18.1 and of India 11.2 [20]. In India, the percentage of urban population in 1971 AD was 20.22, this grew to 23.73 in 1981 AD and to 25.70 in 1991 AD. Though in terms of percentage this appears comparatively low with respect to other countries, in actual numbers this was as large as 217 million in 1991 AD. Apart from this, the larger cities in India have also grown in numbers rapidly in the past 3 decades. In 1961 AD, there were 7 cities with a population of over 1 million. the number of such cities grew to 9 in 1971 A.D. and to 12 in 1981 AD and there were 23 such cities in 1991 AD [7]. The six large cities (Bombay, Calcutta, Delhi, Madras, Bangalore and Hyderabad) themselves accounted for 21% of the total urban population of India in 1991 A.D. [7].

At the beginning of this period of technological progress, the main problems in providing good urban transportation services were technological; motors for vehicles were impractical; vehicle, highway, and track designs were primitive and offered very poor performance. The long series of inventions that subsequently took place created a number of different technological systems. There exists today a "family of urban transportation modes" which offers a nearly continuous spectrum of performance characteristics. These modes are capable of satisfying the needs of any urban area from a small town to a large metropolis.

In light of this abundance of technologies, it appears paradoxical that today many cities suffer from serious transportation problems. The problems include poor quality of service (low speed, poor reliability, discomfort, poor safety, etc.), lack of adequate transportation for some population groups, financial problems and often the most serious one, strong negative effects of urban transportation systems on cities and their environment.

Most major Indian cities started growing outwardly from their original nucleus of ports or governmental centres or commercial areas mainly during British period. As they grew, they absorbed a number of earlier settlements, hamlets and local market places. Most of these settlements had earlier been built around temples and community centres and had intra city narrow roads. The road network in these cities had not been planned to carry present day traffic. Most of the cities have less than 20% of area under transport land use as against 30% or more of land area in many cities of developed countries. It would be difficult to increase the land availability in these cities for transport infrastructure except marginally. There is a need to study how the commuters can be made to choose a desired mode which would result in optimal use of land space and also result in optimal utilisation of scarce resources. This calls for an in-depth study of the factors that influence the mode-choice by the commuters and among the factors of their relative importance. Such a knowledge will help transport planners and policy makers in evolving suitable strategies for transport development in future.

1.2 Travel Habits

Of late, the pattern of land use distribution in most Indian cities is undergoing major changes. The land use development in Indian cities has been brought under planning regulations only recently and specifically since the late sixties or the early seventies when necessary laws were enacted and development authorities were created in major cities. The Development Authorities are responsible for making master plans of cities for efficient land use. Till then, the Municipal Corporations had regulated construction activities, which were mostly concentrating on granting permissions for building layouts and framing physical development standards. In areas not falling within Municipal Corporations or the major municipalities there were no enforcement controls at all. The employment locations in urban areas are so scattered that people have to travel quite a long distance to reach their work places. The per capita trip rates are also increasing in cities. For example in Delhi, the rate increased from 0.49 trips/person/day in 1969 AD to 0.72 trips/person/day in 1981 AD [33] and its present estimated value is 0.91 trips/person/day in 1996 AD. In Madras the same has increased from 0.80 in 1971 AD to 1.35 in 1984 AD [92]. All these are expected to rise substantially by 2001 AD.

1.3 Importance of Urban Railways

Transportation system in its integrated form of network and movements by various modes forms the back bone of development of any country. Its role in the three major aspects of human development viz.; economic, social and political well being (including national security) is well known and established. Starting from the early days of the use of human or animal power as transport energy to the present day development of magnetic levitation. The technological development in the transport sector has been phenomenal, especially in the last 150 years and more, particularly since 1930s. This development has given rise to availability of various modes. While each innovation may add on to benefits from social point of view, each addition has to be examined from the point of view of number of influencing areas such as planning, engineering and management.

On the economic side, selecting a mode may give considerable advantage particularly from the point of view of time and comfort. However, on the overall national consideration it may mean more cost. Hence one has to look at the role played by different modes and choose the best mix for overall benefits of not only the present generation but the future ones as well.

The suburban/regional rail system has helped the development and growth of satellite towns as growth centres and urban nodes, which to some extent has helped to reduce the over-crowding in city centres. In major cities, the metro-rail, has been taking a large share of the transit trips. With a very high increase in the number of private modes, coupled with inadequate road space for buses, the efficiency of the public road transport system in metropolitan cities have been affected and is reflected in the form of reduced speed and lesser sub-system frequency. Another very important factor which needs attention, from the social cost benefit angle is the urgent need for energy conservation, in the context of spiralling price rise in petroleum products. Besides, there is an urgent need to arrest environmental pollution.

1.4 Philosophy of Economics of Operation

Any project appraisal in a normal industry will comprise of working out the fixed cost and variable cost and total earnings out of sale of the product, so as to work out the profit. In most industries, it is easy to forecast and provide for both types of costs, fix commensurate prices and ultimately workout the annual return on the investment. In a major railway system also, similar principles apply except that the price (fare and freight) has to be fixed based on capacity of commodity to pay.

Railways in India started as private industries with profit motive, where they could not earn the minimum profit, the government undertook to make up for the shortfall. Where they made more profit than the minimum, the surplus was shared with the government. However, in overall terms, the government stood to gain.

To deal with any transport project, where it covers major intra-city and/or suburban services, it is not so easy to work out costs and earnings. Since, in an urban transport project, the demands is variable over the day and the infrastructure requirement for meeting the peak hour traffic which is concentrated in one or two hours in the morning and one or two hours in the evening involves heavy investment and varying dependent costs. The general tendency in metropolitan cities is also for the peak traffic to be concentrated in one direction in the morning hours and in the reverse direction in the evening hours. The infrastructure therefore has to provide for meeting the peak demand while the same may be under utilised in the other hours. Hence, it is difficult to clearly draw a line between fixed costs and variable costs which are to be divided over the traffic and different philosophy is called for.

1.5 Policy Studies Carried out for Indian Cities

The study groups on "Alternative Systems of Urban Transport" constituted by the Government of India in 1985 AD has recommended that the modal share of public transport in cities of various population sizes should be targeted as given in Table 1.1 [53].

The working group on urban transport of the 'National Commission on Urbanisation' of India recommended that 'all out efforts should be made to discourage the use of personalised modes of transport and to encourage the use of public transport system in cities in a systematic and concerted manner' [54].

TABLE 1.1 EXISTING AND TARGETED MODAL SHARE OF PUBLIC TRANSPORT

Cities with Population	Modal Share of Public Transport (%)	
	Existing	Targeted
Less than 1 million	-	30
1 million	10	35
1.5 million	15	40
3.0 million	25	50
6.0 million	50	70
9.0 million	55	75-80

Source : Government of India report, [53].

1.6 Need of Public Transport Systems

An increasing quantum of the world's rapidly growing population is living in large urban areas and cities and the metropolitan cities continue to grow bigger in size. Transport is a major cause of this and transportation problems a major symposium.

A population mark of five million has been passed by many major cities of the world. Table 1.2 shows the world's 34 largest metropolis ranked by population size [55]. They are major urban areas and centres of culture, they provide services such as finance and education which serve not just the area of the metropolis or the nation but contribute to the whole world. All this has its social and environmental price, the persuit of excellence and wealth tends to generate degradation and squalor and public policy so often fails to control it. So we see remarkable and shocking contrasts of the strumming glass sky scrappers bathed in sulphorous smog and a heavy noise in massive traffic jams. Lack of resources, inadequate administration, insufficient coordination, inadequate system management and poor relationship between transportation and land use/economic planning are to be seen in all the big cities. In India, there are four mega cities, which reached a population of more than five million each as early as in 1991 AD. These are Mumbai (Greater Bombay), Calcutta, Delhi and Chennai (Madras). The rank of each of these four mega cities among the 34 largest metropolis in the world on the basis of the size of their population is shown in Table 1.2 [55].

The public transport mode available to commuters in all the Indian Cities (except Mumbai, Chennai and Calcutta which have well established suburban rail systems) is mainly the bus and to some extent mini bus in a few cities. The para transit modes available are in the form of taxis, three wheeled auto rickshaws/tempos and cycle rickshaws. Better socio-economic status now enjoyed by urban Indians has made them to look for something better. What happened in developed countries at the end of the second world war in automobile ownership is happening to-day in India. With easy access to loan facilities and hire purchase facilities available, the private vehicle ownership rate in India is growing rapidly. For example in Delhi, the number of motor vehicles has grown from 0.24 million in 1970 AD to 1.42 million in 1988 AD and to 2.5 million in 1996 AD. In Chennai (Madras), it has grown from 0.05 million in 1971 AD to 0.14 million in 1981 AD, 0.38 million in 1985 AD and to 0.52 million in 1990 AD [56].

Public transport facilities are least expensive to the users as they are shared facilities. Due to high occupancy/capacity of public transport system, it is able to move more people at low space wherever and less cost. On the other hand, the user who chooses his own vehicle or a hired vehicle for use has to pay more, but it provides him more comfort and convenience.

Due to low occupancy, private vehicles occupy more road space per person moved, resulting in poor utilisation of available road space. This can be judged by comparing space requirements for different modes in busy urban roads (Table 1.3) [97].

TABLE 1.2 WORLD'S 34 LARGEST METROPOLES RANKED BY POPULATION SIZE

Sl.No.	Name of City/ Urban Agglomeration	Name of Country	Population (million)	Rank
1.	Mexico City	Mexico	20.2	1
2.	Tokyo	Japan	18.1	2
3.	Sao Paulo	Brazil	17.4	3
4.	New York	USA	16.2	4
5.	Shanghai	China	13.4	5
6.	Greater Bombay	India	12.6	6
7.	Los Angeles	USA	11.9	7
8.	Buenos Aires	Argentina	11.5	8
9.	Seoul	Republic of Korea	11.0	9
10.	Calcutta	India	10.9	10
11.	Beijing	China	10.8	11
12.	Rio De Janeiro	Brazil	10.7	12
13.	Tianjin	China	9.4	13
14.	Jakarta	Indonesia	9.3	14
15.	Cairo	Egypt	9.0	15
16.	Moscow	USSR (Russia)	8.8	16
17.	Metro Manila	Philippines	8.5	17
18.	Osaka	Japan	8.5	18
19.	Paris	France	8.5	19
20.	Delhi	India	8.4	20
21.	Karachi	Pakistan	7.7	21

Contd...

Contd.. Table 1.2

22.	Lagos	Nigeria	7.7	22
23.	London	U.K.	7.4	23
24.	Bangkok	Thailand	7.2	24
25.	Chicago	USA	7.0	25
26.	Teheran	Iran	6.8	26
27.	Istanbul	Turkey	6.7	27
28.	Dacca	Bangladesh	6.6	28
29.	Lima	Peru	6.2	29
30.	Hong Kong	Hong Kong	5.4	30
31.	Madras	India	5.4	31
32.	Milan	Italy	5.3	32
33.	Madrid	Spain	5.2	33
34.	Leningrad	USSR	5.1	34

Source : Gupta,A.K. et al [55]

If land values in cities and the practical difficulties in acquiring land for road widening are considered, there is a need to study how effectively we could utilise the given road space and carry more people.

1.7 Directions of the National Transport Policy Committee

The guiding policy of the National Transport Policy Committee (NTPC) of 1980, in respect of urban transport is as follows :

"In the foreseeable future, bus transport will continue to be the principal means of intra-city movements. Priority should, therefore, be given to strengthen and optimise bus services. Electric traction based public transport systems should be preferred, diverting traffic from personalised modes of motor transport to the public transport system. Augmenting the existing suburban rail facilities and providing new electrified intra-urban rail services are essential to meet the traffic demand. Electric trams and trolley buses have an important role to play mainly on considerations of energy conservation" [120].

TABLE 1.3 ROAD SPACE REQUIREMENT FOR DIFFERENT MODES

Mode of Travel	Hourly Capacity Per lane (Persons)	Average Speed (kmph)	Space requirement per person movement (sqm)
Pedestrian	23,500	4.7	0.7
Pedal cycle (1)	5,400	12.0	8.0
Motor Cycle (1.1)	2,400	12.0	17.5
Car (1.5)	1,050	12.0	40.0
Bus	7,700	10.0	4.5
Train (250)	24,000	25.0	2.5

Figures in bracket indicate occupancy per vehicle unit

Source : Leibrand [97]

1.8 Need of the Study

It is evident that rail based mass rapid transit systems have a role to play in an urban transport system. In view of high investments, a realistic appraisal taking into consideration various costs involved, is necessary.

In 1951 AD, the population of motor vehicles in India was 0.3 million (ownership; 1 in 1180), a good deal of small-lead short haul transportation being carried out through animal carts and other such means. By 1991 AD, the vehicle population had increased by 70 times, to a total of 21.31 million (ownership ; 1 in 40) [56].

The growth of registered motor vehicles in Delhi has been increased from 0.24 million in 1970 AD to around 1.42 million in 1988 AD and presently around 2.5 million (July, 1996 AD) [57]. One can imagine as to how much would be the congestion level on roads, when there would be such a growth of vehicles. The improvement of traffic conditions that will be facilitated by both mass transit road modes and automobiles will require a variety of street and traffic engineering solutions including by pass roads, one-way circulation, grade separation at intersections, signal systems and other traffic controls, apart from higher operational costs. If these costs and inputs also are taken into consideration, one may draw the conclusion that the construction of high capacity rail transit system in subways or over elevated structures, if on surface as suburban rail will be advantageous, despite of high cost, in such of the cities where incomes will be sufficiently high to permit the investments required. it has been fully recognised by planners and engineers that solution lies in developing mass rapid transit facilities in the major cities. But the high initial costs involved in developing them and the difficulty in meeting the operation and renewal costs by fare box only has been the dividend in large for development of such facilities. This calls for an in-depth study of alternative forms of mass transit systems, their capacities, costs and economics in the Indian context so that a proper mix can be arrived at for each city. Consideration on development of any rail transit has for long been based on the viability of the project in financial terms. Since, past two decades change has come about to think in terms of providing subsidies due to social necessity and assessing them on social benefit cost basis. The justification for urban railway projects should not be looked at merely on the grounds of commercial profitability, particularly in Indian context.

1.9 Objectives and Scope of the Study

The objectives of the present research study are :

(i) To study trend pattern of urban travel requirements, its likely growth and thus identify the major transportation corridors needing such systems.

(ii) To study how attitudes of an individual towards various travel attributes influence the choice of mode of travel.

(iii) To develop mathematical models incorporating attitude values to forecast mode choice of users in changed conditions.

(iv) To study how behavioural science technique like Trade-Off Game could be used to evaluate the importance of various travel attributes and to estimate future mode choice scenario in Indian context.

(v) To study alternative mass rapid transit systems available in the world and their likely costs and performance characteristics in Indian context.

(vi) To study their costs and economics at different fare structure and capacity utilisation.

(vii) To evolve strategies for choice of systems for cities at different levels of development.

The scope of the study is limited to three proposed MRTS corridors of Delhi City.

1.10 Structure of Thesis

The approach to the problem and presentation of findings are done as discussed below ;

The review of work done so far on mass rapid transit system and mode choice have been discussed in Chapter 2. Chapter 3 describes problem formulation and adopted methodology. It covers various methodologies for this approach and discusses the choice of the methodology considered suitable for Indian cities. Chapter 4 brings out the planning of Mass Rapid Transit System (MRTS) and traffic projections on three identified MRTS corridors of Delhi city. These corridors are (i) Vishwavidyalaya-Central Secretariat Metro Corridor (ii) Shahdara-Nangloi MRTS corridor (iii) Subzi Mandi-Holambi Kalan MRTS corridor. Chapter 5 brings out the need for the use of behavioural science approach to the problem. Chapter 6 describes the measurement of commuter's mode choice attitude and analysis and findings of travel attributes. Chapter 7 covers the various aspects of development of models making use of users attitude values and shifts from existing modes to improved or new modes. In this chapter various aspects of the formulation and development of models like Multiple Linear Regression (MLR), Multi-Nomial Logit (MNL) models have been discussed. The application of findings of attitude study have been discussed. Chapter 8 discusses the behavioural simulation in mode choice analysis and the manner in which the Trade-Off propensities of commuters can be used to forecast shifts from existing modes to improved or new modes. Chapter 9 describes the capital and operating expenses of three identified MRTS corridors. Chapter 10 describes the fare structure and earnings. Chapter 11 brings out the financial analysis of MRTS. Chapter 12 describes the economic analysis of MRTS. Chapter 13 presents the conclusions and recommendations.

CHAPTER 2
REVIEW OF RELATED STUDIES AND STATE-OF-THE-ART

2.1 Introduction

The mass transit system is meant to provide an efficient and attractive link between the different high density parts of the city supporting the industrial and commercial developments and providing the reliable means of transport expected of a modern city and its increasingly affluent society. The mass transit system has to perceived as a viable alternative to the private car, an alternative which would improve the quality of life. Planners and policy makers reviewed and debated both bus and rail based alternatives. Early studies dismissed bus based alternative as impractical, lacking in adequate capacity, reliability and comfort. However, economists and fiscal experts raised concerns about the high capital cost of a rail based system, and therefore public debate and further studies continued.

Gradually, the emphasis of the debate shifted from concerns of initial costs to concerns about the end results, the quality of service that the alternatives could actually provide. Solving transport problems has become one of the chief tasks confronting the city government. Vast number of buses, trucks, cars, bicycles and pedestrians are all competing for limited road space. When demand for road space outstrips capacity, rail mass transit systems, including subway and light rail systems, along the main commuter corridors may appear attractive. Many cities are now discovering that abandoned railway lines, old tramway lines and suburban services linking the city proper with economic development zones are good candidates for in expansive development of rapid transit service.

In India urbanisation is taking place at a rapid space. Growing cities require large movement of people. Such large scale movements, if carried by personalised modes of transport create congestion on roads with usual implications of extended journey times, excessive energy consumption and environmental pollution. Moreover, most of the urban residents can not afford personalised transport and depend upon public transport. The solution is provision of an efficient public transport system [148].

It is believe that the real solution of transit problems for metropolitan areas is to establish a balanced total transit system i.e. the optimum combination of different urban transit modes in which each mode would play its own part. A conventional transport model building comprises of four important stages viz.; trip production (generation and attraction), trip distribution, modal split and trip assignment. Out of these, modal split influences very heavily all the other three stages. Analysis of modal split has become a complicated subject due to its nature of association with a large number of variables. In early transportation studies, modal split aspect was not considered so seriously , since the extent of competition between various modes and their impact on people's choice was not fully felt. In fact, early studies on transportation were generally concerned with the forecast of road vehicle traffic without need to take into consideration the impact of traffic congestion. In some studies, modal split prevalent at the time of analysis was extended to future forecast. With the automobile boon since nineteen fifties, the growing demand for use of the limited available road space and consequent congestion on roads drew the attention of the planners to the need for detailed analysis in this respect.

2.2 Types of Mass Transit Systems

Mass transit modes operate exclusively on transit right-of-way which is a strip of land on which the transit vehicles operate. There are three right-of-way categories distinguished by the degree of their separation from other traffic and are detailed below.

Category A (Rapid Transit)	Fully controlled right-of-way without grade crossings or any legal access by other vehicle or pedestrians. Exclusive freeways, tunnels.
Category B (Semi rapid Transit)	Right-of-way categories which are longitudinally physically separated by curbs, grade separation etc. from other traffic, but with grade crossings for vehicles and pedestrians including regular street inter-sections. Right-of-way of LRT (Light Rail Transit) is the example of this category.
Category C (Slow Transit)	Surface streets with mixed traffic. Buses and tramways of certain types.

Category A and B have high speed, capacity, reliability and safety. All existing rapid transit systems utilize guided technologies, which permit operation of trains and automatic signal control resulting in high safety. Light Rail Rapid Transit (LRRT) and Rail Rapid Transit (RRT) are in this class.

2.3 Characteristics of Individual Rail Modes

On the basis of the main features that define transit modes right-of-way type, technology, and operational/service characteristics, rail systems can be classified into four modes : Streetcars (SCR), Light Rail Transit (LRT), Rail Rapid Transit (RRT) and Regional Rail (RGR). Each mode offers a different range of physical characteristics, performance and cost. In some of them, there is an overlap between these modes, which sometimes causes confusion with respect to definition of concepts and terminology.

2.3.1 Streetcars

Streetcar systems consist of one, two, and occasionally three rail vehicles operated mostly on streets in mixed traffic but sometimes also with limited separation from street traffic by preferential treatment. Separate right-of-way streetcars have excellent dynamic characteristics and riding comfort, but their reliability and operating speed depend greatly on the conditions along their lines. If they run on narrow streets with congested traffic, their performance can be very poor, on wide streets with little traffic interference or with various preferential treatments, SCR vehicle has 4 to 6 axles can be very good.

A typical SCR vehicle has 4 to 6 axles and a length of 14 to 21 metre, seating about 20 to 40% of its 100 to 180 total passenger load. Because of the predominantly shared right-of-way, SCR service generally has operating speed below 20 kmph. Streetcars have a higher capacity better riding comfort, and a more distinct image than highway transit modes. However, they involve considerably higher costs on lightly traveled lines. Moreover, they have serious operational problems in mixed traffic. Need of route extensions in expanding cities and the incompatibility of SCRs with auto traffic caused their extensive replacement by buses, particularly at times when transit was given no priority treatment.

In addition to their substitution by buses and trolley buses, the role of streetcars has also decreased because of conversion of this mode into higher-quality LRT or substitution by RRT systems.

2.3.2 Light rail transit

Light Rail Transit (LRT) systems typically have articulated 6 or 8 axle vehicles or multiple-unit trains of up to 4 or 6 axle, or two 8 axle cars.

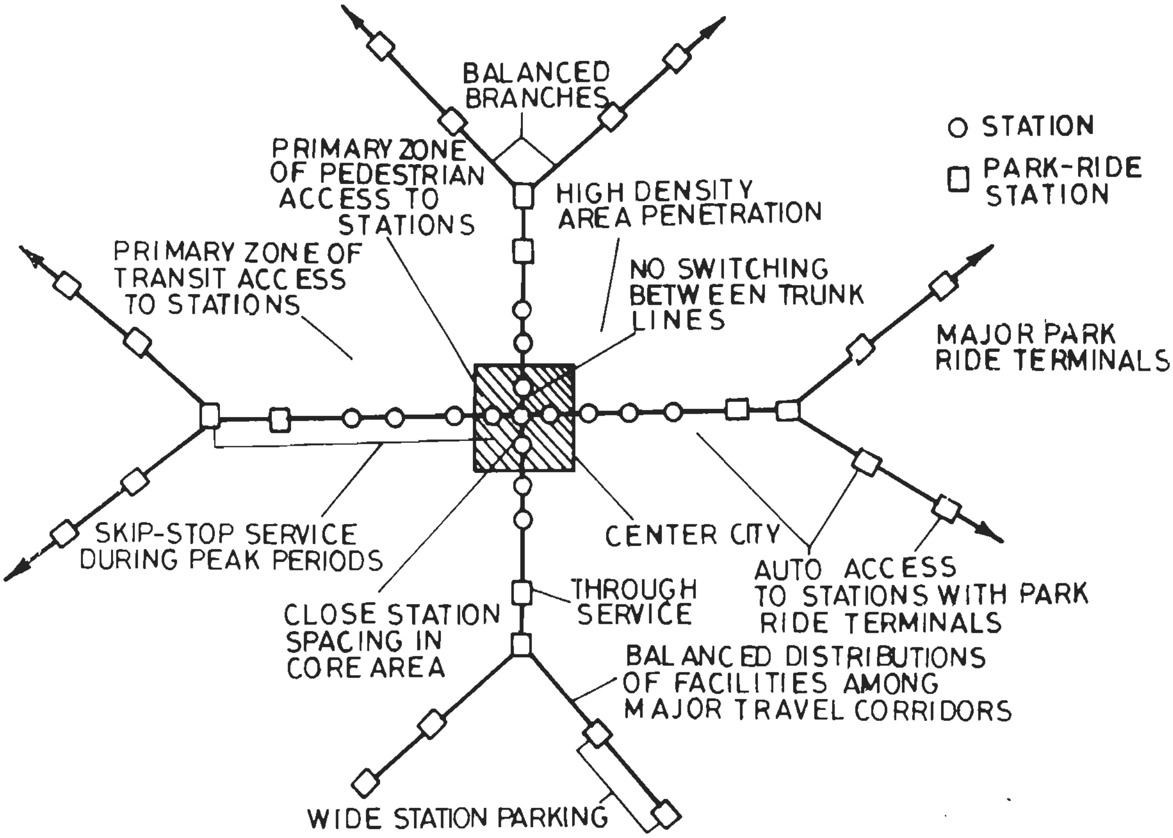
Articulated LRT vehicles range in length from 20 to 32 m, one such vehicle can accommodate upto 250 persons, 20 to 50% of whom are seated. Modern LRT vehicles have high acceleration, deceleration capabilities (1.0 to 2.0, emergency braking 3.0 m/s^2), their maximum speeds depend on the conditions of individual systems, and are usually in the range of 70 to 80 kmph, but there are models capable of achieving 100 to 125 kmph. Operating speeds of LRT are typically between 18 and 40 kmph. Where required, LRT vehicles may be equipped with steps for high and low-level boarding, public address and communication systems as well as sophisticated electronic control of motors with antispin and skid-prevention capabilities also exist on some recent LRT models. LRT operates substantially on exclusive right-of -way, which are sometimes grade-separated. Separation may amount to as little as 40% or as much as 90% of the total network length, but it is a common practice first to separate the most critical sections in central city or on congested arterials, so that most of the sources of service disturbances are eliminated. Thus LRT in many cities utilizes tunnel sections to penetrate the congested areas of the city, a factor that greatly enhances the quality of service they offer. The alignment standards and station features of LRT systems can be the same as those of RRT systems, yet the same LRT vehicles can also operate on existing streetcar line with curb height stop platforms. This flexibility allows a staged upgrading of a network to a new right-of-way without interruption of service and with immediate utilization of new route sections. Such staging permits investments to be tailored to local conditions, the desired service quality, and the availability of capital funds. On separate right-of-way sections transit unit frequencies can approach 90 per hour with little technical or operational difficulty and with good reliability, and upto 140 per hour with elaborate control and reduced reliability.

Volumes as high as 45,000 persons per hour per track have been possible [84]. Consequently, LRT systems can offer the capacities between 18,000 and 24,000 persons per hour per track, although the reported cases are below these ranges.

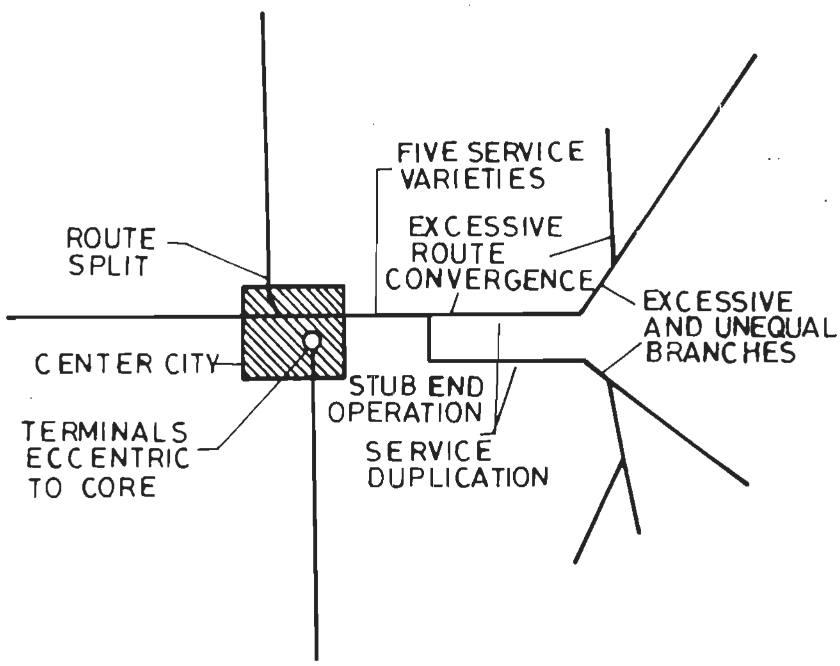
Thus LRT systems in most cases do not have high capacities than streetcars; rather, their superiority over streetcars is reflected in considerably higher operating speeds, and therefore higher productive capacities. Moreover, operation with signals offers higher safety, superior riding comfort, and level-of-service generally.

2.3.3 Rail rapid transit

In many respects, RRT, including rubber-tyred rapid transit (RTRT), represents the optimal transit mode for a high-capacity line or network service, It has a fully controlled right-of-way, without any external interferences. Simple guidance, electric traction, and fail-safe way control allow the maximum speed possible with given station spacings and permitted by passenger comfort, high power utilization efficiency, high reliability, and virtually absolute safety. Operation of a train with up to 10 long 4-axle cars by one person results in a capacity and labour productivity much higher than any other mode except that which its "big brother", Regional Rail (RGR), can achieve. Off vehicle fare collection, high platforms, and simultaneous boarding/alighting through upto 40 double-channel doors allow this mode to operate total boarding/alighting rates three to five times greater than those of LRT, and 10 to 20 times greater than those of buses assuming the ultimate capabilities of all these modes. Because of its physical and operating characteristics, RRT is the mode most conducive to fully automated train operation of all existing and proposed modes. Several RRT systems already have many automated elements, unmanned stations, automated train running, and central control of the entire lines or networks. Rapid transit requires the highest investments costs of all modes (primarily because of its entirely grade-separation right-of-way and large stations), so that its primary applications are in heavily travelled corridors. Desirable and undesirable aspects of rapid transit systems configuration and design are shown in Figure 2.1 [70]. It should be born in mind, however, that where heavy passenger volumes have to served by a high-performance, high level-of-service system, RRT requires



(A) DESIRABLE



(B) UNDESIRABLE

FIG. 2·1 RAPID TRANSIT ROUTE CONFIGURATION CONCEPTS substantially lower investment and lower operating costs than any other technology.

The typical modern RRT vehicle, 16 to 23 m long and 2.5 to 3.20 m wide is operated in transit units (TUs) from 1 to 10 cars. Vehicle capacities range between 120 and 250 spaces; seats represent anywhere from 25 to 60% of vehicle capacity. Operating speeds range from 25 to 60 kmph, with peak-hour frequencies between 20 and 40 trains per hour. Recorded capacities of RRT lines with stations have been as high as 62,000 persons per hour per track (New York). Some of the recently opened systems (Sao paolo, Hong Kong, R.E.R. in Paris) have been designed for capacities of the same magnitude. Volumes as high as 90,000 persons per hour per track have been possible [84].

2.3.4 Regional rail

Regional rail representing local services of long-distance railroads. RGR systems have the highest technical and operating standards of all transit modes. These systems are operated by railroad agencies on their right-of-way which are usually grade-separated, but some have signalized grade crossing. Traction is mostly electric, some time diesel.

The service is characterized by long average trip length, long station spacings, and high speed and reliability.

RGR systems have very high seating capacities, upto 128 seats in single level cars, as many as 175 in double-decker cars. The latter type of car is in use in Chicago, San Francisco, Toronto, Paris and several other cities, operating speeds average anywhere between 30 and 75 kmph, with maximum running speeds of upto 130 kmph. The labour productivity of RGR can be very high, but many systems, particularly those in the United States, Canada and India, are subject to obsolete labour practices and have a labour force greatly in excess of what this mode would require with modern operating methods. Other deficiencies and under utilized potential of some RGR systems can also be traced to these labour practices, frequently to uninterested management, grossly inadequate financial assistance from public sources, and the resulting poor maintenance and lack of modernization or progressive thinking in general. It is because of the inherent high performance of this mode than even the inefficiently run systems provide an extremely valuable service in metropolitan areas. Yet its basic advantages and durability should not be an excuse for wasteful practices and under utilization of the full potential of this mode.

2.4 Future Role of Rail Transit Around the World

With respect to the dominant reasons for RRT construction, cities around the world can be classified into two rather distinct categories. Cities in Western Europe, the United States, and Canada build rail transit systems primarily to improve the quality of their transit services, to make them capable of attracting passengers from the automobile. Cities in Latin America, Asia and to a large extent those in the Russia, build RRT systems primarily to provide the needed high capacity (improved service is, of-course, always a highly desirable contributing factor).

The difference between the two groups can be clearly seen by comparing the density of usage (passenger-km/km of line) on RRT systems in different regions of the world shown in Figure 2.2 [121]. The systems built primarily for "quality" have a lower density than those built for "quantity".

Both of these dominant requirements, quality and quantity of service have intensified in recent years. High auto ownership has resulted in paralysis of cities; urbanization, particularly intensive in the developing countries, has created growing needs for higher capacity systems than highway modes can provide. The result of these trends has been continuously accelerating construction of RRT systems throughout the world, as Figure 2.3 clearly shows [121].

In addition to the needs for increased capacity and improved quality of transit services, several other aspects of RRT (or rail transit in general) have an important

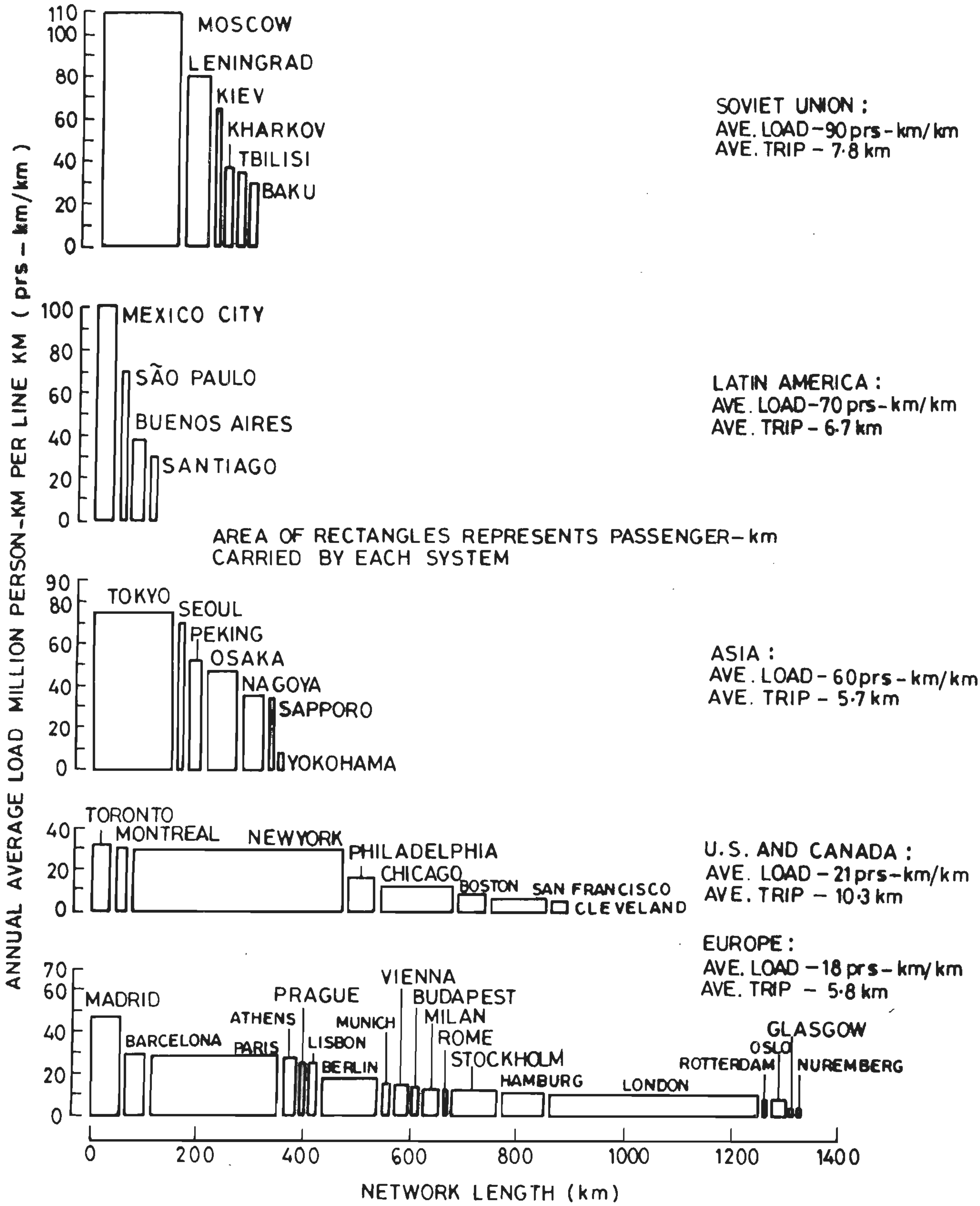


FIG. 2·2 NETWORK LENGTHS AND RIDERSHIP DENSITIES OF WORLD RAPID TRANSIT SYSTEMS

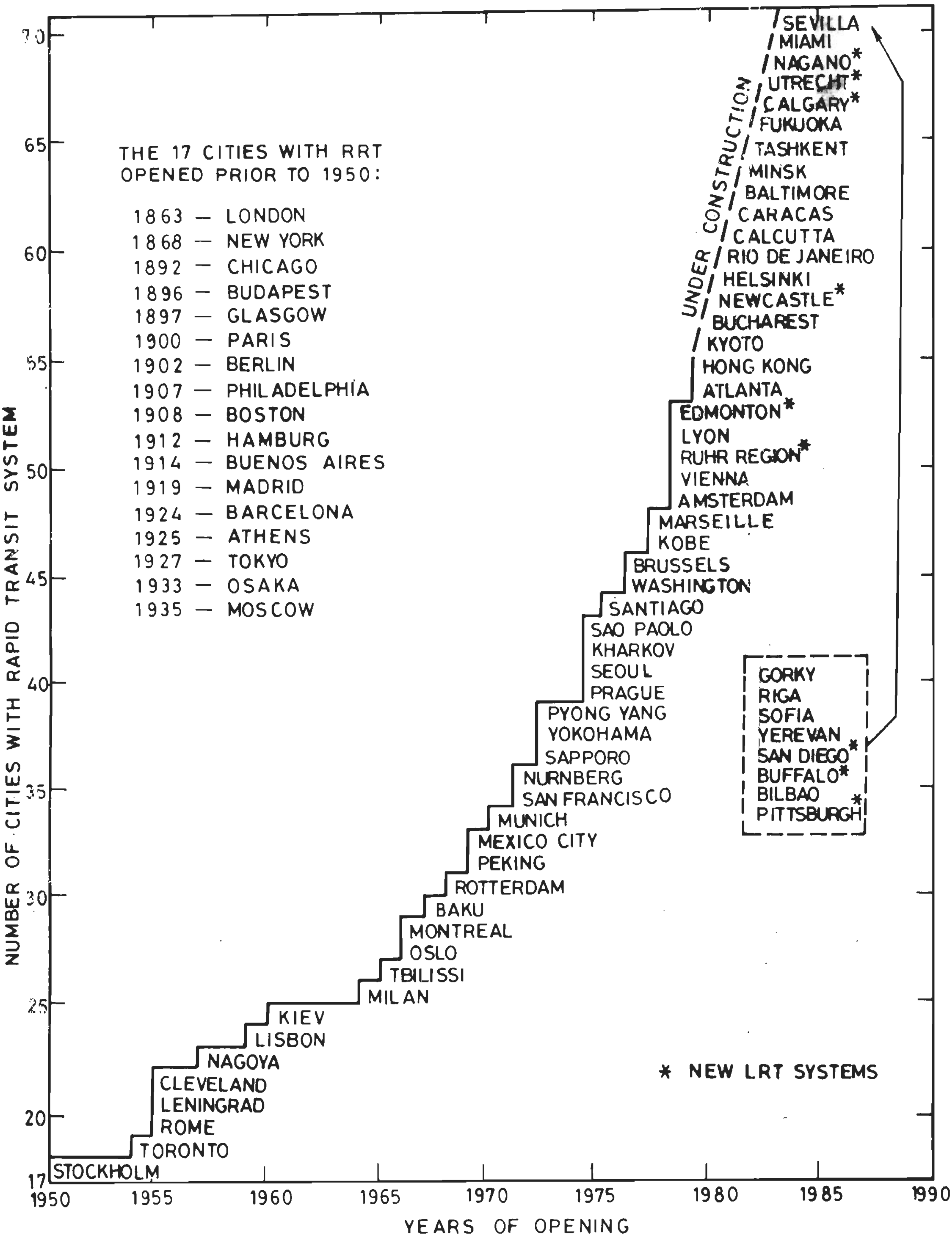


FIG. 2·3 RAPID TRANSIT SYSTEMS OF THE WORLD role in the decisions about their construction. Introduction of RRT is always an important step in the development of a city. Its construction usually represents the largest and most significant public project ever undertaken by the city; it stimulates various planning activities and interest in civic progress in general. Its opening is always a major festivity. The opening of rail transit lines results in a major reduction in energy consumption for transportation, as well as for other purposes.

These savings increase with time through the impact of RRT on urban forms. Moreover, the RRT system becomes a landmark by itself, and it gives the city a certain special identity and image. There is a distinct pride in a city's being a "rapid transit city". Most great world cities are recognised as such partly because of their rapid transit systems. An important part of Paris is its Metro; of London, its underground; of Newyork, its subway; of Moscow, its Metropolitan; and of Berlin, its U-Bahn. The importance and value of rail transit thus considerably exceeds the direct physical and economic results of its operation.

2.5 Summary of the Family of Rail Transit Modes

The four rail transit modes are not distinctly separated from each other. The distinctions between SCR and LRT systems as well as between RRT and RGR are particularly complex. The sharpest difference is between LRT and RRT, full grade separation is a characteristic that distinguishes the later; in addition to higher performance, full right-of-way control usually brings several technical features, such as high-level platforms, third rail power supply operation of long trains, and fully automatic, fail-safe control.

Technical, operational and system characteristics of the four rail transit modes are given in Table 2.1. A review of their basic technical and operating features is shown in a graphical form for clarity in Figure 2.4. These exhibits show the great diversity in characteristics of different rail modes. Statements describing rail transit

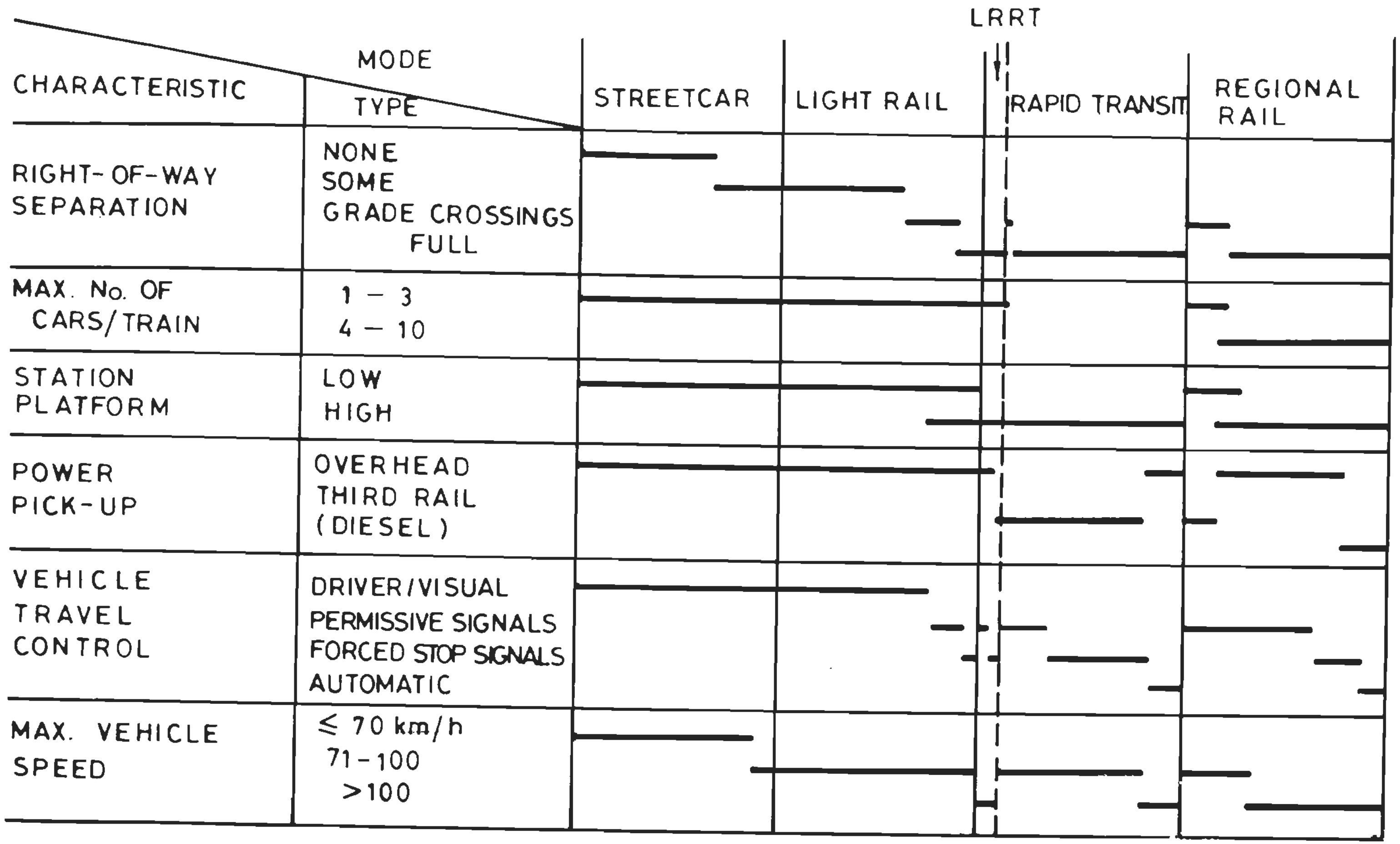


FIG. 2·4 BASIC CHARACTERISTICS OF RAIL TRANSIT MODES as a single mode, such as the one that "rail transit is expensive and its application is limited to a few cities", represent erroneous generalizations. The broad ranges of rail transit characteristics make these modes suitable for application under a variety of conditions. Moreover, if the goal of a transit system is to attract, auto users by a high level-of-service, rail modes are often the lowest cost systems of all available alternatives. This presumes, of course, that the comparison is made taking into account passenger attraction abilities and total, positive and negative, effects of alternative modes, including the indirect ones, for the entire planning time period.

TABLE 2.1 DETAILS OF TECHNICAL, OPERATIONAL AND SYSTEM CHARACTERISTICS OF RAIL TRANSIT MODES

System Component	Street Car	Light Rail	Rapid Transit	Regional Rail
Vehicle/Train Characteristics				
Maximum Operational	1	1 (4-axle)	1 - 3	1 - 3
Maximum Train Composition	3	2-4 (6-8 axle)	4 - 10	4 - 10
Vehicle length (m)	14 - 23	14 - 30	15 - 23	20 - 26
Vehicle Capacity (Seats per vehicle	22 - 40	25 - 80	32 - 84	80 - 125
Vehicle Capacity (total spaces per vehicle	100 - 180	110 - 250	140 - 280	140 - 210
Fixed facilities				
Exclusive right-of-way (% of length)	0 - 40	40 - 90	100	90 - 100
Vehicle Control	Manual/visual	Manual/signal	Signal	Signal
Fare Collection	On Vehicle	On Vehicle/at station	At Station	At Station/ on vehicle
Power Supply Stations	Overhead	Overhead	Third rail/ Overhead	Overhead/ Third rail

Contd...

System Component	Street Car	Light Rail	Rapid Transit	Regional Rail
Platform height	Low	Low or high	High	Low or High
Access control	None	None or full	Full	None or full
Operational Characteristics				
Maximum speed (km/h)	60 - 70	60 - 120	80 - 100	80 - 130
Operating speed (km/h)	12 - 20	18 - 40	25 - 60	40 - 70
Maximum frequency Peak hour, joint section (TU/h)	60 -120	40 - 90	20 - 40	10 - 30
Off-peak, single line(TU/h)	5 - 12	5 - 12	5 - 12	1 - 6
Capacity (persons/h)	4,000-15,000	6,000-20,000	10,000-40,000	8,000-35,000
Reliability	Low-medium	High	Very high	Very high
System aspects				
Network and area coverage	Dispersed, good area coverage	Good CBD coverage, branching is common	Predominantly radial,some CBD coverage	Radial,limited CBD coverage
Station spacing (m)	250 - 500	350 - 800	500 - 2,000	1,200 - 4,500
Average trip length	Short to medium	Medium to long	Medium to Long	Long
Relationship to other modes	Can feed higher capacity modes	P+R, K+R, bus feeders possible	P+R, K+R, bus feeders	Outlying, P+R, K+R, bus feeders; centre city,walk,bus.

Source : Compiled From Records.

2.6 Chronology of Inventions in Urban Public Transportation

The details of chronological development till late 1970's AD have been tabulated in Table 2.2 [118]. Table 2.2 also shows the year, location (city/country) and event of the inventions in the urban public transportation in various parts of the world.

TABLE 2.2 CHRONOLOGY OF INVENTIONS IN URBAN PUBLIC TRANSPORTATION

Year (AD)	Location	Event
Ca. 1600	London	" Hackney coached " - Taxicab services
1612	Paris	" Flacre " - Taxican Services
1662	Paris	First urban public coaches - common carriers, Horse - drawn carriage
Ca. 1765	England	Invention of steam engine (Watt)
1825	Stocton-Darlington England	First railway opend.
1826	Nantes, France	First Horse-drawn omnibuses.
1832	New York	First Horse-drawn Streetcar line.
1838	Boston	First commuter fares on a railway line.
1863	London	First underground rapid transit line.
1868	New York	First elevated rapid transit.
1873	San Francisco	Invention of Cable Car (Hallidie)
1878	Germany	Invention of internal combustion engine (ICE) (Otto)
1879	Berlin	First application of electric motor for traction (Siemens)
1881	Berlin	First electric streetcar (Siemens)
1882	Hallensee,Germany	Demonstration of the first trolleybus (Siemens)
1883	Germany	First light weight ICE (Daimler)

Contd...

Contd.. Table 2.2

Year (AD)	Location	Event
1886	Mannheim,Germany	First automobile built (Benz)
1886	Montgomery,Alabama	Invention of under - running spring-loaded trolley pole for streetcars (Van Depoele)
1888	Richmond,Virginia	First successful major streetcar line (Sprague)
1890	London	First rapid transit with electric traction
1892	Germany	Invention of compression-ignition engine (Diesel)
1893	Ohio and Oregon	First Interurban lines
1897	United States	Invention of multiple-unit train control (Sprague)
1897	Boston	First street-car tunnel
1899	Great Britain	First Motorbuses
1901	Wuppertal,Germany	Practical overhead power pickup for trolleybus
1901	Fontainebleau, France	First trolleybus line in operation (Lombard - Gerin)
1902	Bielatal,Germany	Practical overhead power pickup for trolleybus (Schiemann)
1904	New York	First 4 - track rapid transit line for local and express service
1914	United States	Introductions of Jitneys
Ca. 1920	United States	Use of pneumatic tyres for buses.
Ca. 1927	Nottinghamshire, England	Introduction of diesel motors for bus propulsion
1936	New York	First PCC car in service.
1955	Dusseldorf	First modern articulated streetcar, contributing to the development of light rail transit mode (DUWAG)

Contd...

1955	Cleveland	First extensive park-and-ride system (with rapid transit)
1956	Paris	First rubber tyred rapid transit
1957	Hamburg	First rapid transit with one-person train crews.
Late 1950's	West Germany	First modern articulated buses and trolleybuses
1962	New York (42nd St. Shuttle)	First fully automated rapid transit
1960's	Europe	Widespread use of self-service fare collection
1968	Victoria Line, London	First automated fare collection with graduated fare.
Late 1960's	Western Europe, United States	Introduction of transit (LRT, Bus) malls
1969	Shirley Highway, Washington	First exclusive busway for commuter transit (Later converted into HOV roadway)
Early 1970's	Western Europe, United States, Japan	First major use of thyristor chopper control of electric motors.
1972	BART,San Francisco	First computer-controlled rapid transit system
1970's	United States	Widespread development of innovative types of paratransit Servicers.
1975	Morgantown, West Virginia	First fully automated transit system with unmanned vehicles
Late 1970's	Western Europe, United States	A number of tests of AC electric motors on transit vehicles
Ca. 1978	West Germany	Development of dual-mode trolleybus with auxiliary propulsion and remote trolley pole control.

Source : Narsinga Rao, Kolluru, G.N., (118).

2.7 Mode Comparison

2.7.1 State of the art and its evaluation

The studies involving the comparison of transit modes vary considerably in their approach and purpose, as well as in quality. The most common types of these studies are briefly reviewed here.

Foster and Beesley [39], did socio-economic analysis for underground railway line in London. Meyer et al [103], did mode comparisons for hypothetical urban corridors, utilising average costs from different cities or from one specific metropolitan area. The assumptions and models used in economic comparisons of modes are so unrealistic that their findings are, in most cases, in sharp variance with the studies of transit in actual cities. Their simplistic approach and seemingly clear results, however, give these studies a totally unjustified credibility among some lay persons. Morris Hill [104] developed the concepts transportation plan evaluation, emphasizing the need to consider different affected groups. A method for systematic handling of nonquantifiable factors that is comprehensive, but extremely complicated for application has been proposed by Morris Hill. Manheim [105] and several other authors, emphasized the need to include all major characteristics of transit modes, into their analysis and evaluation. An early study for Frankfurt Germany (1967 AD) analysed alternative modes with some variations in types of service caused by different characteristics of the compared technologies - monorail, LRT and rapid transit. Manheim [105] and Edward [37], emphasized the need to include all major characteristics ("dimension") of transit modes in their analysis and evaluation. An extensive conceptual frame work for the comparison of different transit modes was developed by Deen and James [25]. They showed the deficiencies of comparisons based on costs only and emphasized the importance of including not only direct quantitative factors, but also indirect and qualitative ones. They illustrated the methodology by a framework for the comparison of a freeway and a rapid transit line. Edwin and Joseph [38] presented a comprehensive report on the evaluation of transportation plans. Since a comparison of alternatives became federally required for transit mode selection in the United States during the 1970's AD, these studies have become increasingly comprehensive and sophisticated. Examples of such studies are those performed for, Baltimore, Rochester and Buffalo (New York), Los Angeles and Sacramento (California), Denver, Edmonton (Canada), Miami, Pittsburgh, Portland (Oregon), Honolulu, Dallas, Houston and Phoenix (Arizona). Vuchic (1973 AD) analysed the components of different modes, such as types of rights-of-way, technology (guided versus steered), and vehicle size, and on the basis of their characteristics compared Light Rail Transit (LRT)with several other modes for different sets of conditions (Network types, passenger volumes, and so on). Other comprehensive comparisons of actual systems involving different modes (Commuter buses on a bus way, an extensive bus network, and a rail rapid transit line) that serve similar areas but with different types of service were made by Vuchic and Stanger [152]. Another set of studies focussed on the comparison of actual characteristics of different transit modes. Fabrycky and Thuesen [40], compared the costs of buses and rapid transit for different types of right-of-way (ROW). Other mode characteristics i.e comfort, speed, environmental impacts and the like were not included.

According to Hutchinson [71], practical transport planning is concerned with providing support to the decision making in an environment characterised by variety of factors (fares, patronage, travel times, existing, infrastructures, actual flows, fuel prices, etc.) many of which are outside the control of the transport planner. According to Dickey [32], the choice between RRT, LRT and AGT is often difficult, the really intense controversies seem to be generated in making the choice between these rail/fixed-guided systems and bus systems. Understanding these controversies requires a recognition that very large economic interests are differentially affected by the final choice, with highway-automobile interest groups tending to favour bus systems, while interest groups aligned with the providers of rail equipment and related industry tend to support rail based systems. A third group of studies is those performed for the actual planning of new transit systems in individual cities. The comprehensiveness of these studies varies greatly. The study for San Francisco Bay Area Rapid Transit (BART) was relatively simple task since the performance specifications mandated by the legislation were such that only modes operating on exclusive right-of-way could meet them. The choice of rail technology was logical.

The economic studies are intended to find optimal domains for individual modes defined by the number of passengers they carry during the peak hour. Actually, choice of mode must be based on a number of factors, such as local conditions, alternative means of travel, service quality throughout the day, and short and long-term impacts on the served area. Optimal domains of modes in terms of passenger volumes, therefore, are not delineated by a fixed number for all conditions.

2.8 Value of Time

In the transport planning, the evaluation procedure is primarily concerned with the identification and measurement of benefits to the user of the system and also benefits to the society as a whole. The cost required to develop the system is also to be estimated. In case of cost-benefit analysis done for the large transport projects time savings accounted for about 35-70% of the total benefits. 72% to 81% of the total benefits of United States Interstate highway system have been estimated from travel time savings. Moreover shortened time travel would mean reduction in discomfort and inconvenience caused in traveling. thus time saving result in more efficient functioning of economy and richer quality of life for individual. If it is the time savings which accounts for largest benefits from project, then measurement of time savings and monetizing it in terms of money becomes a sensitive issue. In the last two decades economist, transport engineers, transport planners in India and abroad are meticulously working for justification of placing a certain value on time.

Over the years, economists came out with the arguments and developed economic theories to justify the value of time savings. Some of the arguments are quoted below ; "time like money and other economic goods has value only because people value it. The value of time is determined not by the amount of work required in its production but by its scarcity. Because people have limited amount of time available to them, they allocate time carefully among activities so as to maximize overall utility and satisfaction". Attempts made in abroad are summarised in Table 2.3.

TABLE 2.3 VALUATION OF TIME IN DEVELOPED COUNTRIES

Sl.No.	Country	Author(s)	Statistical Technique Used	Year	Sample
1	U.K.	Lisco	Binary Probit	1964 AD	159
2	U.K.	Beesley	Minimisation of Mis-classification	1965 AD	172
3	U.K.	Peter Stopher	Least Square regression analysis	1969 AD	767
4	U.K.	Local Government Operation Research Unit	Discriminant analysis	1970 AD	1282
5	U.S.A.	Guttman	Binary Logit	1975 AD	922
6	AUSTRALIA	Hensher and Mc Leod	Binary Logit	1977 AD	100
7	CANADA	Hauer	Logit Analysis	1982 AD	731

Source : Compiled from Records

2.8.1 Research in India for evaluating value of time

Systematic research into value of travel time in India started in 1976 AD when Chari and Khanna used home interview data and developed disaggregate models incorporating mode choice and trip frequency choice. Before this some arbitrary value were used by researchers while dealing with economic appraisal of transport projects. Wage rate approach found to be common amongst Indian researchers. Wage rate for travellers is found out from monthly wage and assuming certain hours of working i.e. 8 hours working day or 10 hours working day. Of course, monthly wage rate will give over-estimated value for travel time value.

Muthu Kumaraswami and Thillainayagam [106], used operating cost of vehicle per hour based on existing speeds on transportation network of Madras. But, whether vehicle operating cost, can be taken as value of time is a controversial issue. Study such as Road User Cost Study [22] has used wage rate approach for calculation of value of travel time. Road User Cost Study estimated average wage rates for inter-city travellers on selected roadways as value of travel time. They also added 20% to the wage rates to take into account for overheads.

Veeraragavan and Simha [153] in their study estimated value of travel time as well as value of comfort by willingness to pay approach. They estimated how much one is willing to pay as present of original fares for reduction of twenty five percent of the in-bus travel time. They used method of rankings for calculation of value of comfort.

From above it can be said that very little appreciation is given in India for value of travel time, with use of approaches like "wage rates" used for evaluating travel time values. There is no appreciation for travel components, except by Veeraraghavan and Simha, where they attempted to find out value of comfort. Value of time adopted in different studies are furnished in Table 2.4.

TABLE 2.4 VALUE OF TRAVEL TIME ASSUMED IN ECONOMIC APPRAISAL INVESTIGATIONS

Author	Investigation	Value Assumed	Method of Derivation
Srinivasan, N.S. and Goel H.C.(1968 AD)	Road -Rail Crossing in Delhi	Rs. 0.456/hour for all categories	Monthly wage rate and 8 hour working day
Muthukumara-Swami A. and Thillainayagam R.(1969 AD)	Road-Rail Crossings in Madras	Rs. 0.5/hour for bicycles and pedestrains Rs. 0.4/hour for bus passengers Rs. 18.75 per vehicle per hour for cars. Rs. 7.5 per vehicle per hour for motorised two wheelers Rs. 1.25 per vehicle per hour for slow traffic	Daily wage rate and 8 hour working day. Operating cost of vehicle per hour with assumed average speed.
Sodhi,N.S. (1974 AD)	Level crossings in Ludhiana	Rs.15/ hour for car owners Rs. 3/ hour for bus passengers Rs. 4/ hour for motorised two wheelers Rs. 0.75/hour for pedes-trians	Monthly income and 10 hours working day

Contd...

Author	Investigation	Value Assumed	Method of Derivation
Central Road Research Institute New Delhi (1982 AD)	Road User Cost Study	Rs. 4.49/ hour for bus passengers. Rs. 8.21/ hour for car owners Rs. 4/ hour for bus driver Rs. 3.50/ hour for truck driver Rs. 2.0 / hour for truck cleaner	For passenger time saving average monthly income of passengers was taken. Working trips 40% are to be assessed at the full wage rate while non-working trips 60% are to be evaluated at 25% of the wage rate

Source : Compiled from Records

2.9 Vehicle Operating Cost

Improved condition of road will reduce the vehicle operating cost (VOC) of vehicle. Considerable research has been done in the World over on vehicle operating cost. Reduction of vehicle operating cost is also considered as benefit to be included in the economic analysis of transport system [93].

2.10 Accident Cost

Road accident occurs in direct proportion to the amount of traffic on roads. Simple grievous and non injury accidents were taken to occur in a ratio of 7:1, 9:4 and 1:7.2 with the fatal accidents and same has been used for the year 2000 AD [94]. The accident occurrence has been quantified monetarily as per the values given in Road User Cost Study reports [93] and shown in Table 2.5. The costs given in this table are for the year 1978 AD and 1990 AD. Inflating these figures by 10 percent per annum, the accident cost figures for the year 2000 AD have been obtained.

TABLE 2.5 COST OF ROAD ACCIDENTS

Sl.No.	Accident Category	Rate/Accident (in Rs.)		
		1978 AD	1990 AD	2000 AD
1.	Fatal	49804	210100	546260
2.	Grievous	29510	32000	83200
3.	Simple Injury	321	1100	2860
4.	Non Injury	1900	2510	6526

Source : Kadiyali, L.R., [93]

2.11 Time Horizon

An economic assessment is usually carried out for specific time horizon. For railway projects the economic analysis in India may be done for 25 to 30 years [113]. In this study, economic analysis has been done for 25 years.

2.12 Financial Costs

Financial costs are easy to determine because they represent the actual amount one has to pay to get a road constructed and maintained. It is the engineer's estimate to get the project sanctioned, and are shown in account books and budgets.

In a perfectly competitive market, and where taxes are not levied, the financial cost is very nearly equal to economic cost. But, when the market is imperfect and where taxes are levied, the financial costs and economic costs are not the same [58].

2.13 Economic Costs

The actual cost outflows may not represent the real cost to the economy of the community. They have to be suitably adjusted to arrive at 'shadow prices' so far as developing countries are concerned, the adjustments are required in four classes of costs, viz.; foreign exchange element, taxes element, wages and interest. Due to scarcity of foreign exchange and more demand for same in various sectors, the actual foreign exchange element has to be upvalued. Generally, a rate of 1.75 times the official rate has to be used. The cost of materials used include sales and other indirect taxes like excise on fuel. It is a cost to those who pay tax but does not necessarily reflect 'Economic Cost' to the country as a whole. Thus, this element is to be excluded. Wages actually paid do not represent cost to economy where there is gross unemployment and unskilled labour used may not have other demand. On the other hand, due to shortage of skilled labour (the demand being more than supply) the actual wages paid to them may be under estimated cost to economy. While wages to unskilled labour may be demonetised as much as 50%, the wages to skilled labour has to be upvalued by as much as 25%. Interest charged by government is much less than the actual prevalent interest rate or even borrowing rate.

A 12% interest rate is considered reasonable by World Bank as the minimum required for viable projects in India and Pakistan [58].

2.14 Inflation

The construction of a railway project takes a number of years and during this period, the cost of labour, materials and equipment may undergo an inflatory trend. Similarly, the benefits of the reduced vehicle operating cost may be higher in future years due to inflation. Since general inflation results in the price rise in all goods, the relative process remain constant. Hence, it is the practice to disregard escalation and inflation, both on the cost stream and the benefit stream [58].

2.15 Economic and Financial Analysis

According to a note on economic evaluation methods used by "Planning, Statistics and Monitoring Department, Highway Authority of Yemen Arab Republic, the following facts converge". In financial analysis, one is concerned with the ways and means of financing a project (through taxes) and the financial profitability of the project.

Economic analysis, on the other hand, is not concerned with the sources of financing, the availability of funds and the allocation of funds. Funding of projects is a government/ management decision. For example, the construction of a toll expressway has to be examined on the basis of its cost and the expected toll collections, and the government/management may take a decision to construct it, if the toll collections seem to be attractive enough. Such analysis is financial in nature. Economic analysis, which concerns with the consequences to all segments of the nation, will still be necessary in such a cost to establish its economic viability. Even after the economic viability has been established, the government may not take up the project due to lack of funds, or because of the fact that the financial analysis has indicated that the returns are not attractive for the funding and the recovery procedures selected.

2.16 Transportation System Planning

The transportation system might be considered to include the fixed and movable facilities which make movement possible, the flows of resources and information which promote operation, control and planning of transport services, the functional groups concerned with planning the future states of the system, and the interfaces of the system with its social, political and economic environment. An analysis of this nature differs from the more traditional approaches to transportation planning just as a partial equilibrium economic analysis differs from a general equilibrium study. The former would be concerned with the changes in the process of transportation services which would result from a modification of the system. The later would deal with the changes in the prices of all goods which would be affected by a change in the transportation system. The ability to perform this kind of comprehensive analysis does not yet exist. Such an approach requires an understanding of the functional relationships between transportation system and those elements of the environment which it influences. This understanding must be in sufficient detail to model the consequences of alternative plans. While some important consequences can be modelled today, others can not be measured or predicted, and still others remain unclear or unrecognised. The difficulties associated with predicting and measuring the various consequences brought about by the transportation system, as well as the problems of combining incommensurate and immeasurable factors into a description of an alternative plan suitable for decision making, place severe demands upon the planning process and upon the methods for evaluating alternative transportation plans. These complexities prevent the planner from attempting to optimise all of the various system consequences. The transportation system analysis process is shown in Figure 2.5. The proposed alternatives and information concerning existing and anticipated environmental conditions are inputs to a combined forecasting and testing process. The demand for movement is projected and the operation of each alternative under the given demand conditions is simulated. At the same time, the various impacts of the proposed network upon the environment are forecast. All phases of the forecasting and testing process are interrelated so that the projected travel demands, system operating characteristics and system consequences are internally consistent. The result of the tests are multi-dimensional, and might include operating costs, the expected number of accidents, impacts on urban form and the various social, political, economic and aesthetic consequences of each alternative. The test results are evaluated with respect to the set of system goals. Where necessary, plan revisions are accomplished. Finally, the goals may be revised and the process repeated in order to determine the cost sensitivity of each system goal.

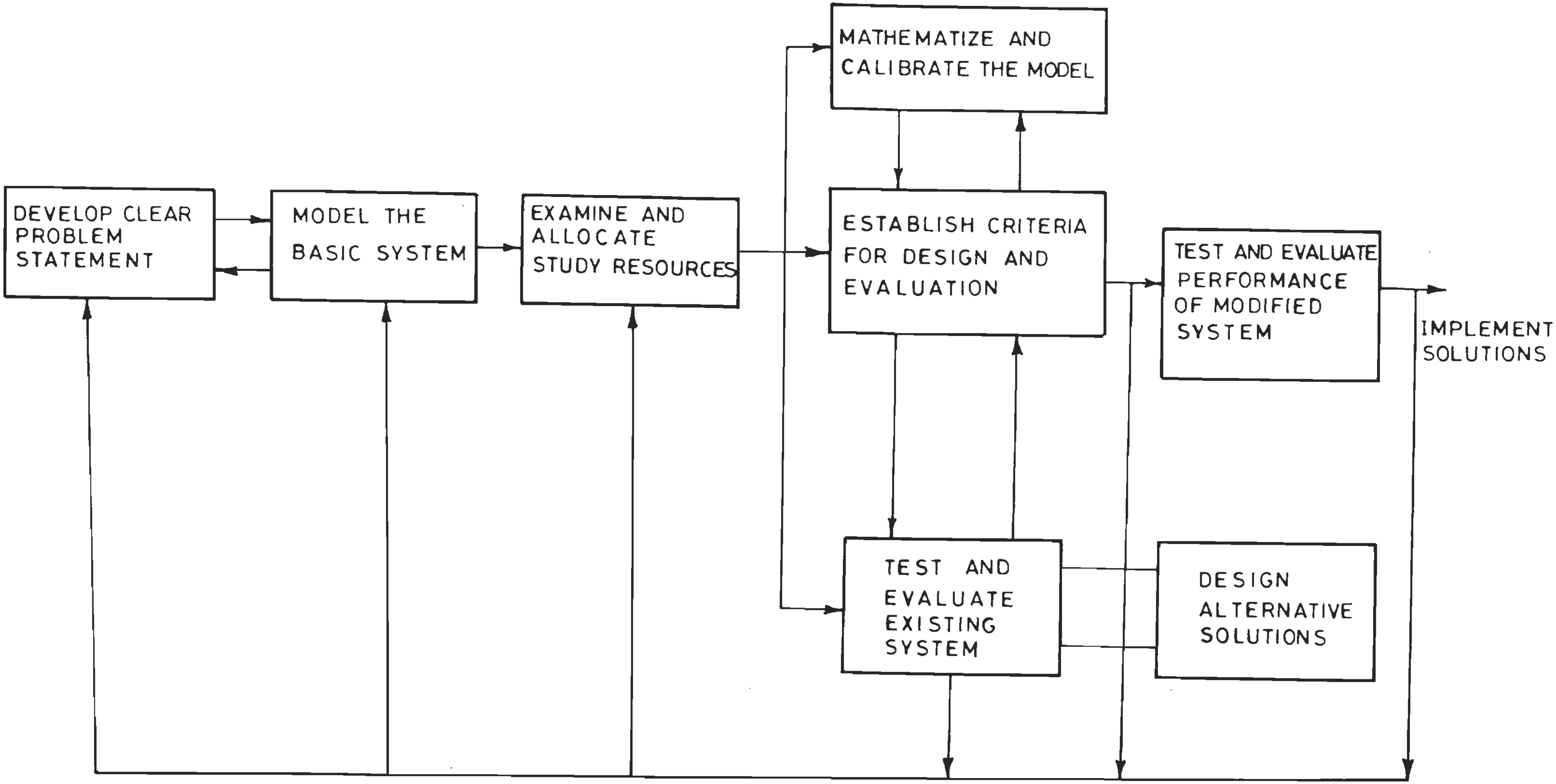


FIG. 2·5 THE TRANSPORTATION SYSTEM ANALYSIS PROCESS

2.17 Landuse - Transportation Models

The landuse models have their beginning based on a number of empirical studies. The studies of Clark [16], Row and Jurkat [128], Blumenfeld [8], Hamburg and Creighton [61] and others have shown that densities of residential and employment activities decline with distance from the CBD and also they change consistently through time. These models, thus projected the city's historical development based on the accessibility to the CBD and zoning controls. Later models attempted to explain the process of landuse intensity by a more generalised concept of accessibility [63].

Subsequently (after 1960 AD), planning agencies were considered with community renewal programmes. The emphasis was less on transport but on provision of housing and slum clearance. As a result, transport sub-model has become less explicit. Lowry [96] provided one of the first comprehensive urban models that was applied to Pittsburgh community renewal programme. The model is a logical extension of Hansen's model with the contention that landuse was a function of the accessibility to employment, while the location of service landuse was a function of accessibility to residential and employment activities.

Crecine in the year 1965 AD has further modified and gave the Time Oriented Metropolitan Model [TOMM model], which tried to predict the location of basic employment through the use of Industrial Spatial Allocation Model and the estimation of the growth of employment by an Input-Output Model. But these models were so complicated and were virtually never used [17].

Subsequently efforts were to concentrate on Lowry system and to improve it. Models suggested by Garin [42], Goldner [44] were successful at Bay Area Transportation Study, Texas, Baltimore etc. Now, the Goldner's model includes Standard Transport Package known as Projective Landuse Model [PLUM]. This model is applied subsequently to a number of sub-regional studies and urban areas, with modifications wherever necessary. Herbert and Stevens [62] have initiated another modelling process - behavioural models, which attempts to simulate the behaviour of different groups of households seeking housing and developers supplying different types. Hill [64] has developed yet another model known as EMPIRIC. It is a statistical model that derives changes based on the level of activity in each zone (landuse) as a function of the changes of other variables such as accessibility, existing level of activities, provision of services etc. Apart from the above attempts, other models, Hutchinson [69], Feo et al [41] have tried to improve the performance by disaggregation and alternative inputs and the measures of evaluating the out-puts. The area of landuse transportation modelling has its own difficulties with respect to their theoretical concepts, application in practice by users and in data availability and handling. Models developed are not always unquestionable, but efforts have to be made to overcome the mistakes and explaining newer issues and observations.

Landuse Transport Demand Models derive landuse allocation and associated transport demands simultaneously. By 1960 AD, transport planners were quite aware that landuse was a more important determinant of transport phenomena than any other characteristics of the phenomena and a natural extension to transport modelling was the birth of landuse modelling. The first attempt to model the urban system were made by traffic engineers. Their models based on various theories about traffic flow, were highly successful and led to more ambitious attempts to model other subsystems of the urban system such as landuse.

The processes which determine the location of activities in metropolitan areas have been of some interest to planners and engineers of various disciplines for almost as long as there have been such areas to puzzle over. However, it was not until the development of electronic data processing equipment and dissemination of the associated information processing capabilities that it became possible to even consider empirical testing of some of the theories which have been developed regarding the location of these activities. The potential advantage of a computer model over adhoc planning procedures derives mainly from computer's ability to deal simultaneously with the large numbers of variables intrinsic to comprehensive planning to provide forecasts of need, normative solutions to problems, or tests of alternative policies which take into account of greater range of relationships, ramifications, and feed-backs than could be managed by the more traditional tools of project planning.

Starting from the lowry model, different authors used different accessibility factors in the allocation functions. Table 2.6 presents a summary of allocation functions. It has long been recognised that transport investments may generate traffic from a wide variety of response mechanisms including changes of route, mode, location, frequency, trip timing, car ownership and availability, activity scheduling and trip linkage, together with possible changes in the intensity and spatial disposition of land uses. The magnitude of these different responses will be dependent on the investment and occur over a variety of time scales [159].

TABLE 2.6 SUMMARY OF ALLOCATION FUNCTIONS

Sl.No.	Author	Function	Parameter Value	Remarks
1.	Lowry	$dij^{-\alpha}$	$\alpha = 1.33$	dij - air line distance between tract centroids
2.	Garin	$dij^{-\alpha}$	$\alpha = 2$	dij - travel time between zone centroids
3.	Batty	$dij^{-\alpha}$ $dij^{-\beta}$	$\alpha = 2.4$ $\beta = 1.7$	dij - average time distance between zone centroids

Contd...

Contd.. Table 2.6

Sl.No.	Author	Function	Parameter Value	Remarks
4.	Batty	exp (-β Cij)	β = 0.23	Cij - generalised cost of travel
		exp (-α Cij)	α = 0.16	between zone centroids
5.	Goldner	dp/dt $\frac{1}{t}[\frac{\beta}{t^2}.e^{(\alpha-\beta/t)}]$	β = 5 to 20	tij - time is represented by stress tree times grouped into three minute intervals between zones.
6.	Hutchinson	exp (-α dij)	α = 0.124	dij - travel time between zones
		exp (-β dij)	β = 0.288	
7.	Sarna	exp (-α dij)	α = 0.105 to 0.120	Considered three income groups-low income, middle income, and high income. dij - travel time between zones.
8.	Putman	exp (-α dij)	α β	
		exp (-β dij)	0.92 2.14	Considered four income groups; -
			2.24 1.36	low quartile, second quartile,
			2.84 1.32	thrid quartile and fourth quartile.
			2.48 1.52	

Source : Compiled from Records

For the majority of major urban studies throughout the world, travel analysis involves a limited range of potential responses embodied in the traditional four stage approach, with travel forecasting subsumed within exogenous projections of the intensity and spatial distribution of land uses. Such variable demand methods include the possibilities of route, mode and locational substitution. Almost invariably the trip production models are inelastic at their trip ends - the total number of trips is insensitive to the cost or accessibility changes associated with the policy [159].

2.17.1 Summary of the development of landuse transport models

A comparative study of the models indicates that each successive model is directed towards the improvement of the previous one to achieve more realistic description of urban spatial structure. Earlier attempts were largely concentrated on economic base mechanism, particularly on the partitioning of the employment and population, leading to greater disaggregation levels at later period. While, such larger breakups have not conclusively proved any operational advantages, it certainly created problems while predicting them into future years. With only a meagre data base available with planning agencies in India, it is doubtful whether such refinement is really warranted. Perhaps a simpler partitioning at input stage may prove operationally superior, which is confirmed by Sarna [134] for Delhi studies. An approach presented by Chari and Khanna [19] may prove helpful in this regard. Later, considerable investigations were carried out on the nature of the allocation function together with their calibrations techniques. Starting from simple inverse functions and population as attraction factors, more and more sophisticated functions and multivariate attraction factors were attempted. As the complexity of the functions increased the calibration efforts went up rapidly and became unmanageable to a practicing planner. Similar trends were observed in Transportation planning.

Subsequently planners have realised the importance of transportation on the urban spatial structure. Transportation facilities are very expensive and long term investments. Very often they become inadequate because of failure to appreciate the relationship that exists between activities, housing and transportation. The realisation of such interdependence has resulted in two major modelling operations being integrated together. The procedure adopted is to forecast land use and populations and to compute travel requirements as a result of the first, then revising the landuse and population allocations on the basis of the second. A transportation model is,therefore, linked with urban landuse model to make it interactive with transportation. This aspect has gained considerable attention with the convergence of urban sprawls created by freeways and expressways.

The emergence of fuel crisis has created a new problem of how best to reduce the travel requirements by appropriate transportation policies and redistribution of activities. The new breed of landuse models are, therefore, concentrating more and more on transportation impacts. It is perhaps most appropriate to devise such models that do consider the inter modal split in transportation pricing policies, level-of-service etc., to any land parking in the cities and redistribute the activities resulting in optimal location of housing stock. Chari and Khanna [18] have demonstrated the sensitivity of transportation requirements to various policies on time and cost. Hence it is valid for Indian context.

Finally, there are efforts about dynamic orientation of the models to make them more useful in long range forecasting. While it is too early to incorporate effect of time on the various parameters calibrated, incremental allocation procedures may be resorted for the time being.

2.17.2 Suggested procedure for landuse model

Based on the criterion for model selection mentioned earlier, the following recommendations are made aimed at developing an operational model to suit the Indian condition. The modifications attempted could be as follows:

(i) Splitting of employment in basic and service need to be refined as suggested by Macket [111]. But in the present study, population, employment and school enrolment (education) have been adopted due to limitations on the availability of the data.

(ii) A simple exponential decay function used in the residential and service employment allocations sub-models need to be refined because of the trip makers in urban areas are not sensitive to the first 5 to 10 minutes travel.

A Tanner's function which is theoretically more appropriate may be tried, because the selection of a correct deterrence function will tremendously improve the operation of the model.

(iii) Calibration of the model becomes difficult and costlier, when trial and error method is resorted for the selection of behavioural parameters. The complexity further increases with increasing the number of parameters by changing from simple exponential function to Tanner's function. Solving the problem by using a numerical method [3] to optimize the set of parameters to yield good results is very essential than a brute force of trial and error method.

(iv) To improve the operation of the model and make it policy sensitive to transportation variables a behavioural modal split technique is very essential to start with. This will incidentally eliminate the spatial disaggregation at calibration stage.

(v) Finally a more appropriate scale is to be devised in place of income [18] which is very difficult to estimate in Indian conditions and such socio-economic parameter is important due to its impact on travel behaviour.

2.18 Factors Affecting Modal Split

It is known that there are a large number of factors influencing commuter in his choice of mode. They are basically grouped as described below :

(i) Characteristics of individual (i.e., trip maker) - age, sex, status, income, vehicle ownership, health condition, attitude.

(ii) Characteristics of journey - purpose, distance and duration of travel time, time of day.

(iii) Characteristics of transportation system - speed, cost, safety, reliability, comfort, convenience, congestion, accessibility, aesthetics, parking area availability, noise and pollution.

Some of the factors are difficult to be measured. Influence of each factor on the decision made by the commuter in choosing a mode is again a critical area. It is also difficult to aggregate the effects of these factors to critically analyse the state of choosing a mode by a commuter. The variables used in five modal split models developed earlier in US cities indicate the complexity of the problem [65] which is described in Table 2.7.

It has been found that number of variables used in most modal split models have varied from 2 to 6. Auto ownership and travel time are the most often used variables. The other important parameters are residential density, income, parking cost and accessibility. The length of trip, workers per household, distance to CBD and employment density have figured as least important in these models [122]. Regarding number of variables to be used in models, the accuracy resulting from increasing number of variables vis-a-vis cost and effort in data collection and processing have to be considered. It was indicated in an analysis made by Federal Highway Administration of U.S. that a maximum of four variables were sufficient, particularly in multiple linear regression models [9].

TABLE 2.7 FACTORS CONSIDERED AS AFFECTING MODE CHOICE IN DIFFERENT STUDIES

Survey Research Centre	Stanford Research Institute	J.Napolitan Associates	University of Maryland	Vitro labs
Expense	Cost	Cost	Cost	Total Cost
Convenience	-	Convenience Need to own car	Convenience	Convenience
Comfort	Tension	Comfort		Comfort
Crowdedness	Sense of Freedom challenge	Status Vehicle condition	Self esteem	
	Safety		Personal safety	Safety
Speed		Traffic parking	Reliability	Mechanical reliability
Traffic Flow		Flexibility	Travel time	Total time
Changing vehicles		Weather	Weather	Weather reliability
Frequency of service	Urgency		Packaging	
Distance	Scenery		Dimensions Fare payment	

Source : Hartgen and Tanner, [65]

2.19 Types of Models

Modal split models have been developed with aggregate or disaggregate data. In the former case, estimates are based on zone-based characteristics just as in developing trip generation models. Aggregate models are not sensitive to variations in intra-zonal characteristics e.g., intra-zonal income variations. The disaggregate models have been constructed at the level of household or individual. Generally the household is taken as the basis for trip generation models, as otherwise data collection and processing will become unmanageable. While applying these models for arriving at future estimates, the contribution of each group of similar household have to be aggregated at zonal level. Most of the models used or developed could be broadly grouped under two heads-one based on interpretation of current level of travel habits (existing state is extended for future projection and the other based on careful study of user's attitude and behaviour), (Figure 2.6).

Stochastic models are of recent development (since seventies) and in this logit models are more popular. Models based on attitude analysis are increasingly discussed in recent years.

2.20 Category Analysis

2.20.1 Development of models

It is a cross-classification method developed in the puget sound Regional Transport study and used later by Wooton and pick, for use in transportation studies in U.K. [9]. This involves division of various households in the zone into relatively small sub-groups for purpose of cross-classification and combination. A multi-dimensional matrix is developed to define categories. Resulting cells are filled with the 'mean rates' of trips generated by each type of household for each mode. The variables chosen should be least correlated with one another. This methodology was developed initially for arriving at trip generation rates, but later extended to determine modal share of

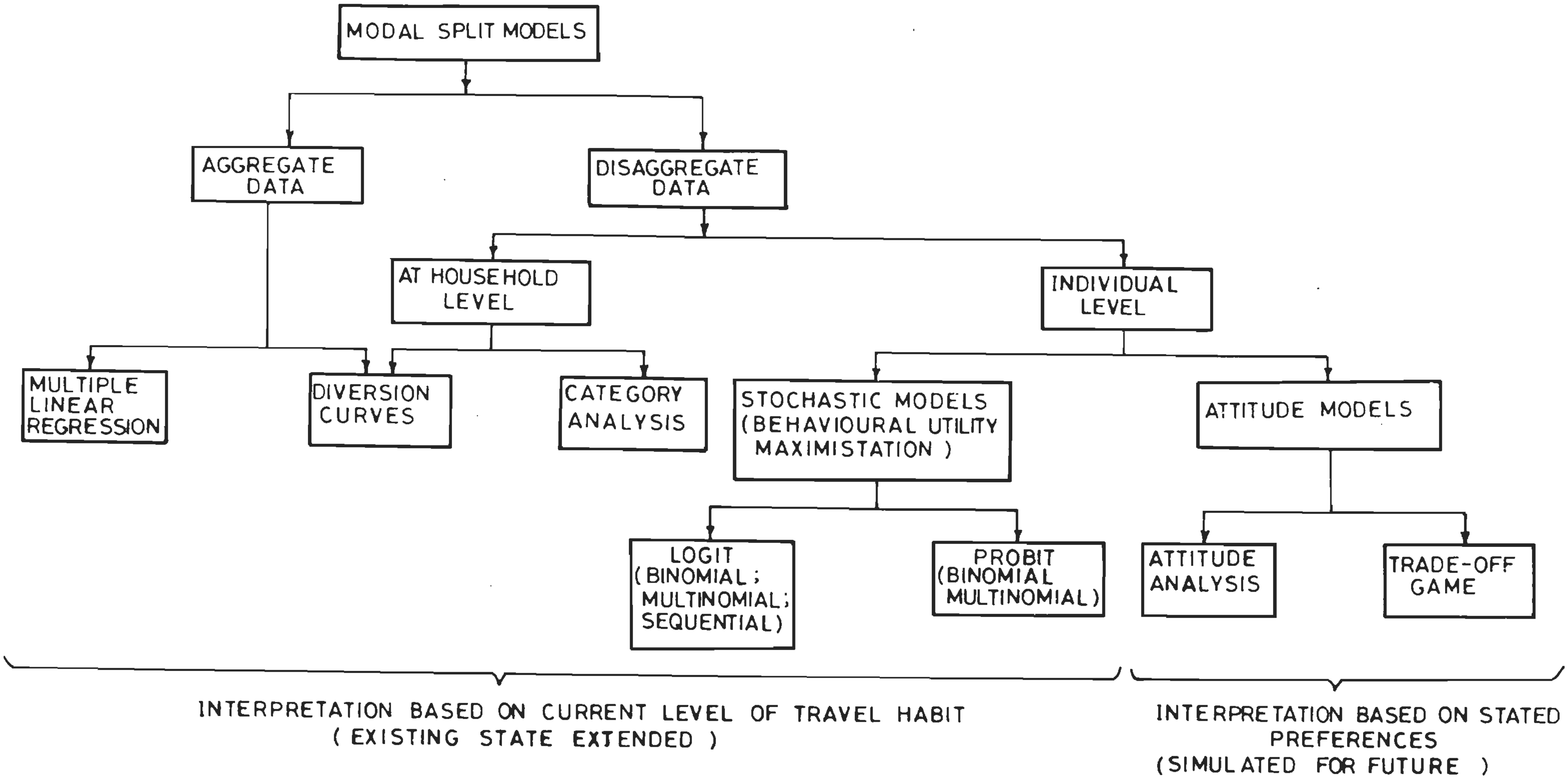


FIG. 2·6 BASIC GROUPING OF DIFFERENT MODAL SPLIT MODELS trips also. In this analysis, the household is treated as an independent and fundamental unit in trip generation as well as mode choice process, since most journeys begin or end in response to various requirements of members of the family. It is assumed that such generated journeys depend on the characteristics of the particular type of household and its location in relation to the destination such as work places, recreation and health centres, schools and shops.

Households with any one set of characteristics produce average trip generation and types of trips different from those of trips produced by households with other characteristics. So long as factors external to household do not change, the trip generation and mode choice by that household is assumed to remain same. In the second phase of London traffic survey, for trip generation estimation, the households were divided into 108 categories viz. 6 by income classification, 3 by vehicle ownership classification and 6 by household structure classification. This resulted in 108 categories of households [9].

Stopher and McDonald [138] have used a modified approach namely "Modified Cross Classification Analysis" for trip generation analysis with 2 area types, 3 vehicle ownership groups and 4 types of household compositions leading to 24 categories.

In the London traffic study, Freeman, Fox, Wilbur Smith and Associates studied modal split under 3 groups of categorisation under each of following 3 classifications viz., disposable income, car ownership and employed residents. They were further subdivided under 3 different levels each for Rail accessibility and for Bus accessibility so that the total number of categories, under which the households in a zone could be classified became 162 [9].

2.20.2 Applications

Sarna et al [139,142] extended this technique of modal split analysis for Delhi and later extended it to Bombay.

They considered that category analysis technique is superior to the multiple linear regression analysis which had been earlier used for Indian cities. The groupings considered in the investigation. used for Delhi for work trips are 'employee per household' [1,2,3,4 or more], 'motor vehicles/household' [0,1,2, or more]. Trip rates were worked out for each type of household for 3 modes [fast private, bicycle and mass transit]. In the study for Bombay, Sarna determined trip rates for 3 trip purposes viz., work, education and other trips. Individuals in each household were grouped under government servants, self-employed and business men, industrial workers, private service and self-service, students and others. Each group was further subdivided into 3 levels. Household income was considered under 5 ranges-upto Rs. 500, Rs. 501-1000, Rs. 1001-1500, Rs. 1501-2000, more than Rs. 2000. Trip generation was splited under 4 modal choices, viz., mass transit, private vehicles (other than car), cars and taxi, and walk. Estimation of trip making by different modes is simplified in this method, making computational process easier, through grouping is voluminous. However, classification is more rational and meaningful in Indian context as the approach explores effects of difference in household composition in a more detailed manner. The results obtained, are considered more reliable for application to future forecasts. But they do not take into consideration (directly) the characteristics of modes of transport, which may change over time and can cause changes in behaviour of commuters. Hence, the results of this analysis i.e., category analysis are not sensitive when changes in modal attributes are made. For results to be reliable for all groups, data required is also very large.

2.21 Diversion Curves

2.21.1 Development of models

Diversion curves were first developed to answer the question of Highway Engineers who wanted to know 'how many drivers would move out of arterial streets to a proposed freeway'. This was done as part of 'trip assignment' studies. The models are in the form of empirically derived curves to estimate the percentage of trips that would use freeway route as against the old arterial route between any two points. The most popularly quoted California diversion curves were developed by Moskowitz in 1956 AD [122] These use travel time and travel distance differences. The Bureau of Public Roads (BPR) developed a set of diversion curves used for traffic assignments. This approach has been extended to modal split estimation [98]. One of the earlier and most quoted example of diversion curve model is that of Traffic Research Corporation used in the Washington Study [122].

2.21.2 Diversion curves in India.

Diversion curves were used in India for trip apportionment between public transport and other modes in transportation studies for Bangalore as part of a study for design of a new rail transit system [4]. In this, the curves were drawn to relate trip lengths between pairs of zones with percentage of trips that will take public transport. Two different sets of curves were used, one for zones grouped under 'Core' and the other for 'Non-Core' zones.

2.21.3 Applications

The advantage of using diversion curves is that they are simple and easy to use. Their limitations are that, they present travel characteristics as existing at the time of survey and their reliability for future is questioned since the trend in travel behaviour is likely to undergo changes due to changes that may occur in various travel attributes. This methodology also needs large amount of data for evolving reliable curves.

Diversion curves approach has not been considered reliable in situations where far-reaching changes in the system are likely, and for areas with heterogeneous character and cities which are growing fast. This models is in a binary form and is not applicable for areas where multitude of modal choice exists.

2.22 Multiple Linear Regression Models

2.22.1 Development of model

Multiple Linear Regression (MLR) had been the most commonly used modelling technique in urban transport studies in fifties and sixties. they have been used at three main modelling stages viz., trip generation, trip attraction, and modal split. This is an aggregate simultaneous model as it takes into account the quantified means of characteristics of the households in the zone of origin or at destination zone and the characteristics of the transport modes as well as of the trips (length, time of travel, cost etc.). The resultant dependent variable refers to the trip per person or trip per household by each mode and purpose. Alternatively proportion of population choosing a particular mode amongst a choice set has been used as the dependent variable. The number of independent variables used in each model varies. This type of model is subjected to statistical tests to examine its reliability. One of the earliest to use this approach was Kain [157].

In his model,

$$Y_1 = 276.5 - 0.9621\ X_1 - 0.01715\ X_2 - 3.384\ X_3 + 0.389\ X_4 - 22.09\ X_5 + 0.0812\ X_6 \quad (2.1)$$

Where Y_1 = Percentage of workers using public transport.

$X1$ = Percentage of car ownership.

X_2 = Percentage of male workers.

X_3 = Mean income of household.

X_4 = Percentage of households.

X_5 = An index for level of public transport service.

X_6 = Residential density in the zone.

Adams also used the multiple linear regression technique to establish a relationship between percentage of work trips by public transport and a number of variables [157].

According to Adams

$$Y = -549 + 517.2 \log P_O - 11.50 \log M_O + 0.8204 \log TSR_O - 517.4 \log H_O + 3.341 \log L_O - 4.681 \log C_O \quad (2.2)$$

Where

Y = Percentage of work trips by public transport.

P_O = Population of Zone.

M_O = Area of all land except vacant land in zone.

TSR_O = Public Transport service index for the zone.

H_O = Number of households in the zone.

L_O = Labour force in zone.

C_O = Number of cars owned in the zone.

Wilson [157] developed MLR models for Coventry with one model each for each of following class/areas entire area; CBD area; non-CBD area; CBD non-industry; CBD industry; non-CBD industry; non-CBD on radials near CBD with industry only; non-CBD radials near periphery; non-CBD radials near periphery with industry only. Wilson concluded that although the model as it was used did not yield satisfactory results, the results did indicate that a model of this type might be useful.Dajani and sullivan [28] have developed MLR models for Raleigh and Durham using data from census of population and housing and obtained an R-squared value of 0.85. Despite development of various behavioural models, a set of Multiple Linear Regression models were developed recently by Charles River Associates for purpose of forecasting of trips and evaluating the existing Houston River Crossing for New York. The independent variables used were cost of travel, line haul time, wait time, transfer time, rail access and egress impedances and modal accessibility factors. Six models were developed for comparing modal shares [116]. A typical model is of the following form.

$$\log(S_i/S_a) = -0.9501 - 0.0779\, x_1 - 0.0104\, x_2 + 0.0208\, x_3 - 0.0312\, x_4 - 0.1593\, x_5 - 0.2367\, x_6 - 0.0363\, x_7\; 0.2865\, x_8 + 0.0098\, x_9 - 0.1301\, x_{10} + 1.14130\, x_{11} \quad (2.3)$$

Where,

S_i = Share of direct commuter rail transit connecting directly from station.

S_a = Share of auto.

X_1 = Direct rail cost.

X_2 = Direct rail line haul time.

X_3 = Direct rail wait time.

X_4 = Direct rail transfer time.

X_5 = Direct rail access impedance.

X_6 = Direct rail egress impedance.

X_7 = Auto time.

X_8 = Auto cost.

X_9 = Rail-to-Path generation cost.

X_{10} = Path Market area flag.

X_{11} = North - east corridor flag.

(Path stands for the rapid transit system connecting Northern New Jersey and Manhattan).

All the models discussed above examine how MLR technique is used to estimate the share of travel by various public transport modes.

2.22.2 Multiple linear regression techniques adopted in Indian cities

Regression analysis has been used in Madras for developing models for trip generation and trip attraction for home-based work and education trips and non-home based trips for 3 different modes, Viz., Car and motorised two wheelers, bicycle and walk, bus and trains [108]. 22 models were developed in total. The variables used include population, number of cars and motorised two wheelers, number of bicycles, residential areas, public and semi-public areas, open space, commercial areas, social and recreation areas and agricultural areas in each zone. In another study it was estimated that, percentage of transit user in Delhi would be 22.0 - 0.559 * (percent high income household) + 0.732 * (distance to CBD) + 0.011 * (residential density) [134].

2.22.3 Applications

Multiple Linear Regression (MLR) analysis is simple to develop and easy to apply. The models developed earlier for Indian conditions have not given satisfactory level of correlation. They do not take into consideration the intra-zonal variation in socio-economic characteristics as the zonal aggregated values are used as variables. Their extension to a future date when there can be changes in behaviour of users particularly when there can be changes in behaviour of users particularly when there are changes in their socio-economic levels, is not quite valid. Their reliability depends on the linearity assumed to exist in the relation between dependent and independent variables. This assumption has not always been established for all variables. Due to their simplicity and ability to be developed using household survey data, they can be tried as quick response models for short term or medium term planning purpose. Model building technique of this type has become a common feature in almost all planning organisations and hence this technique is found to be used extensively by many Indian planners inspite of its built in drawbacks.

2.24 Utility Models

2.24.1 Theoretical background

The various limitations and deficiencies in earlier developed models led later researchers and planners in developed countries to turn to individual choice models. Stochastic approach involving probability of choice was found more suitable in this respect. These statistical techniques reflect better the behaviour of users in a choice situation. The choice of any goods by a user is dependent on its utility or disutility vis-a-vis utility/disutility of the alternatives available to the users. The main characteristics of utility models are described below [135].

(i) Individual choice models are calibrated using observations of individual choice behaviour the advantages are ;

  (a) They are more data efficient than other conventional methods and hence call for less data.

  (b) They make use of the total variation in the calibration of data set, unlike the case of others where variation is lost when individual records are aggregated into zonal means.

  (c) They are less likely to be biased due to correlations assuming the aggregate units.

  (d) They can be applied at any level of aggregation.

(ii) These models are probabilistic and hence can make use of various probability concepts. For forecasting, summation concept is possible i.e., total number of people choosing a mode is equal to sum of their individual choice probabilities. By using Bayesian principle, the joint probability of choice depending on a number of interdependent choice decisions is arrived at by a multiplication process after modelling them separately as conditional probabilities.

(iii) The explanatory variables are included in the choice model by means of a liner utility expression. Hence policy variables can be included in the model. The calibrated linear expression can be used to work out demand elasticities with respect to each attribute. Also, the attributes importance in choice decision can be determined by using the weight coefficients.

Probit model and Logit model are the two sets of models developed based on utility concepts.

The basic premise of the Probit and Logit models is the random utility which is expressed as

$$U(i) = V(i) + e(i) \quad (2.4)$$

Where,

U(i) is the choice function for the alternative (i); V(i) is the deterministic function of the attributes of (i); e(i) is a stochastic component, a random variable that follows a normal distribution.

Probability of choosing the alternative (i) is

P(i) = P [U(i) > U (i) for all j not equal to i]

2.24.2 Probit analysis

It is a statistical technique first evolved by Finney for the analysis of toxicology problems. It was used to determine the relationship between probability that an insect will be killed and the strength of dose of poison administered, where the dependent variable is clearly either 'killed' or not 'killed: The threshold values are assumed to be normally distributed over the population. In general, a Binary Probit model is of the form [14].

$$Pn(i) = \frac{1}{\sqrt{2\pi}} \int_{-\infty}^{(V_{in}-V_{jn})/\sigma} \exp[-1/2*u^2]du = \phi\left(\frac{V_{in}-V_{jn}}{\sigma}\right) \quad (2.5)$$

Where,

V_{in} and V_{jn} represent systematic components of the utility of alternatives i and j (These are deterministic functions).

$\phi()$ denotes standarised cumulative normal distribution function.

σ = K*1 parameter vector .

$$\sigma^2 = \sigma_i^2 + \sigma_j^2 - 2\sigma_{ij} \quad (2.6)$$

In the case where Vin = $\beta^1 {*} X_{in}$ and $V_{jn} = \beta^1 {*} X_{jn}$,

$$Pn(i) = \phi \left(\frac{\beta^1(X_{in} - X_{jn})}{\sigma}\right) \quad (2.7)$$

Probit analysis has the advantage of comparing more than 2 alternatives even where they have attributes that may be perceived as correlated. But the disadvantage is its inflexibility for mathematical manipulation. This disadvantage is now disappearing with use of large capacity computers for computation.

2.24.3 Logit analysis

Logit model is an improvement on the probit model, in that it implies calculations by assuming independence of two alternatives. In this model, e(i)'s of choice utility function are all assumed to be independent and are identically distributed with a double exponential distribution function. The basic logit form is,

$$F\ (e(x)) = e^{-\theta e^{-x}} > 0;\ -x \angle 1 \angle x \quad (2.8)$$

$$Pn(i) = \frac{e^{V_{in}}}{\Sigma\ e^{V_{jn}}} \quad (2.9)$$

Where,

V_{in} being utility function of attributes for mode i and V_{jn} being utility function of attributes of each of modes, j=1,2, ...n, including i.

The main advantages of Logit models for which they are still preferred are ;

- They are easily amenable to mathematical manipulations.
- Their parameter estimation as well as application and interpretation are easier than that of probit models.
- They can be developed with a small sample, provided the sample frame covers all strata of population.

But one main disadvantage of Logit model is its. 'Independence from Irrelevant Alternative'(IIA) property [135]. This property holds that for a specific individual the ratio of choice probabilities of any two alternatives is not affected by the systematic utilities of any other alternative. That is, if his choice probability between mode A and mode B is in ratio x : y (x + y = 1), When a third alternative is introduced the ratio a:b:c (a+b+c = 1) will be such that a:b = x : y. To overcome this, Nested Logit models have been suggested. But it involves more complex calibration process [145]. According to Ben-Akiva and Lerman [14], in a multi-nomial model calibration across the population, if the heterogeneities in the population are perfectly accounted for, this IIA property would be taken care of in respect of the population as a whole. The socio-economic variations generally accounted for in the model calibration thus take care of this. This IIA a property can also be alleviated through better specification of explanatory variables or more careful selection of choice alternatives for the models [135].

The model parameters for both probit models and Logit models are calibrated by using maximum likelihood technique. There are a number of programmes developed for doing the calibration of the models. The main one for Logit model is ULOGIT, a FORTRAN Programme developed as part of UTPS for use on a main frame computer. ALOGIT and BLOGIT are other packages available. Vijaya Kumar [154] has developed a programme usable on a PC or mini computer.

2.24.4 Applications

Logit models have been very widely used since seventies. The earliest to adopt this method for modal choice are Quarmby [126], Quandt [127] and Warner [156], when they applied this approach to work trips. Their initial models were largely binary. Later researchers and planners extended this approach to multi nomial situation. For example, Rassam et al [129] developed a Multi-nomial Logit (MNL) model for a specific case to study access to and from airport. They are equally applicable to analysis at intra-urban and inter-city levels. Jeffrey, Ganek and Raymond, Saulino [80] extended the models to include more modal attribute variables than considered till then, like in-vehicle time, out-of -vehicle time and costs. It has been found that comfort, convenience and flexibility have significant effects while mode reliability and household income were not so significant. They developed separate models for drive alone, car-pool, and transit conditions. Stefan, Algers et al [2] used Logit model form to study effect of waiting time, comfort and convenience in choice of mode for work trips. Train and McFadden [150] have studied the use of Logit models to study goods/leisure trade - off in work trips. Stopher et al [140] developed Logit mode choice models for non-work trips in San-Juan, Minneapolis St. Paul, Miami, New orleans and Los Angeles using in-vehicle time, Out-of-Vehicle time and running costs as variables and have compared how the relative weights of cost and time components differ from those for work trips. Logit models also have been used for assessing value of time for users of various modes.

Ben-Akiva [10] has done considerable work on the logit model. He first developed MNL model for work trips in the Netherlands for walk, bicycle, moped, car, bus and train modes. As a recent improvement, discrete models have been developed for Sao Paulo, Brazil, including constraints [141,144]. Important features of selected Logit models are listed in Table 2.8.

TABLE 2.8 SALIENT FEATURES OF SELECTED LOGIT MODELS

Sl. No.	Model Form	Author (s)	Area of study	Sample Size	Variables Used	Pseudo R^2 Value
1.	Multi Nomial LOGIT	Paul R. Rassam, Paymond H.Ellis and John C. Bennet (1971 AD)	Baltimore Airport	NA	Time and Cost	NA
2.	Multi Nomial LOGIT	Paul Inglis (1973 AD)	Chicago (Access trip to commuter station)	117	Difference in cost, Difference in time, age, parking cost, waiting time, car ownerships, time of day	0.686
3.	Multi Nomial LOGIT	Jeffrey Ganek and Raymond Saulino (1976 AD)	Pittsburgh	740	In-Vehicle time, out-of-vehicle time and cost	NA
4.	Nested LOGIT	David A. Hensher (1981 AD)	Sydney	475	In-vehicle time, walk time, waiting time and in-vehicle cost	NA
5.	LOGIT Model (Binary)	Chari (1982 AD)	Ahmedabad (India)	142	Time of travel, cost of travel	0.83

Contd...

Contd.. Table 2.8

Sl. No.	Model Form	Author (s)	Area of study	Sample Size	Variables Used	Pseudo R^2 Value
6.	LOGIT Model (Binary)	J.P.Dunne (1985 AD)	Livingtone Newtown and Edin Burgh (U.K.)	214	Time and cost	0.374
7.	Multi-Nomial LOGIT	C.S.R.K. Prasad (1988 AD)	Hyderabad (India)	577	Time and cost	0.64 (WVOP) 0.70 (WNVP) 0.19 (OVOP) 0.55 (ONVP)
8.	Multi-nomial LOGIT	S.Vijaykumar (1990 AD)	Madras (India)	405	Time and cost	0.613 (WVOP) 0.321 (WNVP)

WVOP- Work (purpose) - Vehicle Owned Persons;

WNVP- Work (purpose) - Non-vehicle Owned persons;

ONVP - Other (purpose) - No Vehicle (owned) persons ;

OVOP - Other (purpose) - Vehicle Owning persons

Source : Compiled from Records

Krishnan [86] has used a different approach to improve the explanatory power for conventional logit model by introducing the psychological concept of minimum perceivable difference to utility comparisons. He postulated that two alternatives would be perceived as different only if the absolute difference in their utilities exceeds a positive constant (or a threshold). He estimated parameters for a new model, which he developed using data on mode choice made by train commuters for access to station in

Lindenwold, New Jersey. Walking and auto were two modes considered. He used maximum likelihood technique for calibration. He called this as MPD (Minimum Permissible Difference) model. Much of the advancement in the use of discrete choice theory in modelling travel choice is due to the pioneering works of Domenich and McFadden [27], and Ben-Akiva and Lerman [10], who have successfully treated the problems of travel mode choice decisions as problems of consumer choice among discrete alternatives in micro economics. Hensher [72,73] has proposed a technique to indentify relatively homogeneous groups of travellers for segmenting. Jornstone and Lundgen [82] extended the logit modelling approach and developed an entropy based model for modal split and tested it for Stockholm. In this they used the generalised cost of different alternatives as the determinant.

2.24.5 Work in India on utility models

The earliest work done in India to develop such utility models was in Roorkee in late nineteen seventies. Binary Logit models were developed in Roorkee [130]. Equivalent Binary Hierarchy was developed by Sinha [136] for choice of urban transport modes for work trips for Patna city. Later binary Logit models were developed for work trip for Ahmedabad city. Time and cost were the two variants used. The developed models were used for deriving value of travel time for different sets of people based on vehicle ownership. The responsiveness of people to changes in time and cost components of different models also could be derived from these models [19]. A later study for Ahmedabad was aimed at developing a Multi-nomial Logit model covering bus, scooter and bicycle. The model was used to study what would be the impact of introducing a new mode like RTS with different times of travel and fare structure [21]. Multi-Nomial approach has been extended for work, education, and other trips in Hyderabad [123]. Prasad also used total travel time and cost as variables. A sequential approach using Binary Logit Modelling [SBM] has been made for Bombay using journey time, cost and convenience as variables. Convenience is expressed in terms of access and waiting time [145]. Palaniswami and Nair [125] have developed Binomial and Trinomial logit models for Kanpur city in India using along with time and cost, other user variables like wage, number of vehicles owned, age and sex.

In Chennai (Madras), Multi Nomial Logit models have been developed for work trips with survey data collected at work places in different parts of the city. Two models have been developed, one for vehicle owning people for four different modes (Scooter, bicycle, bus, train) and another for share of rail and bus trips for non-vehicle owning population, Rao [145], Vijaya Kumar [154] developed sequential binary mode choice models for work trips. However, discrete choice models have been rarely used in developing nations such as India.

2.25 Summary

In this chapter the studies carried out by different researchers in India and abroad on various rail based systems have been presented. The models developed (Landuse model, MLR, Logit, Probit, Category, Diversion curve) by the different researchers presented in this chapter found to be useful to understand the advantages and limitations. To suit conditions (multi-modal state) prevailing in cities like Delhi, a logit model has been developed and discussed using both household survey data and attitudinal values.

CHAPTER 3
PROBLEM FORMULATION AND ADOPTED METHODOLOGY

3.1 Global Trends and Mass Transportation Problems in Indian Cities

Motorised transport modes have entered into cities of the western countries since industrial revolution. Development of public transport in the form of trams, omnibus or urban rail have been used in developed countries from early part of the nineteenth century and use of animal or human power for transport is almost extinct there.

The problem of congestion on roads has also resulted in wide range of studies being carried out in developed countries on modal split in urban areas in the past 3 decades. These studies are aimed mainly to assess the choice between selected few alternatives e.g. auto, car-pool and mass transit. Mass transit in different forms are considered together in many cases, as in the developed countries. The differences in the major travel characteristics (i.e. time, cost etc.) are not very high. The pricing of public transport in those countries is such that the ratio of cost between use of auto and public transport is not very high. Cost of travel by bus in Indian cities is only about one tenth of cost of same journey by car or one third of cost of same journey by a motorised two wheeler [59]. Funds available with agencies/communities for spending on public transport in India, is also limited. This is because public transport proposals have to take a lower priority amongst various urban needs such as water supply, sanitation, shelter, education and health. Suburban rail facilities have been provided only in four Indian cities as part of inter-city links decades back. Thus, choice before an Indian urban commuter being many, study of mode choice has become difficult. Predominant inter-zonal trips in Indian cities are work trips with trip lengths varying from 8 to 15 km on buses, 15 to 25 km on trains, and 5 to 8 km on bicycles [124]. Most education trips are of short lengths of 2 to 5 km made by walk, bicycle, bus and IPT

[124].

The trend of purpose wise trip distribution and modal split in selected Indian cities is given in Table 3.1 to 3.3 [124]. The public transport modes in all the cities are highly over crowded. For example, during peak hours in Bombay a train with 8 Broad Gauge coaches carries over 3000 persons, in Madras a train of 8 meter gauge coaches carries over 2000, persons, and in Delhi city buses carry over 100 passengers at times in peak hours against a capacity of 60 [59].

TABLE 3.1 PURPOSE WISE DISTRIBUTION OF TRIPS IN SOME CITIES (IN PERCENTAGE)

City	Work	Education	Other
Mumbai (Bombay)	64	19	17
Delhi	43	31	26
Chennai (Madras)	52	30	18
Hyderabad	53	34	13

Source : Patankar, [124]

TABLE 3.2 SHARE OF BICYCLE AND WALK TRIPS IN SOME CITIES (IN PERCENTAGE)

City	Walk	Bicycle
Mumbai (Bombay)	15.00	10.00
Delhi	49.08	8.81
Chennai (Madras)	28.07	10.70
Hyderabad	19.85	21.93
Ahmedabad	43.20	18.20

Source : Patankar, [124]

TABLE 3.3 MODAL SPLIT OF VEHICULAR TRIPS IN MAJOR INDIAN CITIES (IN PERCENTAGE)

City	Rail	Bus	IPT	Car and Motorised Two-Wheeler	Bicycle	Total
Mumbai (Bombay)	34.3	34.4	9.4	10.0	11.9	100
Delhi	2.2	53.9	8.8	14.3	20.8	100
Chennai (Madras)	12.7	63.8	2.0	6.5	15.0	100
Ahmedabad	3.9	47.2	4.9	12.0	32.0	100
Hyderabad	1.0	42.8	9.1	19.8	27.3	100

Source : Patankar, [124]

Increased use of personalised transport contributes to increased road congestion, lower overall speeds and higher energy consumption. All these are not desirable and if this trend has to be arrested, suitable policies will have to be evolved to divert, more of trip makers to public transport modes by improving existing systems and by introducing new modal systems besides introducing transportation management measures. It calls for an in-depth study into, not only the modal split as prevalent but also on how the various factors influence the mode choice of commuters. However, evaluation and comparative analysis of transit systems must include all four categories ; performance, level-of-service, impacts, and costs of each system. The preferred mode is usually not the one with the highest performance or lowest costs, but the one with the most advantageous 'package' or combination of the four. Problems in major Indian cities are to a large extent similar and hence, the study of problems in one major city can lead to the understanding of other similar cities also.Delhi, the third largest metropolitan city in India, and the national capital is considered as the experimental base for detailed studies and for testing the applicability of various techniques developed.

3.2 Delhi Metropolitan City - A Profile

3.2.1 General

Delhi is the most rapidly growing metropolitan city in the country. It has consistently shown high growth of its population since independence. The area of the city has been expanding over the years with the increase in the population. The urban area in 1970 AD was 446 sq.km., which became 592 sq.km. in 1986 AD, again in 1989 AD it reached a figure of 671 sq.km. The present area of Delhi Metropolitan City including rural area and agricultural land is about 1483 sq.Km.

The city of Delhi has also served as the capital of many empires earlier. Therefore, Delhi is distinctly different from other metropolitan cities in the country like Mumbai (Bombay), Calcutta and Chennai (Madras), which are industrial as well as port towns. Table 3.4 and Figure 3.1 show the population in the four metropolitan cities in India. The population is expected to increase from 9.3 million in 1991 AD to 13.2 million by 2001 AD, with an annual growth rate of 4 percent [55]. Indices of the population growth, taking 1951 AD as the base, i.e. 100 for all four metropolitan cities, are shown in Table 3.5 and graphically in Figure 3.2. It can easily be seen from Figure 3.2 that the population of Delhi has the highest growth rate among the four metropolitan cities.

The vehicle population in Delhi is also highest among the four metropolitan cities in India. It has more than 10 percent of the total vehicles in the country. In 1948 AD, there were hardly 11,000 vehicles in Delhi which has now reached a figure of 2.5 millions (July, 1996 AD) and it is expected that Delhi will be crowded by nearly 4.4 million vehicles by the year 2001 AD. One can only imagine as to how the level of congestion on the roads, would be there for such a growth of vehicles ? The rate of road accidents and the level of air and noise pollution are rapidly increasing due to vehicle's over population [24]. The noise levels in many parts of the city have far exceeded beyond the acceptable limits. Motor Vehicle emission standards and their

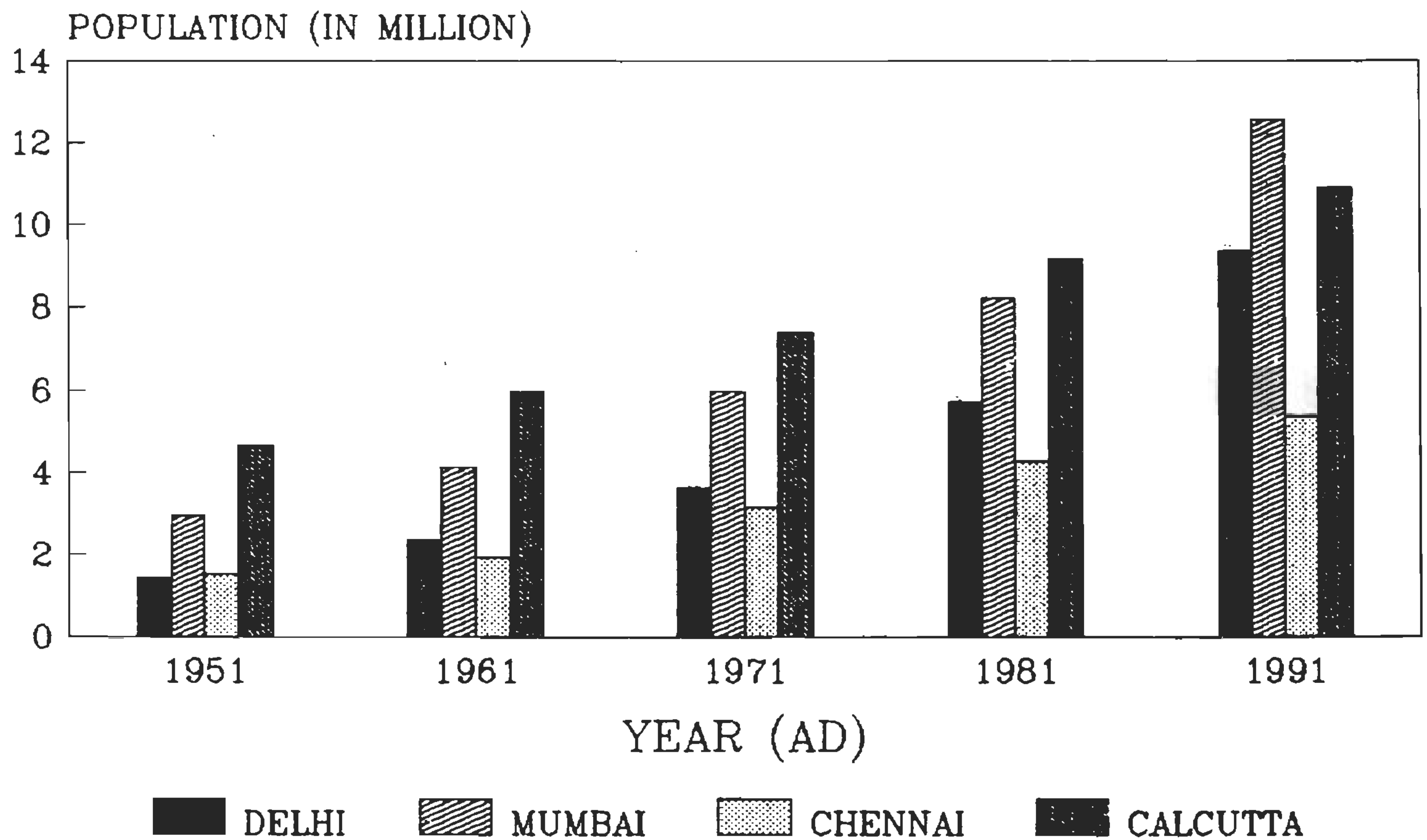


FIG. 3.1 POPULATION IN FOUR MAJOR METROPOLITAN CITIES

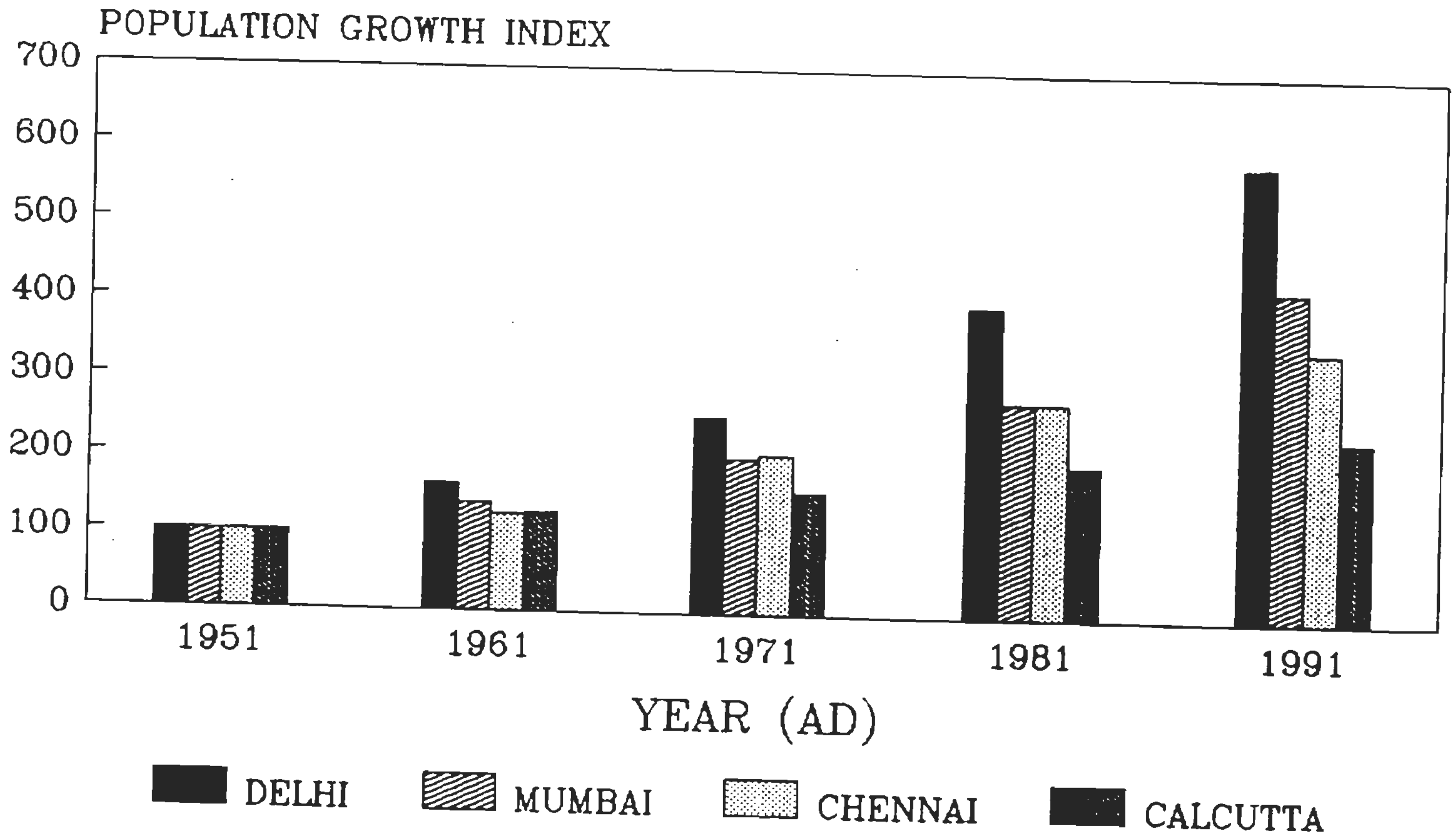


FIG. 3.2 POPULATION GROWTH IN FOUR MAJOR METROPOLITAN CITIES IN PERCENT
(TAKING INDEX NUMBER 100 FOR 1951 AD)

enforcement are very lax in Delhi and way behind the developed countries. There is an air of laissez-faire. The world Health organisation (WHO) has revealed that Delhi is one of the 10 most polluted cities in the world [7]. According to a Central Pollution Control Board report, 70% of air pollution in Delhi is caused by motor vehicles which emit 1296.56 tonnes/day of pollutants (Delhi is called the 'asthma' capital of India) [7].

TABLE 3.4 POPULATION IN FOUR MAJOR METROPOLITAN CITIES

YEAR (AD)	Population (in Million)			
	DELHI	MUMBAI (BOMBAY)	CHENNAI (MADRAS)	CALCUTTA
1951	1.43	2.96	1.54	4.66
1961	2.35	4.15	1.94	5.98
1971	3.64	5.97	3.16	7.42
1981	5.72	8.24	4.28	9.19
1991	9.37	12.57	5.36	10.91

Source : Gupta,A.K., et.al.,[55]

Delhi is the unique city of its size in the world which depends only on bus as the mode of mass transportation. The present system of bus mass transportation is not only insufficient but also responsible for growing use of personalised vehicles which has congested the roads of the city. This has resulted in increasing journey time, longer queues at the intersections, more accidents on the roads and certainly higher level of air and noise pollution. Being the centre of major attraction, migration has been beyond expectation and Delhi has been increasing in its size and population. The present system which takes nearly 55 to 60 minutes for 15 km has not been able to meet the expectation of Delhi commuters. The average trip length which was 14 km in 1989 AD is expected to increase further by the year 2001 AD, this will further deteriorate the situation if no proper action is now undertaken to tackle the problem of the mass transportation in the metropolitan area of Delhi by the year 2001 AD.

TABLE 3.5 POPULATION GROWTH IN FOUR MAJOR METROPOLITAN CITIES IN PERCENT (Taking Index Number 100 for 1951 AD)

YEAR (AD)	Population Growth Index			
	DELHI	MUMBAI (BOMBAY)	CHENNAI (MADRAS)	CALCUTTA
1951	100	100	100	100
1961	164	140	126	128
1971	254	201	206	159
1981	399	278	278	197
1991	583	424	348	234

Source : Gupta,A.K., et.al., [55]

3.2.2. Transport system in Delhi

Delhi metropolitan region is served by five national highways and five main rail corridors, which is shown in Figure 3.3. The rail system carries mostly inter-city traffic from adjoining towns of Haryana, U.P., Punjab, and Rajasthan. EMUs suburban rail services introduced in 1981 AD, provide suburban services and also run on the ring rail for intra-city trips. But the ring railway system is not properly integrated with existing road network and is rather under utilised due to poor information system. Presently, the transport system is basically road based. Mass transport services are mainly provided by buses comprising Delhi Transport Corporation (DTC) buses and

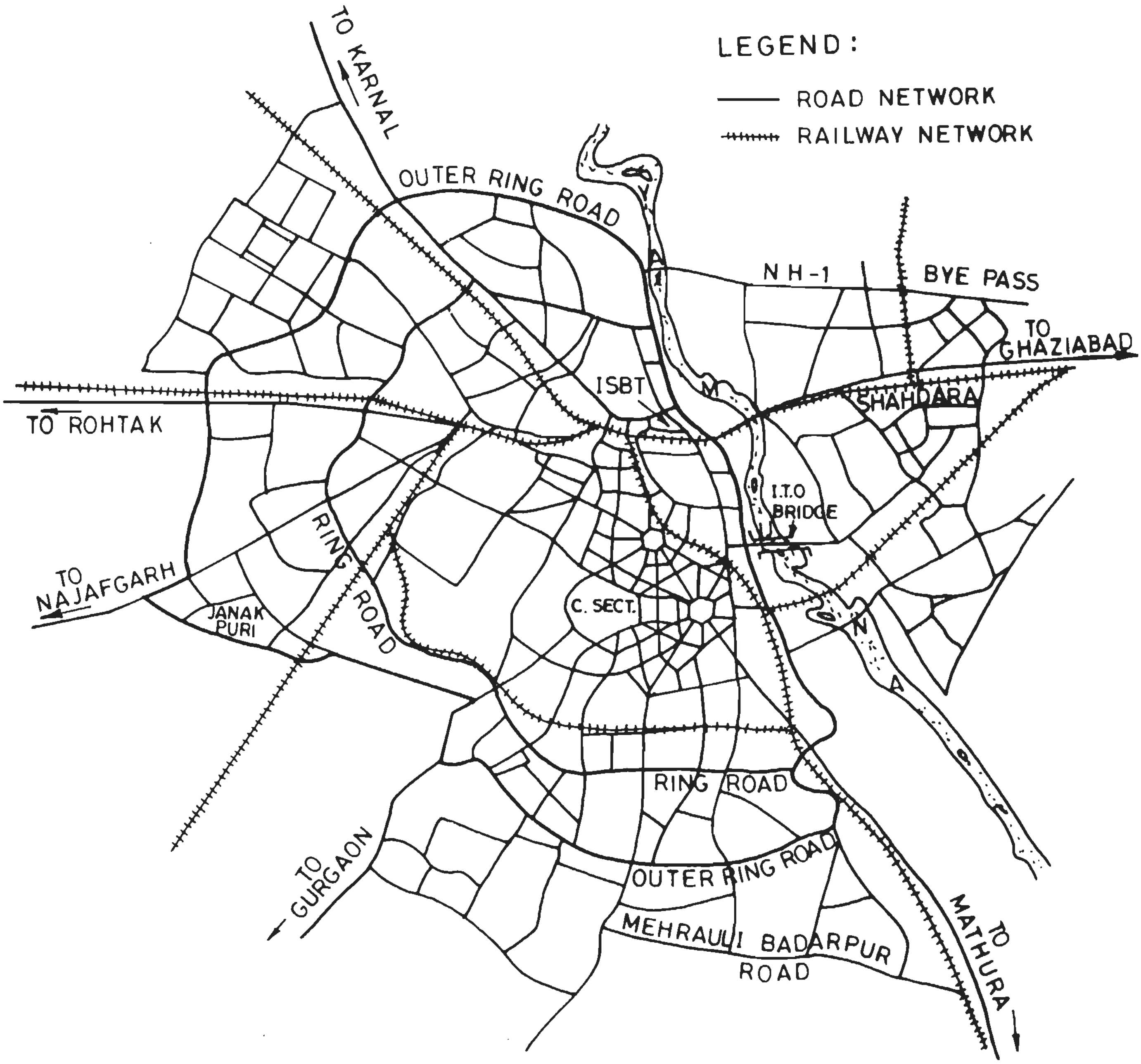


FIG. 3·3 DELHI METROPOLITAN REGION

privately operated buses. Chartered buses are playing a major role in meeting the daily transportation needs of regular commuters during peak hours mainly for work trips, as well as education trips. Therefore, the ever increasing travel demand has contributed to the phenomenal growth of personalised vehicles like cars, motorised two wheelers and variety of other unorganised public transport modes like, three wheeler auto rickshaws, mini buses, taxies, cycle rickshaws etc. on the roads [7].

The issue has come to a head because heavy investments are now required for creating infrastructure capacity for the projected growth in motorised transport and for constructing mass rapid transit systems in cities like Delhi to cater for the bulk movements. Still, the costs of environmental, safety and social impacts remain exogenous to the investment decisions. Traffic demand is worked out starting with the extrapolated growth trend of personal vehicles which 'supply' only a small fraction of urban transport demand and are thus heavily subsidised through public funds. As a result, bus services are over crowded and poorly managed, rail transit suffers for want of investment and pedestrians, bicycles and pedal rickshaws try to squeeze into the same road space as used by motorised vehicles. Mixing of slow and fast traffic causes even more congestion, pollution, accidents and fuel loss. This can be described as 'unsafe inefficient transportation operations'.

It is clear that the business-as-usual approach based on extrapolated growth trends of motorised vehicles is unsustainable because the urban transport scene in Delhi is constrained variously, and particularly by petroleum insufficiency and the financial and strategic considerations against increasing import dependence and the very limited capacity of users and the governments to pay or invest for urban transport services. These constraints are generally not applicable to the high income developed countries.

India may not aim at self sufficiency but can neglect self reliance and its capacity to pay only at the peril of social justice and security. Thus, the goal of urban transport planning may be defined as minimising the dependence on petroleum fuels and the capital requirements of the infrastructure for the transport modal mix (including non-motorised transport) as well as minimising the environmental impact and providing safe, comfortable and convenient services in conformity with the capacity to pay.

A sustainable urban transport system must be socially equitable and meet transport needs of all sections. Urban transport planning should, therefore, broaden its focus from the present over riding concern for the private motorised transport which is affordable only by a small fraction of population towards public transport and non-motorised transport including pedestrians. Scarce resources like road capacity should be shared equitably. Similarly, those generating external social costs like those of polluted air, noise, congestion, accidents, and traffic control and detentions should pay to cover these costs. It also means that direct or incidental subsidies should go to the weaker sections and infrastructure, environmental and health, safety and social costs are adequately reflected in economic assessment of possible options and proposed investments.

3.2.3 Growth of different types of vehicles in Delhi

The traffic and transportation problems in Delhi have been aggravating over the years. The traffic police has identified 47 different kind of vehicles in Delhi. While slow moving animal drawn vehicles are also seen on Delhi roads along with trucks, buses, tempos, cars etc. The composition of vehicles is shown in Table 3.6. The mixing of easy-going slow and fast moving traffic, results in a gigantic mess on roads especially where the roads are confined to two lanes for two-way operations. The different modes and categories of traffic plying on the roads in Delhi are given in Table 3.7.

TABLE 3.6 GROWTH OF DIFFERENT TYPES OF VEHICLES IN DELHI DURING 1978 AD - 1990 AD

Sl. No.	Class of Vehicles	Year (AD)			
		1978	1982	1986	1990
1.	Private Cars	105201	134451	201947	404671
2.	Motorised Two-Wheelers	282338	429897	747677	1233001
3.	Taxis	5580	7744	8738	10184
4.	MCR/TSR and Auto rickshaw	17890	23449	33648	63477
5.	Goods Vehicles and Delivery Vans	31112	42672	68927	102367
6.	Buses (Mini, Private and Others)	6929	10642	14751	19137
	Total Motor Vehicles	449053	648819	1075688	1832837
7.	Tonga	1851	1791	549	2016
8.	Horse-Rehra	323	537	346	583
9.	Bullock-carts	480	815	770	1251
10.	Hand-Carts	5891	6006	5103	9843
11.	Cycle-Rickshaw	5880	3100	7500	5993
	Total Slow moving (including unregistered under challaned)	14425	12249	14277	73636
	Total	463478	661068	1089956	1906463

Source : Gupta A.K. et al [55]

TABLE 3.7 DIFFERENT MODES AND CATEGORIES OF TRAFFIC IN DELHI

Fast Moving (Motorised)	Slow Moving (Non-Motorised)
TWO WHEELERS	- Pedestrians
- Mopeds	- Pedestrians
- Scooter	- Bicycles
- Motor Cycle	- Cycle rickshaws
- Scooter with side car	- Trolleys
THREE WHEELERS	- Rehra
- Auto rickshaw	- Hand Carts
- Tempos	- Tonga
FOUR WHEELERS	- Bullock or Buffalo Carts
- Car	- Camel carts
- Taxis	- Jhota buggies
- Vans	- Horse carts
- Delivery Vans	- Bel thelas
- Electra Vans (Battery Operated)	
- Bus (DTC,STA,Tourist and Chartered)	
- Mini Buses (20 Sheets)	
- Micro Mini Buses (Matadors)	
- LCV/LGV	
- MMV (Medium motor vehicles)	
- HTV (Heavy transport vehicles)	
- Tractors (with or without trailer)	
- Tankers (Water, Milk etc.)	

Contd..

Contd.. Table 3.7

Fast Moving (Motorised)	Slow Moving (Non-Motorised)
- Truck Trailers	
- Emergency Service Vehicles (Police, Ambulance)	
- Armed Forces Vehicles	
- Municipal Service Vehicle	
- Cranes	
- Road Rollers	
- Bulldozers	

Source : Satsangi, P.S.,[146]

3.2.4 Road accidents in Delhi

Road safety is a major concern on Delhi roads. The total number of accidents in Delhi are maximum [35]. The number of accidents in Delhi is shown in Table 3.8. At present, on an average more than 5 persons are killed and around 22 persons injured everyday in road accidents in Delhi. The type of persons killed or injured are predominantly pedestrians, followed by cyclists and riders of motorised two wheelers etc. About 75 percent of the accidents on Delhi roads are caused by driver fault [24]. The percentage distribution of accidents according to their cause is given in Table 3.9. Thus, the more number of vehicles on the road increases the number of accidents, though the comparative figures for other cities are rather low.

TABLE 3.8 GROWTH OF ACCIDENTS IN DELHI

Year (AD)	Fatal Accidents	Injury Accidents	Non-Injury Accidents	Total Accidents	Persons Accidents	Persons Killed
1970	505	3387	4020	7912	3737	531
1975	496	2439	393	3328	3853	510
1980	722	3434	144	4300	3980	747
1985	1185	4903	166	6251	6366	1276
1990	1559	6062	76	7697	7883	1670
1991	1644	6249	132	8025	8212	1795
1992	1560	6900	106	8566	8624	1612
1993	1812	7104	264	8952	9396	1960
1994	1926	7116	228	9270	8415	2004

Source : Delhi Traffic Police, [36]

3.2.5 Environmental pollution in Delhi

Delhi's level of atmospheric pollution (suspended particulate matter) is already three times the permissible limits. The air pollution is adversely affecting human health in Delhi. It contributes to chronic respiratory ailments as emphysema and bronchitis, asthma, acute respiration infection, allergies and it also leads to cancer some times. The vehicular emissions consists of carbon monoxide, sulphur dioxide, hydro carbons, nitrogen oxide, lead photo chemical smog. Noise pollution - noise can not be defined in a wholly satisfactory manner, when the sound is unwanted by the recipient, it may be described as noise. As the problem of noise involves, people and their feelings, its assessment is a matter of human values and environment, than of precise physical measurement. Common noise level sources and typical reactions are given in Table 3.10. The detrimental effects of noise can be considered under the following headings :

(i) Subjective effect.

(ii) Behavioural effect.

(iii) Physiological effect.

TABLE 3.9 DISTRIBUTION OF ACCIDENTS ACCORDING TO CAUSES

Sl.No.	Cause of Accident	Percentage
1.	Fault of driver of Motor Vehicle	74.70
2.	Fault of driver of Vehicle other than Motor Vehicle	2.27
3.	Fault of Cyclists	4.40
4.	Fault of Pedestrians	7.32
5.	Fault of Passengers	3.71
6.	Defective mechanical condition of Vehicles	2.51
7.	Defective Roads	0.81
8.	Bad Weather Conditions	0.18
9.	Other Causes	2.63
10.	Causes not known	1.47

Source : Chandra, Jag Pravesh, [24]

Disturbance, annoyance etc. describe the subjective effect of noise below 40 dB(A). The behavioural effects include communications interference, sleep disturbance and simple task performance such as driving. Performance in classroom and in workshop is affected by irregular burst of noise which are more disruptive than steady noise upto 90 dB(A). Ambient noise standards as per ISOR-362 are given in Table 3.11.

TABLE 3.10 COMMON NOISE LEVELS AND TYPICAL REACTIONS

Sound Source	Noise Level dB(A)	Typical Reaction
Military Jet	130	Painfully Load
Jet take-off at 606 m	120	
	110	Maximum Vocal Effort
Jet take-off at 606 m	100	
Freight Train at 15 m	95	
Heavy Truck at 15 m	90	Very annoying (Hearing damage for continuous 8 hour exposure)
Busy City Street	80	Annoying
Highway traffic at 15 m	70	
Light Car traffic at 10 m	60	
Noisy office	50	Speech Interference
Public library	40	Quiet
Soft whisper at 4.7 m	30	Very Quiet
	10	Just Audible
Threshold of Hearing	0	

Source : Venkatraman, T.S. [155]

TABLE 3.11 INDIAN STANDARDS FOR NOISE CONTROL
(Ambient Noise Standards As Per ISOR - 362)

Sl.No.	Area	Day time* dB(A)	Night time** dB(A)
1.	Industrial	75	70
2.	Commercial	65	55
3.	Residential	55	45
4.	Silence Zone ***	50	40

* Day time - 6.00 am to 9.00 pm (15 hours).

** Night time - 9.00 pm to 6.00 am (9 hours).

*** Silence zone - Area upto 100 m around certain premises like hospitals, educational institutions and courts may be declared as silence zones by competent authority.

Source : Compiled from Records

However IS-1999 has fixed the upper limit of tolerable noise level for 8 hours exposure at 85 dB(A). Drivers subjected to loud noise levels tend to concentrate blindly on control task such as gear and steering and ignore the peripheral such as signals and signboards. According to a survey conducted by the Central Pollution Control Board, New Delhi [1993 AD], almost all the roads of Delhi have a noise level exceeding the acceptable levels. Whereas, the noise pollution levels range from 65 decibles to 90 decibles, the average has been calculated as 80 decibles that is quite high as compared to 50 dB(A) levels that is considered to be within the permissible limits. The survey indicates that in Connaught Place, Darya Ganj and Mathura Road areas, the levels are in the range of 85 to 97 dB(A). Despite minor variations in the permissible levels of noise pollution in residential and industrial areas, the survey has recorded very high levels of noise pollution even in the industrial belt of the capital. The survey indicates that levels of noise pollution vary from a low of 65 dB(A) to a high of 81 dB(A) in a large number of industrial areas.

3.2.6 Major transportation studies conducted in Delhi

The first study entitled " Origin-Destination Survey of Traffic of Greater Delhi" was conducted in the year 1957 AD relating to traffic and transportation problems by the Central Road Research Institute (CRRI) in collaboration with Town Planning Organisation. The result of the study were utilised for the preparation of first Master plan of Delhi. The recommendations included the development of new inner ring road, construction of new bridge over river Yamuna, development of new link roads and facilities for bicycle traffic.

Implementation of Master Plan is considered very successful and has certainly helped in the traffic and transportation problems by way of development of district centres, spot improvement, development and widening of roads, provision of bridges over river Yamuna and construction of fly-overs on railway level crossings. The Master Plan, however has not been successful in providing an efficient mass transport system for Delhi Urban area residents.

Comprehensive traffic and transportation studies for Delhi urban area were carried out by Central Road Research Institute at the instance of planning commission, Government of India and on behalf of Delhi Administration in the year1969 AD. The recommendations of the study which were based on a number of field studies included improvement of roads and road intersections, construction of additional bridges across river Yamuna, road bridges over level crossings, proposals for the improvements in the C.B.D. areas, development of off-street parking facilities and mass rapid transit corridors for efficient movement of passengers.

The implementation part of the recommendations of the studies was confined to spot improvements which helped to improve the situation to a limited extent. As regards the major recommendations for the development of mass rapid transit system for Delhi which included the North-South and East-West corridors as well as improvement of ring railway and spurs, the same has not been implemented.

Besides the above major studies, Metropolitan Transport team of the Planning Commission, Metropolitan Transport Project (MTP) of the Ministry of Railways, Town and Country Planning Organisation (TCPO) and a Group constituted by the Planning Commission, Government of India for "Transport Development Programme for Delhi" submitted the reports with recommendations for the development of transport systems including mass rapid transit system during the various years. Perspective plan for Delhi 2001 AD prepared by the Delhi Development Authority (DDA) has proposals for the development of transport system of Delhi. These transport proposals were based on comprehensive transport studies conducted by the Delhi Development Authority in 1981 AD.

The proposals include the development of Light Rail Transport (LRT) system, development of integrated freight terminals, new passenger terminals and other infrastructural facilities.

The Delhi Urban Arts Commission in 1986 AD suggested modifications to the Delhi Development Authority (DDA) proposals and recommended the development of the existing ring railway with three new radial underground corridors.

In 1986 AD, the Ministry of Railways appointed a study group to recommend a precise alignment for the East-West corridor for construction on priority due to growing congestion in that corridors. This was followed in 1987 AD by a 'Task Force' to recommend the choice of technology for the East-West corridor. M-bahn magnetic levitation system for a small length on a trial basis was recommended for adoption, which if not successful, could be replaced by a Light Rail Transit system.

The Delhi Administration retained RITES, a Government of India Enterprise, in April 1989 AD, to prepare a scheme for a Mass Rapid Transit system (MRTS) for Delhi. RITES completed its study in 1990 AD and proposed 184.5 Kms long multi-modal high capacity network for Delhi to be constructed in three phases, including first phase as 67.5 Kms. The MRTS network was later extended by an additional length of 14 Kms and thus became total length of full network as 198.5 Kms. In 1995 AD, RITES modified first phase and restricted its length to 55.3 Kms instead of 67.5 Kms due to some technical reasons [132].

Major recommendations of the earlier studies of Delhi MRTS are summarised in Table 3.12.

3.3 Proposals of Light Rail Transit System in Delhi

In a bid to ease the already choked situation on Delhi roads, the Government about three years back i.e. in 1993 AD, privatised the bus system and introduced over 3000 additional buses to the existing fleet of DTC. But the situation is far from eased because these buses compete for the same space that was available about a decade ago.

The privatised bus system have already failed, the Central and State Governments, is now looking towards other options. The Mass Rapid Transit System (MRTS) and now the Light Rail Transit System (LRTS) or the trams are the ones on the priority list. MRTS plans are proposed to be carried out initially on corridors.

The proposed trams would run on lines laid on platform top a 5.1 m high precast - Y shaped pillars. The pillars would be inserted into 3m x 3m holes dug by a small machine along the central verge of the road without causing any disruption in traffic. The trams would run on electricity on 1.2 m wide rails. The stations, which would be one to one and a half km apart will be named after the states and build in accordance to the architectural style prevailing in each state. A flight of 20 steps would lead to these 9 m long stations. Each tram will have three bogies which are likely to be imported. Each boggey will have a carrying capacity of 105 persons and the tram would ferry about 350 people at one go. The operating frequency being 5 - 10 minutes [95].

TABLE 3.12 MAJOR RECOMMENDATIONS OF EARLIER STUDIES OF DELHI MRTS

Sl.	Name of Study and Agency	Year of Study (AD)	Major Recommendations
1.	Comprehensive Traffic and transportation planning studies of Greater Delhi-CRRI	1969	(i) Timarpur to South Delhi and Okhla Industrial Estate. (ii) From Western Colonies along Najafgarh Road to Shahdara. (iii) A Feeder line to connect Zone No.23 in the North-West to the ring railway. Total underground length = 51.30 Kms.
2.	Concept plan of town and Country planning office	1973	(i) Underground = 58 kms. (ii) Surface corridors = 195 kms.
3.	Metropolitan Transport team study, Ministry of urban Development	1974	(i) Underground 36 kms. Corridors along two axial (North-South and East-West) (ii) Surface rail corridors = 96 kms.
4.	Study by Metropolitan Transport project (Railways), Ministry of Railways	1975	(i) Underground corridors = 57.6 kms (ii) Surface corridors = 124.7 kms.

Contd...

Contd.. Table 3.12

Sl.	Name of Study and Agency	Year of Study (AD)	Major Recommendations
5.	Perspective Development Plan 2001 AD - DDA (Delhi Development Authority)	1984	(i) Light rail transit system - 200 kms. (ii) Tramway in walled city- 10 kms. (iii) Feeder services for present Ring Railway (iv) Cycle tracks.
6.	Urban Arts Commission	1986	(i) Development of existing Railway (144 kms.) (ii) Three radial underground MRTS Corridors (20 kms.)
7.	MRTS for Delhi-Report of Study Group, Ministry of Railways.	1986	Alignment for the East-West corridors connecting Vivek Vihar in the East and Vikaspuri in the West (36 kms.) only was proposed.
8.	MRTS for Delhi-Report of Task Force of Ministry of Urban Development	1987	Adoption of M-Bahn magnetic levitation system on a trial basis.
9.	Integrated Mass Rapid transport system for Delhi, RITES	1992	Adoption of MRTS network of 184.5 kms.
10.	Integrated mass rapid transport system for Delhi (modified phase-I), RITES	1995	MRTS network of 55.3 kms.

Source : Compiled from Records.

3.4. Proposed Integrated Multi-Modal MRTS Project

The Govt. of India has approved in principle the implementation of the multi-modal MRTS for the Delhi city through a company to be set up under the companies act with participation of the Union Government, Delhi Government, Japanese Government funding agency (OECF).

A Company entitled "Delhi Metro Rail Corporation Ltd." has already been registered on May 3rd 1995 AD with the Registrar of Companies, Government of Delhi and Haryana.

Significantly, the earlier project spread over 67.5 kms, in the first phase has been modified and reduced to 55.3 kms, in consequence of detailed discussion with the Delhi Government. The modified 55.3 kms of the MRTS project (Figure 3.4) consists of (i) Vishwavidyalaya or Delhi University - Central Secretariat metro Corridor (ii) Shahdara - Nangloi MRTS Corridor (iii) Subzi Mandi - Holambi Kalan MRTS Corridor.

In this study, the above three corridors of MRTS have been considered for detailed analysis.

The modified MRTS project is stated to acquire about 337 hectares of land in total. The identified land patches for the project include 188 hectares of Government / Railway land, 32 hectares of urbanised (private) land with the remaining 117 hectares being agricultural land [131].

3.5 Studies on Integrated Urban Form - Urban Transport Planning and Developments

It has been well recognised that travel is a derived demand. In urban areas, different land uses generate different intensities of travel demand. This indicate inter relationship between urban form (land-use) and urban transport has been appreciated, however our planning efforts leave much to be desired. The cities and towns fell short of establishing true integration between land use and transport due to different master plan in one form or an other.

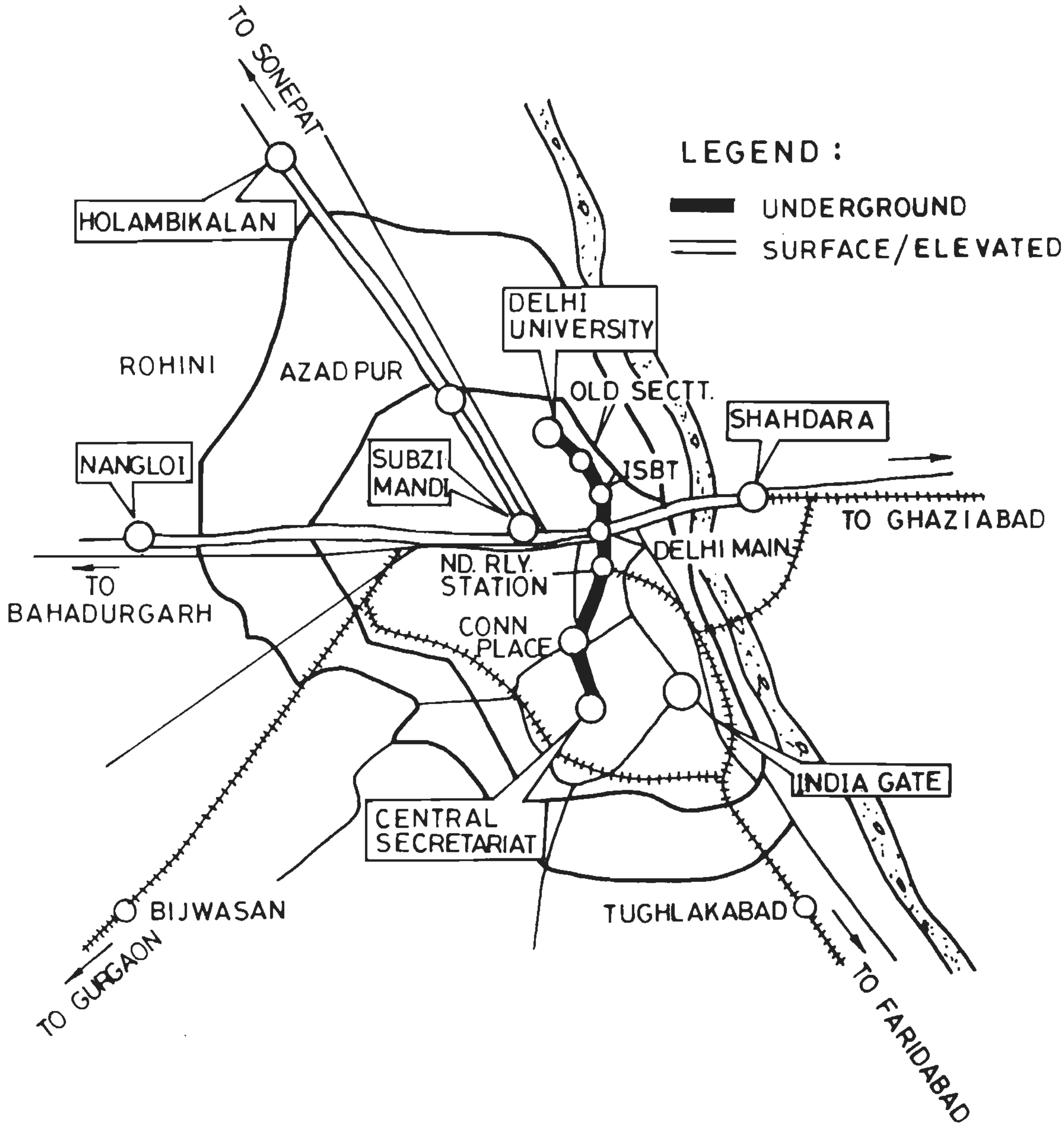


FIG. 3·4 PROPOSED DELHI MASS RAPID TRANSIT SYSTEM

Infact most of our urban transport plan projects are designed to meet the resultant demands of an established or desired land use pattern. The reverse process of using urban transport to develop a rational structure and form for cities and towns is not much in evidence. To ensure true integration and thereby reduce or minimise travel demand, a serious and accelerated effort to review and revise the urban development plans is required.

3.6 Need of Unified Metropolitan Transport Authority

For providing an integrated and efficient inter- modal transport service to the commuters, it is necessary to set up a "Unified Metropolitan Transport Authority (UMTA)" with adequate power and resources to develop integrated rail and road infrastructure. This should be broadly on the lines of similar coordinating agencies in other capitals of the world, like Paris and Washington, D.C.

All land uses plans, which necessarily have an impact on the transport infrastructure, should ordinarily be cleared by 'UMTA' before these are implemented. Enabling legislation would have to be enacted particularly in the matter of laying new railway lines and developing rail facilities, which fall within the central list.

This authority in Delhi to be headed by the Chief Minister should have representatives drawn from amongst the members of the state assemblies, local MPs, MCD, NDMC, Cantonment Board and nominees of the concerned ministries of the Central Government, Northern Railway, DDA, DTC, Delhi Traffic Police etc. Since the effective management of the system will depend on the efficient operation of rail network and road feeder systems. The Metropolitan Authority should have an Executive Board of Management, responsible for its day - to - day functioning and should be manned by experts drawn from Railways and Roadways and have, in addition, a Financial Advisor and a Legal Advisor.

3.7 Requirements of Study

Various transportation studies conducted in the past suggest that transport demand in Delhi is increasing rather rapidly and the travel patterns of resident are changing over the years. The mobility levels of the residents are influenced by socio-economic conditions and the availability of the transport system with expanding city size and dispersal of economic activities, the dependence of population, particularly belonging to low and middle income groups on mass transport modes has been increasing over the years.

The Public bus transportation facilities available in Delhi despite the increase in its fleet strength and improvement in productivity are proving to be inadequate in catering to the growing transportation demand. The other contributing factors responsible for the inadequacy of bus system are the multiplicity of authorities which influence the transport infrastructure, its operation, regulation and developments, the increasing losses which DTC incurrs annually and the limitations of the road based bus system catering to the transport demand of commuters, particularly along high density corridors.

Keeping in view the past trends, the changing travel patterns of Delhi residents, as well as, ever growing transportation demand, dependence of the poor and lower income households are on mass transport system. There is a requirement to have a comprehensive transportation plan for Delhi including high capacity corridors capable of moving passengers efficiently with rapid transit system. For the suitability of proposed MRTS, there is a need for an in-depth study of their capacities, costs and economics in the Indian context so that a proper mix can be arrived at for Delhi city.

3.8 Modal Split Studies in India and Need for New Approach

As described in Chapter 2, the mode choice studies made in India in 1960s AD and early 1970s AD have been parts of transportation planning studies made for respective cities. Planners in Madras had used the conventional Multiple Linear Regression (MLR) models for mode wise analysis. Trip generation and attraction models for each of the principal modes were built. Variables used in these models were one or more of the following- landuse composition, household income, Vehicle ownership, number of employees, number of school going children. Sarna's MLR models for modal split for Delhi considered family income, distance to CBD and residential density as variables [134]. The Category analysis models which were tried for Delhi and Bombay considered income and household composition as main variables [139, 142].

The Diversion curve analysis models developed by Anantharamaiah and Rao [4] covered only one of the modal attributes as a variant (time or cost). On the other hand, category analysis models done at household level and MLR models have not considered any of the modal attributes as a variant.

The above modes have not adequately covered the factors influencing behaviour of the individual in choice of mode of travel. The disaggregate utility models taking into account individual behaviour in India developed by Raghavachari [130], Sinha et al [136], Gupta [51] and Prasad [123] have considered time of travel and cost of trip as the two variants. Socio-economic criteria have been covered by developing separate models for vehicle owning population (VOP) and non - vehicle owning population (NVP). While models for NVP have given good results, the models for VOP especially when all modes are considered together, have either given low statistical fit or low validity, when tested on data from a different location [123, 154].

Sequential Binomial Logit Model (SBM) developed by Sripathi Rao [145] included the convenience measure in terms of separate access time. While time of travel and cost of trips are no doubt the principal determinants in mode choice, to-day an Indian commuter appears to consider other factors like comfort, convenience, reliability, safety etc, while choosing the travel mode or destination.

All these studies indicate how, while time and cost are principal determinants in mode choice. To-day an Indian commuter also considers other factors like comfort, convenience, safety etc., while choosing his travel mode. The different modelling and analysis approaches reviewed in chapter 2 would indicate that while disaggregate utility models using logit and probit analysis are most suited for modal split analysis, the use of time and cost only as variants in a multi-modal situation is inadequate. Need has been felt to account for stated preferences in respect of other travel attributes in mode choice analysis. This has been tried in the various attitudinal analysis in developing countries, where some attempts have been mode to include the attitude measures also in MLR or MNL models but are generally pertain to bimodal or trimodal situations. The category analysis studies call for a large data set and can not be modified to suit changes in the transportation system, which would result in change of modal composition in an area. The MNL models developed using multitude of modes for the VOP have shown low statistical fit and validity when transferred to another area. If attitude of user can be measured and can be included in the modal, it may improve their validity. In a multi-modal situation, with widely varying disparities in economic conditions in Indian cities, it should be all the more useful to probe this aspect and study the impact of attitude on mode choice by commuters. This study is aimed at evolving a methodology by which the influence of attitude of the user towards different travel attributes in a multi-modal choice situation in an Indian city can be accounted for.

3.9 Basic Approach in Collection of Data

The traditional four stage transportation planning process has been utilised for projecting the traffic on the identified mass rapid transit system corridors. The data base for the transport analysis is the Household Travel Survey of Delhi Urban area carried out by Delhi Development Authority in 1981 AD. This data was utilised by the DDA for formulating the land use proposals for the perspective plan 2001 AD. The data collected from Delhi Development Authority consists of the following:

- Socio-economic details of selected household in each zone of the study area.
- Trip details of household members of the selected households.
- Base year 1981 AD planning zones.
- Road network map for the base year 1981 AD.
- Road network map for the horizon years.
- Planning zone system for the horizon years.
- Quantified land use population, employment and school enrolment for the zone systems for the base year 1981 AD and horizon years 2001 AD and 2011 AD.

Two techniques which have been used for attitude assessment for various travel attributes are falling under the approaches: The first one followed by Golob [43,47], Hartgen and Tanner [65], Golob and Dobson [48], Koppelman [88] and others for attitude measurement while the second are followed Trade-off Game approach used by Ira Robinson, et al [78]. Delhi city is taken as a case study for modelling the system making use of attitude measurements using Multiple Linear Regression technique or Logit form. Delhi city is taken as a case study. Since no detailed analytical work appears to have been done in understanding the attitude of people towards various travel attributes in an Indian city. Both the techniques are tried and the usefulness and suitability compared, taking Delhi city as a case study. The studies would indicate policy directions to be followed for purpose of achieving a desirable modal split, if required. Samples to be selected should be truly representative of different mode users and sections of people.

The capital costs estimate of the MRTS projects are based on the unit rates for various elements of the project. These have been calculated on the basis of schedule of rates of Indian Railways, Calcutta Metro and Metropolitan Transport Project of Madras Railways and is duly adjusted to the year 1996 AD, so as to represent cost of facilities if provided at respective percentage rates as adopted by the Indian Railways.

The operating expenses estimate of the mass rapid transit system projects have been worked out using the data collected from various departments of Southern Railway and Metropolitan Transport Project of Madras Railways in the year 1993 AD and using prevalent rates of payment. The operating expenses are duly adjusted in the year 1996 AD, so as to represent cost of facilities if provided now.

3.10 Attitude Studies and Model Development

It first involves measurement of attitude of individual, which comprises of two components i.e., 'feeling' of importance of different components of travel and 'perception' of level of satisfaction derived from different modes on different components of travel.

It calls for identification of the different components of travel in an easily comprehensible form. The analysis for studying includes how attitudes are formed and their influence on choice of mode. The methodology for study has been formulated involving following steps :

- Identification of travel attributes reflecting the characteristics of important modes.
- Arriving at a scale of measurement :

  'Importance' could be measured better using a ratio of scale and 'level of satisfaction' by a semantic differential scale. A hundred point scale for measurement is desirable.

- All income groups of people need to be covered during collection of primary data. Time and cost however will be the constraints in a study of this nature. A minimum sample size of 500 is considered necessary and satisfactory for such disaggregate level study.
- Computation of attitude values could be done using an appropriate mathematical form so that the attitude values can be reduced to a univariate scale.

3.11 Trade - Off Game

This is an experimental approach aimed at understanding what aspects of travel are considered most important and what aspects least important in a constrained situation. The steps involved comprise of design of the game, selecting the sample, playing the game, analyse and interprete the results and use of the results to assess the likely shift from one mode to another mode.

3.12 Methodology

The methodology of study comprises of :

- Study of characteristics of mass transit systems in India, their performance, designated role, costs and capacities.
- Study of available systems in developing countries and their applicability to Indian conditions.
- Design a suitable technique for measurement of attitudes of commuters towards different travel attributes.
- Selection of study areas, deciding sample sizes, design of questionnaire for collection of data on attitudes of commuters towards different travel attributes, and analyse the data.
- Design a suitable 'Game' and study in detail how people of different categories 'Trade-off' while choosing a mode and study the results.

- Use the findings of attitude and Trade - off studies to build models for forecasting future state of modal split in Delhi and also to arrive at desirable policy options to achieve a desirable modal-mix in Delhi metropolis.
- Choice of suitable systems for study and evolving models/ nomograms / capacity range curves indicating capacity ranges for their applicability.
- Evolving average and marginal costs for different systems and evolving curves for capacity v/s cost per passenger km.
- Identifying corridors in Delhi city taken as case study, needing such systems and determining suitable optional systems.
- Evolving strategies for developing such systems.

3.13 Applications of Findings

The thrust of this study is an understanding the impact of user's perception / attitude towards different travel attributes and to determine likely shift from one mode to another, making use of behavioural science technique results. The results are used to estimate the future state of modal split in a selected area of Delhi, where MRTS is likely to be introduced.

Financial analysis of MRTS can be used to determine the suitable fare structure, which should be able to meet day-to-day expenditure of MRTS as well as replacement costs.

Economic analysis of MRTS can be used to determine the socio - economic implications of the MRTS projects, so that a proper decision can be arrived at for developing the systems.

CHAPTER 4
PLANNING OF MASS RAPID TRANSIT SYSTEM AND TRAFFIC PROJECTIONS

4.1 Introduction

Delhi, the capital Metropolis of India, is one of the biggest growth centres in the world and has been expanding its boundaries, population and the motor vehicle registration beyond all rational estimates and expectations. Typical of any growing metropolis, the growth potential has been enormous owing to its employment opportunities and other related economic and social parameters and it can be said to be no exception that a population of 5.2 million in 1981 AD, has projections of growth to 13.2 million by 2001 AD. A ring railway system without proper road based network and support exists but is rather under - utilized. As already described in chapter 3, several proposals have been made from time to time for the development of a transport system for Delhi keeping in view the projected transport demand and recommendations include development of mass rapid transit system corridors as well as the proposals have been given in the perspective plan for 2001 AD for an integrated transport system for Delhi.

4.2 Objectives and Scope of Traffic Projections on MRTS Corridors

- Development of transport sub-models for the base year (1981 AD) and projection of transport demand for the horizon years 2001 AD and 2011 AD.
- Developing an overall transport plan for MRTS of Delhi.
- Selection of MRTS corridors and station to station passenger trips including number of passengers to be handled at each station for the selected/recommended MRTS corridors, so that the suitable fare structures can be arrived at for MRTS in order to meet the operating cost and replacement cost.

The scope of the studies is limited to Delhi urban area.

4.3 Transport Planning Methodology

Considering the objectives and scope of the traffic assignment, traditional four stage transportation planning process has been adopted for the transport analysis in the base year 1981 AD and for projection of transport demand for the horizon years 2001 AD and 2011 AD. The details of transportation planning process as adopted for the study are presented in Figure 4.1.

The process consists of trip generation, trip distribution, modal split and trip assignment stages.

4.4. Development of Transport Sub - Models

4.4.1 Transportation study process

The transportation study process consists of development of mathematical relationship or models, enabling future travel demand to be forecasted and alternative strategies for handling the existing situation can be developed and analysed. The purpose, of a transport planning process, is to maximize performance for a given cost. It is not just one model, but a series of interlinked and inter-related models of varying levels of complexity, dealing with travel demand. Through these models, the transportation study process as a whole is checked and calibrated before it is used for future travel predictions. This is done by developing the formulae or relationships to synthesize the present day movement patterns and adjusting them until they represent observed conditions. Only when the formulae or relationships have been adjusted or calibrated, so that the same can adequately predict the present day travel movements, are used in true predictive mode to determine future conditions.

The models to be developed are generally of two types and these include :

(i) Research models

(ii) Operational models

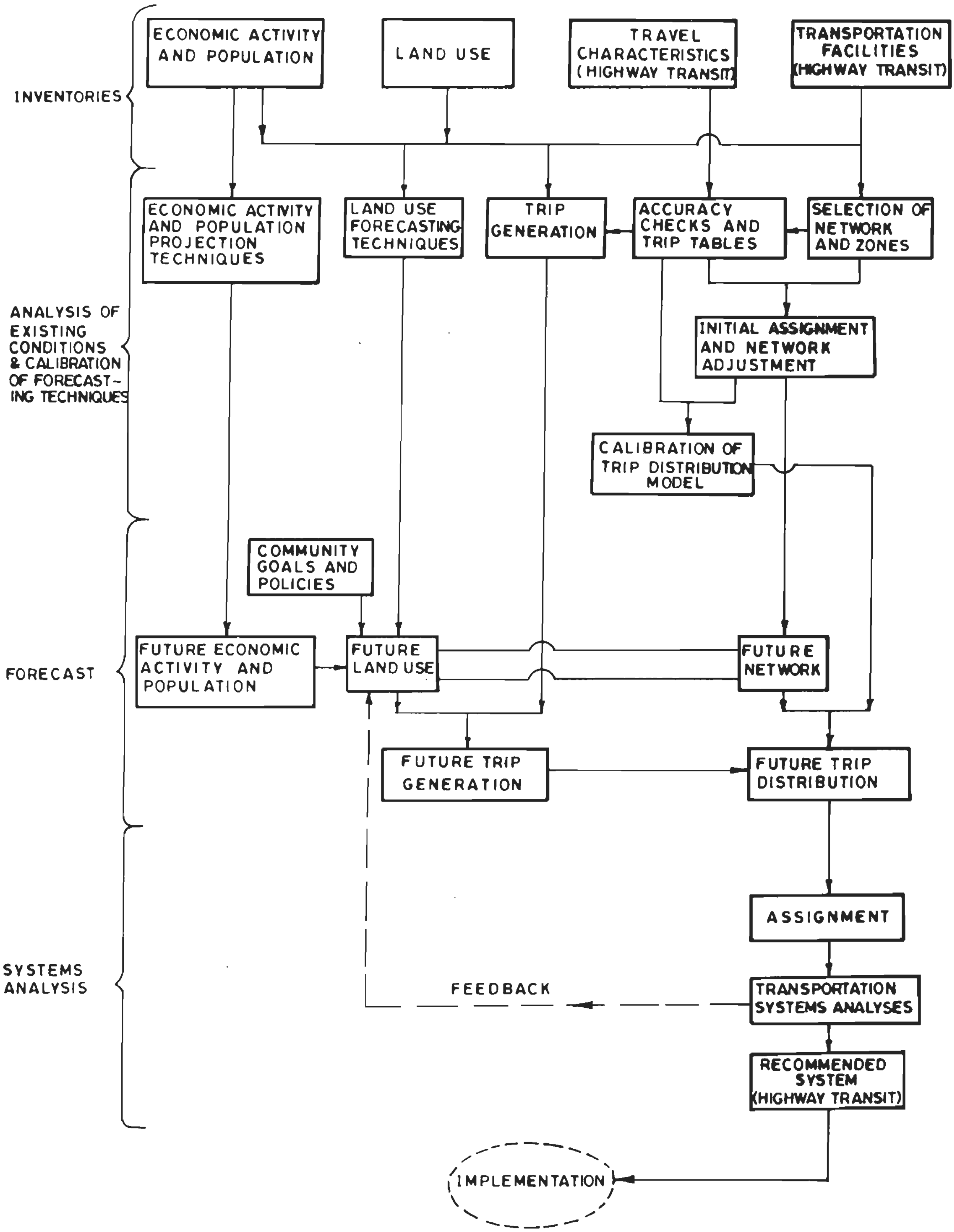


FIG. 4·1 ELEMENTS OF URBAN TRANSPORTATION PLANNING PROCESS

The research models are generally complex in nature. The inputs to such models are generally not available and if available, are difficult to forecast. The operational models require minimum data and that is normally available with the planning agencies.

In the present study, an attempt has been made to develop operational models. The normally and easily available planning variables at zonal levels such as population, employment and school enrolment have been made use of in this transport analysis. The basic functions included in the transportation study process are :

(i) Trip end prediction or trip generation - The determination of the number of person trips leaving a zone irrespective of destination and the number of trips attracted to a zone, irrespective of origin.

(ii) Trip distribution - The linking of the trip origins with their destinations or generations and attractions.

(iii) Modal split - The separation of trips by public transport modes or by private or personalised modes.

(iv) Traffic Assignment - The allocation of trips between a pair of zones to the most likely routes on the network.

(v) Evaluation - Assessing the comparative effectiveness of alternative strategies in meeting the transport demand.

4.4.2 Data base for the analysis

The data base for the transport analysis is the "Household Travel Survey" of Delhi urban area carried out by Delhi Development Authority (DDA) in 1981 AD. This data was utilised by the DDA for formulating the land use proposals for the perspective plan 2001 AD. The data collected from DDA consists of the following :

(i) Socio - economic details of selected household in each zone of the study area.

(ii) Trip details of household members of the selected households.

(iii) Base year 1981 AD planning zones.

(iv) Road network map for the base year 1981 AD.

(v) Road network map for the horizon years.

(vi) Planning zone system for the horizon years.

(vii) Quantified land use population, employment and school enrolment for the zone systems for the base year 1981 AD and horizon years 2001 AD and 2011 AD.

The surveyed data projected total population as 5.21 million in 1981 AD and indicated that around 2 percent of households spread over different areas of Delhi were selected for the purposes of obtaining travel information from the residents. The travel information thus obtained for the year 1981 AD and as analysed has been summarised and presented in Appendix 1.

4.4.3 Assumptions regarding modifications of data

The base year (1981 AD) household travel survey data as collected form DDA was analysed. The analysis revealed certain deficiencies and warranted updating. For modifications and updating of the data, the underlying assumptions were :

(i) Modification in base year per capita vehicular trip rates are to be based on past studies and reported trip rates by DDA.

(ii) Assumption regarding proportion of non-home based trips and the intra - zonal trips are that the non-home based trips, as observed in the base year, were around 10 percent of total home based trips, whereas intra-zonal trips were around 8 percent of total inter-zonal trips. The same have been adopted in this study.

(iii) Assumptions regarding distribution of inter-city trips by various modes (roads, rail and air).

(iv) The zoning systems adopted for study area are reduced in 24 zones, which are given in Table 4.1 and Figure 4.2 respectively.

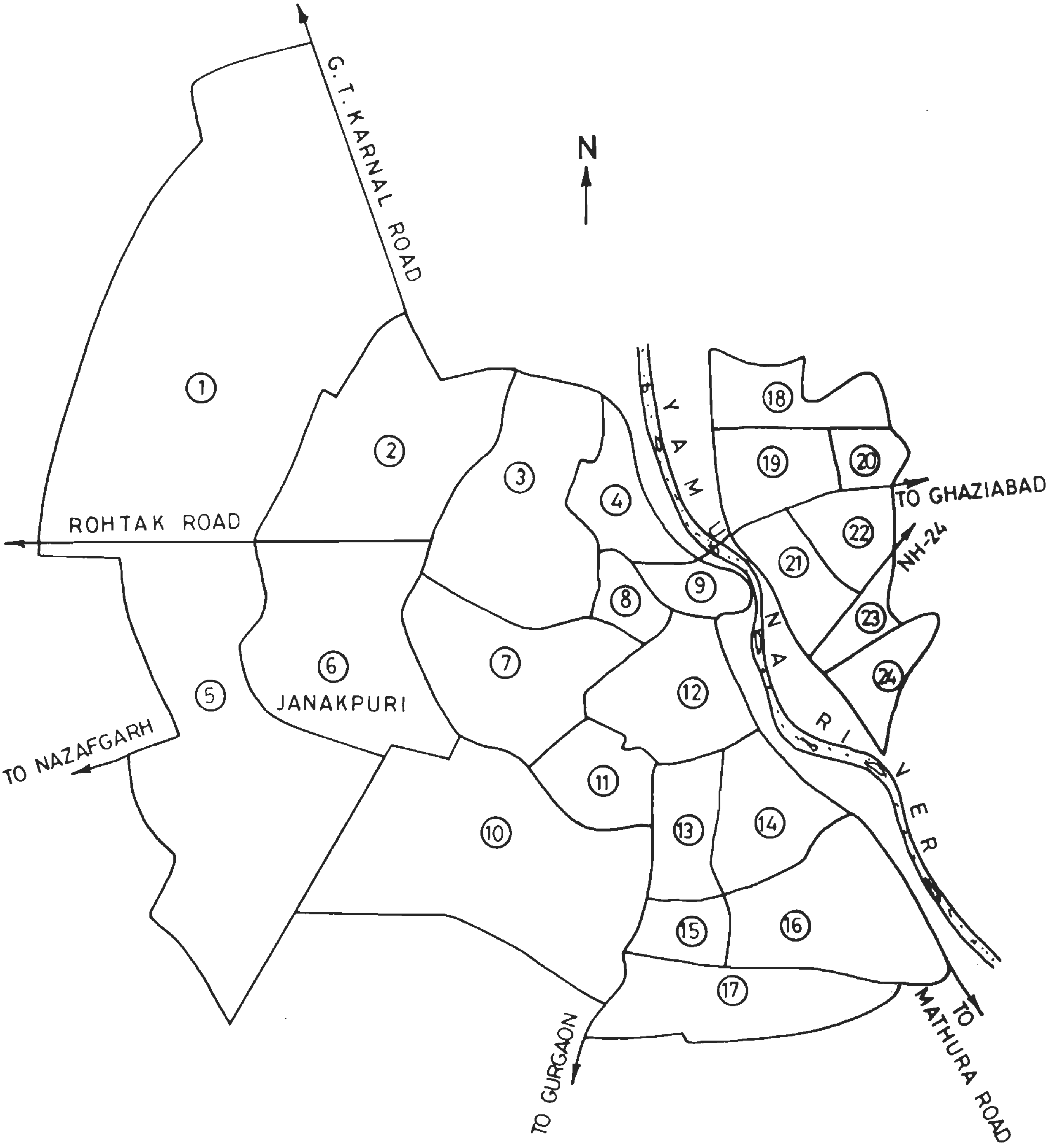


FIG. 4·2 STUDY ZONES FOR DELHI METROPOLIS

TABLE 4.1 ZONING SYSTEM FOR DELHI

Traffic Zone Number Adopted for the study	DDA - Zones
1.	148, 149, 150, 151, 152, 153, 154, 155,156, 157, 158, 159,160, 161, 162, 163, 164, 165, 166, 167, 168, 169
2.	55, 132, 133, 134, 135, 136
3.	29,30,32,33, 34, 112, 115, 120,130,131, 50, 51, 52, 53,54,40,43,44
4.	39, 28, 36, 41, 42, 46, 47, 37, 38, 45, 48, 49
5.	137, 138, 139, 140, 141, 142, 143, 144,145, 146, 147, 170
6.	118, 119, 120, 121, 124, 125, 127, 128
7.	31, 61, 60, 65, 116, 35, 113, 114
8.	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12
9.	13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23,24, 25, 26, 27
10.	96, 97, 98, 103, 104, 105, 106, 107, 117,122, 123, 126
11.	68, 69, 76
12.	56, 57, 58, 59, 62, 63, 64, 66, 67
13.	70, 71, 75, 85, 95
14.	72, 73, 74, 93, 94
15.	102, 108
16.	101, 109, 110, 99, 100, 111
17.	172
18.	176, 177
19.	90, 91, 78, 79, 81
20	82, 92
21.	77, 84, 88
22.	80, 83, 86, 87
23	89
24.	173, 174, 175

4.4.4 Trip categorization

The passenger transport demand in terms of daily passenger trips have been broadly categorized as intra-city and inter-city trips. The intra - city trips have further been considered as inter-zonal trips and intra-zonal trips. The Inter-zonal trips are the most important so far as transport analyses are concerned and have further been classified as home based trips and non-home based trips. Home based trips for the purposes of transport modelling have been classified as work trips, education trips and other trips. The non - home based trips and inter-city trips which do not form a significant proportion of total transport demand are not being modelled due to inherent difficulty and non availability of data. The proportion of non-home based trips which was around 10 percent of total home based trips as observed in base year is being assumed 15% for the horizon years. The distribution of passenger trips is given in Figure 4.3. The methodology for the distribution of inter - city trips which is given in Figure 4.4 and is being adopted in this study.

For studying the distribution of trips by mode, the trips were classified as (i) by public transport, labelled as 'mass modes' (ii) by fast modes, including private and hired 'fast vehicles' and (iii) by 'slow modes', including pedal bicycles etc.

4.5 Trip Generation

The first of the sub-models in the conventional study process is that which predicts the number of trips starting and finishing in each zone. The techniques developed attempt to utilize the observed relationships between travel characteristics and the urban environment and are based on the assumption that trip making is a function of three basic factors. The factors are :

(i) The land use pattern and development in the study area.

(ii) The socio - economic characteristics of the trip making population of the study area.

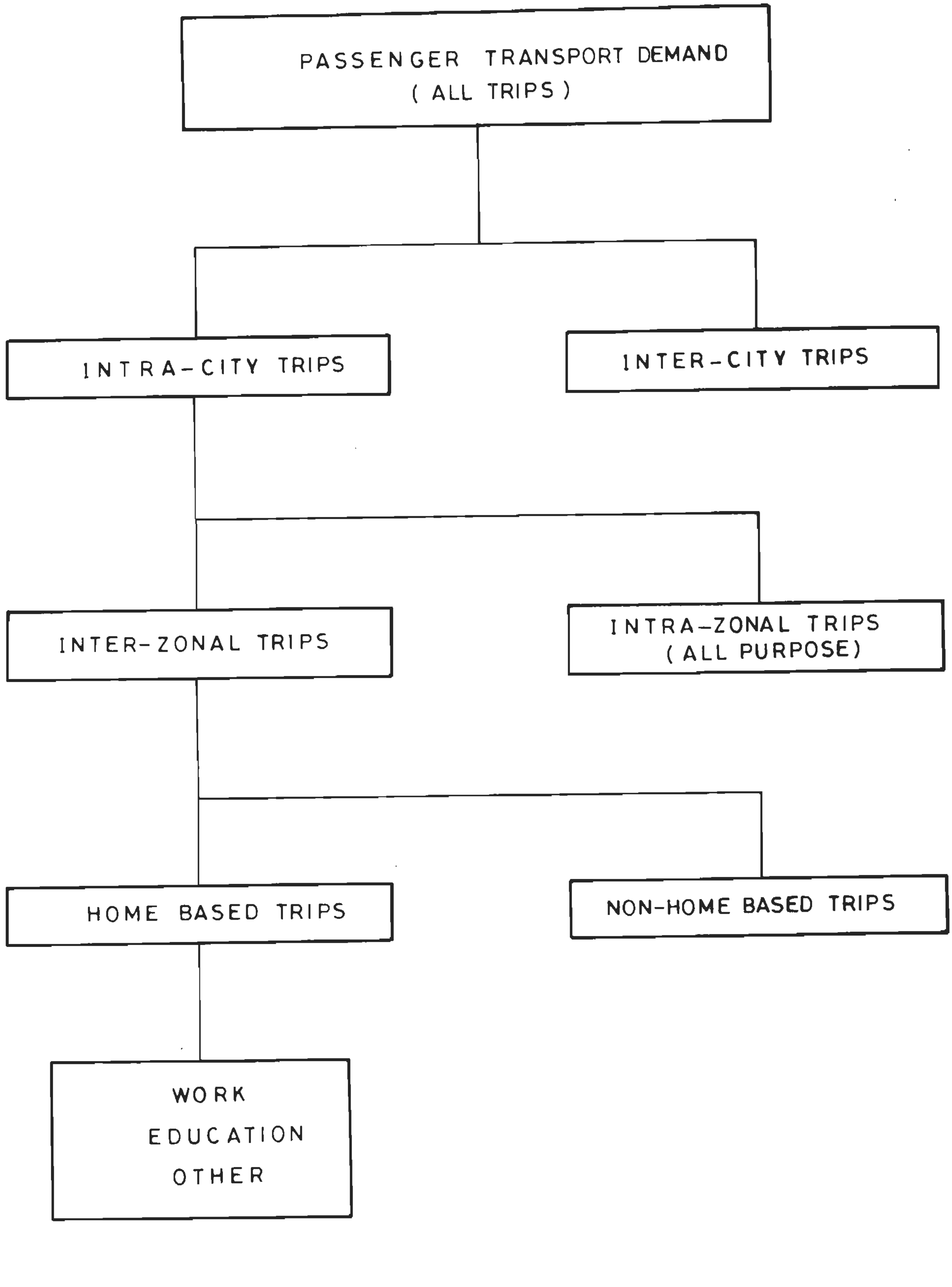


FIG. 4·3 TREATMENT OF PASSENGER TRIPS

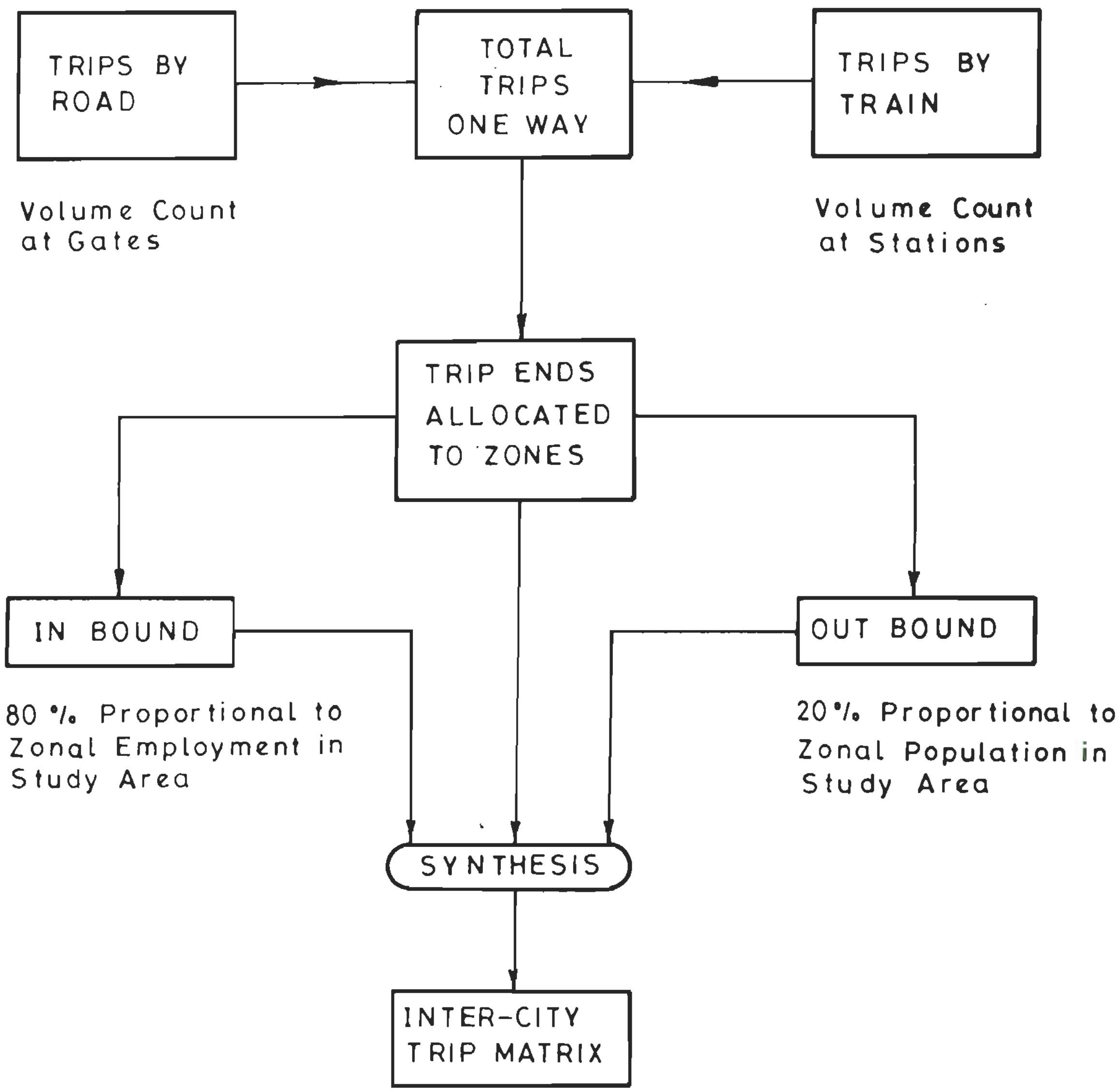


FIG. 4·4 TREATMENT OF INTER-CITY TRIPS

(iii) The nature, extent and capabilities of the transportation system in the study area.

Various techniques for developing trip generation models are available and notable among these include :

- Zonal regression Method.
- Household regression Method.
- Category analysis
- Person trip models

In this study, the zonal regression method has been used, because it uses the present trip making and demographic data at zonal level. The regression model assumes that some variable 'y' responds to changes in other 'x' variables. The 'y' variable is the quantity under study and is known as response or dependent variable. The 'x' variables are those which exhibit a casual effect on the value of 'y' and are known as the explanatory or independent variables. This is expressed in the following form :

$$y = b_o + b_1 x_1 + b_2 x_2 + \dots\dots\dots + b_k x_k \qquad (4.1)$$

Where,

b_o, b_1, b_2, ..., b_k are the least squares estimators of the unknown parameters, b_o is the intercept, while b_1, ..., b_k are the regression coefficients. The parameters are chosen in such a way, as to, minimize the squared sum of residuals or deviations from the estimated line.

The major issues in the development of this model are :

(i) The indentification of those variables which have significant and separate effects on trip generation.

(ii) The model must not only provide good statistical fit to the present day data but also be of a logical and meaningful form.

(iii) The variables must be meaningful in explaining the trip making behaviour .

(iv) The model must be capable of being estimated for future years. With such an equation developed, it is possible to develop future levels of trip productions at given future predictive indicators.

Generalised form of the linear equation developed for this study is as under :

$$y = a + bx \tag{4.2}$$

Where,

y = Number of one way trips produced or attracted in a zone for n^{th} purpose (work, education, other)

x = Independent variable (population, employment, school enrolment).

a = Constant

b = Regression coefficient trip rate to be determined from least square analysis for n^{th} purpose.

Summary of regression analysis for home based one-way work, education and other trips produced/attracted from/to a zone by all modes (mass, fast and slow) is presented in Table 4.2). The values of coefficients of determination (R^2) obtained from the regression analysis are significant at 1% level and are of high statistical quality.

Summary of one-way home based trip rates as obtained from regression analyses and empirical trip rates as obtained from observed data for various purposes are presented in Table 4.3. As is seen from the Table, the different purpose trip rates match and tend to be approximately equal.

TABLE 4.2 TRIP GENERATION SUB-MODELS FOR HOME BASED ONE-WAY TRIPS - 1981 AD

Dependent Variable	Independent Variable	Constant term	Coefficient	Co-efficient of Determin-tion (R^2)
- Work Trips				
Trip Production	Population	18	0.343	0.78
Trip Attraction	Employment	27	0.558	0.76
- Education Trips				
Trip production	Population	14	0.107	0.69
Trip Attraction	School enrolment	11	0.170	0.72
- Other Trips				
Trip production	Population	22	0.193	0.67
Trip Attraction	Employment	32	0.385	0.74

TABLE 4.3 COMPARISON OF HOME BASED ONE-WAY REGRESSED TRIP PRODUCTION RATES AND EMPIRICAL TRIP RATES - 1981 AD

Trip Purpose	All Modes	
	Regressed	Empirical
Work	0.34	0.29
Education	0.11	0.06
Other	0.19	0.22
All	0.64	0.57

4.6 Trip Distribution or Interzonal Transfers

After determining the trip productions (T_i) and trip attractions (T_j), the next stage is to link the productions with attractions in order to quantify how the trips produced in a zone are distributed among all other zones (T_{ij}). In other words, it is the process of predicting how people decide on their possible destinations. There are a number of reasons as to why one destination would be chosen over another. Generally, the traffic distribution can be considered as a function of the following factors :

(i) The socio - economic characteristics of the population.

(ii) The type and extent of available transportation facilities.

(iii) The pattern of land use, including the location and intensity.

The theories developed to predict and explain the distribution of traffic can be broadly classified into the following :

(i) Growth factor models.

(ii) Gravity models

(iii) Opportunity models

(iv) Stochastic behavioural models

Despite the diversity of formulation used in the various mathematical procedures developed, the underlying principle in all the distribution models is the same, i.e. 'travel between any two points will increase with increase of attraction for such travel, but decreases as the resistance to travel increases'.

In this study, the gravity model has been used, because it is the most widely used synthetic method of trip distribution and it is simple to understand and apply and is will documented. Despite many developments during the last three decades the gravity model, with proper inputs, provides reasonably good estimates and accuracy.

4.6.1 Gravity model

One of the well known synthetic models is the gravity model. Based on Newton's concept of gravity, model as proposed by Voorhees (151) assumes that the trip interchanges in area is dependent upon the relative attraction between the zones and the spatial separation between them as measured by an appropriate function of distance. This function of spatial separation adjusts the relative attraction of each zone for the ability, desire or necessity of the trip maker to overcome the spatial separation. Whereas, the trip interchange is directly proportional to the relative attraction between the zones and it is inversely proportional to the measure of spatial separation. For any given trip purpose, the generalised relationship is more usually expressed as;

$$T_{ij} = K\ P_i\ A_j\ \ F\ (d_{ij}) \qquad (4.3)$$

Where,

T_{ij} = Total trips from zone i to zone j.

P_i = Total number of trips produced in zone i

A_j = Total number of trips attracted to zone j.

K = Constant

$F(d_{ij})$ = Deterrence or impedance or trip decay function and is based on the generalised cost of the journey from zone i to zone j.

The deterrence or impedance or trip decay function is usually in one of the following three basic forms ;

(i) Polytropic function or power function $F(d_{ij}) = d_{ij}^{-\alpha}$

(ii) Exponential function $F(d_{ij}) = e^{-\alpha d_{ij}}$

(iii) Tanner function $F(d_{ij}) = e^{-\alpha d_{ij}}\ d_{ij}^{-\beta}$

Where, α and β are impedance parameters.

It has been found that power function, is more appropriate and fits better to longer distance trips, basically for inter-urban trips. The exponential function has been used in many studies and has been found to be particularly appropriate in shorter distance intra-urban trips [63].

The Tanner's function offers the opportunity to combine the advantages of each of the above two functions. The constant K in the general formula is effectively balancing the two constants combined together, one each for correcting the number of generations and attractions.

Thus $$K = a_i \, b_j \tag{4.4}$$

Where,

$$P_i = a_i \sum_j T_{ij}$$

$$A_j = b_j \sum_i T_{ij}$$

The determination of each of the constants in the distribution model is known as calibration.

4.6.2 Generalised cost

In recent years, the favoured and most commonly used measurement of impedance is the perceived inter-zonal generalised cost that is, what the traveller unconsciously thinks it costs to travel from one place to another. For each pair of zones, generalised cost for a trip by public transport or by any other mode are determined. For any inter-zonal trip, the cost between each of the two zone centroids and the appropriate actual network nodes is added to the least cost journey through the whole network between the zones. For example, for a trip including one or more public transport links and walk links there to, the public transport generalised cost would be made up of;

(i) Cost of walking time to bus stops (by notional centroid link).

(ii) Cost of waiting time at bus stops.

(iii) Cost of travelling time in buses.

(iv) Bus fare.

(v) Cost of interchange waiting time, where appropriate.

(vi) Cost of walking time from bus stop to destination (by notional centroid link).

Generalised cost for other modes are determined in somewhat similar way. The least cost journey from any zone to another is determined by a process known as building trees. This process is undertaken through computer and separate least cost journey trees are built for public transport trips and for trips by other modes.

4.6.3. Assumptions for generalised cost

For the purposes of analysis in this study the exponential form $e^{-\alpha d_{ij}}$ as impedance function has been utilised to have comparisons with earlier studies carried out for Delhi. The (d_{ij}) values which should normally be based on generalised cost have been taken in terms of access time, waiting time, travel time and ingress time, depending on the mode. Travel time matrices have been computed and skim trees built representing shortest travel paths between each pair of zones.

4.6.4. Gravity model adopted

For the distribution of home based trips for different purposes, standard formulation of Gravity Model is to be utilised. The output of trip generation sub-model is primarily the inputs to trip distribution sub-model along with deterrence on impedance or separation function. Gravity Model to be utilised for its calibration is as under ;

$$T_{ij}^{k} = P_i^k A_j^k \exp(-\alpha^k d_{ij}) / (\sum_j A_j^k \exp(-\alpha^k d_{ij}) \qquad (4.5)$$

T_{ij}^{k} = The number of trips produced in zone i and attracted to zone j for k^{th} purpose (work, education, others),

P_i^k = The total number of trips produced in zone i for k^{th} purpose.

A_j^k = The total number of trips attracted to zone j for k^{th} purpose

α^k = Parameter calibrated for base year for k^{th} purpose.

d_{ij} = Total travel time between pair of zones i and j.

4.6.5 Calibration process

The sequence of activities involved in the calibration of gravity model are shown in Figure 4.5. Only the home based trips for different purposes (work,education,and others) which have been modelled and have been simulated for comparison with the observed flows. The calibrated values of gravity model parameter for home based trips for various purposes are presented in Table 4.4, where x,y,z denote parameters for work, education and other purposes respectively. Calibration process included comparison of observed and simulated mean trip lengths as well as shapes of the trip length frequency distribution and comparison of observed and simulated trips on selected corridors for the base year.

The observed trip length frequency distributions for different purposes (work, education and others) were obtained from the 1981 AD travel survey data. For simulated trip length frequency distribution the parameter values (negative exponential) were varied until the simulated and observed trip length frequency distributions for each purpose exhibited the following :

(i) The shape and position of both curves were relatively close to one another when compared visually.

(ii) The difference between mean trip lengths were within ± 3 percent.

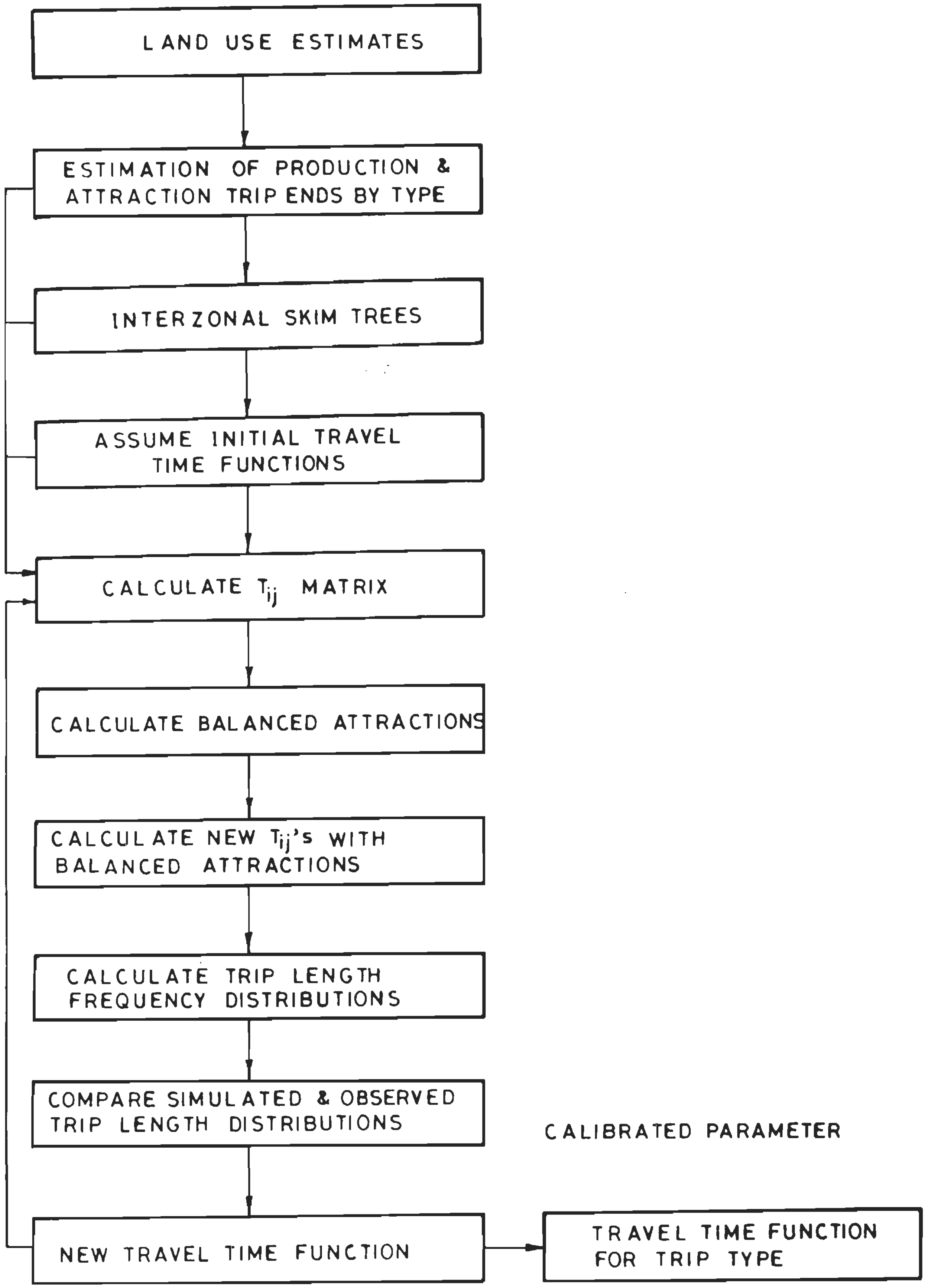


FIG. 4·5 SEQUENCE OF ACTIVITIES FOR CALIBRATING GRAVITY MODEL

TABLE 4.4 CALIBRATED GRAVITY MODEL PARAMETERS

Trip Purpose	Parameter	Parameter Value
Work	α^x	0.099
Education	α^y	0.127
Others	α^z	0.108
All	α^a	0.107

Comparison of observed and simulated trip length frequency distributions for work, education and other trip purposes, as well as for all trips (aggregated) are presented in Figures 4.6 to 4.9 respectively. A further check on the quality of calibration is made when the total (as opposed to one purpose) base year synthesised flows are assigned to the road network. At this stage, although the synthesised flows on individual roads can not necessarily be expected to correspond with observed flows, it is reasonable to expect a significant proportion of corridor flows, i.e. groups of more or less parallel roads, across a screen line or cordon to correspond within say ± 25 percent, depending on the actual link flow level. Comparisons of observed and simulated passenger trips on selected ten arterials are presented in Table 4.5. It is seen from this table that on most of the selected arterials the observed and simulated trips are within ± 25 percent of permissible limits except for Netaji Subhash Marg and Aurbindo Marg. For these two arterials the difference in observed and simulated trips is perhaps mainly due to preponderence of mass (bus trips) and the existence of parallel roads. It may be mentioned here that the observed passenger trips on selected arterials have been developed from available data from previous studies on traffic flows and occupancy factors for various types of vehicles including buses.

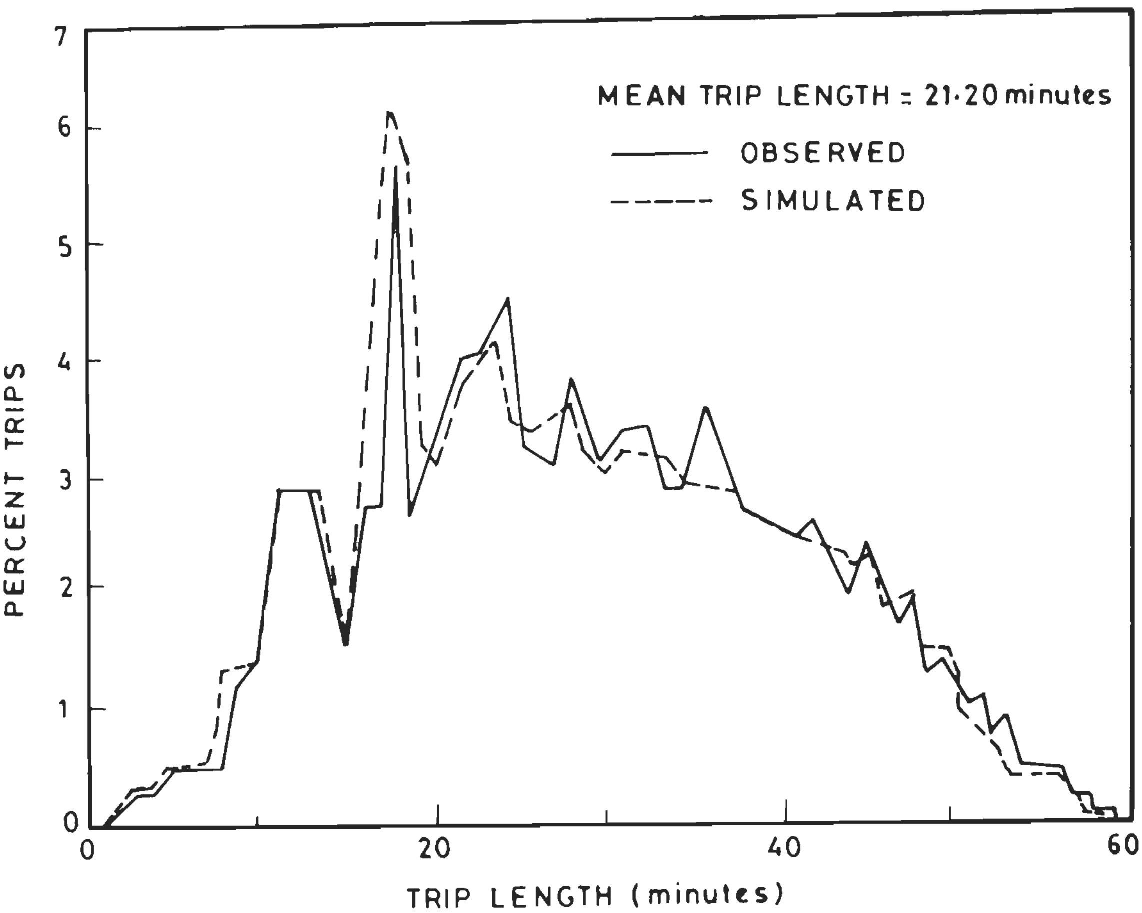


FIG. 4·6 COMPARISON OF TRIP LENGTH FREQUENCY DISTRIBUTION (HOME BASED WORK)

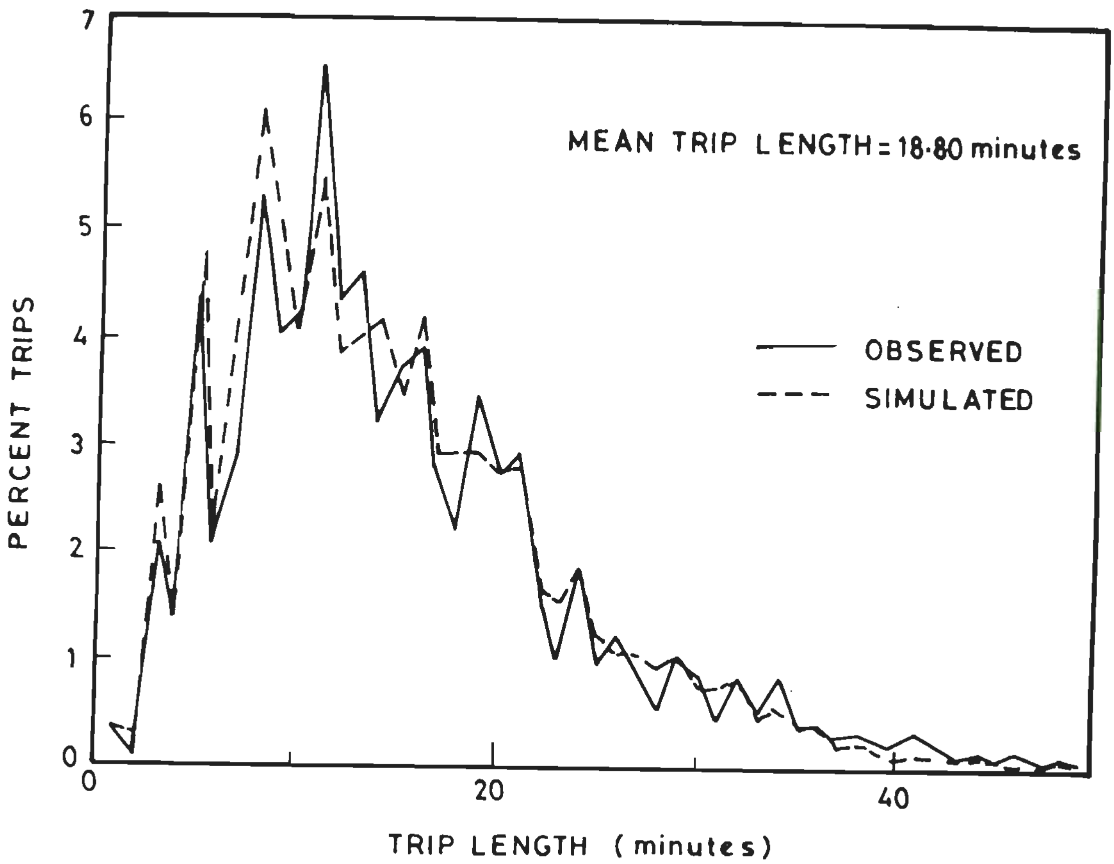


FIG. 4·7 COMPARISON OF TRIP LENGTH FREQUENCY DISTRIBUTION (HOME BASED EDUCATION)

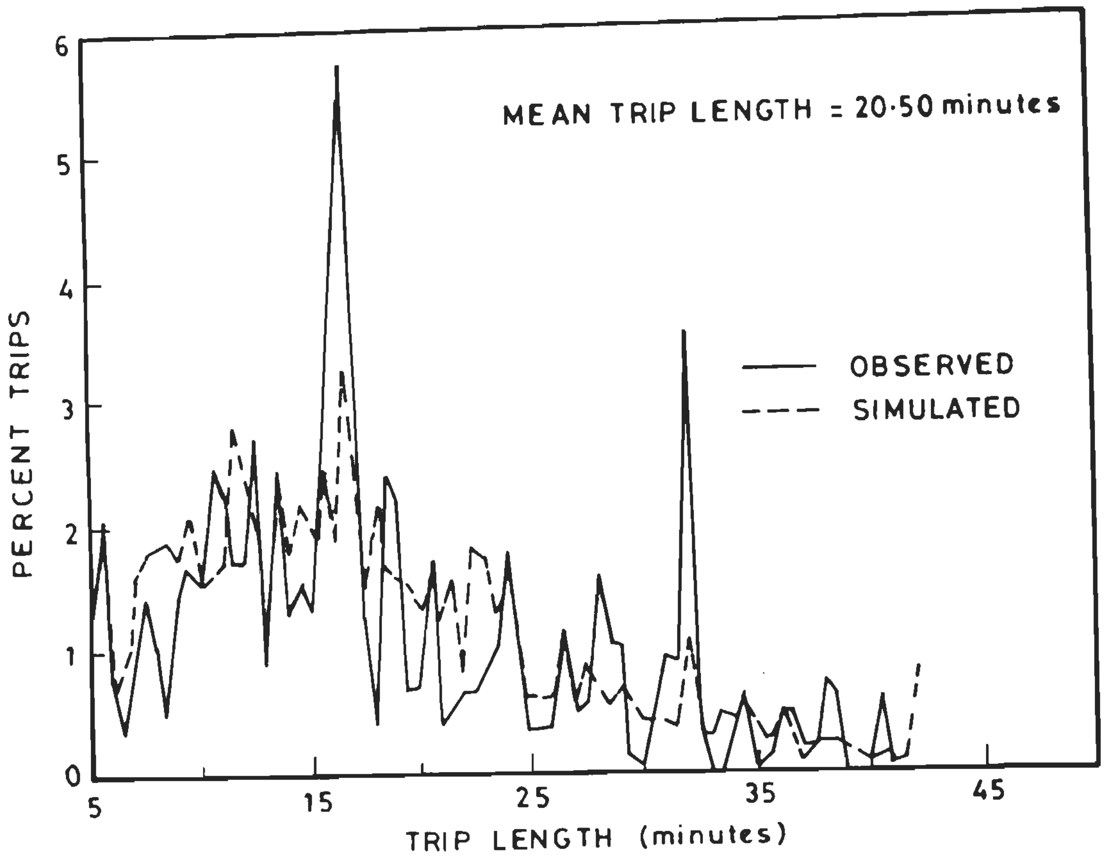


FIG. 4·8 COMPARISON OF TRIP LENGTH FREQUENCY DISTRIBUTION (HOME BASED OTHER)

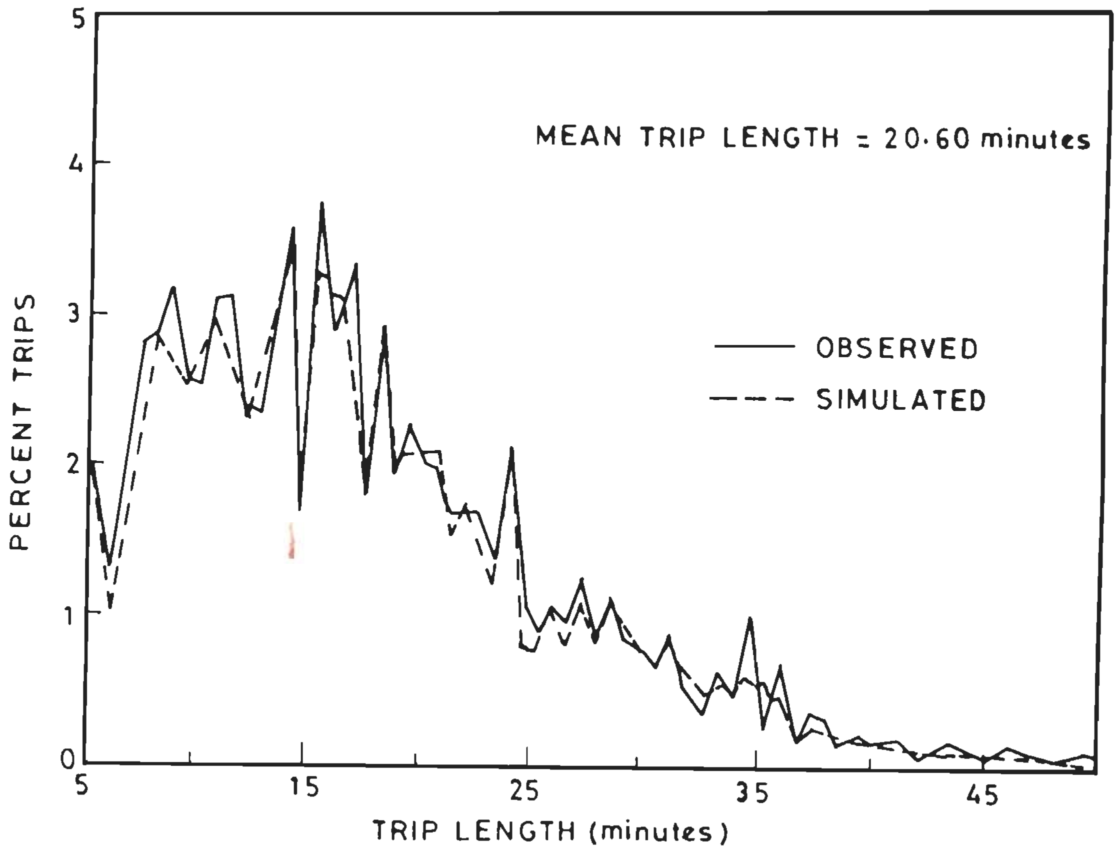


FIG. 4·9 COMPARISON OF TRIP LENGTH FREQUENCY DISTRIBUTION (HOME BASED ALL PURPOSE)

TABLE 4.5 COMPARISON OF OBSERVED AND SIMULATED PASSENGER TRIPS ON SELECTED ARTERIALS - 1981 AD

(THOUSANDS)

Arterials	Observed Trips*	Simulated Trips			
		Intra-city (Home based)	Inter-city	Non-Home based and Intra-zonal**	Total
Aurobindo Marg	224	113	15	17	145
S.Patel Marg	62	37	20	6	63
Patel Road	294	178	31	27	236
New Rohtak Road	162	97	2	14	113
Shamnath Marg	126	133	32	20	185
N. Subhash Marg	342	106	64	2	172
Minto Road	176	101	29	15	145
Panchkuian Road	117	72	51	10	133
Janpath	90	61	20	9	90
Dr. Z.Hussain Marg	84	112	51	17	180

* Traffic Flow Trends in Delhi, CRRI, New Delhi [23]

** 15% of Intra - city trips.

4.7 Modal Split

The modal split for home based trips (all purposes) as observed in the base year (1981 AD) was 62 percent by mass modes and 38 percent by all other modes (fast and slow). Models for the mode choice behaviour of Delhi residents could not be developed due to the inadequacy of data. Aggregated data from past studies however indicates that the proportion of trips by mass transport are increasing significantly over time. Under the circumstances, it was thus appropriate to estimate modal split in favour of mass transport based on past trends and at the same time incorporating these variations at the zonal level. This approach appears quite logical for Indian cities where modal split in favour of mass transport is greater than 60 percent and also it does an opportunity for intervention at policy level.

4.8 Trip Assignment

Traffic assignment is the process of allocating a given set of trip interchanges to a specific transportation system and is generally used to estimate the volume of travel on various links of the system to simulate present conditions and to use the same for horizon years. The process requires as input to a complete description of either the proposed or existing transportation system and a matrix of inter-zonal trip movements. The output of the process is an estimate of the trips on each link of the transportation system, although the more sophisticated assignment techniques also include directional turning movements at intersections. There are at least four factors which lead people to choose one route over another. These are travel time, travel cost, comfort and level-of-service (volume/capacity /operating speeds).

The most common factors employed are the travel time and costs. The purposes of trip assignment are;

(i) To assess the deficiencies at the existing transportation system by assigning estimated future trips to the existing system .

(ii) To evaluate the effects of limited improvements and extensions to the existing transportation system by assigning estimated future trips to the network which includes these improvements .

(iii) To develop construction priorities by assigning estimated future trips for intermediate years to the transportation system proposed for these years.

(iv) To test alternative transportation system proposals by systematic and readily acceptable procedures.

(v) To provide design hour volumes and turnning movements

The major alternative procedures which have been developed to assign estimated future trips to a transportation system include;

(i) All or Nothing Assignments.

(ii) Capacity Restraint Assignments.

(iii) Diversion Curves.

(iv) Multiple Route Assignments.

The choice of assignment procedure to be adopted in any particular transportation study depends largely on the purpose of that study and the degree of sophistication required in the output.

4.8.1 Assignment procedure adopted

For the purpose of assignments of trips on to the network the "Shortest path Algorithm" with "All or Nothing assignment" procedure has been adopted for various purpose home based trips (intra-city trips). The same procedure was also adopted for inter-city trips which were distributed through Gravity model with assumed distribution parameter and assigned separately on to the network and super-imposed on the intra-city trip assignments. The assigned home based trips were increased to the extent of 15 percent for taking into account the non-home based trips (not modelled) and the intra-zonal trips. It has been assumed that a certain proportion of the intra-zonal trips should also get assigned on to the network. This proportion was estimated at 5 percent and the balance 10 percent are the non-home based trips.

4.9 Development of Network

The traffic assignment procedure is based on the selection of a minimum time path over an actual route between a pair of zones. This process is invariably carried out by computer and is difficult to do manually. For the task to be accomplished by computer; it is necessary to describe the highway network in coded form and store it in the computers memory. The computer then chooses the minimum path between zonal pairs, assigns estimated trips to this path and accumulates trips for each section of the route. For coding purposes, the highway network is broken down into links and nodes.

A link is defined as the one-way part of the route between two intersections and depending upon the assignment techniques to be used, detailed information concerning the length, speed and travel time etc. is coded and stored in the computer, Nodes are of two types-zone centroid, and intersection nodes where two or more links meet. Nodes are identified by a numeric code which is applied systematically, while links are identified by node number at each end of the link.

4.9.1. Base year road network (1981 AD)

For the purposes of trip assignments for this study arterial roads and major sub-arterial roads have been included and the networks have been developed. The road network for the base year 1981 AD as developed and coded is presented in Figure 4.10. The details of links for the base year road network are given in Appendix 2.

4.9.2. Assignment of trips on road network-base year (1981 AD)

As mentioned earlier, all home based base year trips (Work, education and other purpose) along with inter-city trips were assigned on to the base year network through "Shortest Path Algorithm" with "All or Nothing assignment" procedure. The salient features of peak hour peak direction trips by mass transport are as under;

(i) Majority of the road links (around 65 percent carried trips below 5,000 and the links carrying trips between 5,000 and 10,000 constituted around 25 percent.

(ii) Around 10 percent of the links carried heavy volume of trips. The prominent such links/roads were old Yamuna Bridge, G.T. Road, Shahdara, I.T.O. Bridge, Boulevard Road, Rani Jhansi Road, Patel Road and certain sections of Ring Road near I.S.B.T., Punjabi Bagh, Ashok Vihar etc.

The total intra-city trips by vehicular modes were estimated to be around 3.6 million of which 90 percent were home based trips and balance 10 percent as non-home

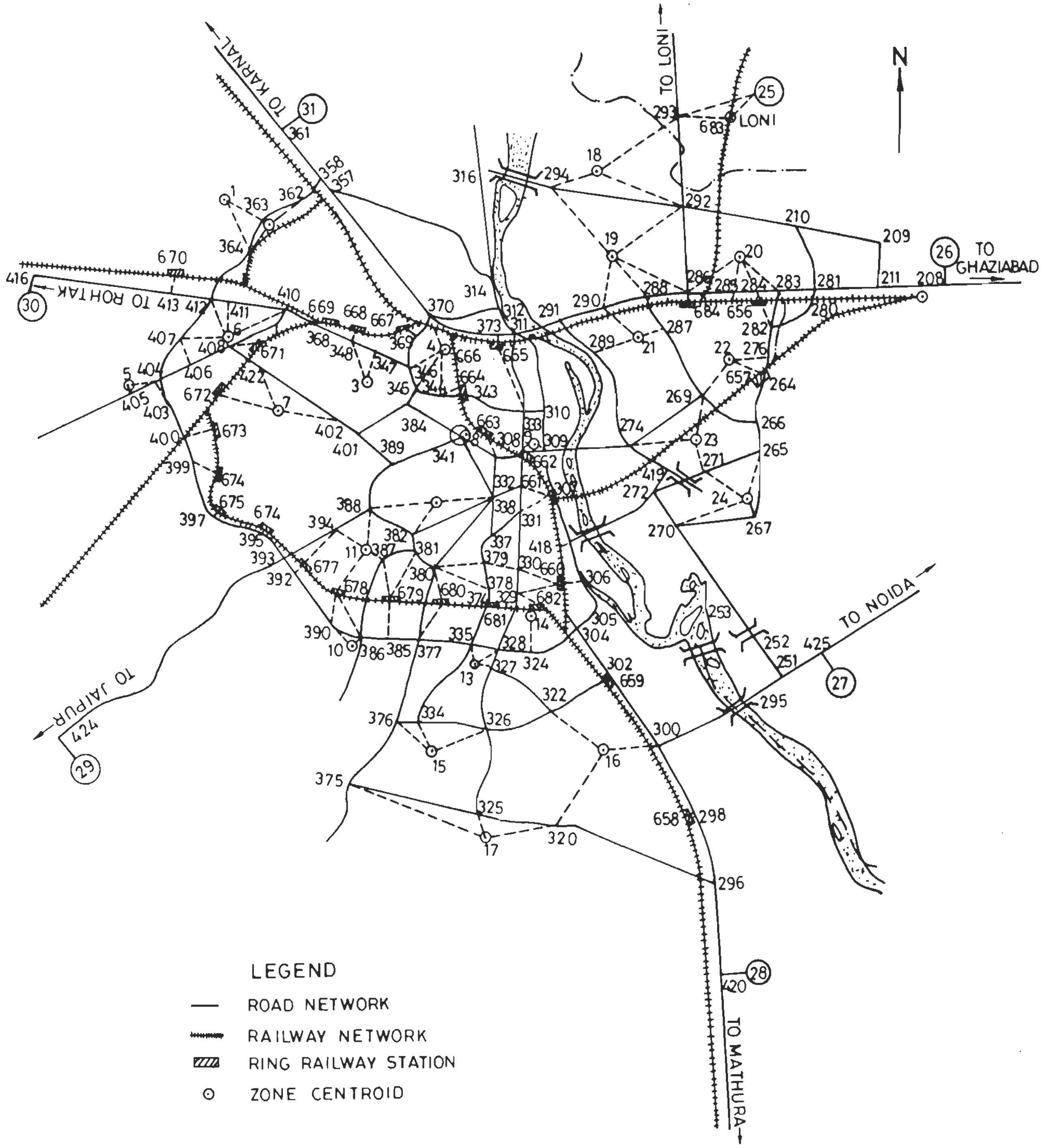


FIG. 4.10 NETWORK FOR PASSENGER MODELLING OF DELHI – BASE YEAR 1981 A.D.
(ROAD + RAIL)

based. The distribution of home based trips by vehicular modes for different purposes indicated that 54 percent of work trips were made by mass transport modes, 16 percent by slow modes and 30 percent by fast modes.

The proportion of trips catered to by mass modes were around 41 percent in 1969 AD which increased to 62 percent in the year 1981 AD . The estimated trips by mass transport are 2.34 million for the year 1981 AD.

4.10 Transport Demand Forecasts and Systems Analysis

As described in earlier paragraphs, various transport sub-models have been developed and calibrated for the base year conditions and movement pattern. Various steps for the application of models to horizon year forecasts in a simplistic form are shown in Figure 4.11. The initial requirements, for the application of models for the horizon years forecast are as under :

(i) Zone-by-zone land use and general planning data and the population characteristics for the horizon years conditions, which are given in Table 4.6.

(ii) Future transportation network details, which are given in Figures 4.12 to 4.15 respectively. The details of links for the horizon years road network are given in Appendices 3,4,5 and 6 respectively. As regards requirement of land use and planning data, the perspective plan for Delhi for the year 2001 AD envisages that the population within Delhi urban limits will be restricted to around 13.2 million and to accommodate the urban population by the year 2001 AD, a two pronged strategy has been recommended, i.e, firstly by increasing the population holding capacity of the area within urban limits declared till 1981 AD and secondly by extending the present urbanisable limits to the extent necessary. Studies have revealed that Delhi urban area 1981 AD, urban limits by the year 2001 AD would be able to accommodate about 9.2 million population by judicious infill and selected modifications of densities. The remaining 4 million

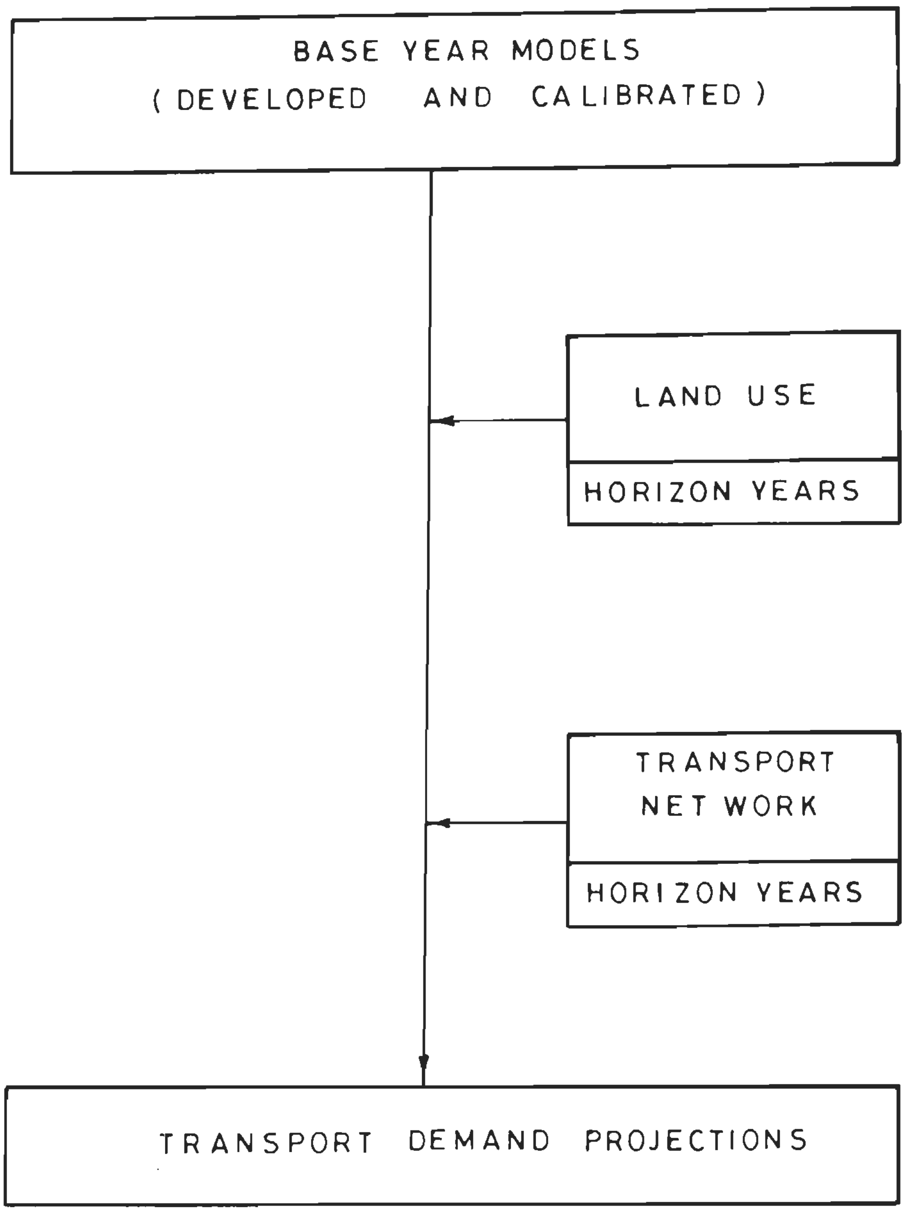


FIG. 4·11 APPLICATION OF MODELS TO HORIZON YEARS FORECAST

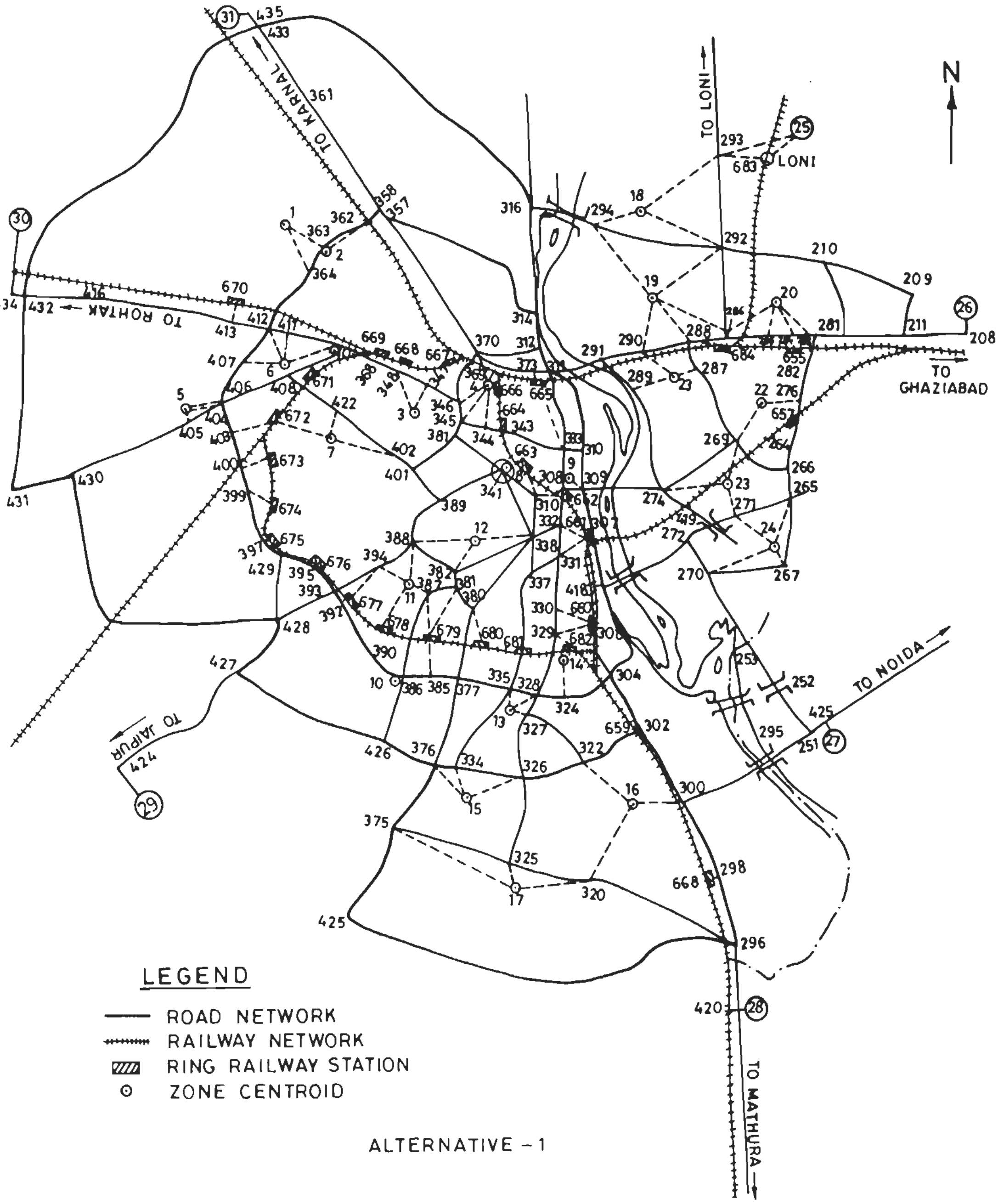


FIG. 4·12 NETWORK FOR PASSENGER MODELLING OF DELHI 2001 A.D
(ROAD + RAIL)

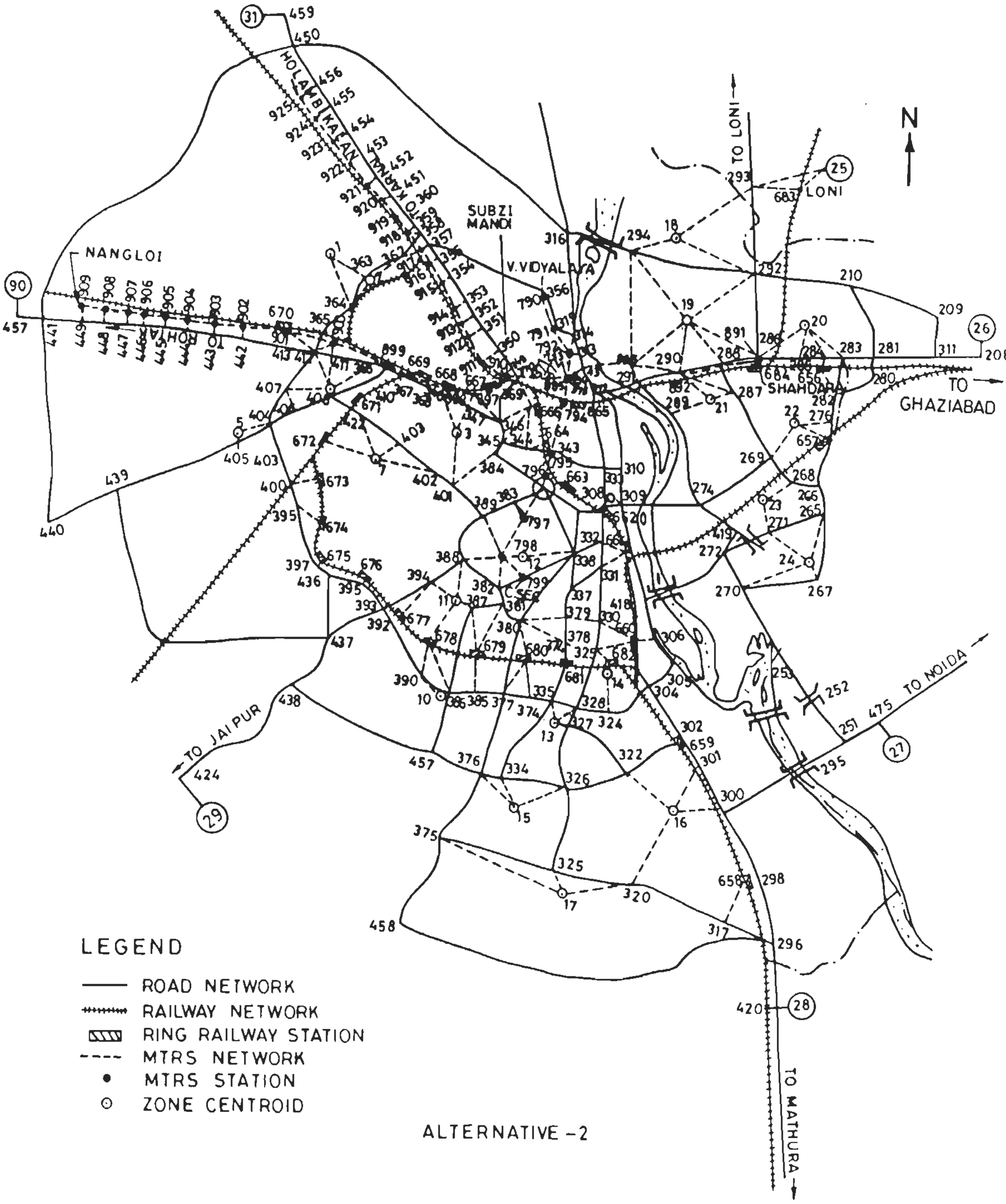


FIG. 4·13 NETWORK FOR PASSENGER MODELLING OF DELHI 2001 A.D.
(ROAD + RAIL + METRO)

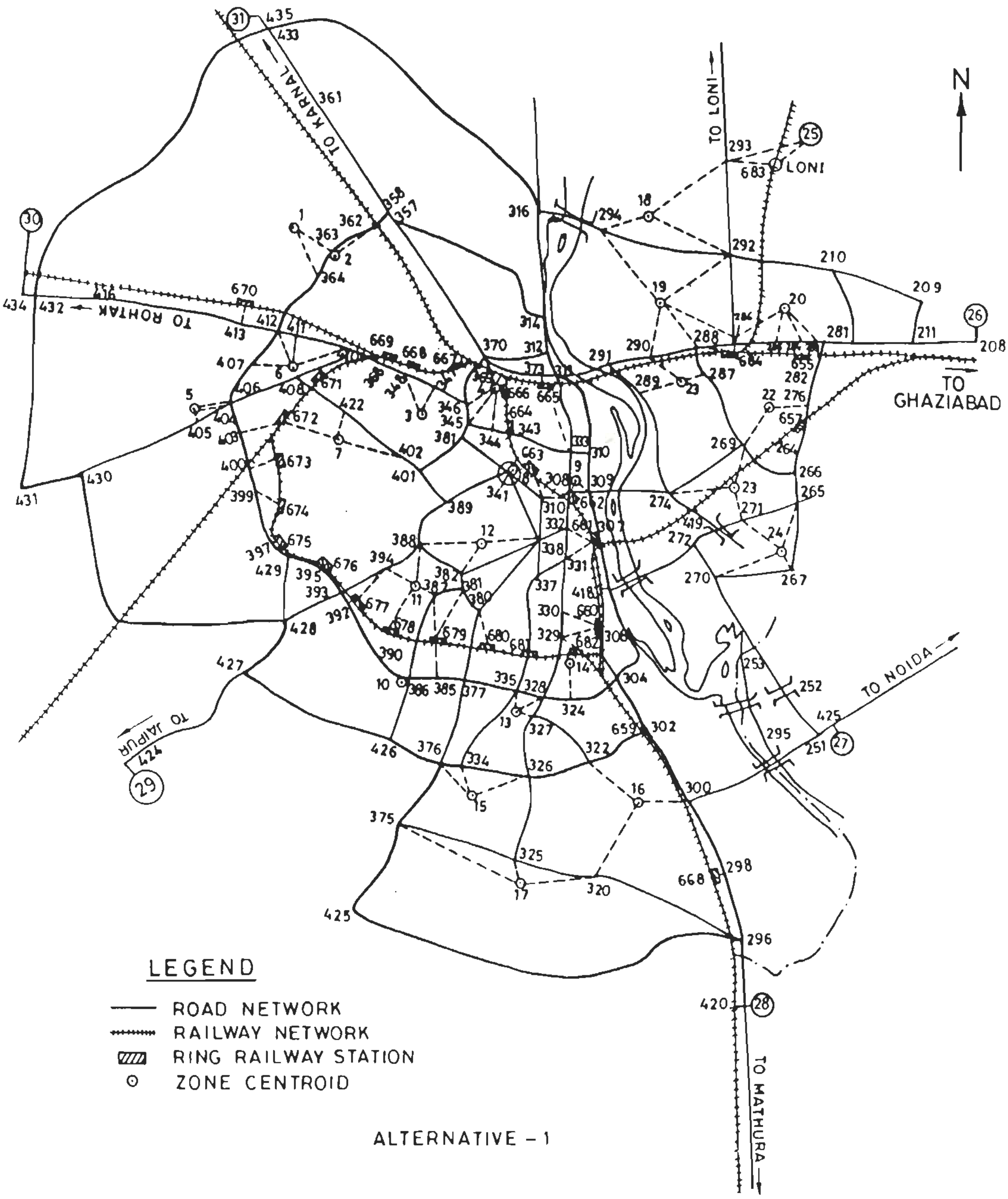


FIG. 4·14 NETWORK FOR PASSENGER MODELLING OF DELHI 2011 A.D (ROAD + RAIL)

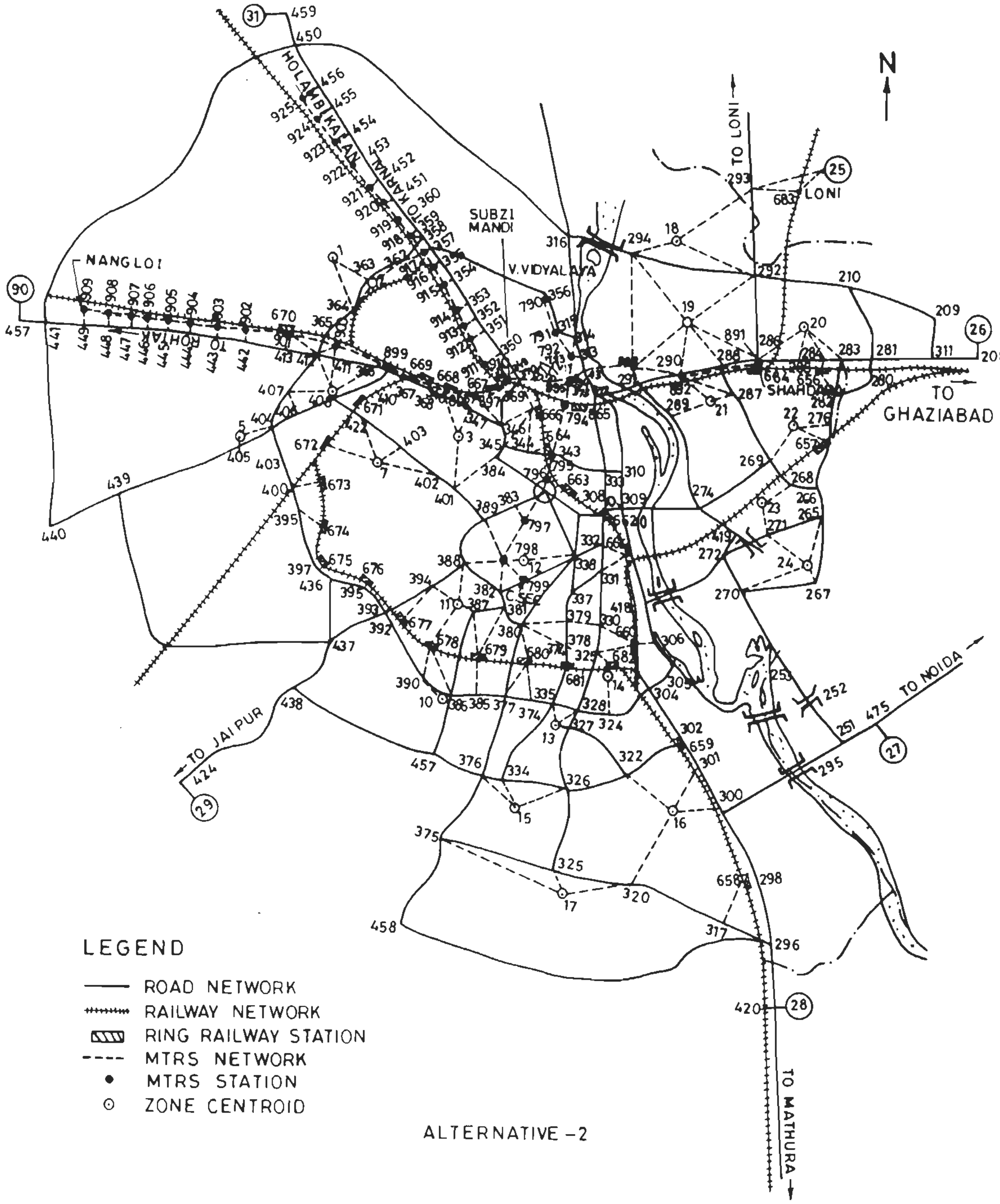


FIG. 4.15 NETWORK FOR PASSENGER MODELLING OF DELHI 2011 A.D.
(ROAD + RAIL + METRO)

population shall have to be accommodated in the urban extensions. Thus for the given perspective plan 2001 AD for Delhi a suitable transport system including mass rapid transit system is to be planned. As regards the horizon years transport demand, the road system alone will not be sufficient. For this purpose assignment of the horizon years trips on alternative network will be considered, i.e., Mass Rapid Transit System network.

4.11 Transport Demand Forecasts for Alternative Networks

It is, however, mentioned again that while making horizon years forecast there have been many underlying assumptions which in explicit terms are as under :

(i) The estimation of per capita trip rate is based on past trends and also takes into account the increase in mobility levels of the study area residents based on the assumption that mobility levels are bound to increase with economic well being and also provision of better transport facilities associated with the development of MRTS (Mass Rapid Transit System).

(ii) Shortest path algorithm as assumed in the assignment of trips is based on the assumption that the MRTS will be attractive enough with integrated and affordable fare structure, level-of-service and also with adequate feeder services to facilitate the change of mode to MRTS.

4.11.1 Need for alternative transportation networks

The population and employment projections which have been made for Delhi urban area (including urban extensions) for 2001 AD, beyond doubt, suggest the need for the introduction and development of multi-modal transportation system. To achieve this goal, it will be more appropriate to test and evaluate alternative networks and select the network which is able to cater to the projected transport demand of Delhi urban area for 2001 AD and 2011 AD.

TABLE 4.6 POPULATION, EMPLOYMENT AND SCHOOL ENROLEMENT OF DELHI (All Figures are in Thousands)

	1981 A.D.			1991 A.D.			2001 A.D.			2011 A.D.		
Zone No.	Population	Employment	School Enrolment	Population	Emploment	School Enrolmt	Population	Employment	School Enrolment	Population	Employment	School Enrolment
1	0	0	0	1114	234	229	2980	1158	837	5215	2319	872
2	362	53	74	834	256	291	1397	456	425	1793	522	443
3	1031	334	218	1132	386	283	1222	435	325	1354	484	371
4	192	90	82	112	112	99	233	132	110	237	142	129
5	0	0	0	642	127	203	1724	624	503	3015	1234	531
6	619	108	129	835	199	192	1062	317	281	1241	360	296
7	269	108	75	301	138	125	343	116	211	378	186	2331
8	219	139	62	212	139	59	123	138	56	238	142	81
9	381	215	73	330	215	70	236	252	52	235	217	86
10	134	58	104	149	124	127	362	187	161	440	209	278
11	102	43	22	128	69	28	163	94	35	194	105	43
12	118	286	62	177	312	72	243	336	75	325	372	103
13	177	40	48	191	79	62	206	117	77	231	132	54
14	277	91	59	296	99	78	324	105	94	344	112	107
15	98	13	18	142	43	34	196	71	45	256	84	49
16	284	96	53	339	159	93	403	218	118	475	215	95
17	0	0	0	117	9	3	314	33	33	539	70	37
18	0	0	0	11	7	2	30	14	4	39	32	7
19	352	49	75	422	73	103	500	94	141	601	108	162
20	72	15	12	112	41	30	172	66	38	250	78	43
21	375	67	69	413	83	89	460	97	111	505	107	117
22	118	33	30	169	45	37	228	53	61	285	61	83
23	31	10	9	54	37	13	88	61	18	110	73	23
24	0	0	0	78	16	9	235	66	43	400	136	52
	5210	1848	1274	8400	3000	2325	13244	5240	3854	18700	7500	4293

4.11.2 Trip generation for horizon years

Estimates of daily per capita trip rates (for different purposes) for horizon years as presented in Table 4.7, shows that daily per capita trip rate for home based trips for 2001 AD is 1.00.The non-home based trip rate is 0.15 which has been assumed to be 15 percent of home based trip rate, again based on past trends due to non-availability of accurate data.

TABLE 4.7 ESTIMATES OF DAILY PER CAPITA TRIP RATES FOR HORIZON YEARS

Purpose	Year				
	1969 AD	1981 AD	1991 AD	2001 AD (Projected)	2011 AD (Projected)
- HOME BASED					
Work	0.29	0.34	0.41	0.56	0.61
Education	0.08	0.11	0.12	0.18	0.23
Other	0.12	0.19	0.23	0.30	0.36
Aggregated	0.49	0.64	0.76	1.00	1.20
NON-HOME BASED	-	0.08	0.10	0.15	0.15
All purpose	0.49	0.72	0.86	1.15	1.35

4.11.3. Trip distribution for horizon years

The estimates of Gravity Model parameters for the horizon years as presented in Table 4.8, shows that parameter for work trip for 2001 AD is around 15 percent less as compared to the calibrated value for the base year. This is based on the assumption that the mean work trip length will increase in the horizon year due to expansion in the physical size of the city.

TABLE 4.8 **ESTIMATES OF GRAVITY MODEL PARAMETERS FOR HORIZON YEARS**

Home based Trip purpose	Parameter	Year			
		1969 AD	1981 AD	2001 AD	2011 AD
Work	α^x	0.110	0.099	0.084	0.084
		(12.64)	(21.20)	(26.20)	(29.34)
Education	α^y	-	0.127	0.127	0.127
		-	(18.80)	(21.16)	(22.43)
Other	α^z	-	0.108	0.108	0.108
		-	(20.50)	(23.84)	(25.74)
All	α^a	-	0.107	0.097	0.097
		-	(20.60)	(24.68)	(27.15)

Figures in ( ) show mean trip lengths in minutes.

The parameter values for education and other purpose trips have been assumed to be the same as calibrated for the base year.The simulated trip length frequency for home based work trip is presented in Figure 4.16.

4.11.4 Modal split for horizon years

As stated earlier, no models have been developed for the modal split stage of the transportation planning process due to the non-availability of adequate data. The estimates for proportion of trips by mass transport for various years including 2001 AD and 2011 AD are presented in Table 4.9. As is seen from this table, modal split in favour of mass transport is increasing over the years. Keeping in view the prevailing state of congestion on the road system and aggravating transportation situation and also in view of the requirements of vast majority of residents of urban area as well as goals as envisaged in perspective plan, it was decided to adopt a proportion of 73 percent at

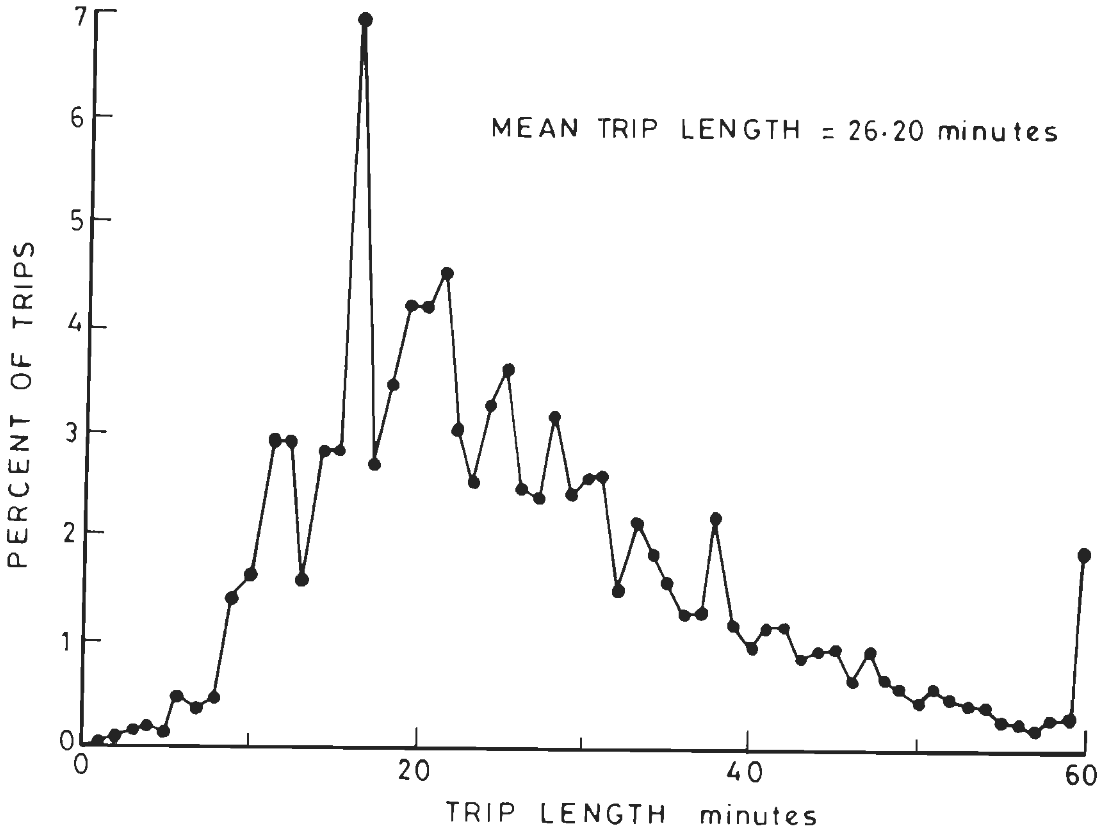


FIG. 4·16 TRIP LENGTH FREQUENCY DISTRIBUTION-2001 AD
(HOME BASED WORK)

aggregated level in favour of mass transport.

TABLE 4.9 ESTIMATES FOR PROPORTION OF TRIPS BY MASS TRANSPORT FOR DELHI

(Percent)

Purpose	Year				
	1969 AD	1981 AD	1991 AD	2001 AD (Projected)	2011 AD (Projected)
Mass Transport	41	62	62	73	78
All others	59	38	38	27	22

Source : Delhi Development Authority, New Delhi [33,34]

4.11.5 Trip assignment for horizon years

As stated earlier the shortest path algorithm with "All or Nothing Assignment" procedure has been adopted for assignment of estimated horizon years trip interchanges. The various logical steps for assignment of passenger trips are presented in Figure 4.17.

4.11.6 Summary of transport demand forecast

The summary of horizon years (2001 AD and 2011 AD) transport demand forecast is presented in Table 4.10. The total passenger trips at estimated in 2001AD are 15.10 million out of which 13.12 million (86.89 percent) are the inter-city trips and 1.98 million (13.11 percent) are the intercity trips. The estimated trips by mass transport are 11.50 million (76.16 percent).The total passenger trips at estimated in 2011 AD are 25.65 million out of which 22.30 million (86.94 percent) are the intra-city trips and 3.35 million (13.06 percent) are the inter-city trips. The estimated trips by mass transport are 20.30 million (79.14 percent).

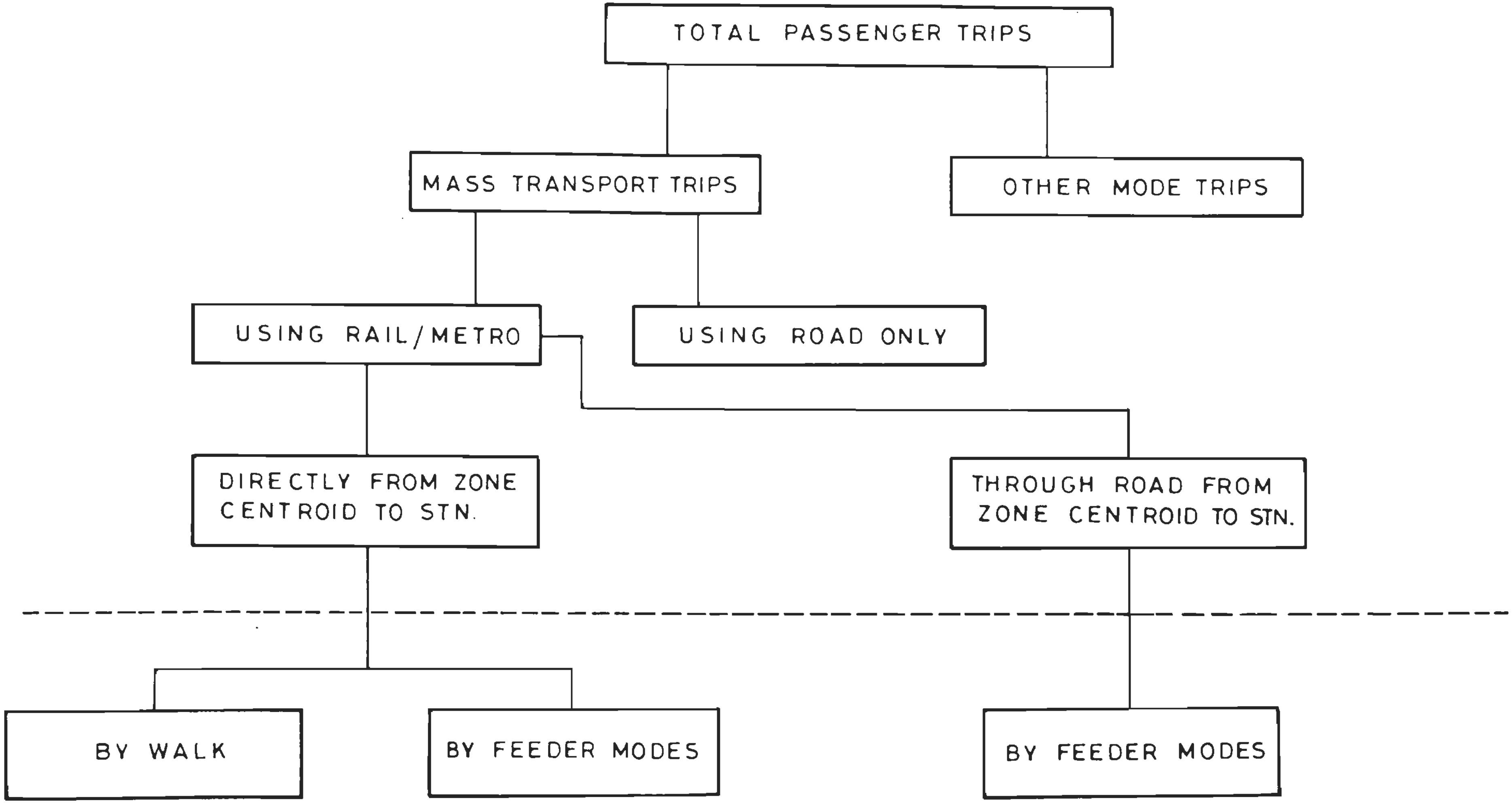


FIG. 4.17 STEPS FOR ASSIGNMENT OF PASSENGER TRIPS

TABLE 4.10 SUMMARY OF PASSENGER TRANSPORT DEMAND FORECAST FOR DELHI

Year	Details	Magnitude
2001 AD	LAND USE	
	- Population	13.24 million
	- Employment	5.24 million
	- School Enrolement	3.85 million
	TRANSPORT	
	- Total Trips	15.10 million
	- Intra-city trips	13.12 million
	- Inter-city trips	1.98 million
	- Mass transport trips	11.50 million
2011 AD	LAND USE	
	- Population	18.70 million
	- Employment	7.50 million
	- School Enrolement	4.29 million
	TRANSPORT	
	- Total Trips	25.65 million
	- Intra-city trips	22.30 million
	- Inter-city trips	3.35 million
	- Mass transport trips	20.30 million

4.12 Development of Alternative Networks

For satisfying the transport demand as projected and keeping in view the estimated modal split for the horizon years two alternative transport networks have been developed. The approach adopted for the development of alternative transport networks considered the following aspects :

(i) For a fixed land use, the estimated demand varying proportions of mass transport demand are to be satisfied by the road system, the existing rail system including ring railway and spurs and high capacity mass rapid transit system.

(ii) Other consideration included the availability of existing infrastructure, socio-economic environment prevailing and anticipated for Delhi urban area for 2001 AD and 2011 AD and anticipated passenger transport demand etc. In view of the above two alternative transport networks to be developed for the horizon years 2001 AD and 2011 AD, are illustrated as under :

(a) Alternative Network-1

Road system superimposed by ring railway and spurs.

(b) Alternative Network-2

Road system superimposed by ring railway and spurs and with MRTS network of 55.3 km.

The alternative networks 1 and 2 are shown in Figures 4.12 to 4.15 respectively.

4.12.1 Horizon years trip assignment on alternative networks

Alternative networks developed have to be studied in relation to the transport demand for the horizon years. As has been stated in para 4.10 with regard to various assumptions for trip assignment and the factors utilised for converting the passenger trips into peak hour trips by mass transport and utilising the same the trips were assigned on to the four networks with the help of computer programme.

In view of the complexity of the network, the assigned passenger trips have been interpreted in terms of peak hour trips by mass transport by plotting on the links of the two alternative networks in the following ranges :

(i) Trips between 10,000 - 20,000

(ii) Trips between 20,000 - 30,000

(iii) Trips between 30,000 - 40,000

(iv) Trips between 40,000 - 50,000

(v) Trips above 50,000

The assignments have also been interpreted in terms of peak hour trips by mass transport on various components (Road, Surface Rail and MRTS) of the alternative transport network in terms of trip ranges as stated above are described in Tables 4.11 and 4.12 respectively.

TABLE 4.11 DISTRIBUTION OF PEAK HOUR TRIPS ON SYSTEM COMPONENTS IN 2001 AD.

Alternative - 1

Passenger Trip Range	System Components			
	Road Length in km	No.of links	Rail Length in km	No. of links
Above 50,000	4.5	6	0.0	0
40,000-50,000	2.1	2	8.3	4
30,000-40,000	7.3	5	6.7	3
20,000-30,000	61.5	36	20.5	10
10,000-20,000	184.6	98	8.2	3
Total	260.0	147	43.7	20

Contd...

Contd... Table 4.11

Alternative - 2

Passenger Trip Range	System Components					
	Road Length in km	No. of links	Rail length in km.	No. of links	MRTS Length in km.	No. of links
Above 50,000	0.0	0	0.0	0	2.4	2
40,000-50,000	0.0	0	4.3	2	1.2	1
30,000-40,000	11.8	9	16.8	11	1.3	1
20,000-30,000	27.9	14	43.6	17	7.5	6
10,000-20,000	139.4	83	5.8	2	19.7	16
Total	179.1	106	70.5	32	32.1	26

TABLE 4.12 DISTRIBUTION OF PEAK HOUR TRIPS ON SYSTEM COMPONENTS IN 2011 AD

Alternative - 1

Passenger Trip Range	System Components			
	Road Length in km	No.of links	Rail length in km	No. of links
Above 50,000	13.2	9	26.5	12
40,000-50,000	22.5	13	9.3	5
30,000-40,000	38.6	17	6.9	2
20,000-30,000	112.5	93	12.8	6
10,000-20,000	178.6	96	13.4	6
Total	365.4	228	68.9	31

Contd...

Contd.. Table 4.12

Alternative - 2

Passenger Trip Range	System Components					
	Road Length in km	No. of links	Rail length in km.	No. of links	MRTS Length in km.	No. of links
Above 50,000	2.5	2	13.3	5	11.1	9
40,000-50,000	5.1	4	17.4	7	6.0	5
30,000-40,000	29.4	17	23.8	11	11.2	9
20,000-30,000	78.6	42	21.0	9	17.3	14
10,000-20,000	134.7	76	20.2	8	8.7	7
Total	250.3	141	95.7	40	54.3	44

4.12.2 Evaluation of alternative networks

The prime objective of any type of urban transportation planning study is the development of an optimum comprehensive strategy. This is achieved as a result of comparative assessment of largely subjectively developed alternative networks. The comparative assessment is carried out in an objective manner as possible which is of course many times subjected to political or collective decision, reflecting the public's view of desirability and/or acceptability. Selection of the best combination of transit modes is the central decision in planning new or expanding existing transit systems.This decision is very important because it not only determines technological, operational and network characteristics of the planned system, but through these elements it has a major influence on the role the system will assume in the city's physical, economic, social and environmental conditions and development. Because of their interdependence all these factors must be considered in the mode selection. However, the task of the transport planner is to compare sensible alternatives on a uniform basis and advise the decision makers for the quantifiable facts. The methods open for the assessment/evaluation of urban transport options are basically those of operational and environmental assessment and economic evaluation.The various alternatives developed for the study are, however, being assessed/evaluated based on operational assessment, which takes into account the demand aspects and other operational aspects. The other aspects of evaluation that is economic evaluation and environmental assessment have been considered in chapter 12. For the purposes of this study however, comparative evaluation of alternative networks have been attempted from the point of view of passenger transport demand for the horizon years and ability of the various networks to cater to this demand as well as the operational aspects of the transport alternative systems,which are given in Tables 4.13 and 4.14 respectively. The development of MRTS (Mass Rapid Transit System) calls for heavy investments. Considering the fact that the construction activities for the development of MRTS need high technological skill and require considerable period of time entailing disruption to traffic and land uses along its alignment, there has been a general consensus to align the MRTS on optimum corridors which could cater to the estimated demand projections. Finally, in view of the interpretation presented in para 4.12.1 and the comparative evaluation of alternative networks, alternative-2 is recommended.

TABLE 4.13 PASSENGERS SERVED BY ALTERNATIVE NETWORKS IN 2001 AD

(Million/Day)

Alternative Network	By			Number of Buses Required
	Road	High Capacity System	Total	
1. Road+Rail	8.68	2.87	11.55	8680
2. Road+Rail+MRTS	6.14	5.36	11.50	6140

TABLE 4.14 PASSENGERS SERVED BY ALTERNATIVE NETWORKS IN 2011 AD
(Million/Day)

Alternative Network	By			Number of Buses Required
	Road	High Capacity System	Total	
1. Road+Rail	12.88	7.44	20.32	12880
2. Road+Rail+MRTS	8.78	11.52	20.30	8780

4.12.3 Recommended network for 2001 AD and 2011 AD

The recommended network comprises of existing surface rail corridors and mass rapid transit system corridors. These are :

(i) Surface rail corridors

Surface rail corridors (144km) comprises of a ring component and 7 spurs. The spurs connect the Central Business District (CBD) with regional towns of Ghaziabad, Faridabad,Gurgaon, Ballabgarh, Badli and Loni. The total length of the ring component is 36 km.The ring component or ring railway of surface rail corridors comprises of 20 stations and the average inter-station distance is 1.80 km. Whereas the total length of the spurs is 108 km. The spurs of the surface rail corridors consist of 17 stations and the average inter-station distance is 6.75 km.

(ii) Mass rapid transit system corridors

MRTS corridors consist of :

(a) Vishwavidyalaya - Central Secretariat Corridor (North-South Corridor)

The total length of the corridor is 11 km, and it has 10 stations. The average inter- station distance is 1.2 km. The corridor will be fully underground.

(ii) Shahdara - Nangloi Corridor (East-West Corridor)

The total length of the corridor is 25 km, and it has 19 stations. The average inter-station distance is 1.39 km. The 17.7 km length of the corridor will be an elevated and 7.3 km will be at-grade.

(iii) Subzi Mandi - Holambi Kalan Corridor (North-West Corridor)

The total length of the corridor is 19.3 km, and it has 16 stations. The average inter-station distance is 1.28 km. The 4.45 km length of the corridor will be an elevated and 14.85 km will be at grade.

In this study the MRTS corridors have been considered for detailed analysis. The peak hour passenger loading on the MRTS corridors for the horizon years 2001AD and 2011 AD are presented in Tables 4.15 ,4.16 and 4.17 respectively. Passenger loads on each station of the recommended MRTS network have been worked out by adding the following :

(i) Trips involving walk at origin/ destination.

(ii) Trips involving other modes at origin /destination.

(iii) Interchange trips.

Diagramatically the process is shown in Figure 4.18. During the process of trip assignment precautions were taken to ensure that unnecessary trips in view of the shortest path algorithm do not pass through the stations resulting in over estimation of passenger loads at stations. The peak hour passenger loadings have been derived by taking as 10 percent of the total daily passenger loads. Station loadings given in Tables 4.15, 4.16 and 4.17 will however depend upon the development of MRTS with proper interchanges and feeder services.

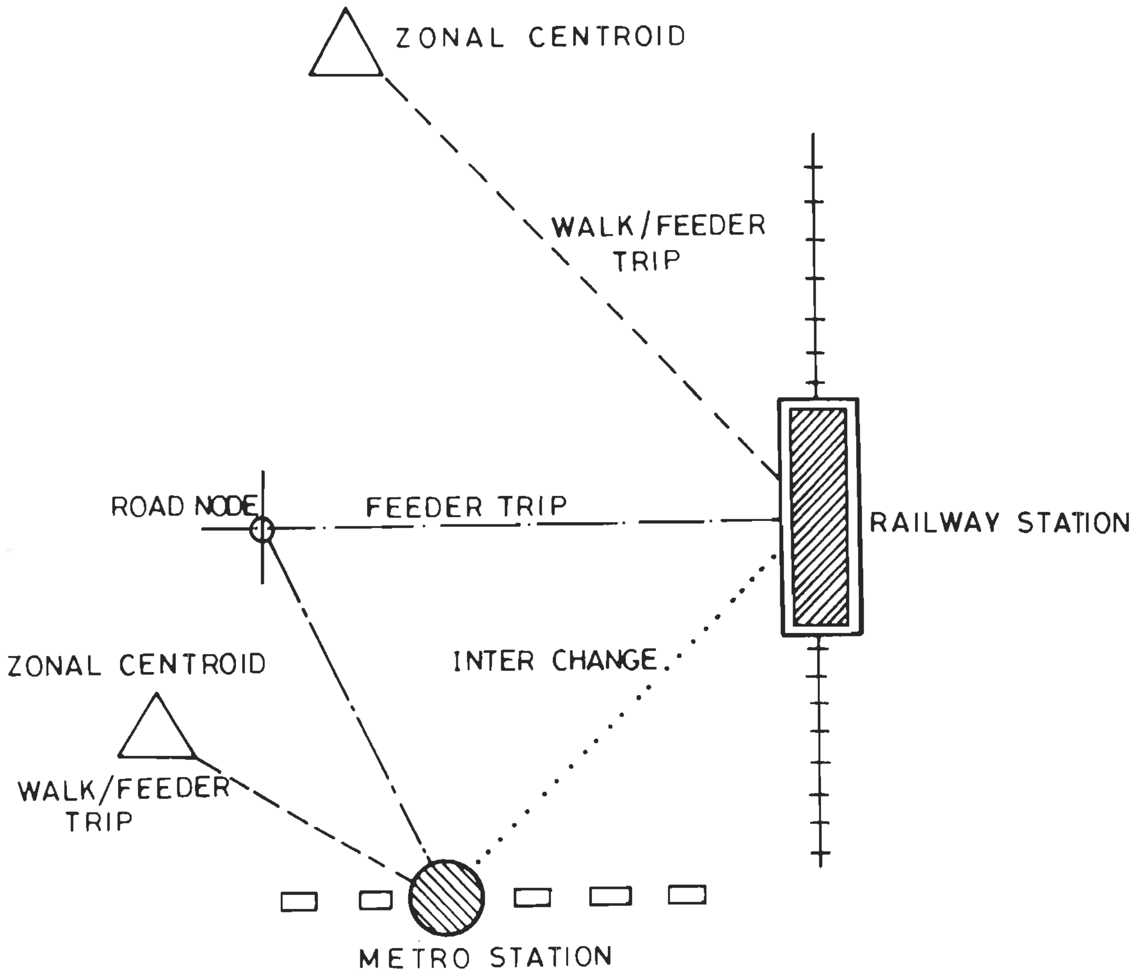


FIG. 4·18 TYPE OF LINKS OF METRO / RAIL STATION

TABLE 4.15 PEAK HOUR PASSENGER LOADING ON VISHWAVIDYALAYA-CENTRAL SECRETARIAT METRO CORRIDOR

Sl. No.	Link No.	Name of the Station	Year	
			2001 AD	2011 AD
1.	790	Vishwa Vidyalaya	18386	43207
2.	791	Old Secretariat	13573	31896
3.	792	Civil Lines	1569	6276
4.	793	I.S.B.T.	77841	94661
5.	794	Delhi Main	23297	54748
6.	795	Chawri Bazar	11631	40126
7.	796	New Delhi Railway Station	6721	30244
8.	797	Connaught Place	21736	51079
9.	798	Patel Chowk	6579	23026
10.	799	Central Secretariat	8647	29832

TABLE 4.16 PEAK HOUR PASSENGER LOADING ON SHAHDARA-NANGLOI MRTS CORRIDOR

Sl. No.	Link No.	Name of the Station	Year 2001 AD	Year 2011 AD
1.	891	Shahdara	60144	80216
2.	892	Seelampur	36019	57361
3.	893	Gautampur	5219	12265
4.	894	Shastri Park	16783	39440
5.	895	I.S.B.T.	23288	54726
6.	896	Tis Hazari	5472	12859
7.	897	Pulbangash	14798	34775
8.	898	Pratap Nagar	17624	41416
9.	899	Vivekanand Puri	10344	25343
10.	900	Tri Nagar	20004	47010
11.	901	Rampura	14260	33511
12.	902	Sri Nagar Garden	15150	35603
13.	903	Shakur Basti	23228	54586
14.	904	Surya Enclave	5013	22558
15.	905	Multan Nagar	25268	59379
16.	906	Mangolpuri	5013	22558
17.	907	Jwalapuri	9765	23924
18.	908	Kavita Colony	9468	23196
19.	909	Nangloi	16396	38531

TABLE 4.17 PEAK HOUR PASSENGER LOADING ON SUBZI MANDI-HOLAMBI KALAN MRTS CORRIDOR

Sl. No.	Link No.	Name of the Station	Year	
			2001 AD	2011 AD
1.	910	Subzi Mandi	10386	26355
2.	911	Shakti Nagar	7666	24914
3.	912	Rana Pratap Bag	7539	22617
4.	913	Sawan Park	5238	16761
5.	914	Azadpur	12484	29275
6.	915	Shalimar Bag	11296	26489
7.	916	Naya Azadpur	4567	14386
8.	917	Udyog Nagar	8080	23028
9.	918	Transport Nagar	19125	48960
10.	919	Surajpur	5845	18996
11.	920	Badli	3647	12764
12.	921	Siraspur	14275	33476
13.	922	Khera Kalan	5625	14781
14.	923	Ambedkar Colony	16466	38530
15.	924	Iradat Nagar	6709	21804
16.	925	Holambi Kalan	43702	74581

4.13 Summary

The study has considered the transport system consisting of road, rail and the proposed MRTS corridors as an integrated system. Traffic projections on each link of the three different components have been viewed for the system as one multi-modal system supported by interchanges and feeder services. The bus routes will need to be restructured to meet the demand.

To improve the predictability of patronage on mass rapid transit system, two types of techniques can be adopted. One is stated preference (SP), a survey and modelling technique designed to present respondents with a range of realistic choices between real and hypothetical transport modes. By analysing these choices expressed by the respondent the relative importance of various characteristics like frequency, fares, quality of service etc. of the modes can be established. These results can be used to forecast consumer behaviour more accurately, when new modes are introduced. The second technique revealed preference (RP) method is to draw an experience of systems which have opened in recent years where before and after data may be available. Data collected from such studies will provide some valuable information about the effects of a real mass rapid transit system, especially in respect of transfer of passengers from individual mode of transport providing a mass rapid transit system is bound to have effect of the traffic flow on the road system.In this study stated preference (SP) technique has been used for detailed analysis of MRTS. Detailed studies both regard to technical and financial considerations have been carried out for the proposed mass rapid transit system. Environmental impact of mass rapid transit system as well as its energy related aspects related to the integrated transport system also have been studied.

CHAPTER 5
ATTITUDINAL AND TRADE - OFF STUDIES ON MODE CHOICE

5.1. Concept of Attitude and its Measurement

Changes in attitudes of people and their behaviour towards choosing various modes due to environmental and other changes in system characteristics that take place have not received serious attention of transport planners in early days. Psychologists, economists and market researchers started increasingly involving themselves in transportation studies from late sixties. Since then, the fact that consumer behaviour is influenced to a large extent by the emotional appeal of objects and personal values of individuals has been recognised. These elements form the essence of attitude, which is a complex process. According to Levin [100] there are as many definitions of attitude as their are researchers who have dealt with this aspect. A comprehensive definition as given by Benjamin [15] described it as 'a set of motivations, emotions and perceptions held by a person about his world'. But the most generally accepted concept is that attitudes are 'formed by complex processes involving perceptions, evaluations and judgements'. It can also be 'defined as an organised and enduring set of beliefs and feelings, predisposing us to behave in a certain way' [47].

Attitudes are thus, predictors of behaviour. Hence, it is considered possible that a relationship can be established between attitudes and behaviour [101]. Hensher [68] formulated a hypothesis for 'perception and commuter mode choice'. Generation of effective hypothesis based upon the reactions of individuals to available methods of travel for journey to work, and over varying time-horizons, depends critically upon understanding their underlying habits and preconceptions of the travel mode (e.g., time, cost, comfort, convenience). It is often these, rather than the actuality, that determine the final choice. It will thus be seen that need for going a step further than developing disaggregated utility models based on interpretation of behaviour in making a choice, began to be felt from early 1970's AD.

One difficulty in understanding attitude has been on 'how to measure it'. It was recognised that the consumer behaviour towards transport is also affected by individuals attitude just as in any other market situation. But the method of evaluating it was considered to be difficult. After understanding the need and usefulness of studying attitude, researches had to look in for methodologies to be followed for using the data of observations in modelling. The first step was to arrive at a scale for measuring it. Thurstone's early works had set a methodology by using semantic differential scales [149].

There were difficulties in using the rating scale observations for attitudes directly. Attitude itself has two components viz. importance rating (comparative component) and satisfaction rating (affective component) [43]. Hartgen and Tanner [65] used five point Likert scale to measure both the aspects. A functional measurement using a continuous rating scale was adopted by Levin [100] and Meyer et al [112]. These set the trend for later studies.

Koppelman [88] has brought out the linkages between various components of system characteristics and personal characteristics with travel behaviour indicating how perceptions and feelings of people influence the choice (Figure 5.1). The 'perception' and 'feelings' are two parts of attitudes. Preference and choice are those as revealed by the choice as observed directly or through experiments.

5.2. Application of Attitude Studies to Transportation Planning

Early works involving attitudes in transportation planning studies were mostly research oriented. Later on the need for involving planners also in the study was felt. Transportation Research Board, Washington brought out a special Report No. 149 [1974] on this subject. A series of International Seminars were conducted to discuss various

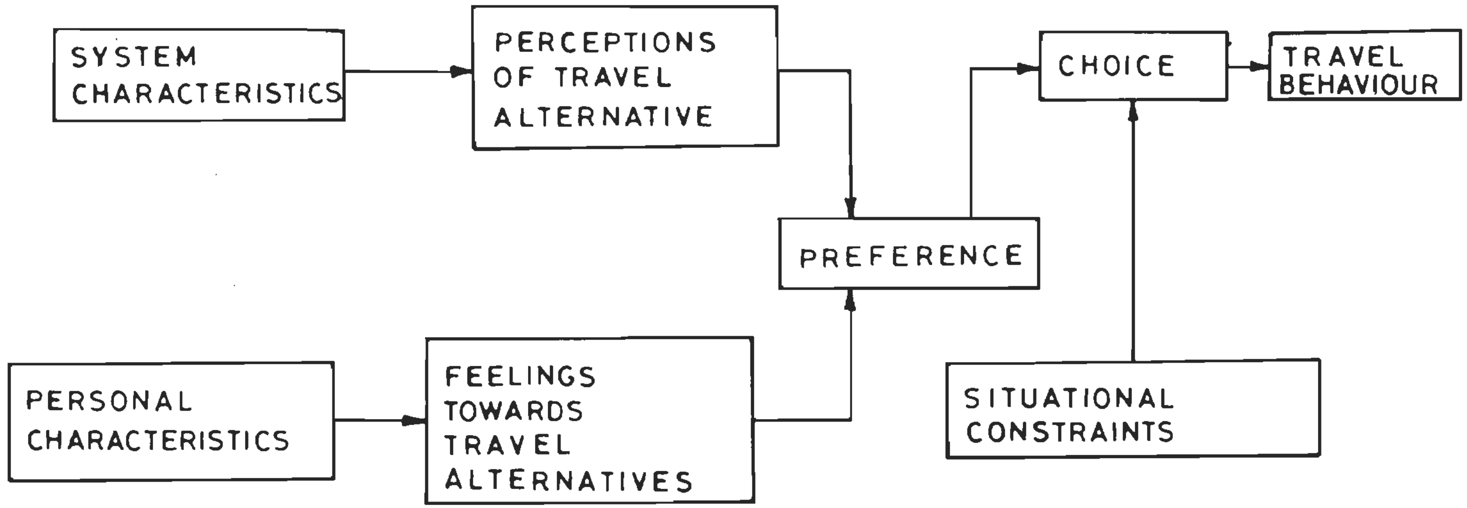


FIG. 5·1 INFLUENCE OF SYSTEM AND USER CHARACTERISTICS ON TRAVEL BEHAVIOUR aspects of 'Behavioural Travel Demand Models', between 1973 AD and 1985 AD. An extension of these approaches is the panel study which involved study of changes in travel habits of some population after passage of some time [52].

Transportation Research Board Organised a conference in October 1982 AD to cover 'Travel Analysis Methods for the 1980's AD' and National Research Council of USA brought out its special Report 201 [1983]. presenting reviews and papers submitted in the conference. As part of this report, Golob and Golob [50] have reviewed the work done on various approaches to Travel - Behaviour analysis under 19 (combination) groupings. The different approaches used and conclusions arrived at or models developed can be covered under five main headings e.g. Activity based approacheds; Approaches using subjective variables; Approaches using population segmentation; Approaches using controlled experiments; Approaches directly involving choice models.

Some of the studies are the results of combination of two heads. The most important models developed would come under various combinations; Activity-Experiment, Activity-Choice, Attitude-Segmentation, Segmentation-Experiments, Segmentation-Choice, Experiments-Attitude, Experiment-Segmentation, Choice - Attitude, and Choice - Segmentation.

The activity oriented models call for data to be collected on a continuous basis or at periodical intervals and in Indian situation (as explained later) it is difficult to be carried out. Works falling under attitude, segmentation, choice and to some extent on those using experimental approaches and combinations there of are discussed further.

5.3 Attitude Based Studies

5.3.1 Activity - Experiment

Activity analysis is of recent interest. Though, it was first considered as early as in 1970's AD in U.K. Activity analysis was used early by Oxford University to study travel behaviour so as to overcome many of the problems involved in use of traditional models like category analysis models for trip generation in terms of assumptions on trip rate stability and their insensitiveness to supply characteristics of transport. This was proposed to be overcome by analysing the daily activities of each individual in a household in which travel formed a constituent [81]. As part of the activity studies, there is a need for understanding more comprehensively travel behaviour in the social contexts like life cycle, life style, social roles due to sex difference, (auto availability rather than auto ownership) etc., before any modelling is done.

How some of these can be observed and covered have been brought out by Bourgin and Goddard [12]. For example, depending on needs of a growing child, mother's activities may undergo change and consequently her travel habits would be affected. More emphasis is now being placed in some of developed countries on this type of study [83]. Another technique being used is the 'Panel' study which goes into changes in travel habits using longitudinal data [52]. Taking part in an 'Activity' study calls for good level of understanding of purpose of study by the respondent. It requires co-operation from all members of the family since each of them has to maintain a diary on the full day's activities faithfully recorded. It is too early to try such a methodology in any Indian city. Same applies to 'panel' study.

5.3.2 Attitudes towards travel attributes

One of the earliest studies covering attitude towards travel attributes is that of Gustafson et al [45]. The study was aimed at finding how commuters valued various attributes of a public transportation system. For this purpose, the investigators considered 34 attributes ranging from 'having a seat' and 'lower fares', to number of finer aspects like 'Vehicle/neighbourhood compatibility'. For eliciting opinion, a method of paired comparison using semantic differential scale was adopted. Analysis was done for full sample and for individual groups classified as elderly, young people, low-income persons, housewives, etc. [46]. The survey revealed that the low-income people valued 'waiting time', 'shelter at pick-up' and 'longer service hours' more important than 'lower fare'. The views of the above were very similar to the views of full population. Elderly put more importance on 'comfort' and 'convenience' items like 'having a seat' and 'no transfer trips' followed by 'lower fares'. The investigations were successful in throwing light on how 'low income people as a whole' and different sections of people value 'comfort' and 'convenience' factors in relation to 'cost' and 'time' factors [133].

Stopher, peter R. [133] investigated the effect of two alternative ways of measuring convenience. The First one is in the form of a proxy that could be introduced in the available data and developing disaggregate utility models (Logit models). The second was to develop a scale model using psychological scaling techniques after collection of new data. For the first part Stopher used travel data available for 2 areas (London and Stokie in Chicago). Cost difference and time difference between two models as measures for cost and time variables was used. For convenience variable, 'Journey units' measure were assigned to the two modes on the basis of one for each of separate elements involved in taking a mode. The model coefficients gave the measure of relevance or importance of how convenience was perceived in the choice. The second methodology given by Stopher was to use a list of 14 attributes concerning convenience and to ascertain opinion of commuters in the form of a paired comparison question. It involved a total of 42 comparisons. Users were asked to indicate 3 most important attributes. The ranking computed, placed the following 5 attributes as important ranging down the full length of scale - Arrive at the intended time; Able to travel in all weather; Avoid numerous stops; Avoid a long walk; and Avoid undesirable areas.

Summing up the discussions held in a workshop conducted on the subject of 'Attitudinal data', Demetsky [26] observed that the travel demand analysis requires that a single survey should provide attitude or preference data, socio-economic information and travel choice behaviour. It was felt that surveys should be longitudinal in nature to reflect the changes which the travel behaviour undergoes in relation to system changes and in relation to individual attitudes. It was recommended that in the first stage, incorporation of psychological dimensions of level-of-service into mode choice model should be done to make it more complete than the prevalent models. The psychological data is to be transformed in such a manner as to indicate model satisfaction which would indicate in turn the modal choice. In the next stage, it was felt that the psychological model should be applied to the activity site selection (destination) and route choice. Finally, the scope should be widened to trip generation by extending the observations to show sensitivity to activity importance and consequently need to travel.

5.3.3 Scale for attitude measurement

For purpose of combination of the two components, a uni-dimensional vector is required in order to arrive at the final dimension which stands for 'affect towards any type of object'. Fishbein and his colleagues proposed two distinct models. Firstly, the affective part or attitude towards object and secondly for the prediction of a specific behavioural intention [47, 75]. Out of these, the first part has been taken as basis for further model development by many. This is in the form of a linear relationship.

$$Ao = \sum_{i=1}^{n} Bi.\ a_j \tag{5.1}$$

Where,

Ao	=	attitude towards object o,
Bi	=	strength of belief i about o,
a_j	=	the evaluative aspect of Bi,
n	=	number of beliefs.

One of the problems in applying attitude measures or combining impact of various attributes in final choice is that of finding ways to do vector addition of the magnitudes of basic attributes. There should be a rationalisable means of combining several attribute dimensions into one scale measure. A method suggested by Michaels [109] is to consider the fact that people scale attributes and then compare objects on each attribute ordered from highest to lowest importance. An alternative rated high on the most important attribute is then evaluated on the second most important attribute. If the alternative is rated low on the highest important attribute, it is rejected for further consideration. This technique however has difficulties in putting it into practice in a situation, involving various groups of vehicle users where most of them are not trained to look into issues in a step-by-step process of comparison and eliminations.

5.3.4 Attitude - segmentation

This is an approach used for comparing attitude among population segments. Based on this approach, some studies have been made to test response on hypothetical transportation systems. One such study was done to assess difference in attitude towards an alternative between those of users and non-users. Dobson et al [31] found that users of a mode view that mode used by them more favourably than how the non-users view that mode. One research work to illustrate a relatively uncomplicated and effective market-segmentation technique applied to mode choice analysis was done using a sample of Los Angeles Central Business District workers [30]. The data was collected through a home interview survey pertaining to (i) frequency of choice of mode from single occupant auto, bus and car (ii) their attitude (belief) towards 19 travel attributes for each of the modes in a semantic differential (seven point) scale and (iii) their socio-economic characteristics. The attitudes towards different modes were factor analysed and used for segmentation. The procedure used is indicated in the flow diagram given in Figure 5.2,

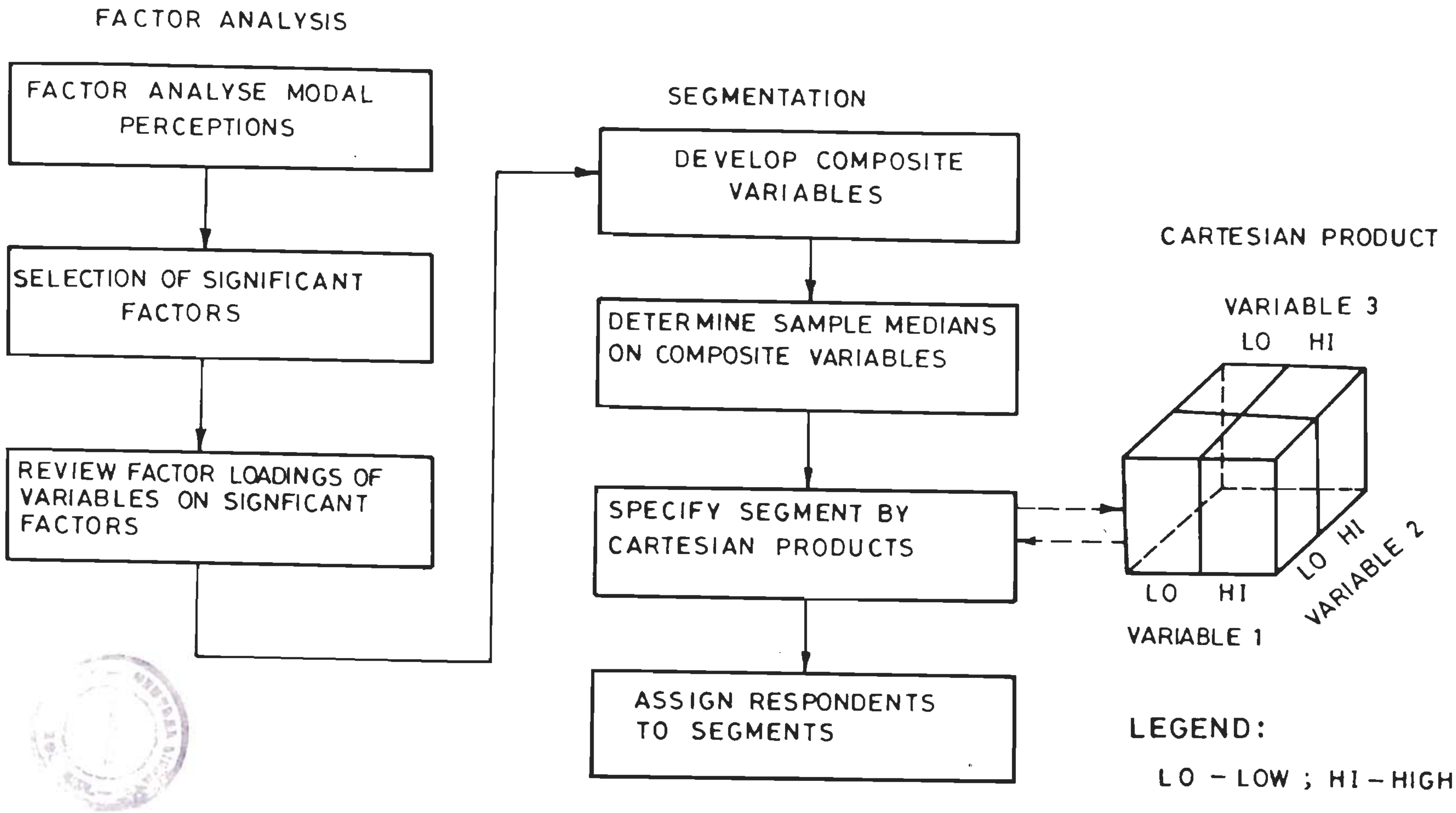


FIG. 5·2 SEGMENTATION BY FACTORING MODAL PERCEPTION where the respondents are segmented into 8 groups. Such segmentation approach would become more complicated when choice alternatives are multifarious as in the case of Indian cities.

5.3.5 Attitude and choice : paired comparison models

Paine's study in University of Maryland was perhaps the first study specifically designed to collect data which would establish a link between 'trader's perception of system attributes in conjunction with his travel pattern' [65]. The growing feeling that behavioural (choice) studies should take into account the awareness and attitudes of people has led to works done for establishing a relationship between attitude and choice. Attitudes and awareness define a set of preferred activities which are capable of satisfying the person's needs [65].

The study obtained opinion on the ability of two systems (transit and auto) to satisfy user's requirements in respect of each of the selected 33 system attributes and also opinion on importance of each attribute to him (7 point semantic differential scale was used for the measurement). From these, average score for each attribute for the two modes and corresponding level of importance of attribute were worked out. Factor analysis was carried out for grouping the attributes. It resulted in 11 factors. Composite importance and satisfactions to represent each factor was to be judged by the attribute having the highest importance score within the factor. Attitudinal indices were developed for different types of households viz, for single person and families stratified income - wise.

In a study done for General Motors Research Laboratories, Golob [43] developed a choice model including the awareness of user regarding disutility of an attribute. It uses 'utility theory application of a statistical inference' technique. In this, respondent's measure of disutility for 15 travel attributes for use of mode and for the second choice of mode were collected on a 7 point semantic differential scale [48].

Disutility of attributes for various modes are given below :

$$U_{i,k}^{j} = I_i . A_{i,k}^{j} \tag{5.2}$$

Where,

$U_{i,k}^{j}$ = disability of attribute i for mode j, as perceived by user k,

I_i = importance users place on attribute i

$A_{i,k}^{j}$ = measure of disutility for attribute i of mode j as perceived by user k.

Allen and Isserman [1] first developed a deterministic utility model in a binary situation (auto and transit) for Philadelphia. This model linearly combines satisfaction of various modal characteristics weighted by importance of characteristic. Later they developed a probabilistic linear utility model, including, in addition, characteristics of the individual (income, age, sex etc). The latter model was found to have better fit. Using these models, limited policy prescriptions were suggested. The importance of attributes (Characteristic) and level of satisfaction were measured on semantic differential scales 1 to 7. Sample size was 72 (27 public transit users and 45 auto users). The Probability model took the form,

$$P_i = \alpha + \sum \beta_a (S_i^a - S_j^a) + \sum \gamma_b M_b + e \tag{5.3}$$

Where,

α, β_a and γ_b are parameters to be estimated.

S_i^a = level of satisfaction in characteristic a with mode i,

S_j^a = level of satisfaction in characteristic a with mode j,

M_b = the b^{th} socio-economic variable,

P_i = probability of using mode i,

= 1 if i is used,

= 0 if j is used.

A total of 15 modal characteristics were considered for ascertaining levels of satisfaction including dependability, cost, convenience, speed, waiting time, privacy, safety from crime, direct trip, length of trip etc. Model parameters and their significance gave an idea of what characteristics need improvement. Allen and Isserman [1] concluded that attitudinal data can play an important role in policy determination. For applying this approach to a multi - modal situation, a series of binary tests using transitivity will have to be done.

Hartgen [67] built up an index of bias towards transit and auto modes based on respondent's reported attitudes towards selected characteristics of each mode. These were tested statistically to determine how socio-economic variables particularly to user and mode can serve as indicators of travel bias towards alternative modes. A set of 28 socio-economic variables (like sex, race, age of different members, relation to head of household, occupation, rented or own house, family size, distance to CBD, auto availability, trip purpose, time started, etc.), were used for testing variation in index. Index itself was built up using attitudes expressed on 33 attributes pertaining to the trip in terms of importance and level of satisfaction expressed on 7 point semantic differential scales.

The bias index y_i for individual i is expressed as

$$Y_i = \sum_{j=1}^{33} I_{ij} \left(1 - \frac{ST_{ij}}{SA_{ij}}\right) \qquad (5.4)$$

Where,

I_{ij} = subjective importance for respondent i on attribute j,

ST_{ij}, SA_{ij} = level of satisfaction to respondent i in respect of attribute j for transit and auto respectively

The population is segmented into groups by constructing an analysis of variance model using Automatic Interaction Detector (AID) algorithrn. It breaks down each data set into two smaller sub-sets according to one of the independent variables, which are entered in the order of their power in explaining the variations in the dependent variable (the index y_i here). The study found socio - economic variables (except auto ownership) to be of less importance in explaining modal bias, but they were useful for classification schemes.

Hensher [68] has discussed the problem of aggregation in behavioural travel choice modelling with respect to specific data needs and also structural forms for developing of travel choice models (for assessing choice of mode or a measure of overall attitude, or frequency of trips).

The basic structure considered was,

$$A^i = f \sum_{ij} [I_j^i (S_{1j}^i - S_{2j}^i), (K_{1j}^i - K_{2j}^i), (AT)_j^i] \qquad (5.5)$$

Where,

$I_j^i (S_{1j}^i - S_{2j}^i)$ = affective index for individual i for mode 1 versus mode 2 in attribute j,

$(K_{1j}^i - K_{2j}^i)$ = inquisitive awareness index for individual i on modes 1 & 2

$(AT)_j^i$ = conative index for individual i on attribute j

Subscript 1 and 2 refer to usual and alternative modes. For measuring awareness, Hensher used a 100 point ratio scale. The four principal travel attributes considered the above study were time, cost, comfort and convenience. Paired comparison models have inherent problems, since they are not truly representing the actual state where comparisons among a group of modes are to be considered.

5.3.6 Attitude and choice : Multi - modal analysis approach

Golob and Dobson [48] brought out the need for merging of economic and psychometric theories to facilitate proper understanding of how individuals make decisions on the transportation - related alternatives.

The models have to firstly be founded on theories and tested on hypotheses which directly describe or represent the decision - making behaviour of individuals. Secondly, models should be defined with respect to at least some subjective data, such as stated preferences and perceptions. They have described in a number of ways in which the psychological variables are assessed and also the forms in which the models are developed based on the explanations offered by econometric theory regarding role of utility in decision-making. The econometric theory does not, however, significantly cover how the psychological variables are measured. The measurement approaches described by Golob and Dobson cover indirect scaling through a paired questionnaire, or direct scaling in the form of (i) rating by assigning numbers as a joint function of respondent judgments, (ii) use of ratio scale (iii) use of semantic differential scale or (iv) use of a ranking scale. The genesis of evolving the two-component cognitive theory of attitude using summation principle broughtout and described in section 5.3.3. A questionnaire format was formulated for assessing similarity of choice judgement by respondent among a number of alternatives used by him.

Different possibilities of analysing the data using canonical analysis, factor analysis, non-linear technique of logit analysis and multi-dimensional scaling have been brought out in this study. Need for deriving reasonable functional forms other than what is offered by economic utility theory has been stressed by them.

5.4 Experimental Approach

One form of experimental approach in a choice situation is to use controlled simulation. Controlled experimental models developed by psychologists have been extensively used in market research. Experiments in transportation field, have been conducted in the form of ascertaining stated preference (Presenting hypothetical alternatives) rather than revealed preference of user since direct observation in real world behaviour have been considered to have limited scope of being applied. Also, for study of revealed preference on altered situation, longitudinal data is called for. Simulation methods have met with less wide acceptance for application in this field, though indirect application is possible. Two important types of analysis viz, functional measurement, and conjoint measurement are explained [13].

5.4.1 Functional measurement and analysis

Functional measurement (also called information integration theory) uses preference ratings made by respondents for hypothetical alternatives on a bad-to-good scale 1 to 20 or 1 to 100. Analysis of response are made using ANOVA techniques. Hypothetical alternatives can be specified in terms of design combination of different levels-of-service in major attributes like time, cost and comfort. This method has been applied to a mode choice study of home-to-work trips by Meyer et al [112]. A survey was conducted in which respondents were given descriptions of 27 hypothetical alternatives giving a combination of 3 levels of time differences, 3 levels of cost differences and 3 levels of comfort differences. Respondents were asked to indicate their relative preferences for their choice of bus or car on a 20-point scale i.e., 20 for 'certain to take bus' 0 for 'certain to take car' and intermediate values for others . Based on the replies, respondents were clustered into 3 groups viz, car-biased, unbiased and bus-biased. For the total valid sample of 97 for campus and 72 outsiders, two multiple linear regression models for mode choice were developed.

Louviere [99] used 'Functional Measurement' in a study on employment and residential location as part of a two step modelling approach for identifying the form of utility functions to be used in travel demand models. In the study a Multi-Nomial Logit Model was choosen.

5.4.2 Conjoint measurement and concurrent analysis

Conjoint measurement is similar to functional measurement but can be done with rank-order preferences. This method which is just a variant of multi-dimensional procedure has been used in a research study for deriving models for choice of shopping centres. It has been applied in modal choice studies to a limited extent as for example study of ratio of preferences between two hypothetical alternatives, testing threshold and interaction effects, assessing relative weight of travel time, waiting time, access time and transfer time under various conditions of weather, seat availability etc., [50]. It is considered to be a method suitable for direct measurement of preferences or choice amongst multi-attribute items.

A study was made by Louviere [99] for determining choice of a supermarket amongst a choice of 12 selected supermarkets. 'Concurrent analysis' as an extension of conjoint analysis was used. The 'concurrent analysis' is a method using a combination of factorial experiments and real - world analysis for developing and / or testing empirical hypothesis about human behaviour. This methodology has been considered preferable to paired comparison procedures for studying travel behaviour. This method uses a multiplication function to arrive at the preference rating,

$$U_i = \pi_{j=1}^{n} (P_i^j) \qquad (5.6)$$

Where,

U_i = Preference for an alternative/object

P_i^j =A function denoting preference level for attribute j of the object i

5.5 Trade - Off Game

Trade-off Game is used for determining behaviour of individuals in a constrained choice situation. This can be used both in micro and macro level studies. Trade - off method as the name implies is used to observe .what choices or trade - off users would make when confronted with a variety of conditions.

This is a method which goes beyond the normal attitude surveys as they attempt to study the preferences in a simulated situation amongst individuals towards choice, amongst alternatives which affect one individually or a group to which one belongs collectively. This is a method integrating two basic approaches by inter - relating attitude measurement with behaviour information. This approach has been found by many social science researchers as a tool holding out considerable promise and potential for future studies. This method has been used extensively to study preferences in planning field.

Wilson game comprises of use of a number of cards (16 cards) one for each of the various facilities required, say in a house [110]. One each card, various choices available under the facility concerned and cost of each choice is specified. The player is given a fixed amount to allot, for his choice under different items. Based on the amount he allots to each, his 'minimum choice of level' of the facility he needs is determined. A number of players play the game and majority preferred choices (one under each item) are determined by analysing the preferences.

Wilson's method has been used in a study for evaluating different development aspects of a neighbourhood with reference to various aspects e.g. a preferred layout involving different densities and distance relationships [85].

Hoinville and Associates [66] used a Game Board with electronic switches in the form of tags at different levels to represent different cost levels. Respondents were given option to make choice amongst different alternatives within a maximum fixed cost. The electronic equipment gave a continuous idea of the cumulative cost expended as game proceeded. It is thus a simulation device used for indicating respondents priorities between competing and costed alternatives. The choice covered 5 environmental variables and 5 accessibility variables with 3 choices under each and alternatives were presented in the form of sketches to indicate 'level of service'. University of Southern California was devised for deciding on preferences of various ethnic and economic groups towards 11 attributes representing various aspects of residential environment. Six items related to accessibility to various facilities (opportunity attributes) and five related to residential environment influencing characters of the area (density, quality of air, etc.) were considered. Results were presented so as to indicate rank ordering of importance as indicated by different groups and also patterns of trade-off propensities towards 5 top-most preferred attributes for each of the five groups [78].

5.5.1 Application of trade-off game to mode choice

Donnelly et al [29] applied Trade -off analysis to develop an algorithm for the computation of Trade-off utilities. It was applied to determine the extent of public support likely to be received for complex transportation policies and to identify the population groups which would favour a potential policy and those who would oppose it. Thus, trade-off Game can be tried for policy level mode choice analysis in a manner similar to how Anantharajan [5] had used it on assessing neighbourhood facilities. The results can be used for evolving indicators and guidelines for planning new transportation system or modification of existing ones in a multi-choice environment. The Gaming method can give an adequate idea on how such changes will alter the choice situation. Such an application does not appear to have been tried in any city where large disparities in economic conditions of people and proliferation of modes extending from bicycle to personal car exist. The data requirement for such a study need not be extensive. Data collection involves intensive probing. A research study applying this methodology in a real life situation can help to understand its effectiveness and appropriateness for a mode choice study.

5.6 Summary

Important research studies made in transportation planning and analysis have given an idea of the various approaches attempted by researchers and planners in this area. Indian cities, which experience a multi - modal environment having a wide ranging, slow moving and fast moving, and motorised and non-motorised modes, could be studied more appropriately by developing models which could respond to competitions as seen by users among various modes in their operation. This is probably the area requiring the attention of researchers in Indian cities.

CHAPTER 6
MEASUREMENT OF COMMUTER'S MODE CHOICE ATTITUDE AND ANALYSIS OF TRAVEL ATTRIBUTES

6.1 Attitude Study

Attitude of an individual is formed out of feelings and perceptions of the individual. The feelings are revealed in terms of the importance one attaches to various components or attributes of the object. The perceptions are expressed by way of the level-of-satisfaction one derives from the same. In order to judge or evaluate the attitude of an individual towards the end product of any service, one has to evaluate these two components for various attributes of the product and arrive at a total measure. The total measure can be an additive sum or a multiplicative product of the attitude individual attributes. In arriving at a measure of an individual's attitude towards a service like transport system there are two steps involved viz., measuring the importance, the individual attaches to various travel attributes and the level-of-satisfaction one derives in respect of each travel attribute from the particular system or mode. The importance attached to each attribute itself would depend upon the purpose of travel.

Sinha et al [136] have done studies to measure attitudes of people on travel attributes for Patna city in India. The first study called for measuring level-of-satisfaction of commuters in respect of travel time, travel cost, comfort, convenience and system reliability. However, no attempts were made to quantify the relative levels of importance of the attributes in this study.

6.2 Comparison of Methods and Choice

Most of the attitudinal studies carried out in the field of transportation planning in other countries adopted one or more of the following steps.

(i) Rank-ordering the various travel attributes like time, cost, comfort, convenience, reliability, dependability, safety, etc., for alternative modes.

(ii) Finding the relative importance of various attributes of travel modes.

(iii) Working out modal share using the above data.

(iv) Developing trend analysis in modal share using segmentation techniques.

Most of the studies referred have been concerned with three alternatives, viz., auto, public transport and car-pool. No attempts have been made to study a situation similar to Indian cities where a large number of modes compete to share travel trips.

The rank ordering of various attributes according to importance can give only broad indications for planners to decide what aspects need more attention than others to improve transport systems. Such studies call for finer divisions and definitions of various modal attributes for eliciting opinion. Time and cost involved in obtaining such information in a heterogeneous community using household survey techniques would be too high. In a situation, where, the choice alternatives are 6 to 7 as in Indian conditions, the segmentation technique becomes difficult to operate calling for large computational work. Development of MLR or MNL models using attitude scores as variables along with other variables may give better results and this can be used to forecast shifts from existing modes to improved or new modes such as MRTS.

6.3 Objectives of Attitude Study

The objectives of attitude study for the present research programme are :

(i) Determine what level of importance the commuter attaches towards each of various travel attributes and examine how importance rating undergoes changes according to purpose of travel.

(ii) Determine the level of satisfaction the commuters derive in respect of the various travel attributes of different modes.

(iii) Determine the relationship existing between socio-economic characteristics of people and their attitude towards travel attributes.

(iv) Determine the relationship existing between the user's attitude towards a mode and their choice.

(v) Determine the value of time the commuters derive in respect of different modes.

6.4 Design of Survey

6.4.1. Study questionnaire - Appendix 7

The questionnaire designed to be administered at household level comprises of 7 sections directed to collect the following basic data :

(i) Socio-economic characteristics of household covering composition, age, income, vehicle ownership and expenditure on travel.

(ii) Particular of trips made by all members of the household for one working day.

(iii) Distance to bus stop and railway station and level of comfort they get from them while travelling.

(iv) Value of importance to the various travel attributes (travel time, cost of travel, distance of travel, reliability of transport, safety during travel, comfort in travel and convenience in travel) for each type of trip (work, education, shopping, recreation/entertainment and social call).

(v) Level of satisfaction the commuters derive from the mode of use and for two other alternative modes of choice.

(vi) Time taken for each of the travelling component such as walking, waiting and in-vehicle travel time.

(v) Willingness to pay information for public transport users with a given condition of reduction in total travel time by 30%.

Level of importance of the various attributes are measured by asking the respondents to distribute a total value of 100 scores amongst the attributes according to level of importance perceived by them. Level of satisfaction in respect of any attribute is to be measured in a semantic differential scale, 1 to 100, 'most unsatisfied' is represented by 1 and 'most satisfied' by 100.

6.5 Survey Area and Sample Size

In the absence of any secondary data on attitude studies, collection of primary data directly for this study has become necessary. There are time and cost constraints when primary data has to be collected for a study. The size of sample may be limited, but has to be such that it is adequate to cover all sections of people of the study area [117]. Five locations in Delhi city were selected for the study and the same is shown in Figure 6.1. Care was taken to cover all strata of the society from all the five areas. Systematic random sampling surveys were conducted in the five locations of Delhi city. The total sample size is 605.

6.6 Analysis of Attitude

The individual attitude towards a mode has to be expressed in terms of a single determinent as attitude value. The advantage of using summation approach, commended by Golob [47] and others has already been discussed in Chapter 5.

The analysis of attitude is described below :

$$C_k^i = 0.01 * \sum_{j=1}^{n} P_j^i * A_j^i (k) \tag{6.1}$$

Where,

C_k^i = The attitude value of individual i for the mode k.

P_j^i = Importance factor for travel attribute j for individual i for the chosen trip purpose (say work trip).

$A_j^i (k)$ = Level of satisfaction derived from mode k by an individual i in respect of attribute j.

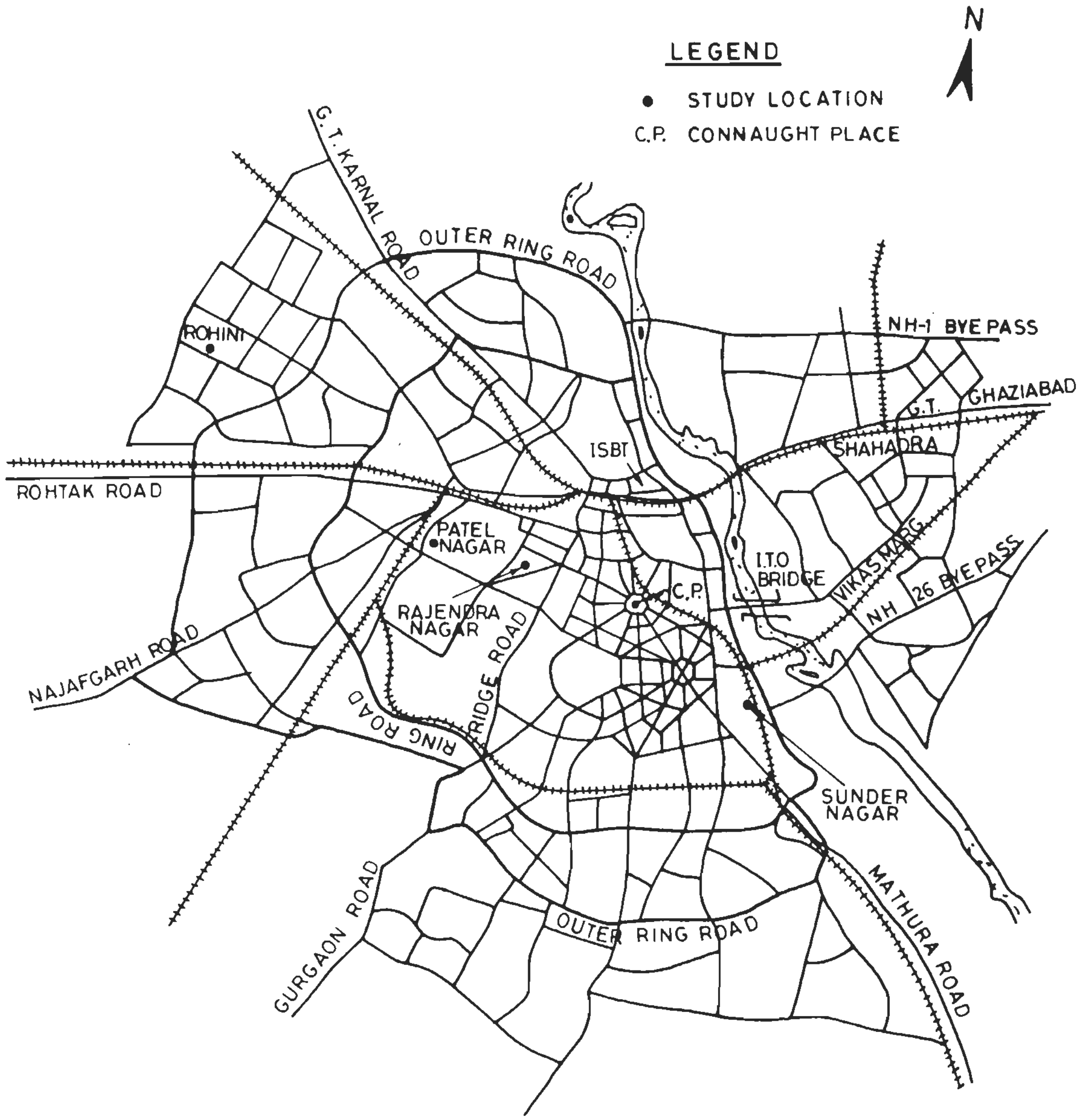


FIG. 6·1 FIVE DIFFERENT STUDY LOCATIONS OF DELHI n = The number of attributes (i.e.travel time, cost of travel, distance of travel, reliability of transport, safety during travel, comfort in travel and convenience in travel).

After arriving at level of satisfaction score, from each individual in respect of each mode, first the data have been stratified mode wise, by grouping the respondents who have given level of satisfaction scores. Attitude values have been worked out mode wise for all cases. Such grouped data has been subjected to various statistical analyses [102, 114]. The data for each mode is stratified under 5 income groups (in Rs. per month) viz., income upto Rs. 900 (EWS); Rs. 901 to Rs. 2000 (LIG); Rs. 2001 to Rs. 3000 (MIG); Rs. 3001 to Rs. 5000 (HIG-I) and over Rs. 5000 (HIG-II).

6.7 Statistical Analysis

6.7.1 Socio - economic characteristics

General characteristics of the sample population studied are given in Table 6.1 for five different areas. The values assigned by respondents for various trip characteristics for different type of trips for the five areas are given in Table 6.2.

6.7.2 Level of satisfaction

The level of satisfaction for different modes, as expressed by the respondents for the seven travel attributes, have been similarly analysed and the results are presented in Table 6.3. In overall analysis, train is considered most satisfying for travel time, distance of travel, and safety during travel, bicycle for cost of travel, car for comfort in travel, reliability of transport and convenience of mode. If bicycle which involves no cost of travel is excluded, bus is best for cost of travel. The quantification gives a good basis for relative comparison of the level of satisfaction in respect of various modes. The attitude of people is well reflected by results of these analyses.

TABLE 6.1 GENERAL CHARACTERISTICS OF SAMPLE POPULATION

Characteristics	Unit	Mean Values for the Sample				
		Rohini	Patel Nagar	Sunder Nagar	Rajendra Nagar	Connaught Place
	Numbers	124	128	116	117	120
Family Income	Rs./Month	4096	4660	4289	4301	4889
House Composition at age group						
Over 60 years	Numbers	0.74	0.59	0.52	0.39	0.54
16 to 60 years	Numbers	2.81	2.87	3.14	2.76	2.83
6 to 15 years	Numbers	0.92	0.74	1.00	0.86	0.89
Children upto 5 years	Numbers	0.25	0.26	0.18	0.17	0.22
Total	Numbers	4.72	4.46	4.84	4.18	4.48
Vehicle Ownership per household						
Car	Numbers	0.25	0.78	0.32	0.38	0.81
Motorised two wheeler	Numbers	1.52	2.00	1.85	2.67	2.12
Bicycle	Numbers	2.56	2.29	2.05	2.17	1.35
Others	Numbers	0.04	0.05	0.03	0.02	0.01
Total	Numbers	4.37	5.12	4.25	5.24	4.29
Expenditure of of Household on transport	Rs./month	910	1226	894	861	1186

Source : Survey data, 1995 AD

TABLE 6.2 VALUES OF IMPORTANCE ATTACHED TO VARIOUS MODAL ATTRIBUTES BY COMMUTERS IN FIVE DIFFERENT AREAS

Trip purpose	Value of Importance (P_j^i) Assigned to Travel Attributes*							Total Score
	1	2	3	4	5	6	7	
				AREA SURVEYED - ROHINI				
Work	28.15	18.42	6.53	9.53	13.01	15.67	8.69	100
Education	28.36	10.51	6.33	12.46	16.58	13.98	11.78	100
Shopping	19.78	18.98	9.38	6.86	16.58	18.14	10.28	100
Social Call	24.68	16.24	6.22	10.16	16.31	16.20	10.19	100
Entertainment	23.80	16.60	12.18	6.95	10.56	18.38	11.53	100
				AREA SURVEYED - PATEL NAGAR				
Work	37.61	14.26	8.44	9.21	9.89	10.16	9.43	100
Education	37.35	15.27	8.47	7.11	12.15	10.29	9.36	100
Shopping	16.98	16.21	12.41	10.94	14.47	15.31	12.68	100
Social Call	16.21	14.96	8.85	14.21	16.39	15.12	14.26	100
Entertainment	21.58	15.26	9.74	12.58	14.68	14.21	11.56	100
				AREA SURVEYED - SUNDER NAGAR				
Work	31.67	19.21	7.94	6.30	7.24	16.38	11.26	100
Education	30.37	16.84	9.31	8.34	5.01	14.87	15.26	100
Shopping	16.41	20.32	9.32	10.83	7.05	20.21	15.86	100
Social Call	16.92	21.63	8.27	9.86	6.53	19.21	17.58	100
Entertainment	22.25	20.68	12.91	7.03	1.43	20.49	15.21	100

Contd...

Contd.. Table 6.2

	AREA SURVEYED - RAJENDRA NAGAR							
Work	36.41	14.46	9.29	9.13	11.16	10.12	9.43	100
Education	35.85	13.27	9.17	9.35	13.15	9.89	9.32	100
Shopping	18.38	17.31	11.73	10.49	13.93	14.88	13.28	100
Social Call	16.39	17.21	10.11	13.69	15.12	14.12	13.36	100
Entertainment	21.38	15.36	11.41	13.03	12.98	13.49	12.35	100
	AREA SURVEYED - CONNAUGHT PLACE							
Work	29.16	16.31	5.94	9.46	14.31	14.51	10.31	100
Education	36.78	13.37	8.67	8.76	12.21	10.89	9.32	100
Shopping	17.94	17.87	9.85	11.23	15.93	15.93	10.25	100
Social Call	14.89	17.25	9.57	14.29	15.21	15.21	13.58	100
Entertainment	21.38	14.36	11.53	11.68	14.28	13.52	13.25	100
	AREA SURVEYED - ROHINI + PATEL NAGAR + SUNDER NAGAR + RAJENDRA NAGAR + CONNAUGHT PLACE							
Work	33.37	14.18	7.98	10.71	11.16	12.52	10.08	100
Education	35.08	12.50	7.89	9.19	12.43	12.48	10.43	100
Shopping	17.72	17.20	11.86	10.67	13.90	16.30	12.35	100
Social Call	17.10	15.85	10.23	13.43	15.19	14.58	13.62	100
Entertainment	22.81	15.26	10.43	11.48	12.92	14.83	12.27	100

* ATTRIBUTE NUMBERS :

(1.Travel time 2. Cost of travel 3. Distance of travel 4. Reliability of transport 5. Safety during travel 6. Comfort in travel 7. Convenience in travel.)

TABLE 6.3 LEVEL OF SATISFACTION EXPRESSED BASED ON THEIR EXPERIENCE FOR DIFFERENT MODES IN RESPECT OF VARIOUS TRAVEL ATTRIBUTES

(Maximum 100)

Mode	Sample Size	Level of Satisfaction (A_j^i (k)) in respect of Attributes *						
		1	2	3	4	5	6	7
		AREA SURVEYED - ROHINI						
Car	38	79.53	64.84	68.12	78.99	74.27	85.29	87.23
Motorised Two Wheeler	67	79.62	63.20	68.39	67.36	52.25	64.58	71.23
Bus	115	54.20	73.20	52.38	53.27	58.23	42.69	54.87
Train	5	81.27	51.38	67.46	69.58	79.22	67.16	67.38
Bicycle	57	58.38	91.73	52.16	65.23	58.47	48.82	65.60
IPT	67	76.16	42.47	58.39	62.27	58.05	66.26	71.25
		AREA SURVEYED - PATEL NAGAR						
Car	36	74.00	40.21	73.25	79.34	62.37	85.46	81.24
Motorised Two Wheeler	93	76.47	57.20	64.49	74.34	54.15	64.43	73.52
Bus	157	64.15	74.15	61.34	61.25	67.29	59.32	58.48
Train	8	83.28	75.84	80.46	76.53	82.59	73.28	67.83
Bicycle	48	79.22	84.48	61.34	74.32	64.12	71.57	74.56
IPT	126	79.23	48.35	58.86	64.76	58.81	67.36	67.18

Contd...

		AREA SURVEYED - SUNDER NAGAR						
Car	47	86.47	59.00	59.00	72.33	58.37	72.33	90.67
Motorised Two Wheeler	86	79.83	49.50	68.33	64.05	16.69	63.00	84.03
Bus	98	56.07	76.62	63.82	47.88	20.30	44.92	45.81
Train	3	76.42	63.12	64.00	71.00	29.86	69.24	68.06
Bicycle	67	56.12	98.25	43.60	64.75	21.80	47.62	51.38
IPT	108	79.00	34.30	63.00	74.00	17.00	81.00	71.30
		AREA SURVEYED - RAJENDRA NAGAR						
Car	33	76.43	61.46	68.13	79.92	74.27	84.39	86.33
Motorised Two Wheeler	39	81.34	62.30	69.29	69.16	54.15	64.38	70.23
Bus	72	56.10	73.80	53.98	53.87	59.63	43.36	56.49
Train	4	83.27	54.78	67.33	71.20	79.23	67.04	66.13
Bicycle	59	57.28	91.73	52.05	65.53	58.17	47.29	64.30
IPT	112	78.17	45.17	61.19	60.19	62.34	69.16	71.35
		AREA SURVEYED - CONNAUGHT PLACE						
Car	52	76.00	41.31	73.25	79.14	63.47	86.34	81.24
Motorised Two Wheeler	74	77.27	57.30	64.79	76.24	56.15	67.12	74.32
Bus	103	65.16	76.15	63.14	63.35	68.19	61.32	59.38
Train	13	84.18	78.34	81.46	78.93	84.99	75.98	69.13
Bicycle	36	79.22	84.98	61.74	76.32	66.32	73.67	75.26
IPT	79	76.53	43.16	60.42	59.16	61.16	65.73	72.43

Contd...

		AREA SURVEYED - ROHINI+PATEL NAGAR+SUNDER NAGAR + RAJENDRA NAGAR + CONNAUGHT PLACE (Total Sample)						
Car	206	79.55	59.88	69.15	79.69	69.24	85.48	87.45
Motorised Two Wheeler	359	79.86	59.84	67.26	73.45	51.28	67.38	73.80
Bus	545	59.29	74.34	58.77	57.09	59.35	53.03	56.49
Train	33	81.44	59.29	68.34	71.38	69.14	69.29	67.32
Bicycle	267	73.88	86.27	59.16	73.29	57.40	67.06	71.14
IPT	492	79.04	49.32	61.48	65.64	59.06	69.01	69.35

* ATTRIBUTE NUMBERS :
(1.Travel time 2. Cost of travel 3. Distance of travel 4. Reliability of transport 5. Safety during travel 6. Comfort in travel 7. Convenience in travel)

6.8 Attitude Measure

Table 6.4 shows the major economic indicators of those amongst the sample population, who have expressed opinion on levels of satisfaction for different modes. Most of them are regular or occasional users of respective modes. The tabulated data give good indication regarding socio-economic characteristics of those who have used these modes for some purpose or other, and of others who have expressed opinion in respect of same modes.

Analysis of attitude is the next step. Since the importance values for different modes are varied, the attitude values in respect of each would be different. Homogeneity of population is necessary for a meaningful analysis. One desirable way of ensuring homogeneity of population to be considered for such analysis in the attitude studies is to consider one trip purpose [133]. Work trips have been considered in this study as they form bulk of trips in the Delhi city and also contribute maximum to peak hour traffic. Attitude towards different modes are expressed in terms of judgment values. The judgment values for each mode and attribute have been worked out for the work trips by cross multiplying the importance factor for attribute and level of satisfaction value given for mode by the method indicated in section 6.6. These values are herein after called 'attitude values' for further discussions. All results have been reduced to values on a 100 point scale and tabulated in Table 6.5. These are given in 6 parts, one for Rohini, one for Patel Nagar, one for Sunder Nagar, one for Rajendra Nagar, one for Connaught Place and sixth for full sample. An ANOVA test conducted showed that there is no significant difference between the mean attitude values arrived at for different areas for each mode. Differences in attitude values for Car, Motorised Two wheeler, Bus and Train from different areas are not significant at 0.05 level of significance and for bicycle the difference is not significant at 0.01 level of significance.

Table 6.6 shows the attitude values for different modes for different income groups for the total sample. F-test analysis done on the mean attitude values for different income groups of same modes has indicated that they are not different at 0.05 level of significance for bus and train, and at 0.01 level of significance for motorised two wheeler, bicycle and Intermediate Public Transport (IPT). For car, samples are only from two HIG groups and there is hardly any difference between their means. Hence, for the purpose of general discussion and trend analysis, the samples have been grouped together and studied. For the purpose of detailed analysis and modelling work, they are dealt with at more disaggregated level. The analysis is done first to see what factors (Socio-economic or trip characteristics) influence the attitudinal value.

TABLE 6.4 BASIC CHARACTERISTICS OF SELECTED COMMUTERS WHO EXPRESSED VIEWS ON MODAL ATTRIBUTES, AND THEIR BEHAVIOUR ON AVAILING VARIOUS MODES

Name of Characteristics	Mean Characteristic Values for those who have expressed opinion on				
	Car	Motorised Two Wheeler	Bus	Train	Bicycle
Users of Respective Modes					
Family income (Rs.)	7641	4249	3091	3704	1432
Family size Index*	7.39	7.98	7.67	7.13	8.78
Vehicle Ownership					
Car-Numbers	1.41	0.29	0.08	0.00	0.00
Motorised two wheeler Numbers	0.74	2.12	0.23	0.13	0.18
Bicycle-Numbers	0.59	0.86	0.56	0.38	1.12
Distance to work (km)	9.18	14.54	14.20	14.89	4.16
Distance to Railway Station (Km.)	1.26	2.18	1.98	1.10	2.13
Expense on Transport per month (Rs.)	906	578	291	229	68
Non-Users of Respective Modes					
Family income (Rs.)	4691	4854	3703	3148	3180
Family size Index*	6.92	7.68	7.64	8.33	7.69
Vehicle Ownership					
Car-Numbers	0.69	0.33	0.21	0.16	0.18
Motorised two wheeler Numbers	0.79	0.98	0.58	0.59	0.38
Bicycle-Numbers	0.39	0.56	0.49	0.45	0.92

Contd...

Contd.. Table 6.4

Name of Characteristics	Mean Characteristic Values for those who have expressed opinion on				
	Car	Motorised Two Wheeler	Bus	Train	Bicycle
Distance to work (km)	9.86	9.95	9.89	8.15	7.84
Distance to Railway Station (km)	1.84	1.94	1.68	1.10	1.96
Expense on Transport per month (Rs.)	661	461	519	296	239

Source : Survey data, 1995 AD.
* See Section 6.9 for definition

TABLE 6.5 ATTITUDE (JUDGMENT) VALUES FOR DIFFERENT MODES FOR DIFFERENT AREAS AND FOR AGGREGATED SAMPLES

Mode	Sample Size	Attribute Wise Attitude Value							Attitude Value for mode (out of 100) C_k^i
		1	2	3	4	5	6	7	
AREA SURVEYED - ROHINI									
Car	38	21.38	17.19	6.48	8.17	9.29	13.85	9.06	85.42
Motorised two Wheeler	67	23.42	18.29	4.92	6.19	7.41	10.26	5.96	76.45
Bus	115	14.48	20.89	3.91	4.58	8.76	7.13	4.96	64.81
Train	5	19.69	16.71	5.61	5.98	10.96	8.79	5.06	74.27
Bicycle	57	17.97	22.64	2.21	6.35	8.83	6.37	6.53	69.33
IPT	67	20.43	16.89	4.31	5.33	6.73	10.71	7.19	71.59

Contd..

Contd.. Table 6.5

Mode	Sample Size	Attribute Wise Attitude Value 1	2	3	4	5	6	7	Attitude Value for mode (out of 100) C_k^i
		AREA SURVEYED - PATEL NAGAR							
Car	36	29.10	15.12	5.46	7.13	9.36	10.58	12.51	89.26
Motorised two Wheeler	93	29.65	17.09	6.06	5.53	5.96	7.73	7.13	79.15
Bus	157	25.63	20.22	4.86	5.38	7.29	6.49	5.68	75.55
Train	8	25.19	21.93	4.89	8.04	8.11	8.35	7.64	84.15
Bicycle	48	28.74	20.53	5.74	6.09	7.15	7.46	7.08	82.79
IPT	126	29.04	16.13	5.43	5.15	6.58	7.71	6.73	75.87
		AREA SURVEYED - SUNDER NAGAR							
Car	47	28.12	16.35	5.06	8.04	1.39	8.36	14.19	81.51
Motorised two Wheeler	86	25.60	16.36	4.98	7.32	1.29	10.68	10.13	76.36
Bus	98	16.14	13.29	3.56	5.37	12.29	5.14	5.04	60.83
Train	3	20.81	11.06	5.97	5.24	15.65	6.51	6.95	72.19
Bicycle	67	21.08	18.69	5.61	6.63	11.17	6.38	7.19	76.75
IPT	108	28.30	13.93	8.93	7.97	0.49	13.97	6.15	79.74
		AREA SURVEYED - RAJENDRA NAGAR							
Car	33	21.20	17.15	6.43	8.12	9.12	13.80	9.00	84.82
Motorised two Wheeler	39	23.12	18.29	4.88	6.16	7.38	10.21	5.96	76.00

Contd...

Bus	72	14.46	10.85	6.95	8.57	8.76	7.12	7.96	64.67
Train	4	19.69	16.71	5.64	5.97	10.96	8.79	6.53	74.29
Bicycle	59	17.96	17.61	7.21	6.35	8.83	6.34	4.96	69.26
IPT	112	20.48	16.88	4.31	5.33	6.73	10.71	7.18	71.62
AREA SURVEYED - CONNAUGHT PLACE									
Car	52	29.10	15.10	5.43	7.08	9.26	10.58	12.51	89.06
Motorised two Wheeler	74	29.51	17.04	6.02	5.42	5.88	7.60	7.12	78.59
Bus	103	25.50	20.18	4.86	5.29	7.19	6.45	5.58	75.05
Train	13	25.10	21.88	4.85	8.00	7.95	8.29	7.60	83.67
Bicycle	36	28.70	20.48	5.70	6.04	7.13	7.41	7.03	82.49
IPT	79	28.98	15.97	5.39	5.06	6.49	7.65	6.69	76.23
OVERALL - FULL SAMPLE									
Car	206	24.30	16.61	6.16	7.93	8.71	12.73	10.21	86.65
Motorised two Wheeler	359	26.98	17.36	5.53	5.96	5.81	8.88	7.07	77.59
Bus	545	19.30	20.89	4.39	5.09	7.19	6.51	5.36	68.73
Train	33	20.56	18.43	5.69	5.99	9.27	8.16	6.79	74.89
Bicycle	267	24.39	22.24	4.64	6.25	6.76	6.97	6.43	77.68
IPT	492	27.19	16.15	5.32	5.27	6.43	8.56	6.83	75.75

* ATTRIBUTE NUMBERS :

(1.Travel time 2. Cost of travel 3. Distance of travel 4. Reliability of transport 5. Safety during travel 6. Comfort in travel 7. Convenience in travel)

TABLE 6.6 MODE WISE ATTRIBUTE VALUES STRATIFIED ON INCOME BASIS

Income Based Population Group	Individual Attitude Value $(0.01xP_j^i * A_j^i(k))$ for Attributes*							Total Attitude value (out of 100) C_k^i
	1	2	3	4	5	6	7	
For Car								
HIG - I	24.8	16.7	7.9	7.8	8.2	12.3	11.2	88.90
HIG - II	25.1	17.4	5.6	8.9	10.1	13.7	10.3	91.10
Overall	24.0	16.2	6.3	7.1	7.3	19.0	10.2	90.10
For Motorised Two Wheeler								
EWS	18.9	15.9	3.8	3.7	10.4	9.7	4.2	66.60
LIG	43.7	15.6	2.7	4.9	4.3	9.9	5.7	86.80
MIG	31.7	15.6	7.6	5.9	5.4	10.7	6.9	83.80
HIG - I	27.1	17.6	5.3	5.9	6.9	8.9	7.3	79.00
HIG - II	22.7	18.7	5.7	6.7	5.6	8.1	7.6	75.10
Overall	28.2	16.3	5.7	5.7	6.4	9.7	6.3	78.30
For Bus								
EWS	15.3	14.8	3.6	4.1	5.3	5.4	4.9	53.40
LIG	22.5	11.4	4.4	4.8	5.8	6.2	5.5	60.60
MIG	18.9	10.4	4.6	5.1	6.7	7.9	6.1	59.70
HIG - I	19.7	9.3	4.5	4.7	8.3	5.8	5.0	57.30
HIG - II	18.6	11.2	4.3	5.4	7.3	5.8	5.1	57.70
Overall	19.1	10.8	4.5	5.1	6.7	6.4	5.2	57.80

Contd..

Contd.. Table 6.6

Income Based Population Group	Individual Attitude Value ($0.01 x P_j^i * A_j^i(k)$) for Attributes*							Total Attitude value (out of 100) C_k^i
	1	2	3	4	5	6	7	
For Train								
EWS	20.9	19.1	5.1	3.9	7.3	10.7	6.3	73.30
LIG	23.4	16.9	4.6	4.3	12.9	7.3	5.7	75.10
MIG	16.3	19.3	8.2	5.7	7.5	10.9	7.8	75.70
HIG - I	22.1	17.2	6.9	10.5	10.9	6.4	5.3	79.30
HIG - II	21.4	20.7	6.4	8.6	8.8	6.4	8.3	80.60
Overall	20.9	18.7	5.9	6.4	9.6	8.5	6.8	76.80
For Bicycle								
EWS	21.9	21.8	4.2	6.3	4.3	6.3	7.9	72.70
LIG	31.4	12.3	4.6	6.1	7.2	8.1	6.7	76.40
MIG	21.3	10.1	6.2	6.1	5.4	8.7	7.3	65.10
HIG - I	24.3	11.6	3.7	5.3	8.2	5.7	5.1	63.90
HIG - II	18.4	10.3	4.3	8.6	6.3	6.1	6.4	60.40
Overall	24.3	12.4	4.7	6.1	6.9	6.9	6.4	67.70
For IPT								
EWS	23.4	16.3	5.6	4.8	6.3	7.1	6.2	69.70
LIG	29.7	17.2	6.3	5.2	6.5	8.4	7.6	80.90
MIG	28.9	16.5	5.3	5.9	6.5	9.8	6.5	79.40
HIG - I	26.9	16.2	5.2	4.8	7.3	8.9	6.7	76.00
HIG - II	25.7	15.8	5.5	5.8	6.2	7.6	6.7	73.30
Overall	27.3	16.2	5.1	5.3	6.7	8.4	6.9	75.90

* ATTRIBUTE NUMBERS :

(1.Travel time 2. Cost of travel 3. Distance of travel 4. Reliability of transport 5. Safety during travel 6. Comfort in travel 7. Convenience in travel)

6.9 Influence of Different Factors on Attitudinal Value

The prime objective of this attitude study, as stated in Chapter 5, is to determine to what extent attitude is influenced by the socio-economic characteristics of individuals and the characteristics of trip and mode. The socio-economic characteristics to be considered are the household size, household income and vehicle ownership. The variation in household size is not very large. Also the travel habits depend on the stage of life the members of household are in and their need to travel. Some studies have been using a family index to represent this [74]. A similar approach has been tried here as follows. Children below 5 years do not travel independently. Those in years 6 to 15 generally go to schools nearby and use walk, bicycle, bus or IPT mode.

Similarly many people above 60 years do not travel for work and hence their travel habits are limited. Taking these into consideration, a family size index (FI) has been worked out in this study with a multiplication factor 0 for number of those in household upto 5 years, 1 for those above 5 years but upto 15 years, and for those above 60 years; and 1.5 for those above 15 but upto 60.

A correlation analysis has been carried out between the attitudinal values and different factors discussed above. Table 6.7 gives a summary of the coefficients of correlation between attitude values for six modes and some socio-economic and travel characteristics. It also gives the range of table values of coefficients of correlation for respective sample sizes.Direct linear correlation at 0.01 level of significance exists only with income and vehicle ownership amongst socio-economic characteristics. Household composition in terms of number of family members or family size index has very low correlation. It may be noted that Israel [79] based on the analysis of London survey data had concluded that the effect of income on trip making, apart from its influence on car ownership levels was small and that "The effects of socio-economic variables are usually non-linear and it is therefore unlikely that they would be of much help as a factor with a fixed number of levels".

TABLE 6.7 CORRELATION BETWEEN ATTITUDE VALUES AND VARIOUS TRAVEL FACTORS

Factors / Attributes	Coefficient of Correlation (r) values in relation to Attitude Values for Different Modes				
	Car	Motorised Two Wheeler	Bus	Train	Bicycle
Family income	0.42	0.26	0.24	-0.18	-0.34
Family size Index	0.07	-0.17	-0.31	0.23	-0.16
Vehicles owned					
Car	0.64	0.09	-0.26	-0.32	-0.23
Motorised Two Wheeler	0.06	0.67	-0.38	-0.15	-0.40
Bicycle	-0.13	-0.12	-0.29	-0.31	0.27
Trip length	-0.07	0.36	0.11	0.25	-0.08
Cost of Trip	0.26	0.29	-0.24	-0.15	-0.09
Distance of Bus Station	-0.08	0.17	0.003	0.07	-0.21
Distance of Railway Station	-0.13	0.30	0.30	-0.39	0.34
Frequency of Bus	0.05	-0.30	-0.30	0.06	-0.36
Frequency of Train	0.23	-0.18	-0.18	0.24	-0.28
Number of Respondents	206	359	545	33	267
Table value of Correlation Factor at 0.05 level of Significance *	0.136	0.104	0.084	0.413	0.12

* Wright [158]

Amongst travel attributes, significant correlation exists between distance to railway station with respect to attitude values for train and bus at 0.05 level of significance. Trip length has some significant correlation only in respect of motorised two wheeler value. Cost of trip in case of private vehicle use and bus use has noticeable correlation. The attitude values for car and motorised two wheeler have significant correlation with respective vehicle ownership levels. Attempts were made to evolve Multiple Linear Regression (MLR) models using data at individual disaggregated level to relate the attitude values on different modes to these variants (Family income, Family size, Vehicle ownership, Trip distance). Statistical inferences in terms of coefficient of determination were satisfactory in a smaller sample size collected during pilot survey, but were poor when carried out for the larger sample. The models gave R^2 and F-Ratio values and the same is given in Table 6.8). An analysis has been done to determine if any discernible trend can be established between attitude values and the population segmented into five groups on the basis of income of respondents (Table 5.9).

An analysis was then made to see how users of different modes view the attributes of modes of their use and other modes.

Table 6.10 gives the sample means of the attitude values on various modes by users of different modes (Blanks indicate either no user or that the user of the mode in that group has not not given opinion for the particular alternative mode).

Amongst (both bus and bicycle user) bicycle is favoured very much followed by train. All LIG (Low income groups) consider bicycle best followed by motorised two wheeler. They value bus lower than train though marginally. The MIG (Middle income groups) consider motorised two wheeler best and train next. HIG (High income groups), as expected, value car as best. In all income groups users of bus value train better than bus. Obviously their choice is governed by other considerations.

TABLE 6.8 STATISTICAL FIT TEST VALUES FOR MLR MODELS TO RELATE ATTITUDE VALUES AND SOCIO-ECONOMIC FACTORS

Mode	Statistical Inferences		
	R^2	Adjusted R^2	F - Ratio
Car	0.124	0.115	0.518
Motorised Two Wheeler	0.098	0.009	1.068
Bus	0.048	0.008	1.333
Train	0.149	0.035	1.276
Bicycle	0.224	0.116	2.082
IPT	0.103	0.048	1.779

Source : Survey data, 1995 AD

TABLE 6.9 MEAN ATTITUDE VALUES (C_k^i) FOR VARIOUS MODES BY DIFFERENT INCOME GROUPS (WORK TRIPS)

	Different Modes					
Income Group	Car	Motorised Two Wheeler	Bus	Train	Bicycle	IPT
Upto Rs. 900 (EWS)	-	-	53.56	62.75	72.27	68.75
Rs. 901 - 2000 (LIG)	-	75.89	59.84	65.37	76.73	69.50
Rs. 2001 - 3000 (MIG)	-	73.85	60.32	65.75	64.96	62.40
Rs. 3001 - 5000 (HIG-I)	78.96	69.23	56.83	69.77	62.45	64.23
Above 5000 (HIG-II)	81.30	64.69	57.78	70.63	59.26	61.39
Overall	80.10	68.30	57.80	66.80	67.0	64.80

TABLE 6.10 ATTITUDE VALUES (C_k^i) FOR VARIOUS MODES OF USE AND NON-USE BY DIFFERENT GROUPS

Income Group	Exclusive Mode users	Vehicle Ownership			*Attitude values for different Modes					
		Car	Motorised Two Wheeler	Bicycle	ACR	ATW	ABS	ATR	ACY	AIPT
EWS	Bus	0.00	0.00	0.48	-	-	55	62	74	61
	Bicycle	0.00	0.00	0.82	-	-	71	64	71	69
LIG	Motorised Two Wheeler	0.00	1.10	0.59	-	80	61	67	79	69
	Bus	0.00	0.06	0.54	-	65	63	66	76	72
	Train	0.00	0.14	0.46	-	-	55	68	63	-
	Bicycle	0.00	0.00	0.18	-	-	63	58	74	78
MIG	Motorised Two Wheeler	0.00	1.06	0.27	-	76	65	-	68	77
	Bus	0.09	0.19	0.47	72	75	64	67	72	68
	Train	0.00	0.12	0.43	-	81	57	66	64	-
	Bicycle	0.00	0.52	1.13	-	52	63	-	59	61
HIG-I	Car	1.14	0.49	0.41	77	73	56	68	55	63
	Motorised Two Wheeler	0.33	1.07	0.34	78	68	59	76	62	68
	Bus	0.05	0.35	0.32	79	73	62	68	65	64
	Train	0.00	0.24	0.31	-	59	56	63	69	71
	IPT	0.00	0.65	0.48	-	56	51	83	-	65

Contd...

Contd.. Table 6.10

Income Group	Exclusive Mode users	Vehicle Ownership			*Attitude values for different Modes					
		Car	Motorised Two Wheeler	Bicycle	ACR	ATW	ABS	ATR	ACY	AIPT
HIG-II	Car	1.19	0.64	0.74	<u>78</u>	65	49	-	49	58
	Motorised Two Wheeler	0.32	1.28	0.72	76	<u>66</u>	61	69	74	56
	Bus	0.13	0.45	0.63	82	63	<u>64</u>	73	69	68
	Train	0.00	0.43	0.65	-	69	52	<u>58</u>	76	-

* Sample size between 12 and 15.

Note: Underlining indicates value for the mode of use by the group.
ACR = Attitude value for Car, ATW = Attitude Value for Motorised two wheeler, ABS = Attitude value for Bus, ATR = Attitude value for train, ACY = Attitude value for Bicycle, AIPT = Attitude value for Intermediate public transport.

In order to establish a relationship between the attitude value and travel characteristics some form of analysis other than MLR is called for. The alternative method could be to determine the attitude value by computing values (P_j^i, A_j^i (k)) for each of the seven attributes and summing them up. Such computation can be done in respect of those attributes which can be related to any measurable characteristics. Except for reliability and safety, such analysis is possible for public transport modes. For these two attributes the mean value over sample population for respective modes can be used by suitably stratifying the samples. This can preferably be done on income basis. The attribute values for time of travel can be related to time taken by the respondent for making the trip. Cost attribute can be related to the out-of-pocket expenses people defray for trips. Comfort attribute for public transport can be related to travelling conditions in respect of the mode by use of surrogate variables. As the comfort also depends on distance over which one travels in a particular condition, an attempt was made using the product of a surrogate variable (i.e., 1 for seated, 2 for partly seated or standing comfortably, and 3 for crush load condition) and trip distance. Convenience in accessing public transport can be related to walking distance (access distance) to bus stop or railway station as the case may be. The value for travel distance can be directly related to trip length.

It is difficult to relate 'comfort in travel', 'convenience in travel', 'reliability of transport', and 'safety during travel' to any measurable quantity for computing attitude values for private vehicles. In those cases, it can be done by category grouping using mean attitude values (for respective travel attributes) for such homogeneous groups as is done for the attitude values for 'reliability of transport' and 'safety during travel' for public transport modes. For travel time, cost of travel and distance of travel, the values can be computed based on principles described earlier for public transport modes.

It may be possible to work out $(0.01 * P_J^i * A_j^i(k))$ values based on certain measurable parameter like travel time (total journey), travel cost etc. If models could be built for computing attitude values for each of the seven travel attributes, then they could be used to work out C_k^i values for each mode $(0.01 * \Sigma P_J^i * A_j^i(k))$.

The best form of this model is found to be

$$Y_j = \alpha . x_j^{B} \tag{6.2}$$

Where,

Y_j, stands for $(0.01 * P_j^i * A_j^i(k))$ travel attribute j of mode k,

X_j, stands for the measurable parameter for j,

α and β are constants to be evaluated,

The various models built are given in Table 6.11. In the Table,

Y_t = The attitude value $(0.01 * P_j^i * A_j^i(k))$ for travel time.

Y_c = The attitude value for cost of travel.

Y_{cm} = The attitude value for comfort in travel.

Y_{cn} = The attitude value for convenience in travel.

Y_{dist} = The attitude value for distance of travel.

X_I = Actual time of travel for the trip in minutes.

X_c = Cost of travel for the trip in rupees.

X_{cm} = 1 for seated, 2 for standing comfortably, and 3 for crush load conditions.

DIST = Trip length in km.

DTRS = Distance to Railway station in km.

DTBS = Distance to Bus stop in km.

The equations derived for different attributes and model parameters are given in Table 6.11.

It will be noted that the 'r' value for these relationships vary from 0.273 to 0.728. It may be felt that the relationship with low 'r' value is too weak to be accepted. According to Kerlinger [87], like other statistics 'r' must be tested for statistical significance. According to Kerlinger, it is inappropriate, to bother with 'r' s, 0.10, 0.20 and 0.30. With r's of about 0.10 or less, this point is well taken, but with 'r' s of about 0.30, it is not. If an r of 0.30 is statistically significant, it may help the investigator later to find an important relation, if he can clear up, say his measurement problems.

TABLE 6.11 REGRESSION MODELS DEVELOPED FOR ATTRIBUTE WISE ATTITUDE VALUES FOR DIFFERENT MODES

Travel Attribute	Mode	Model form	R-value for model	Sample Size
Travel Time	Car Motorised	$Y_t = 26.546 * X_t^{(-0.006)}$	0.297	60
	Two Wheeler	$Y_t = 27.737 * X_t^{(-0.074)}$	0.345	147
	Bus	$Y_t = 17.366 * X_t^{(-0.024)}$	0.363	248
	Train	$Y_t = 24.395 * X_t^{(-0.113)}$	0.276	8
	Bicycle	$Y_t = 19.868 * X_t^{(-0.078)}$	0.390	87
Cost of Travel	Car Motorised	$Y_c = 27.701 * X_c^{(-0.518)}$	0.728	53
	Two Wheeler	$Y_c = 10.879 * X_c^{(-0.312)}$	0.514	96
	Bus	$Y_c = 9.634 * X_c^{(-0.498)}$	0.432	216
	Train	$Y_c = 10.485 * X_c^{(-0.746)}$	0.482	7
Comfort in Travel	Bus	$Y_{cm}=22.668*(X_{cm}*DTBS)^{-0.506}$	0.613	269
	Train	$Y_{cm}=38.919*(X_{cm}*DTRS)^{-0.690}$	0.717	9
Convenience in Travel	Bus	$Y_{cn} = 3.786 * (DTBS)^{-0.047}$	0.368	232
	Train	$Y_{cn} = 5.443 * (DTRS)^{-0.011}$	0.273	7
Distance of Travel	Car Motorised	$Y_{DIST}=8.541 * (DIST)^{-0.112}$	0.376	48
	Two Wheeler	$Y_{DIST}=7.458 * (DIST)^{-0.156}$	0.394	148
	Bus	$Y_{DIST}=6.239 * (DIST)^{-0.117}$	0.345	229
	Train	$Y_{DIST}=8.937 * (DIST)^{-0.132}$	0.327	9
	Bicycle	$Y_{DIST}=4.367 * (DIST)^{-0.023}$	0.410	69

That is, he may, by dropping a statistically significant r of 0.30, be losing a valuable lead for theory and subsequent research. In the light of this and since the relationships derived are logical ones which can be used for quantifying the attribute wise attitude values for different modes in relative terms these models have been used in this study. With a larger size of data to be collected when the study is extended as part of actual planning exercise, more reliable relationship can be obtained. Synthetic attitude values for the study can be determined using such models in absence of attitudinal data from surveys.

Attitude values for other attributes (like reliability, comfort, convenience and safety) can be taken from Table 6.6. The results could be used directly for computing C_k^i. Here Table 6.12 is constructed for the five attributes in the case under study extracted from values in Table 6.6.

TABLE 6.12 ATTRIBUTE WISE VALUES FOR DIFFERENT ATTRIBUTES FOR VARIOUS MODES FOR USE IN COMPUTATION OF ATTITUDE VALUES

Mode	Mean Attitude Values for Attributes			
	Reliability	Safety	Comfort	Convenience
Car	7.1	7.3	19.0	10.2
Motorised Two Wheeler	5.7	6.4	9.7	6.3
Bus	5.1	6.7	- to be Computed -	
Train	6.4	9.6	- to be Computed -	
Bicycle	6.1	6.9	6.9	6.4
IPT	5.3	6.7	8.4	6.9

Source : Table 6.6

6.10 Value of Travel Time by Opinion Survey and Willingness to Pay Approach

Travel time is a critical factor in forecasting the use of transportation facilities and provides the primary means for estimating transportation benefits. As such, the value of travel time is the major benefits in most of the economic analysis justifying the transportation projects. Study on road user's value of travel time by willingness to pay approach is of very limited nature in India. As the road user's themselves evaluate their value of travel time under different conditions, it can be taken as one of the accurate methods of valuing the travel time.

The main three methodologies for monetary evaluation of passenger's travel time are :

(i) Average wage rate approach.

(ii) Willingness to pay approach.

(iii) Revealed preference approach.

  (a) Choice of mode of travel.

  (b) Choice of route within a mode.

  (c) Choice of destination of trip or trip frequency.

  (d) Choice of location of home.

Willingness to pay approach is a better method, wherein the travellers themselves evaluate their travel time by stating the price they would like to pay for reduced travel time of different durations. The most scientific approach in determining the value of travel time is studying the choice of people actually make when faced with a number of alternatives involving different time and cost parameters for the journey. This method relies on the principle that the results will reflect the preference of people and therefore will be nearer to reality.

Hauer and Greenough [77] tried a novel method of estimating the value of travel time by making offer of a certain amount of cash in return for the loss of a specified amount of time. Kadiyali et al [90], investigated the quantification of travel time under Indian conditions by opinion survey methodology. In the study, the value of travel time of inter-city travellers was found by average wage rate approach and willingness to pay approach. Chari [20] tried the revealed preference approach through a modal split model employing the disaggregated stochastic behavioural model.

A typical data form used in the present study is described in Appendix 7. The data was collected with the help of the opinion survey questionnaire by adopting home interview technique.

Where,

Y_{TW} = Travel time in Rs./hour for motorised two wheeler user.

Y_{CR} = Travel time in Rs./hour for car user.

Y_{BS} = Travel time in Rs./hour for Bus user.

Y_{TR} = Travel time in Rs./hour for train user.

X_1 = Age in years.

X_2 = Monthly income in Rs.

X_3 = Monthly expenditure on transport for work trips in Rs.

X_4 = Travel time in minutes.

Table 6.13 shows the summarised details of regression models developed for travel time values for different modes including sample size and r value for the model.

TABLE 6.13 REGRESSION MODELS DEVELOPED FOR TRAVEL TIME VALUES FOR DIFFERENT MODES

Mode	Model form	r-Value for Model	Sample Size
Car	$Y_{CR} = 1.57+0.48X_1+0.0018X_2-0.00022X_3-0.037X_4$	0.94	106
Motorised Two Wheeler	$Y_{TW} = -2.29+0.20X_1-0.00035X_2+0.016X_3-0.078X_4$	0.97	159
Bus	$Y_{BS} = -1.80+0.27X_1+0.00036X_2+0.000061X_3-0.011X_4$	0.98	230
Train	$Y_{TR} = -1.39+0.27X_1+0.00045X_2-0.00013X_3-0.013X_4$	0.98	33

6.11 Summary

The user's attitudes towards their choice of travel mode for work purpose have been analysed and discussed. As a result major conclusions drawn are described below :

i) Attitudes of people towards attributes of various modes do not vary significantly with respect to locations in the city. However, they vary to a large extent on the level-of-service available.

ii) Broadly, describing people attach different values of importance to various travel attributes depending upon the purpose of trip. All income groups consider, travel time most important for work, education and entertainment trips. Cost in travel generally takes second place in most of the cases. Comfort and safety travel generally takes third place.

iii) Car travel derives highest level of satisfaction with respect to comfort in travel, motorised two wheeler and train derive the highest level of satisfaction with respect to travel time, Bus and bicycle derive the highest level of satisfaction with respect to cost of travel.

iv) Overall attitude value is a sum of total of product of importance and level of satisfaction in each attribute. The attitude values thus computed for work trips are poorly correlated with the socio-economic characteristics of the users except for vehicle ownership. Overall attitude values are better correlated with the characteristics of the modes like distance of travel, frequency of services, accessibility and level of comfort in travel.

v) Car and motorised two wheelers are rated high by all with respect to attitude values whether they use them or not. Overall attitude value for bicycle is rated high by the economically weaker sections. Between train and bus, train is prefered by majority even though only a small proportion choose train for travel.

vi) Attitude values can be computed using mathematical models for attributes on, comfort in travel, convenience in travel (both for public transport only), travel time, cost of travel and distance of travel. For other travel attributes, they have to be based on sample means.

Travel time, comfort in travel, safety in travel and convenience in travel need to be improved on public transport if more private vehicle users are to be drawn to it. However, cost has to be low enough in comparison with private modes. It has become possible to measure attributes for each mode through opinion expressed by commuters. This helps to probe into the behaviour of people in choosing various modes for different travel purposes.

CHAPTER 7

INFLUENCE OF COMMUTER'S ATTITUDE AND CHOICE OF MODE FOR WORK TRIPS

7.1 Background

Attitude values expressed could be used to examine whether these values have any relevance on the mode the commuter selects for his actual use. This can be tested by one of the following approaches :

(i) Compare the overall attitude values of an individual for different modes based on his stated preferences and examine whether the mode of his normal travel is the same as the one for which his attitude value is the highest.

(ii) Aggregate the sample and divide it into different segments so that each set would form a homogeneous group. Develop Multiple Linear Regression (MLR) models, using proportion of trips by each mode by the selected group as dependent variable and determinants like family income, vehicle ownership, family size, distance of travel, availability of mode and attitude values for the mode chosen and other modes as independent variables.

(iii) Developing disaggregate utility models using data at individual level. Multi-Nomial Logit (MNL) models could be built using attitude values for different modes as additional variables. The model can be applied to a selected area where Mass Rapid Transit System (MRTS) is likely to be introduced.

7.2 Straight Comparison of Attitude and Choice of Mode

All respondents during the survey have given their opinion on level of satisfaction derived for the modes of their choice. Many for one additional mode, but only a few for 3 modes. An attempt is made to examine in the cases where the level of satisfaction scores are available for more than one mode, whether the attitude value has any direct bearing on choice of mode. It is done by examining whether the mode for which the (C_k^i) is found maximum is also the mode of his choice in real-world. 224 sets of data have been compared. Out of these, there is agreement between the preferred mode and mode of choice in 108 cases indicating 48.2% matching. Most of such respondents are either car or motorised two wheeler users.

A second comparison is made by using the Maxi-Max principle. In this, the travel attribute considered most important for the trip purpose by each individual is first determined. then the mode which gives the individual maximum satisfaction in respect of that attribute is selected as the most satisfying mode. It is then checked to see if the mode chosen by the individual is the same as the most satisfying mode. Such a comparison moade amongst the sample population showed that 78.4% of the people choose the mode which gives maximum satisfaction in the most important travel attribute for them.

These two discrete analysis findings indicate that the attitude value has significant influence on the commuter's choice of mode for work trips.

7.3 Multiple Linear Regression Models

Though MLR model is not considered by many as a reliable model for modal split analysis, the model has still certain basic advantages, due to its simplicity and ease with which variables can be added on or deleted during model calibration. The determinants which normally are belived to influence choice of mode are income, vehicle ownership, trips length and the level of service. The last one can be represented by the attitude values. Meyer et al [112] had used the following form,

$$\text{Prob}_B = [a(\text{mean}) + b(\text{cost difference}) + c(\text{time difference}) + d(\text{riders})] * \text{avail} + e \quad (7.1)$$

Where,

Prob_B	= Proportion of bus trips.
Mean	= Mean response to an experimental task (represents a measure of attitude).
Cost difference	= Estimate of actual cost (Car-bus) difference.
Time difference	= Estimate of actual time (Car-bus) difference.
riders	= Number of riders who share mode for work trip.
avail	= 0 if no bus available, 1 if otherwise.
e	= Error term.

In Indian situation, proportions of trips for different modes have to be derived. There are number of modes operating from bicycle to Car. Two public transit modes are also availabe in Delhi. While bus is available in all parts of the city within walking distance. A ring railway system without proper road based network and support exists but is rather under-utilized.

In order to develop a MLR model, segmenting of the sample population was done into 6 groups each comprising the respondents who have given opinion on a particular mode, whether the respondent uses it or not. Each of these groups has been subdivided into five income groups. Thus, a total of 30 sub groups are formed. Basic structure of MLR equations derived is of the following form :

$$P_K = a + b * FINC + c * CAR + d * TW + e * CY + f * DT + g^* DTRS + h * C_m^i + j * \frac{\sum_{i=1}^{n} C_k^i}{(n-1)} \qquad (7.2)$$

Where,

P_K = Proportion of commuters choosing mode K.

FINC = Family income for group in region.

CAR = Number of car owned per Household.

TW = Number of Motorised Two Wheeler owned per household.

CY = Number of bicycle owned per household.

DT = Trip length in km.

DTRS = Distance to nearest suburban railway or ring railway station in km.

C_k^i = Attitude value for mode K.

C_m^i = Attitude values for any mode m excluding the mode K (i.e., k = i ..... n, m $\neq$ K).

a = Constant.

b,c,d,e,f,g,h,j = Model coefficients to be calibrated.

The model coefficients and R^2 values are given in Table 7.1. The total number of records considered are 359 which have been divided into 22 homogeneous groups based on income strata and primary mode of use. The models have been built by step wise approach. The models have yielded good R^2 values except in 3 cases. One difficulty in using the model is when all the proportions (P_K's) derived independently, are summed up, the total for a target group may not necessarily result in 1. In order to overcome this complexity and to make use of the attitude values more effective, models were tried using L_n (P_k/P_b) as dependent variable [119].

TABLE 7.1 MODEL PARAMETERS OF MULTIPLE LINEAR REGRESSION MODELS USING ATTITUDE VALUES FOR MODAL SPLIT

Mode	Constant (Intercept) a	FINC b	CAR c	TW d	CY e	DT f	DTRS g	C_k^i h	$\sum_{k=1}^{n} \frac{C_m^i}{n-1}$ j	R^2	Sample size
Car	0.129	-0.00002	-0.002	0.780	-0.002	0.051	0.008	-0.0013	-0.003	0.934	48
Motorised Two wheeler	-1.390	-0.00003	-0.080	-0.302	0.784	0.006	0.00007	-0.0079	0.038	0.873	83
Bus	-1.400	-0.00008	-0.081	-0.389	-0.482	0.291	-0.013	-0.0060	0.026	0.732	156
Train	1.120	-0.00002	-1.460	-0.073	-0.056	-0.206	0.005	0.0003	-0.024	0.543	7
Bicycle	1.024	-0.00005	-0.079	-0.176	-0.328	0.021	0.016	-0.0028	-0.0028	0.483	39
IPT	0.903	-0.000006	-0.013	0.048	-0.038	0.006	-0.007	0.0036	-0.016	0.376	18

The selected form of model is :

$$L_n (P_K/P_b) = a+b*FINC_k + c*DIST + d * \frac{C_k^i}{C_b^i} + e * AVAIL_k + f * AMV \tag{7.3}$$

Where

P_k = Proportion of those using mode k.

P_b = Proportion of those using Bus.

(Bus is taken as the basic mode accessible to all and the mode for which almost all respondents during the survey have expressed attitude values).

$FINC_K$ = Mean family income of Household in Rupees.

DIST = Mean trip length per Household in Km.

C_k^i = Attitude value for mode K for the group i.

C_b^i = Attitude value for bus for the group i.

$AVAIL_k$ = Availability factor for mode K as compared to Bus.

[$AVAIL_k$= DTBS (Distance to Bus stop in km) * availability of the mode K on Household basis for the group considered].

[For Train, AVAIL is taken as DTBS/DTRS, where DTRS is distance to railway station in km.]

AMV = Average number of motorised vehicles owned by a Household.

Step wise regression runs were made and the results of statistical test obtained are presented in Table 7.2. Model parameters derived are given in Table 7.3. All these models have good R^2 values. Further, the values obtained from all the models when added would lead to a total value of 1. The correlation between dependent variable and the variable representing attitude value has been found high for motorised two wheeler, train and IPT related models.

TABLE 7.2 MODELS FOR THE VARIOUS COMBINATION OF MODES

Mode	Sample size	R-Squared value	Corrected R^2	Standard error
Car/Bus	48	0.819	0.721	0.574
Motorised Two Wheeler / Bus	83	0.912	0.874	0.386
Train/Bus	7	0.743	0.613	0.693
Bicycle/Bus	39	0.923	0.874	0.329
IPT/Bus	18	0.694	0.432	0.487

For a total Bus sample of 156.

TABLE 7.3 MODEL PARAMETERS FOR DIFFERENT COMBINATIONS, MLR MODELS USING ATTITUDE VALUE RATIOS

Model Combination	Intercept value	Coefficients for Variables FINC	DIST	$\frac{C_k^i}{C_b^i}$	$AVAIL_k$	AMV
	a	b	c	d	e	f
Car/Bus	-1.674	0.000186	-0.16200	0.2670	8.645	0.632
Motorised two wheeler/Bus	-5.468	-0.000025	-0.00142	3.0030	5.986	0.967
Train/Bus	-1.743	-0.00017	-0.30400	1.2340	5.123	-0.116
Bicycle/Bus	-2.632	-0.00028	0.08310	-0.4806	19.487	0.304
IPT/Bus	-3.584	0.000128	-0.24900	1.1980	47.843	0.809

The t-statistic for the model coefficient (d) of attitude related variable for these are 3.003, 1.234 and 1.198 respectively indicating their level of significance of 0.01 and 0.05 respectively. This reflects the extent of influence of attitude on choice of these three modes, motorised two wheeler, train and IPT.

7.4 Multi-Nomial Logit Model

7.4.1 Modelling process and basic issues

The model is developed using a ULOG programme based on logic provided in the ULOGIT part of UTPS package (developed by U.S. Department of Transportation) and further adopted for use on a PC by Vijayakumar [154]. The programme is capable of giving over 20 output files, of which the main ones used for application and testing of model in this study are : Statistical summary of variables, correlation matrix of independent variables, Final coefficient values, standard errors and t - ratios, statistical fit in terms of Log likelihood and pseudo R^2, observed and estimated values of totals for each alternative. Compound Disutility plots for probability of selecting various modes, table of elasticities, probabilities at average values of variables.

The statistical summary helps in finding the means, standard deviation, and the spread of different variables. Correlation matrix gives a general idea about the internal relationship between variables and helps in eliminating those variables which are closely interrelated. Final coefficients and their t-ratios indicate the significance of different variables in influencing choice and their relative importance.

The calibration is done using Maximum likelihood technique, adopting an interative process [14]. The Log likelihood and pseudo R^2 values indicate statistical fit of the model. Negative pseudo R^2 value is taken to indicate inadequacy of data. The observed and estimated values of total indicate how the model is able to test the convergence of data and thereby helps to understand the acceptability of the model. The compound disutility plots give the logit curve representing the choice as per model along with the plots of observed values. The more the number of observed points lie close to the curve, more would be the acceptability of the model. The table of elasticities provide an idea on how modal choice would undergo changes in respect of patronage of the same mode or patronage of competing modes when characteristics of variables in respect of that mode are changed. This is a very important output which helps to assess changes in choice when there are changes in level-of-service. The logit form of the model built has been used to determine to what extent the attitude in respect of a mode influences individual's choice of the mode taking into account the actual time of travel and cost of trip.

7.4.2. Application to determine relative influence of major attributes

The data required for developing a model are the user's travel time by the mode travel cost and attitude towards the user mode which is computed from his expressed opinion (C_k^i). For other modes travel time and travel cost details are computed making use of the information given by him regarding origin and destination of the trips. With respect to attitude values, (C_k^i) computed based on his opinion, if available, is used. Otherwise (C_k^i) is assumed to be the mean of the attitude values for the group for the respective mode.

7.4.3 Development of model

In the disaggregate model development, for each individual concerned the values of different variables for all modes considered can be subjective values as ascertained by respondent or objective values as computed based on the trip length, accessibility, prevalent speeds, delays, fares and costs. In this study, it is proposed to use the values given by respondent for his mode of choice and objective (computed) values for the alternative modes.

Walk time is computed at 4.5 kmph and in-vehicle travel time at 8 kmph for bicycle, 20 kmph for bus, 25 kmph for motorised two-wheeler and 30 kmph for train and car. Assuming that access trips are all made by walk may not represent the true picture in practice in case of rail trips. Hence, the set of models were derived assuming an access time based on an averaging of access time as reported in the survey depending on accessibility to railway station at either end. Access and walk times have been assumed as 5 minutes for cars and motorised two wheelers, 15 minutes for buses and 20 minutes for train if it is accessible at least at one end and 40 minutes if not accessible at both the ends. The objective functions for cost were computed on the assumption :

Car at 180 paise/km, motorised two-wheeler at 60 paise/km, bus as per bus fare table or [100 + (DT - 2) * 15] paise, and train [150 + (DT-5) *15] paise (here DT = distance in km). Where train is not accessible within 2 km, an extra 100 paise is added for cost of access trip by bus. All train users for work trips are treated as season ticket holders. These are based on actuals, observed from survey.

The sample size for MNL model development has also been kept at a minimum of 60 for each group so that it satisfies the minimum computation need in order that the maximum likelihood estimator is well behaved [107].

Earlier Multi-Nomial Logit (MNL) models developed for, Indian conditions were mostly for NVP (Non vehicle people) and VOP (Vehicle Owning People). While NVP models developed gave good fit and reliability, Developing single model for VOP including Car, motorised two-wheelers, bus, train and bicycle either gave low statistical test values or inadequate convergence when validated for test data. Hence, it was felt that the population have to be divided into more vehicle owning groups and models developed for each group [123, 154].

In this case also, first a VOP model derivation was tried using 180 records of travel of owners of car or motorised two-wheelers or both. The models developed without attitude values gave illogical (negative) coefficients for both time and cost and the estimated values of proportion of users of different modes were highly biased in favour of car and train. The pseudo R^2 values were also highly negative. The addition of attitude value gave pseudo R^2 values of 0.297 when bus and train trips were combined as public transport trips but the coefficients for travel time and travel cost were both negative and illogical. Hence it was decided to split this data into two further groups ie. TWP and COP.

Four sets of models have been developed by disaggregating the sample into 4 groups viz. NVP Non Vehicle owning people (NVP), Bicycle owning people (CYP), Motorised two-wheeler owning people (TWP) with or without bicycle, Car owning people (COP) with or without other vehicles.

7.5 Formulation of MNL Models

7.5.1 Basic form of modal choice model

The Multi-Nomial Logit (MNL) model is based on utility maximisation as per the following form :

$$P_m = \frac{e^{-G_{x(m)}}}{\sum_{j=1}^{n} e^{-G_{x(j)}}} \qquad (7.4)$$

Where,

P_m = The probability of an individual choosing mode m.

$G_{x(m)}$ = Utility function for mode m and x stands for one or more variables contributing to the utility of the mode in making the trip.

$G_{x(j)}$ = Utility function for mode j = 1 to n including m.

n = Number of modes available to the individual to choose.

In this case the function is as follows :

$G_{x(j)}$ = Travel time coefficient * travel time by mode j + travel cost coefficient * travel cost by mode j + attitude value coefficient * combined effect of attitude value of the mode j (i.e. C_k^i) + Bias value for the mode j.

C_k^i is estimated as detailed in section 6.9. As already mentioned, the calibration of the coefficients for different variables and the constants for different modes is done by maximum likelihood method. Acceptabilities of the coefficients are tested through the Log likelihood test and pseudo R^2 values. The test is done by calibrating L(o) and L(θ). Where L(o) = Initial Log likelihood value for estimated coefficient, L(θ) = Final Log likelihood value for estimated coefficient θ standing for vector of coefficients.

The pseudo R^2 value (ρ^2) is given by

$$\rho^2 = 1 - \frac{L(\theta)}{L(o)} \qquad (7.5)$$

The statistical tests used comprise of determining pseudo R^2 (similar to R^2 in multiple Regression Model) and $- 2 \log \lambda$ value for equal probability hypothesis (similar to Chi-square test).

where,

$$- 2 \log \lambda = -2 [L(o) - L(\theta)] \qquad (7.6)$$

The significance of the coefficient for any variables is tested by its t-statistic which should not be less than ± 1.645 for 0.05 level of significance and ± 2.326 for 0.01 level of significance. The formulation of various models are :

(i) NVP without attitude value variable

(ii) NVP with attitude value variable

(iii) CYP without attitude value variable

(iv) CYP with attitude value variable

(v) TWP without attitude value variable

(vi) TWP with attitude value variable (vii) COP without attitude value variable, and

(viii) COP with attitude value variable.

Coefficients for various variables of the models are described in Table 7.4 to Table 7.7.

TABLE 7.4 MODEL COEFFICIENTS FOR NON-VEHICLE OWNING PEOPLE WITH AND WITHOUT ATTITUDE VALUES

Choice Model Parameters	Without Attitude value		With Attitude value	
	Coefficient	t-value	Coefficient	t-value
Travel time coefficient	0.0276	2.46	0.0276	2.46
Travel cost coefficient	-0.0063	-0.73	-0.0063	-0.73
Attitude value coefficient	-	-	0.0018	0.13
Bus bias	-0.8306	-0.88	-0.8734	-0.78
Train bias	-0.1306	-0.19	-0.2630	-0.21
Walk bias	0.0	-	0.0	-
Initial log likelihood				
L(o)	-85.86		-85.60	
Final log likelihood				
L(θ)	-64.86		-60.28	
-2 log λ for equal probability hypothesis	50.64(df=4)		50.65(df=5)	
Pseudo R-square	0.306		0.306	
Adjusted Pseudo R-square	0.257		0.245	

TABLE 7.5 MODEL COEFFICIENTS FOR BICYCLE OWNING PEOPLE WITH AND WITHOUT ATTITUDE VALUES

(Sample Size 76)

Choice Model Parameters	Without Attitude value		With Attitude value	
	Coefficient	t-value	Coefficient	t-value
Travel time coefficient	0.0546	3.54	0.0530	3.39
Travel cost coefficient	-0.0026	-0.43	-0.0039	-0.68
Attitude value coefficient	-	-	-0.021	-1.06
Bus bias	-1.1406	-1.26	0.1456	0.10
Train bias	0.1346	0.14	1.4674	0.96
Bicycle bias	-0.7467	-0.93	0.5672	0.38
Initial log likelihood $L(o)$	-93.70		-93.70	
Final log likelihood $L(\theta)$	-63.64		-63.10	
-2 log λ for equal probability hypothesis	62.21(df=5)		63.28(df=6)	
Pseudo R-square	0.334		0.338	
Adjusted Pseudo R-square	0.276		0.273	

TABLE 7.6 MODEL COEFFICIENTS FOR MOTORISED TWO WHEELER OWNING PEOPLE WITH AND WITHOUT ATTITUDE VALUES

(Sample size 109)

Choice Model Parameters	Without Attitude value		With Attitude value	
	Coefficient	t-value	Coefficient	t-value
Travel time coefficient	0.0618	3.69	0.0583	3.61
Travel cost coefficient	0.0001	0.01	0.0001	0.02
Attitude value coefficient	-	-	-0.0217	-1.46
Motorised two wheeler bias	-0.2163	-1.33	-0.2134	-1.33
Bus bias	-0.9362	-1.97	-1.0286	-2.12
Train bias	-0.2620	-0.45	-0.1978	-0.32
Initial log likelihood L(o)	-97.58		-96.57	
Final log likelihood L(θ)	-137.54		-137.64	
-2 log λ for equal probability hypothesis	79.69(df=5)		81.76(df=6)	
Pseudo R-square	0.298		0.296	
Adjusted Pseudo R-square	0.272		0.273	

TABLE 7.7 MODEL COEFFICIENTS FOR CAR OWNING PEOPLE WITH AND WITHOUT ATTITUDE VALUES

(Sample size 60)

Choice Model Parameters	Without Attitude value		With Attitude value	
	Coefficient	t-value	Coefficient	t-value
Travel time coefficient	0.0276	0.63	0.0190	0.46
Travel cost coefficient	-0.0085	-2.78	0.0001	0.19
Attitude value coefficient	-	-	-0.0732	-2.19
Motorised two wheeler bias	2.6953	3.12	0.1397	0.17
Car bias	14.6059	3.14	0.1976	0.17
Initial log likelihood L(o)	-53.24		-53.24	
Final log likelihood L(θ)	-26.35		-41.69	
-2 log λ for equal probability hypothesis	41.28(df=4)		24.32(df=5)	
Pseudo R-square	0.132		0.243	
Adjusted Pseudo R-square	0.138		0.249	

7.5.2. Model for non-vehicle owning people

Table 7.4 gives the model parameters and statistical test details for the non - vehicle owning people.

For example the model for NVP is described below :

(a) NVP model without 'attitude value' Variable

G(x(Bus)) = 0.0276 * Travel time by bus

-0.0063 * Travel cost by bus -0.8306

G(x(Train))= 0.0276 * Travel time by train

-0.0063 * Travel cost by train -0.1306

G(x(Walk)) = 0.0276 * walk time

(b) NVP model with 'attitude value' variable

G(x(Bus)) = 0.0276 * Travel time by bus

-0.0063 * Travel cost by bus

+0.0018 * Attitude value (Bus)-0.8734

G(x(Train))= 0.0276 * Travel time by train

-0.0063 * Travel cost by train +0.0018

* Attitude value (Train)-0.2630.

G(x(Walk)) = 0.0294 * Walk time

Where,

travel time is expressed in minutes and travel cost is paise.

The coefficients of variables for NVP model indicate how travel time has much higher influence on choice both in terms of magnitude and level of significance. Cost coefficient is low though negative and hence has very low effect.

Level of significance of the model coefficient is much higher in case of time than in case of cost with significance level of 0.02. The other coefficients are not significant. The bus bias is not significant even at 0.20 level. When attitude value is included in the model only bias coefficients undergo some changes. The Value coefficient itself is very low compared to that of other coefficients. The t-statistic for attitude value coefficient is not significant indicating that attitude values are not important in case of non-vehicle owning people.

7.5.3. Model for bicycle owning people

Table 7.5 gives the model parameters and statistical test details for the bicycle owning people. In the case of CYP models cost coefficient is negative and low while time coefficient is positive and logical. The t-ratio for time is highly significant, while the t-ratio for cost coefficient is low and same is the case with bias for train. Between the two, bus bias is more significant when attitude value is not considered.

The negative factors for bus bias and cost indicate shift to bus even with increase in cost. When attitude values are introduced in the model, the change in the cost coefficient is small. Bias values for bus and train change considerably. Attitude coefficient is logical and fairly high. The t-statistic for attitude value is not very high indicating low significance. It marginally reduces significance in respect of time coefficient but significance in bus bias is almost nullified. It can be concluded that the attitude value has low but noticeable influence on choice of mode by this group of commuters.

7.5.4 Model for motorised two wheeler owning people

Table 7.6 gives the model parameters and statistical test details for the motorised two wheeler owning people. None of the 109 motorised two wheeler owners has used walk as a mode for work trip. Hence, modes available for them are considered as motorised two wheeler, bus, train and bicycle. The models with attitude value give better fit in terms of statistical parameters and convergence. The coefficients are positive and bias values negative and are all logical in both sets of models. Difference is minor when attitude value variable is added, the coefficients decreasing and bias constants increasing. Cost coefficient is least significant and time coefficient is significant at 0.01 level of significance. The bus bias values are significant at 0.05 level of significance. Attitude value coefficient is negative and logical and has a significance level of 0.10 (Close to 0.05 level of significance) indicating that attitude value has some influence on the choice of the mode though not very marked over the population.

7.5.5 Model for car owning people

Table 7.7 gives the model parameters and statistical test details for the car owning people. The group comprises of households having cars with and without other vehicles like motorised two wheelers and / or bicycles. The modes available for them are car, motorised two wheeler, bus train and bicycle. Non of the sample population has used walk as a mode for work trip. Multi-Nomial Logit model for 5 modes were first derived. In this case also, with inclusion of bicycle with no trip recorded in the sample population, and a total of 4 trips by public transport (one only being by train), the models developed first had logical coefficients but low statistical fit and low convergence when tested on original data.They were recasted combining bus and train as public transport trips and excluding bicycle trips. Such a procedure would be somewhat similar to Sequential Binomial Logit model (SBM) development where subdivision between bus and train can be done subsequently using a binomial logit sub-model. Model developed for NVP can be used for splitting these few trips or alternatively another sub-model can be developed, for which larger sample size is required. Out of 60 samples in this model only 4 are public transport users. Since, public transport trips made by COP would be small, they can be proportionally distributed based on the ratio of 2:1 as in the sample. The Models developed without attitude value is poor in that the cost coefficient is not logical, the pseudo-R^2 value is low and the convergence is poor.

When attitude value is added, the model performs better giving pseudo-R^2 value of 0.243. Both time and cost coefficients become positive and logical. The time coefficient is higher than that of cost coefficient which is almost negligible. Its high value of significance (Level of confidence being over 98.5% or level of significance of 0.015) indicates high importance of attitude value in choice of mode by the COP. The convergence in this case is 100%.

Typical plot relating probability of selection of a mode with compound disutility difference are given in Figures 7.1 to 7.14 to illustrate the difference for some sets of models 1 mode for NVP, and 2 modes each for CYP and TWP and for COP. They indicate how inclusion of attitude value improves the model predictability in different cases.

7.5.6 Elasticity of variable values of the models

The elasticity of various variables in choice of alternatives have also been studied. A study of elasticities for the COP models, for example, shows that the direct elasticity for 'travel cost' in all cases for all modes is low (i e. for Car = 0.538, motorised two wheeler = 0.321 and public transport = 0.13).

Direct elasticities for 'duration of travel time' for car owners are fairly high in all cases (i e. for Car = 2.78, motorised two wheeler = 6.12, and public transport = 7.88). The elasticity for attitude value for car owners is high in all the cases (Car = 3.17, motorised two wheeler = 5.42, and public transport = 5.64), indicating its importance in choice of mode. In a multi-modal choice situation, the 'attitude value' is an important variable and it explains the effect of other intangible factors. This is also confirmed by the fact that the bias coefficients are less for all modes when attitude value variables are included in the models. The cost is inelastic in all cases for COP also. Elasticity of time is marginally less for private modes as well as for public transport modes when attitude value is included in the model.

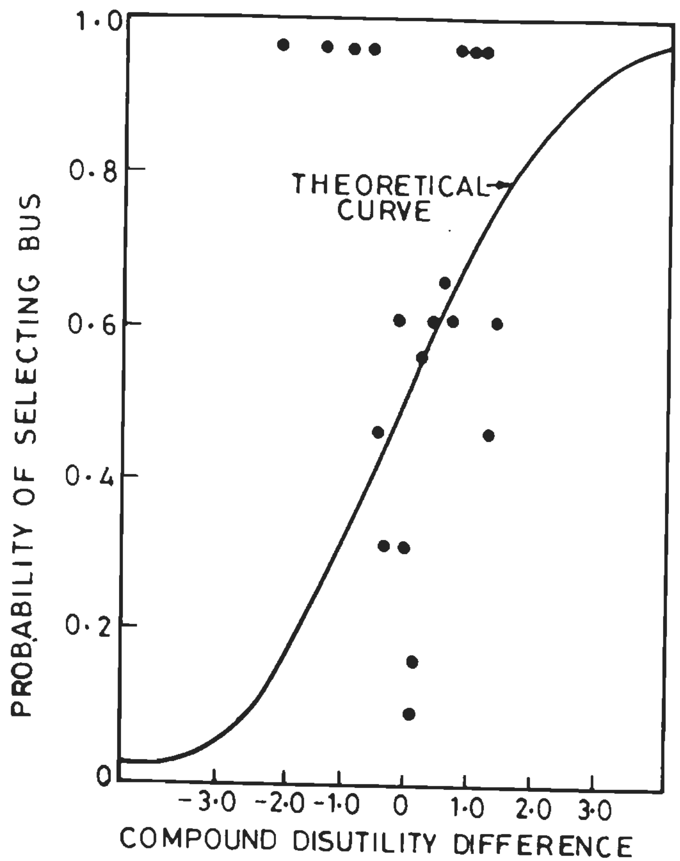


FIG. 7·1 PROBABILITY OF SELECTING BUS VS COMPOUND DISUTILITY DIFFERENCE FOR NVP
(CONSIDERING ATTITUDE VALUE)

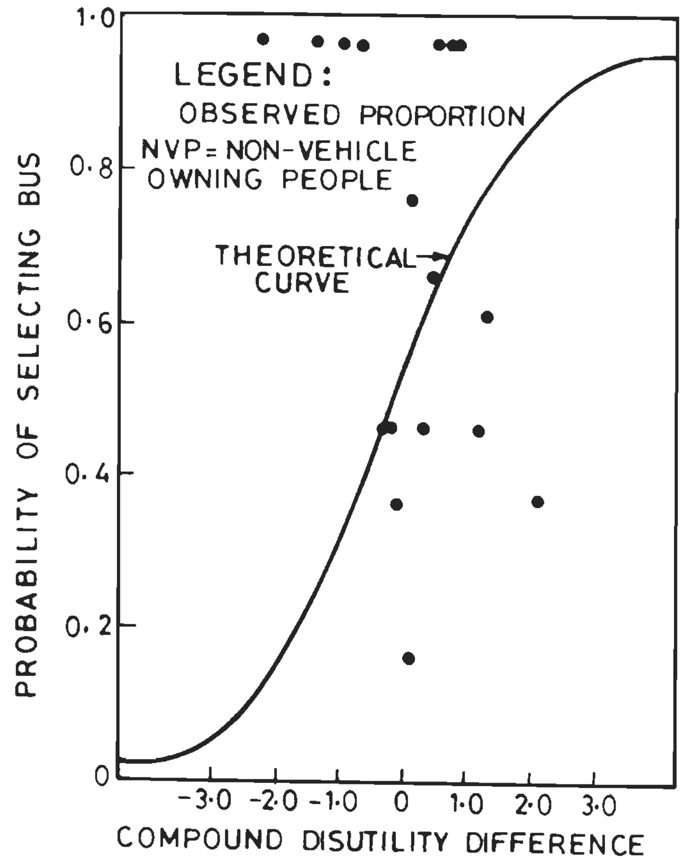


FIG. 7·2 PROBABILITY OF SELECTING BUS VS COMPOUND DISUTILITY DIFFERENCE FOR NVP
(WITHOUT CONSIDERING ATTITUDE VALUE)

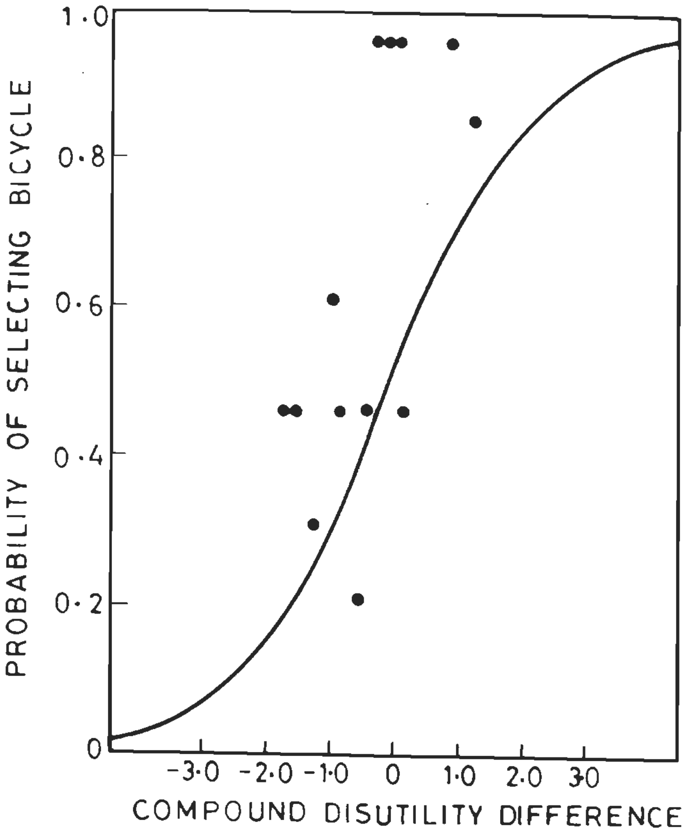


FIG. 7·3 PROBABILITY OF SELECTING BICYCLE VS COMPOUND DISUTILITY DIFFERENCE FOR CYP

(CONSIDERING ATTITUDE VALUE)

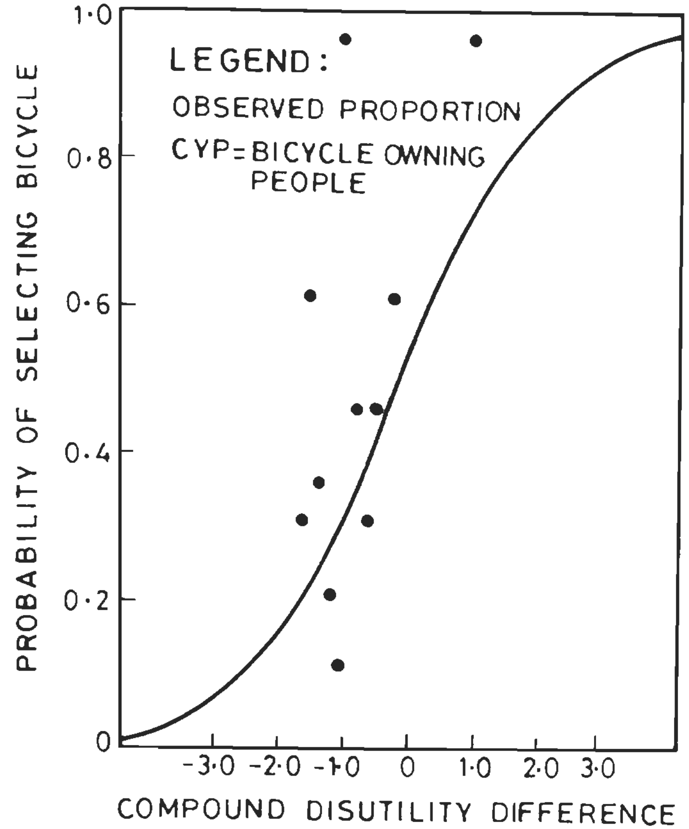


FIG. 7·4 PROBABILITY OF SELECTING BICYCLE VS COMPOUND DISUTILITY DIFFERENCE FOR CYP

(WITHOUT CONSIDERING ATTITUDE VALUE)

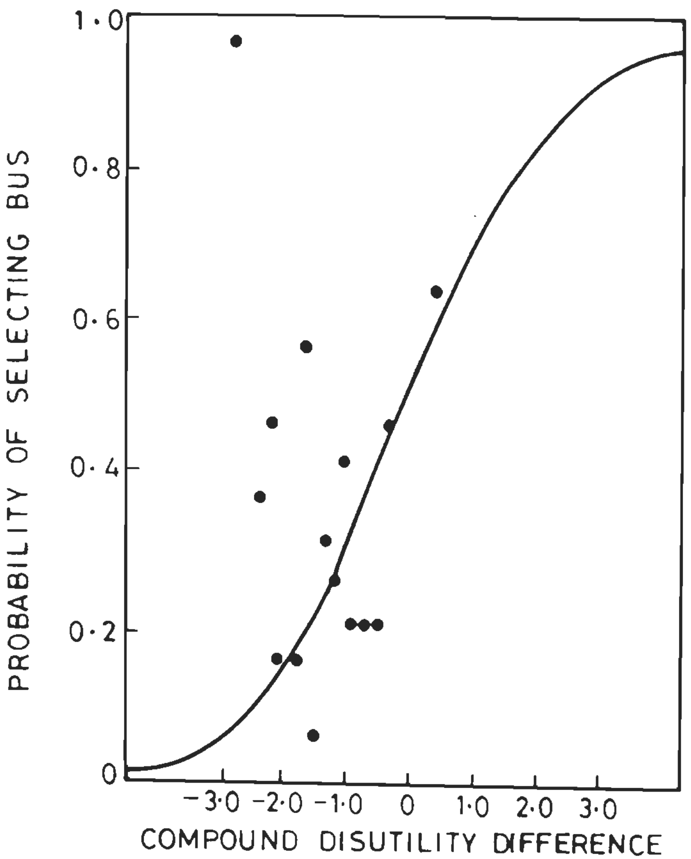


FIG. 7·5 PROBABILITY OF SELECTING BUS VS COMPOUND DISUTILITY DIFFERENCE FOR TWP

(CONSIDERING ATTITUDE VALUE)

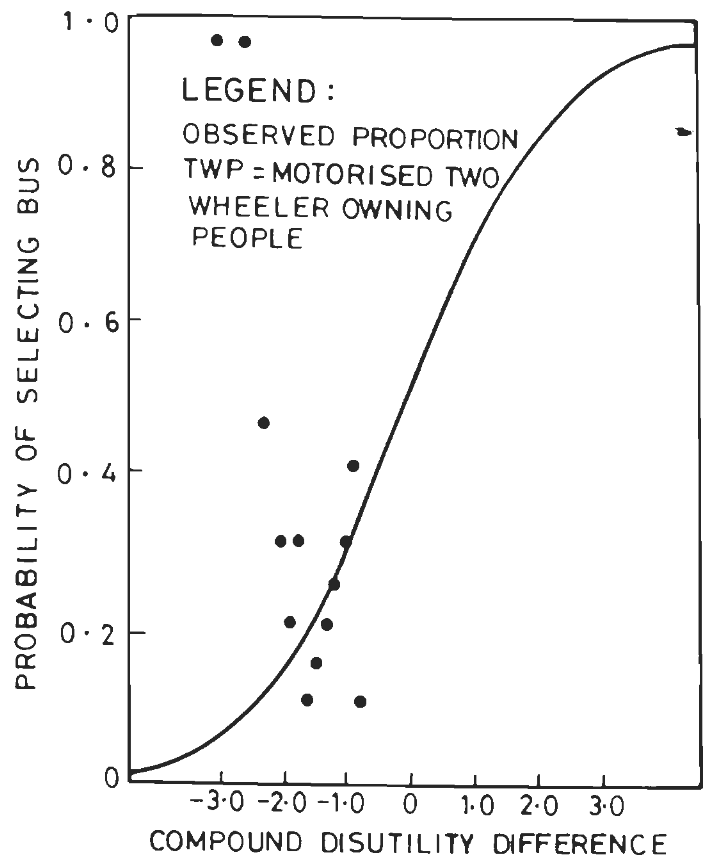


FIG. 7·6 PROBABILITY OF SELECTING BUS VS COMPOUND DISUTILITY DIFFERENCE FOR TWP

(WITHOUT CONSIDERING ATTITUDE VALUE)

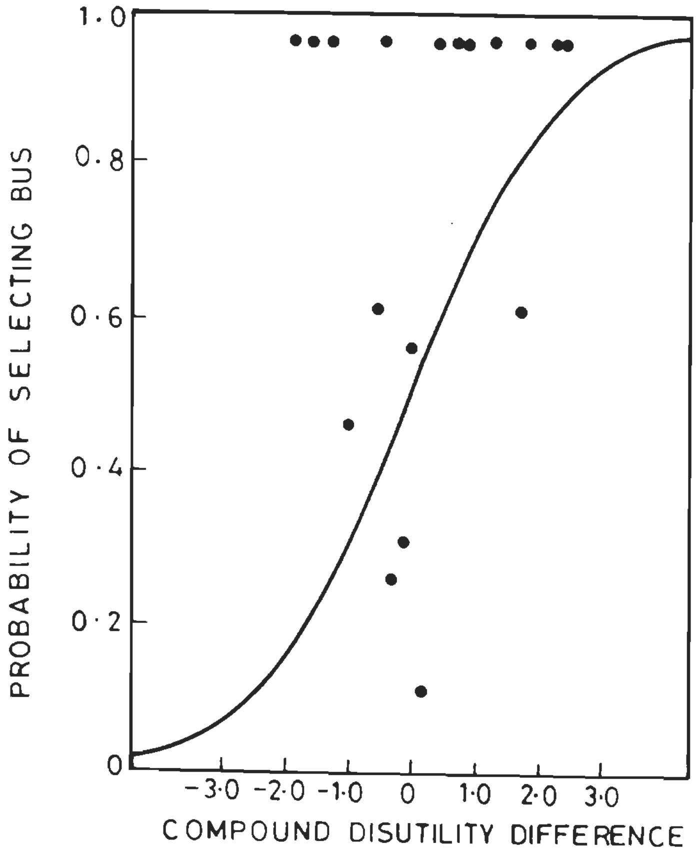


FIG. 7·7 PROBABILITY OF SELECTING BUS VS COMPOUND DISUTILITY DIFFERENCE FOR CYP
(CONSIDERING ATTITUDE VALUE)

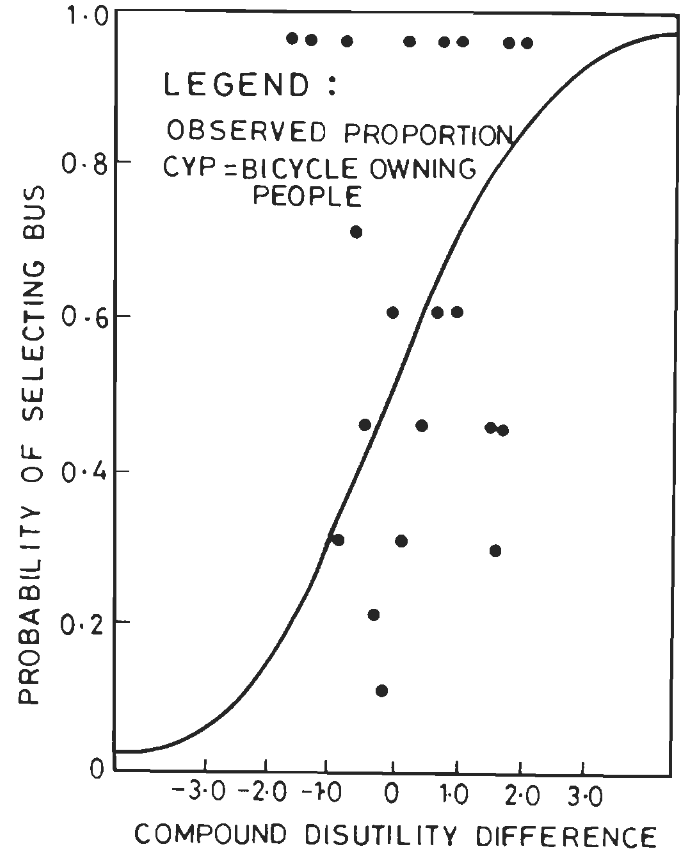


FIG. 7·8 PROBABILITY OF SELECTING BUS VS COMPOUND DISUTILITY DIFFERENCE FOR CYP
(WITHOUT CONSIDERING ATTITUDE VALUE)

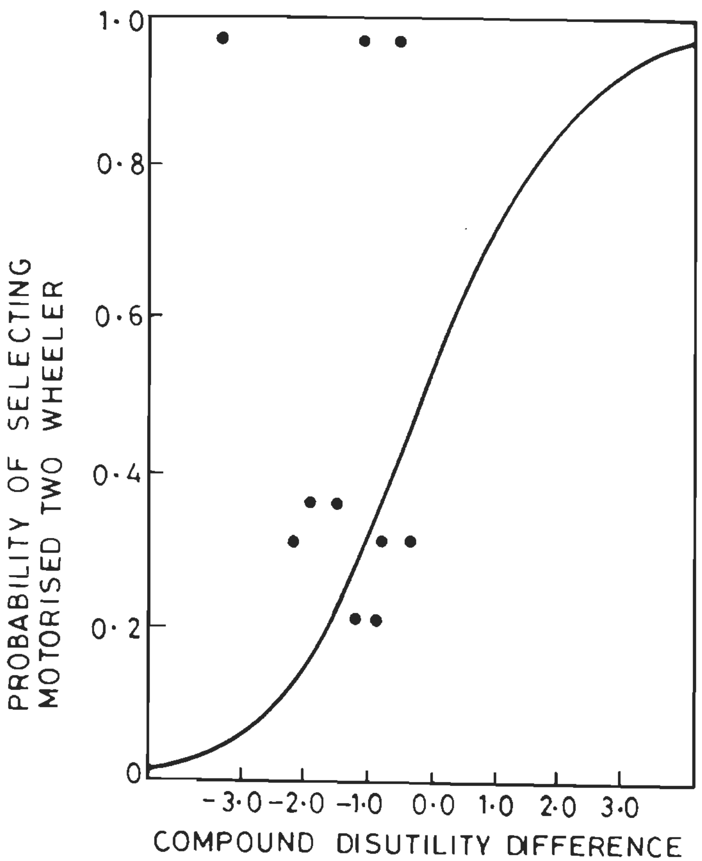


FIG. 7·9 PROBABILITY OF SELECTING MOTORISED TWO WHEELER VS COMPOUND DISUTILITY DIFFERENCE FOR COP

(CONSIDERING ATTITUDE VALUE)

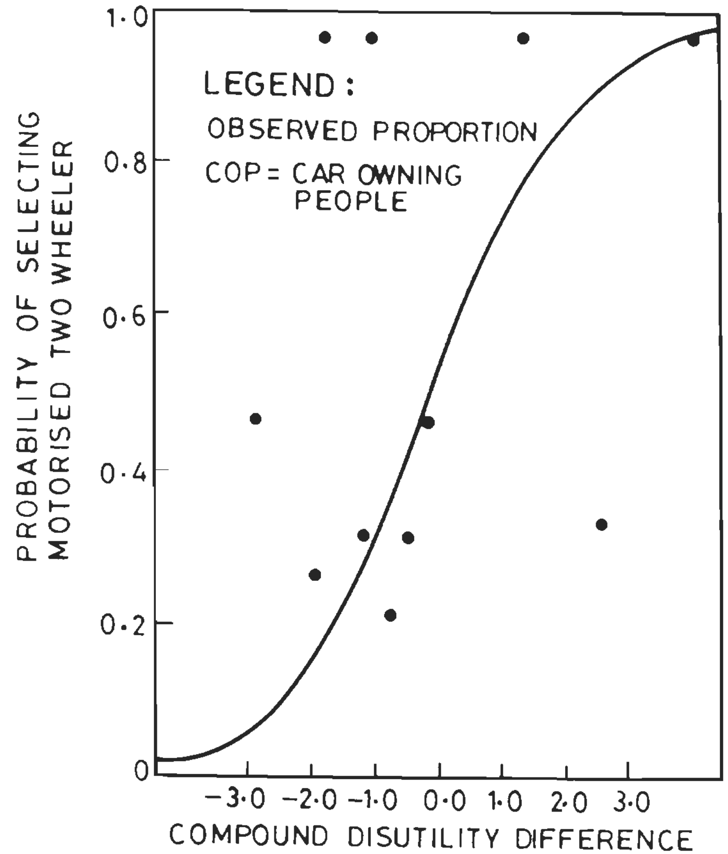


FIG. 7·10 PROBABILITY OF SELECTING MOTORISED TWO WHEELER VS COMPOUND DISUTILITY DIFFERENCE FOR COP

(WITHOUT CONSIDERING ATTITUDE VALUE)

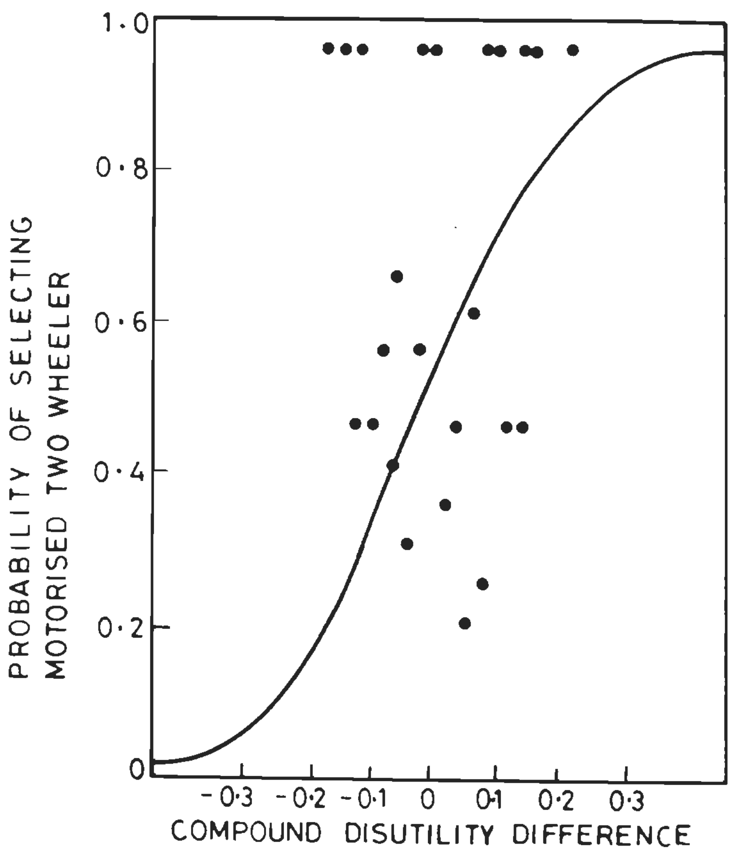


FIG. 7·11 PROBABILITY OF SELECTING MOTORISED TWO WHEELER VS. COMPOUND DISUTILITY DIFFERENCE FOR TWP (CONSIDERING ATTITUDE VALUE)

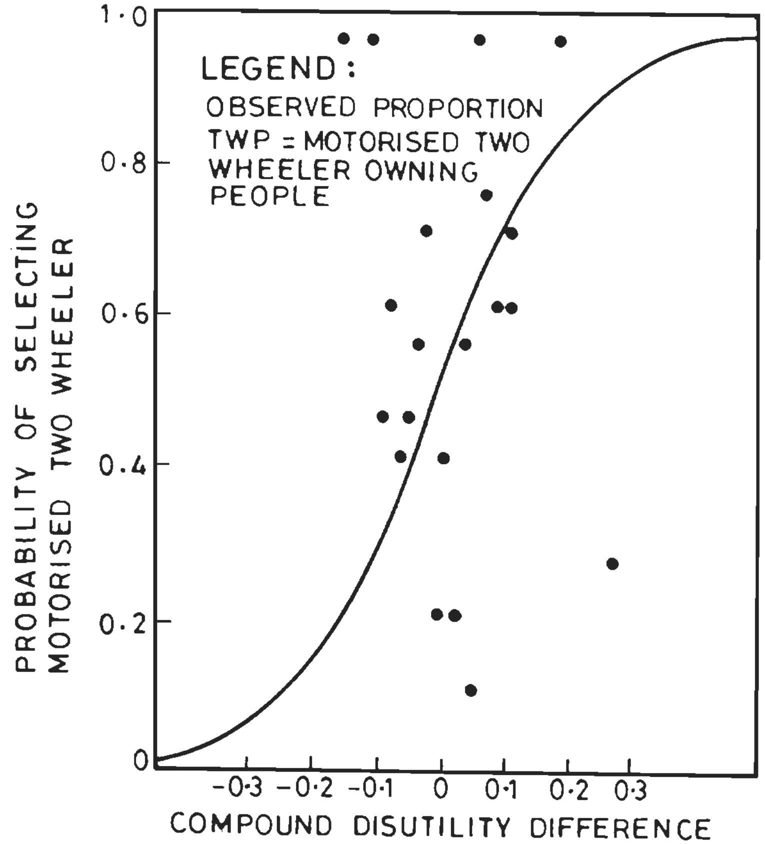


FIG. 7·12 PROBABILITY OF SELECTING MOTORISED TWO WHEELER VS. COMPOUND DISUTILITY DIFFERENCE FOR TWP (WITHOUT CONSIDERING ATTITUDE VALUE)

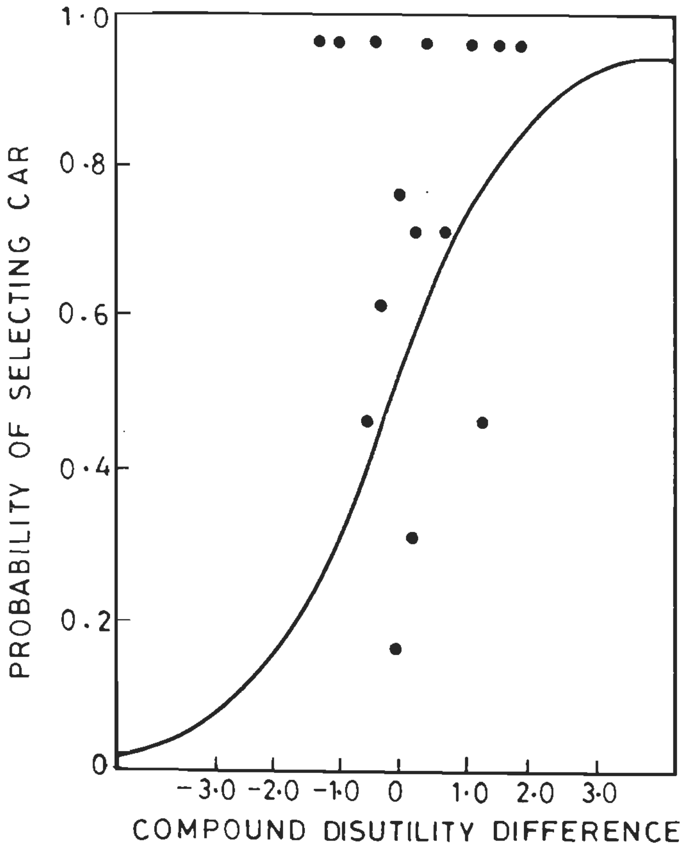


FIG. 7·13 PROBABILITY OF SELECTING CAR VS COMPOUND DISUTILITY DIFFERENCE FOR COP

(CONSIDERING ATTITUDE VALUE)

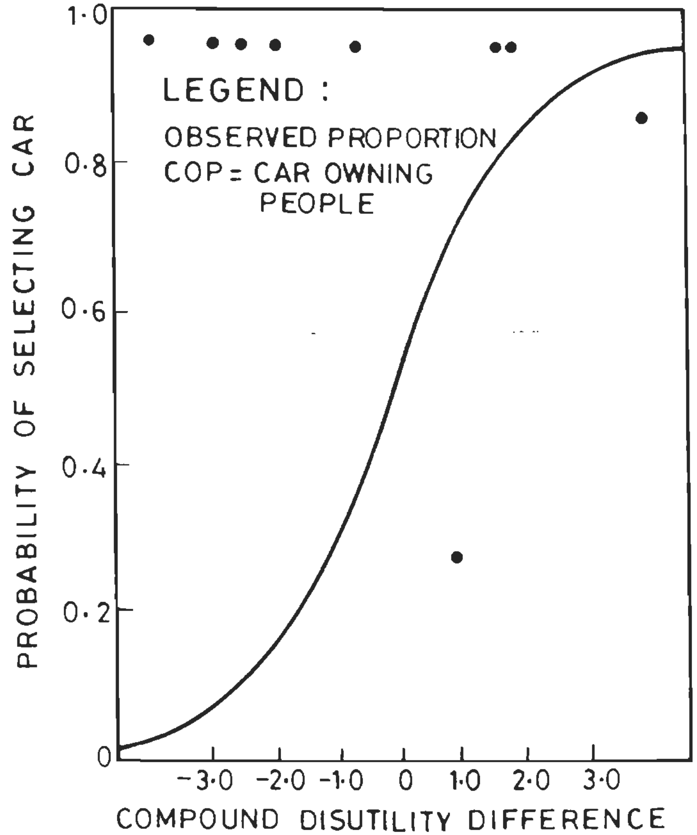


FIG. 7·14 PROBABILITY OF SELECTING CAR VS COMPOUND DISUTILITY DIFFERENCE FOR COP

(WITHOUT CONSIDERING ATTITUDE VALUE)

7.6 Indications from Models

The MNL models developed indicate that the vehicle owner choice is very much influenced by time of travel and next by their attitude towards various modes excepting in case of non-vehicle owning people and to some extent bicycle owning people. In most of the models developed, pseudo-R^2 values are not high enough, though satisfactory. This can be attributed partly due to fewer users of some modes in the sets of sample used in deriving them and comparatively small sample size. As indicated by Koppelman et al [91] and Stopher [137] if sample size is enlarged in detailed studies so that each group would have about 300 records, more reliable models can be built.

7.7 Application of Findings of Attitude Study

The main objective of this study is to develop models for modal choice analysis based on attitudes and applying them to examine their suitability in our conditions for future estimation. It is in this context, the various models developed, which are already described above have been tested for a selected area (Shahdara) in Delhi City. Shahdara in Delhi has been chosen to study the applicability of the models derived/findings of this study. The area selected has access to both road and rail facility. The proposed Mass Rapid Transit System (MRTS) in Delhi will pass through this area by 2001 AD which has already described in Chapter 4, and would link this area directly to CBD and number of important work centres. The study area has been chosen such that the samples fall on both sides of the proposed railway station. The sample surveyed is selected on random sampling technique. The socio-economic characteristics of the sample surveyed are as follows :

Mean household income Rs. 4058 per month (Indian Rupees (INR) can be signified as US$ 1.0 = INR 35.0), household size 4.68, vehicle ownership per household (i e. for Car = 0.28, motorised two wheeler = 1.89, Bicycle = 2.16), Mean distance to work place = 14.3 km. The survey also collected information on primary mode of travel for work trips currently use and the mode they may choose if Mass Rapid Transit System (MRTS) facility is made available to them. Primary mode here refers to the mode on which the major part of the work trip is made (Table 7.8). The use of attitude based logit model for the study area to work out the final modal split is explained in Figure 7.15.

Four sets of MNL models developed earlier are considered-Non vehicle-owning people (NVP), Bicycle owning people (CYP), Motorised Two wheeler-owning people (TWP), and Car owning people (COP).

These models require data such as total travel time (in minutes), cost of travel (in paise), computed user attitude value towards the mode (maximum 100) involved in applying these models and basis for total cost and total travel time computed are presented in Table 7.9. In the table 7.9 ;

DT = Distance of travel in km.

DTBS = Distance of bus stop in km.

DTRS = Distance of railway station in km.

FQBR = Frequency of arrival of bus in minutes.

FQTR = Frequency of arrival of train in minutes.

The following two assumptions have been considered in making use of the model in this study.

(i) Train fare has been computed assuming that all work trips are performed with season ticket holders (Based on 1996 AD price level).

(ii) All access trips to public transport upto 1.0 km are assumed to be made by walk.

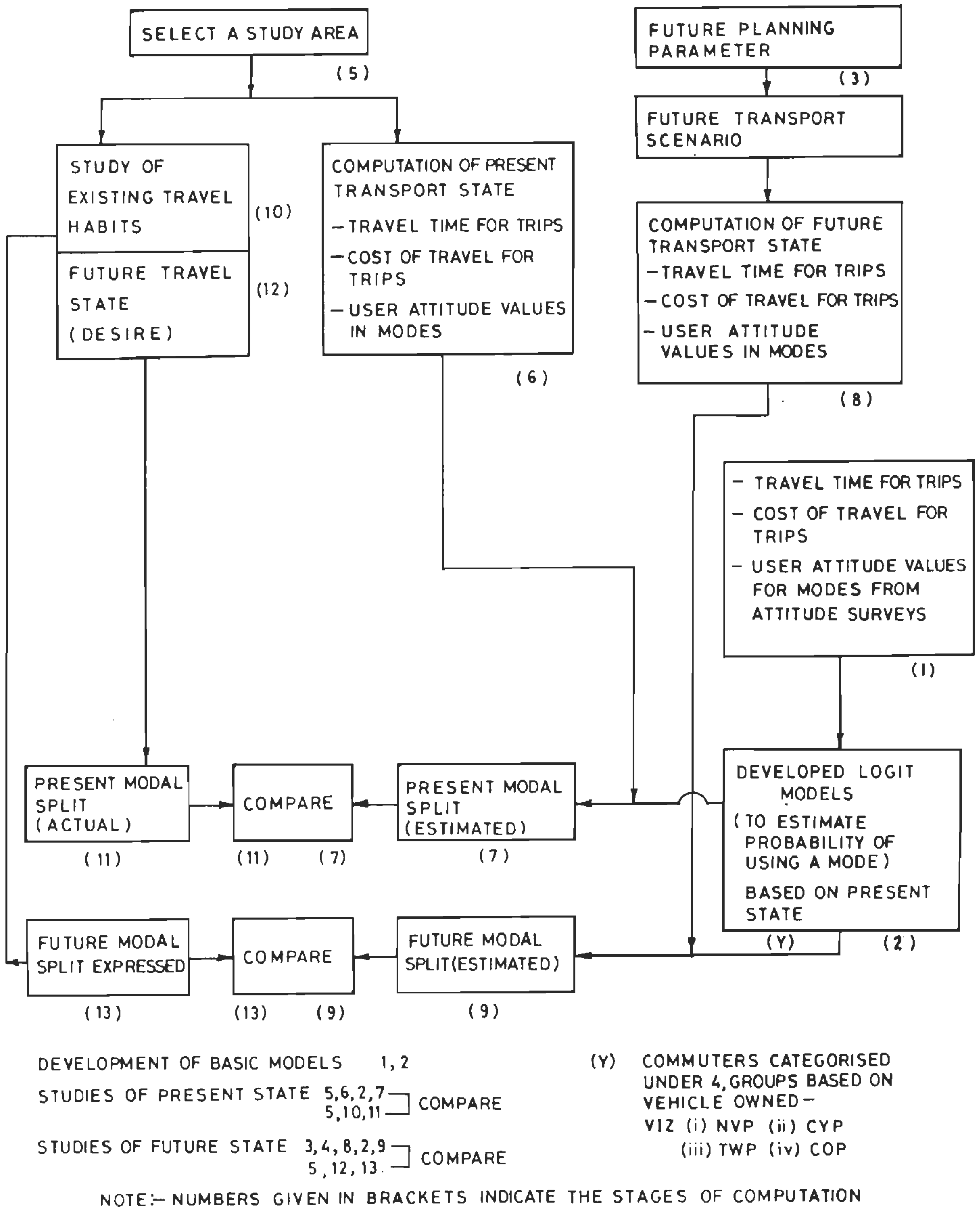


FIG. 7.15 ATTITUDE BASED LOGIT MODEL FOR A STUDY AREA FOR FULL SAMPLE

TABLE 7.8 SHARE OF DIFFERENT MODES FOR WORK TRIPS PRESENT (WITHOUT MRTS) AND FUTURE (WITH MRTS) AS EXPRESSED

Mode	Share of Different Modes (Percentage)		Difference
	Present (Without MRTS)	Future (with MRTS)	
Bus	59.8	42.7	-17.10
Train	2.2	32.5	+30.3
Car	8.4	6.1	-2.3
Motorised two wheeler	10.1	7.2	-2.9
Bicycle	19.5	11.5	-8.0
Total	100	100	

TABLE 7.9 ESTIMATION OF TOTAL TIME AND COST OF TRAVEL

Mode	Total Travel Time (in minutes)	Cost of Travel (in paise)
Car	2 DT + 5	180 * DT
Motorised two wheeler	2.2 DT + 5	60 * DT
Bus	3 DT+5+FQBS +13.3 * DTBS	100+(DT-2)*15
Train	2 DT+20+FQTR+13.3 * DTRS	150+(DT-5)*15
Bicycle	7.5 * DT	NIL
Walk	13.3 * DT	NIL

Note : costs based on 1996 AD fare level

DT = Distance of travel in km.
DTBS = Distance of bus stop in km.
DTRS = Distance of railway station in km.
FQBS = Frequency of arrival of bus in minutes.
FQTR = Frequency of arrival of train in minutes.

User attitude values for different modes between different zones have been computed using the models established earlier in Chapter 6 (Table 6.11, Table 6.12). Comfort in travel is assumed to be 2 for bus both for present and future and for 2 for train for the present state and 1 for future. The value is taken as 1 since the Shahdara people may get seat in the train as the Mass Rapid Transit System (MRTS) would be the first stop from the terminal. For each trip between different sets of zones, the values of travel time and travel cost are worked out.

Substituting the computed values in appropriate models for each vehicle owning group, the probability of choice of using different modes for each individual is worked out. By summing the estimated probabilities for each mode, number of persons who would choose each mode from that group could be worked out. Number of users computed for different vehicle owning groups are then totaled and there from modal split for the area as such is worked out (Stage 7). In order to explain the use of model, the computed values of travel time, cost of travel and user's attitude towards modes for a given set of origin-destination, the actual modal split as observed in the sample survey is worked out (Stage 11). The results at stage 7 and stage 11 when compared should be close.

The procedure discussed above should be adopted for future state following step 3, step 4, step 8, step 2, and step 9. The findings reached at step 9 could be compared with what the user's have expressed as their desire on modal split for future (Step 13). The various input values computed are given in Table 7.10 to Table 7.12.

Number of commuters who would take different modes under each of the future groups of population (NVP,CYP,TWP and COP) are given in Table 7.13 both for present and future states as computed using the MNL models.

Introduction of Mass Rapid Transit System (MRTS) causes a shift of 11.5% from bus, 2.4% from motorised two wheelers, 3.5% from car and 8% from bicycle trips to train and MRTS increasing its share by 25.4%. A comparison can now be made with what is seen now as per survey and what the desires for future indicate. Table 7.14 gives a comparative statement.

TABLE 7.10 TRAVEL TIME BY DIFFERENT MODES FOR WORK TRIPS TO DIFFERENT ZONES FROM THE STUDY AREA

Destination Zone	Travel time from Shahdara to different Zones (in minutes)								
	Present State (Without MRTS)				Future State (With MRTS)				
	Bus	Train	Car	Motorised two wheeler	Bicycle	Bus	MRTS & Train	Car	Motorised two Wheeler
A	61	59	25	27	75	47	37	25	27
B	66	72	31	34	98	56	43	31	34
C	69	75	33	36	105	59	45	33	36
D	76	84	35	38	113	62	47	35	38
E	78	87	37	40	120	65	49	37	40
F	84	92	41	45	135	71	53	41	45
G	116	117	61	67	210	101	73	61	67

Where Group destination,

A = Krishi Bhawan, Mandi House, Jagatpuri.

B = Mourice Nagar, Delhi University, Nanaksar, Bhajanpura.

C = Mori Gate, Old Secretariat, Yamuna Vihar, Jyoti Nagar.

D = Laxmi Nagar Temple, Shivaji Stadium, Delhi Gate.

E = Karol Bagh , Paharganj, ITO, Krishna Nagar.

F = Dhaula Kuan, Moti Bagh, Lajpat Nagar.

G = Janakpuri, DESU Colony, Tilak Nagar, Raja Garden.

TABLE 7.11 COST OF TRAVEL BY DIFFERENT MODES FOR WORK TRIPS TO DIFFERENT ZONES FROM THE STUDY AREA

Destination Zone	Travel cost from Shahdara to different Zones (in paise)							
	Present State (Without MRTS)				Future State (With MRTS)			
	Bus	Train	Car	Motorised two wheeler	Bus	MRTS & Train	Car	Motorised two Wheeler
A	200	225	1500	500	200	150	1500	500
B	260	270	1950	650	260	200	1950	650
C	280	285	2100	700	280	200	2100	700
D	300	300	2250	750	300	270	2250	750
E	320	315	2400	800	320	270	2400	800
F	360	345	2700	900	360	285	2700	900
G	560	495	4200	1400	560	450	4200	1400

Where Group destination,

A = Krishi Bhawan, Mandi House, Jagatpuri.

B = Mourice Nagar, Delhi University, Nanaksar, Bhajanpura.

C = Mori Gate, Old Secretariat, Yamuna Vihar, Jyoti Nagar.

D = Laxmi Nagar Temple, Shivaji Stadium, Delhi Gate.

E = Karol Bagh , Paharganj, ITO, Krishna Nagar.

F = Dhaula Kuan, Moti Bagh, Lajpat Nagar.

G = Janakpuri, DESU Colony, Tilak Nagar, Raja Garden.

TABLE 7.12 USER'S ATTITUDE VALUES FOR DIFFERENT MODES FOR WORK TRIPS TO DIFFERENT ZONES FROM THE STUDY AREA

Destination Zone	Present State (Without MRTS)				Future State (With MRTS)					
	Bus	Train	Car	Motorised two wheeler	Bicycle	Bus	MRTS & Train	Car	Motorised two wheeler	Bicycle
A	53.4	78.4	82.4	61.8	53.2	51.4	79.3	80.6	63.2	54.3
B	48.9	72.4	80.3	59.7	51.4	47.6	73.8	78.7	60.6	52.9
C	56.4	69.6	79.3	58.4	49.7	53.2	68.6	76.5	59.7	48.6
D	62.3	71.8	76.5	63.6	47.8	60.7	69.4	74.3	61.8	51.4
E	54.3	64.6	73.2	67.2	52.6	52.3	63.2	71.9	65.5	51.9
F	63.2	72.4	69.6	56.8	58.7	59.8	73.6	68.3	55.6	60.4
G	49.6	73.8	69.3	58.9	51.9	48.6	62.4	67.2	52.3	48.8

Where Group Destination,

A = Krishi Bhawan, Mandi House, Jagatpuri.

B = Mourice Nagar, Delhi University, Nanaksar, Bhajanpura.

C = Mori Gate, Old Secretariat, Yamuna Vihar, Jyoti Nagar.

D = Laxmi Nagar Temple, Shivaji Stadium, Delhi Gate.

E = Karol Bagh , Paharganj, ITO, Krishna Nagar.

F = Dhaula Kuan, Moti Bagh, Lajpat Nagar.

G = Janakpuri, DESU Colony, Tilak Nagar, Raja Garden.

TABLE 7.13 COMMUTERS OF DIFFERENT CATEGORIES USING DIFFERENT MODES (ESTIMATED FROM MODELS)

Mode	Number of Commuters likely to use different Modes from amongst different Vehicle owning groups					
	No-Vehicle owner (NVP)	Bicycle owner (CYP)	Motorised Two Wheeler owner (TWP)	Car owner (COP)	Total sample (Number)	Modal split (Percentage)
Present Condition - Without MRTS (Mass Rapid Transit System)						
Bus	33.2	33.4	9.1	1.2	76.9	61.7
Train	4.6	1.8	0.6	0.4	7.4	5.8
Car	-	-	-	13.7	13.7	10.9
Motorised Two Wheeler	-	-	8.5	1.8	10.3	8.3
Bicycle	-	13.6	3.1	-	16.7	13.3
Total	37.8	48.8	21.3	17.1	125.0	100
Future State - With MRTS (Mass Rapid Transit System)						
Bus	26.9	25.9	8.6	1.4	62.8	50.2
Train	16.1	13.8	8.7	0.5	39.1	31.2
Car	-	-	-	9.2	9.2	7.4
Motorised Two Wheeler	-	-	5.8	1.6	7.4	5.9
Bicycle	-	5.6	0.9	-	6.5	5.3
Total	43.0	45.3	24.0	12.7	125.0	100

TABLE 7.14 COMPARISON OF MODAL SPLIT - SURVEY FINDINGS WITH MODEL PREDICTIONS

Mode	Present - Without MRTS		Future - With MRTS	
	As per Actual	As Estimated	As per desires expressed	As Estimated
Bus	59.8	61.7	42.7	50.2
Train	2.2	5.8	32.5	31.2
Car	8.4	10.9	6.1	7.4
Motorised two Wheeler	10.1	8.3	7.2	5.9
Bicycle	19.5	13.3	11.5	5.3
Total	100.0	100.0	100.0	100.0

7.8 Summary

To sum up, the different modelling trials done on the data collected from a population in a multi-modal environment in Delhi city has brought out the following :

(i) Attitude value has significant influence on choice of mode for work trips. Attitude value being a 'stated preference ' using it in conjunction with other variables would be a desirable approach to understand more logically the behaviour of commuter in selecting the mode. Two approaches made use of are MLR and MNL models.

(ii) Multiple linear regression models have been be developed using the attitude of users towards different modes, and in this the form using log of ratio of proportion of use of different modes. to the proportions of use of a base mode (say bus) as dependent variable gives better result. The models developed indicate that attitude has a significant influence on choice of motorised two wheeler, train and IPT users.

(iii) Multi-Nomial Logit (MNL) models developed in this study have clearly brought out that attitude of users towards a mode influences actual choice significantly in case of motorised vehicle owners. Amongst non-vehicle owners, attitude has very little impact on choice.

(iv) When attitude value is added as a variable in the logit model, it results in models with better statistical fit and better explanatory power. Thus disaggregate models using multi-Nomial logit approach is found more suitable to study the influence of attitude on choice of mode.

(v) It has been shown as to how a logit model built, based on attitude value of commuter towards various modes, could be used to estimate the share of various modes for a future state, when MRTS is introduced. The study area selected has been assumed to have MRTS as a new facility. The example shown in this chapter has not accounted for changes likely to happen in travel time and travel cost of road user modes due to increased congestion on roads and changes in traffic environment in the city. It is assumed that reduction in road traffic due to the shift of many road users to train and MRTS and the additional traffic that would come on roads due to natural growth of traffic would balance each other by the target year.

CHAPTER 8
BEHAVIOURAL SIMULATION IN MODE CHOICE ANALYSIS

8.1 Trade - Off Technique

8.1.1 Scope of technique

The concept of 'trade-off' implies compromises, substitution or exchange amongst one another out of or amongst a number of issues involved in a choice situation. Since it is a method used to observe what trade-off or choice, commuter would make when confronted with a variety of alternatives under resource constraints. It overcome the main weakness of commonly used attitude studies where preferences are stated under unconstrained conditions. Hence this approach can give a more true picture to planners about choice in a real world situation. It can be used to interrelate attitude measurements with behaviour information and to simulate behaviour of commuter in the changed conditions. This method has been found useful by many futurologists and social science researchers as a tool to study preferences in urban planning in respect of environmental activities, housing preferences in neighbourhood layout planning, location of common facilities in residential areas, improvement of slums and squatter settlements and consequent formulation of schemes, plans, policies and programmes.

The trade-off methodology can be used to assess attitudes of people in any choice situation. The choice mechanism is itself a result of trade-off in choosing between various services or articles. Where within one's means of affordability, need for a service or article can not be dispensed with completely , choice lies between selecting one with its attributes at different levels- of-service so that the sum of the total that goes to make up the article or service of choice satisfies one's needs. Choice of travel mode is one such needs. Once a decision has been taken by a person to make a trip, one or other mode has to be chosen within user's means. The result is based on utility or satisfaction the user derives from the travel attributes that form part of performance of the travel. For example, a mode which takes less time may cost more.

Other conditions remaining same, the user has to trade-off between time and cost. The problem becomes more complicated when the discernible modal attributes are not just two but many like travel comfort, accessibility, reliability of the service, need for changing modes, behaviour of co-passengers, safety and security in travel, smoke and noise etc. Number of attributes which can be considered in a study of this nature is again a trade- off between time available for study, cost involved in collection of data and facilities available for computation. It is only in a trade-off situation, where respondent is forced to make the choice with known constraints, that a true picture can be obtained. The trade-off technique in such situations can give clear indications of relative levels of importance of different attributes. The main purpose of this study is to assess how commuters make the choice at present, and how they would choose a mode when levels-of-service of all competing modes are changed by intervention measures or due to growth of traffic or due to introduction of new modes viz., Mass Rapid Transit System (MRTS).

What planner needs, is a knowledge of impact of proposed or likely changes in modal attributes on the choice mechanism on individual basis, at aggregated levels considering all attributes of each mode. This is possible through working on trade-off game which itself is a behavioural simulation approach.

8.1.2 Trade - off game methods

There are four different methodologies tried in planning studies using trade-off technique. These are : (i) Wilson game (ii) Redding and Peterson's game (iii) Hoinville Associates game and (iv) University of Southern California game.

Wilson game and Hoinville Associates game call for estimating cost of various project(s) components of competing facilities. This is difficult where cost assessment for attributes become difficult.

In Indian conditions, this methodology has been modified and used to study preferences of slum dwellers with regard to provision of various facilities and services where each could be provided at four levels [6]. Redding and Peterson's game is for a limited choice situation. The University of Southern California approach has been used to judge the relative levels of attitude amongst a heterogeneous population towards different choice situations. This has also been used to study preferences in provision of facilities in residential neighbourhoods [5].

While analysing the modal choice in a multi-modal environment having a large number of modes, the commuter preferences are to be ascertained in respect of a number of travel attributes which vary from mode to mode. The above can not all be quantified in terms of any specific single commodity unit or measured in terms of a basic unit like cost or time. In a situation like this, the method developed by University of Southern California, modified and adopted for residential area facilities planning by Anantharajan [5], could be further adopted and extended to suit Indian conditions with respect to study of travel of mode choice of commuters in urban areas, like the Delhi city of national capital of India the present study has been planned on the above premise.

8.2 Design of The Game

8.2.1 Selection of attributes

In an attitude study made in Detroit ( ) to determine weightage of importance attached to different attributes of a public transport system, a total of 34 attributes were considered [46]. These included items like 'having a seat', 'no transfer trip' and also items like 'room for 'baby strollers and wheel chairs' and 'ask ' questions of system representative'. In Indian conditions, such finer divisions like the last two items can not be understood by many respondents and are truely meaningless. Neveu [115] used 19 attributes for factor analysis, before using them in a utility model of mode choice.

The procedure described below has taken the above into account along with constraints in conducting the game in Indian context.

* Identify all attributes related to operation of transport system (Set A) (12 attributes have been identified in this study, as listed below):

  1. Waiting time 2. In-vehicle travel time 3. Access time 4. Saving in total travel time 5. Travel cost 6. Interruption in flow of traffic 7. Convenience during travel 8. Comfort during travel 9. Distance of travel 10. Reliability of arrival of transport 11. Safety during travel 12. Air pollution and noise.

* Identify for each attribute a possible set of levels-of-services that could be made available. Also, introduce a seven point semantic differential scale spanning between most unsatisfied and most satisfied (Values ranging between 1 and 7) to measure the degree of satisfaction the user derives with respect to that attribute. The attribute "waiting time" as presented for analysis, as an example, is given in Figure 8.1.
* Identify a set of players
* Collect socio-economic characteristics of all the players.
* Each player will then follow the following steps to play the game.

(i) The player will be given 12 cards (one card for each attribute) presenting all the possible levels - of - service in each case along with a seven point scale of satisfaction (Figure 8.1). The player is asked to assign points to each of the 12 attributes depending upon his perceived level of importance, making use of 100 points. Player has to distribute all the points without any saving.

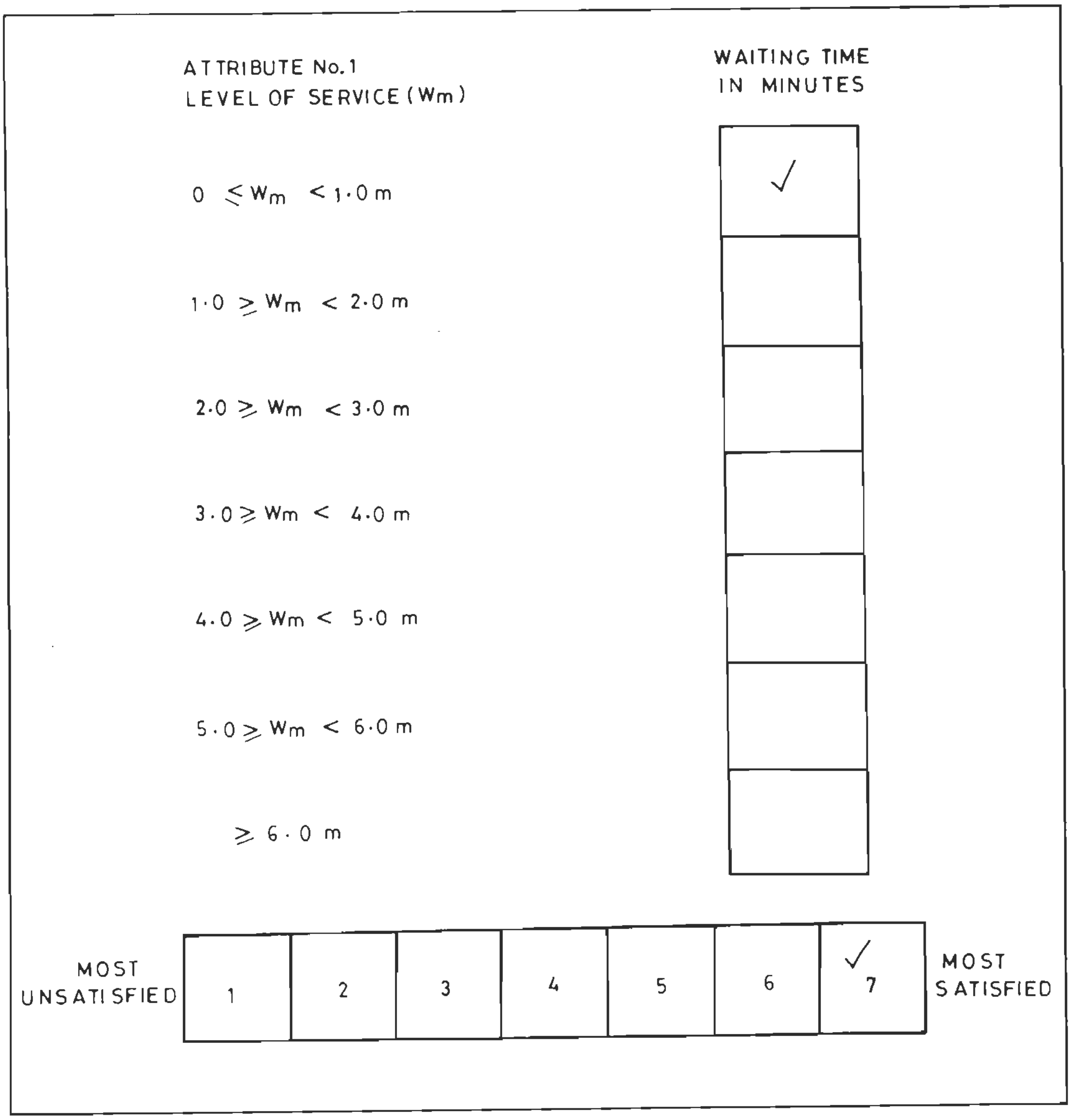


FIG. 8·1 SAMPLE OF TRADE-OFF CARD FOR A TRAVEL ATTRIBUTE

(ii) The player will then identify one or more attributes (Set B) which he considers as necessary for improvement so as to upgrade the operation of transport system in the city.

The user is told that it should then take one attribute from the group of the attributes identified for improvement (Set B) and compare it on a pair-wise basis with all the attributes (Set A) except the attributes which has been identified for improvement (Set B). While doing pair-wise comparison the player will at a time consider the attribute to be improved, and the one attribute which he would consider to trade - off by lowering down the level-of-service. The player will indicate the level to which he will improve the attribute considered for improvement and express correspondingly to what level he would trade-off in the other attribute considered (lowering the level). This trading-off has to be made since the user is allowed to gain some benefits by way of improving the level-of-service in the attribute considered for improvement. While doing such pair-wise comparisons, the player may not be willing to trade-off in the case of any of the attributes considered in pair-wise comparisons.

(iii) The player will identify what would be considered levels of satisfaction, if the trade-off is done, both for the attribute improved and for the attribute traded-off.

The procedure is repeated involving all the participants.

The next stage of survey is addressed to private vehicle users to find out whether they would switch over to public transport if improved level of service in public transport is provided at higher travel cost.

The next issue is directed at finding out what proportion of extra income of an individual would be spent on transport, and what aspects of improvement in transport system, respondent would like to have when his income goes up and his affordability increases.

8.3. Selection of Sample

Trade-off game of this type requires involved participation from respondents and is time consuming. The basic aim of the game is to understand the behaviour trend at a manageable group level and extend it to larger groups later. Hence, if the population is stratified and sample is selected, the observations can be used to study the behaviour of different sections of the population. It can be used to see whether there is any significant difference amongst the groups. All income strata of the population have been covered by the sample. The present study has been confined to work trips only. The respondents were selected at random from various work centres and residential areas in the Delhi city so that at least there would be 32 from each income group. A total of 174 users played the game.

8.4 Analysis

A study was made on the choice of primary mode of travel by respondents for work trips. Overall level of satisfaction enjoyed in respect of the primary mode on a semantic differential scale 1 to 7 was analysed. The results are given in Table 8.1.

8.4.1 Importance of attributes

Most of the respondents have selected within 5 to 8 attributes out of the 12 attributes identified while assigning importance rating, indicating that they accord not much important to other attributes. If rank ordering methodology had been used, this aspect would not have been reflected. The mean values of importance assigned for the attributes and their rank ordering are given in Table 8.2 and Figure 8.2 for the total

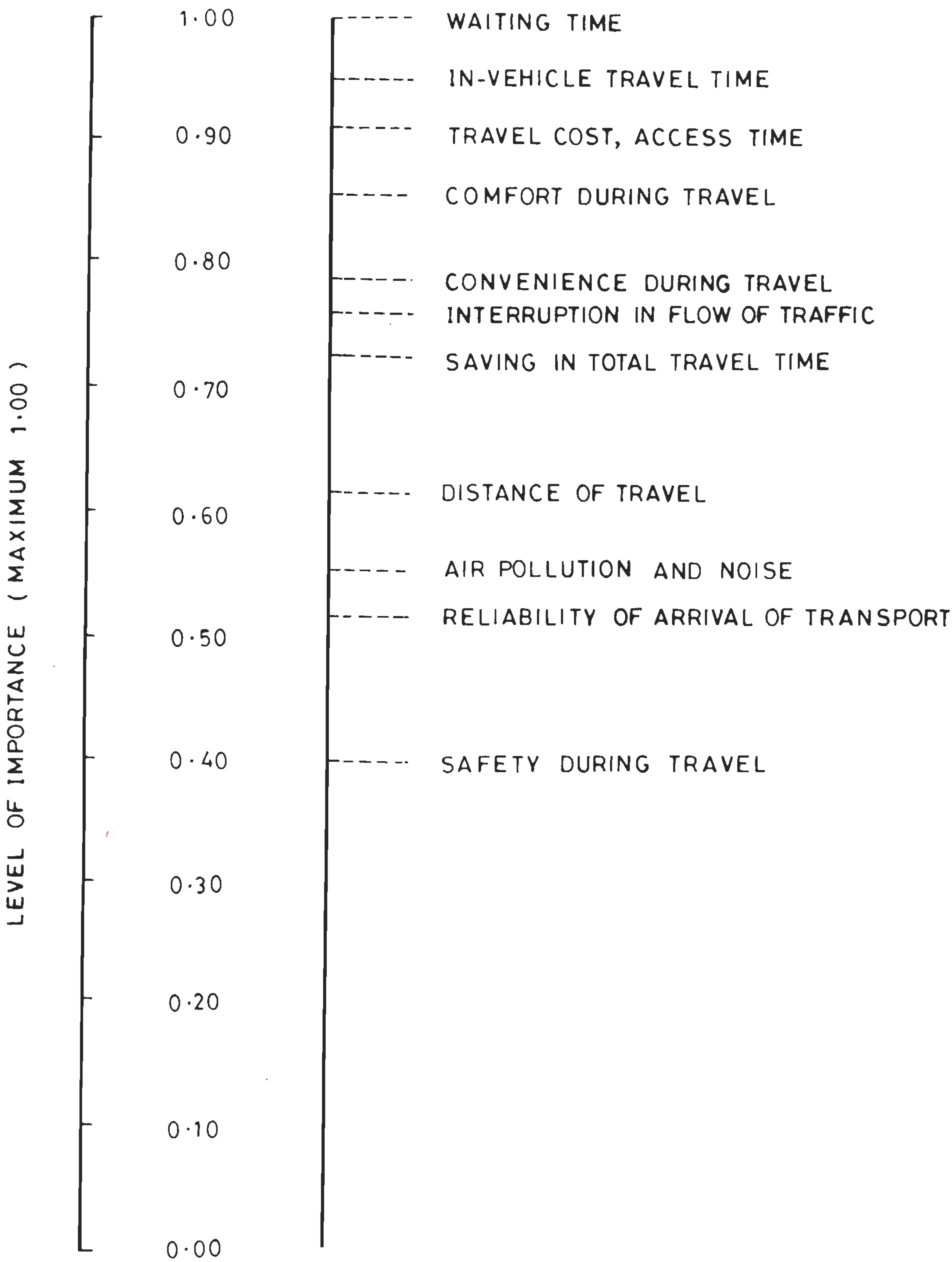


FIG. 8·2 RELATIVE LEVEL OF IMPORTANCE OF DIFFERENT TRAVEL ATTRIBUTES FOR ALL GROUPS WITHOUT TRADE-OFF analysed sample of 174. As many as 48 players did not change the scores after playing the trade-off game. The attributes considered as important and unimportant are given in Table 8.3. The computed importance rating has also been given for different income groups in Table 8.4. The most important and unimportant items are listed in Table 8.5 for different income groups on same analogy as indicated for the whole group. These are represented in a scale form in Figure 8.3.

TABLE 8.1 CHOICE OF PRIMARY MODE AND LEVEL OF SATISFACTION ENJOYED BY DIFFERENT INCOME GROUPS

Primary Mode	EWS (upto Rs. 900/ per month)		LIG (Rs.901 to Rs. 2000/ per month)		MIG (Rs.2001 to Rs.3000/ per month)		HIG-I (Rs.3001 to Rs.5000/ per month)		HIG-II (> Rs.5000/ per month)	
	P	MLS	P	MLS	P	MLS	P	MLS	P	MLS
Car	-	-	-	-	0.04	3.80	0.22	4.35	0.38	4.80
Motorised										
Two wheeler	-	-	0.25	3.80	0.22	5.70	0.37	4.80	0.28	3.30
Bus	0.72	2.10	0.56	2.80	0.52	2.70	0.38	3.10	0.33	2.50
Train	0.02	2.00	0.07	4.30	0.04	3.80	0.03	4.20	0.01	4.60
IPT	-	-	-	-	0.06	3.80	-	-	-	-
Bicycle	0.26	1.20	0.12	3.10	0.12	3.30	-	-	-	-
Total	1.00		1.00		1.00		1.00		1.00	

Source : Survey data, 1995 AD

Note P = Proportion of sample choosing the mode as primary mode.

MLS = Mean level of satisfaction for the mode.

(Maximum = 7, Minimum = 1)

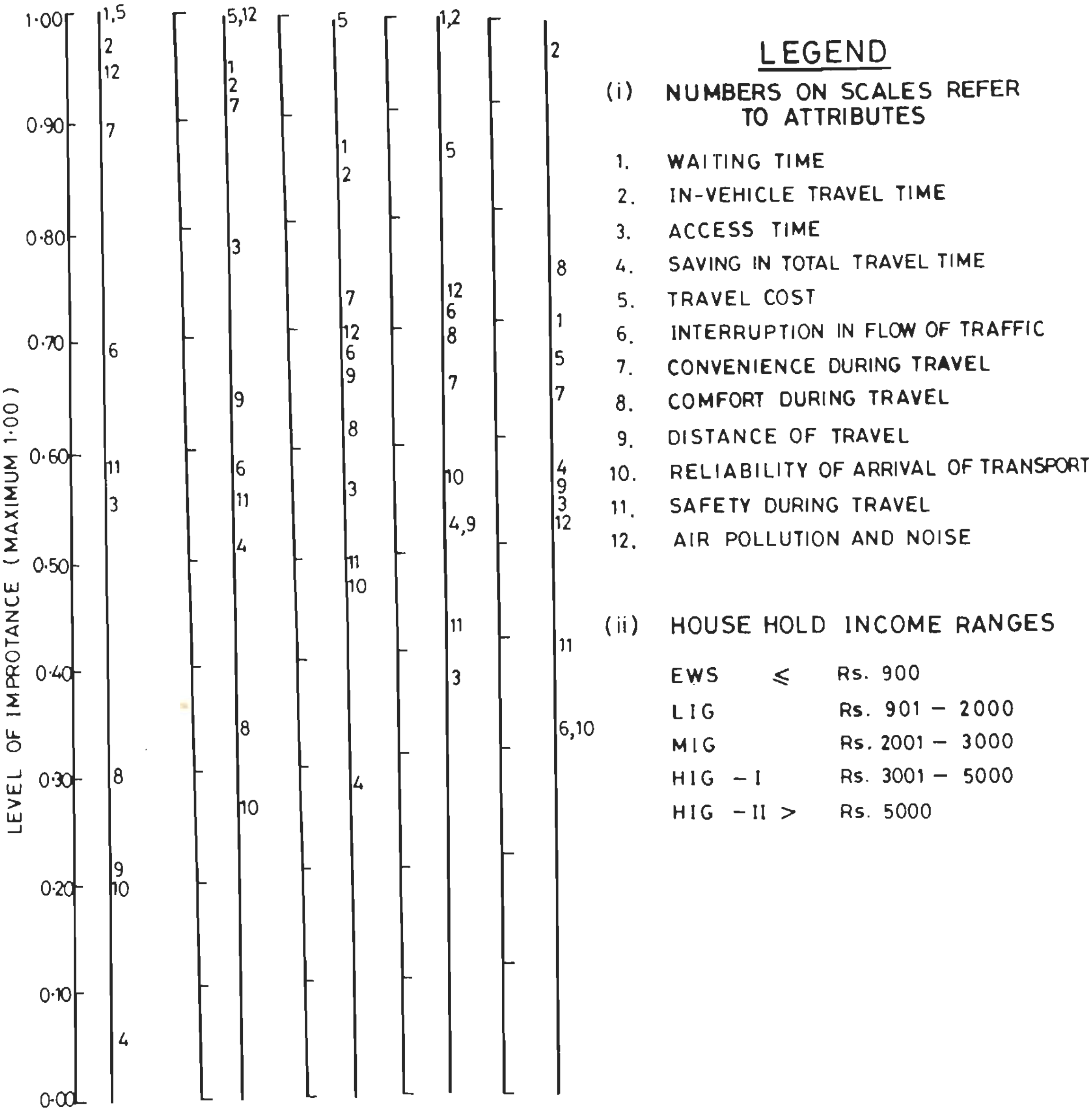


FIG. 8·3 RELATIVE IMPORTANCE OF TRAVEL ATTRIBUTES FOR DIFFERENT INCOME GROUPS WITHOUT TRADE-OFF

TABLE 8.2 RESULTS OF TRADE-OFF GAME ON TRAVEL ATTRIBUTES

Attribute	Attribute characteristics									
Number	a	b	c	d	e	f	g	h	i	j
1.	11.16	11.11	1	1.000	52	1	1.000	20	5	0.322
2.	10.89	10.69	2	0.962	36	3	0.692	28	3	0.452
3.	10.58	10.13	4	0.912	6	8	0.115	34	2	0.548
4.	7.26	8.14	8	0.733	0	12	0.000	6	10	0.097
5.	10.76	10.14	3	0.913	16	6	0.308	62	1	1.000
6.	7.81	8.54	7	0.769	28	4	0.538	11	6	0.177
7.	8.72	8.71	6	0.784	39	2	0.750	27	4	0.430
8.	8.58	9.40	5	0.846	13	7	0.250	4	12	0.435
9.	7.15	6.82	9	0.614	3	10	0.057	6	9	0.097
10.	6.14	5.74	11	0.517	5	9	0.096	7	8	0.113
11.	4.09	4.39	12	0.395	1	11	0.019	5	11	0.081
12.	6.86	6.19	10	0.557	20	5	0.385	9	7	0.145
Total	100	100			219				219	

Attributes :

1. Waiting time 2. In-vehicle travel time 3. Access time 4. Saving in total travel time 5. Travel cost 6. Interruption in flow of traffic 7. Convenience during travel 8. Comfort during travel 9. Distance of Travel 10. Reliability of arrival of transport 11. Safety during travel 12. Air pollution and noise.

Columns :

a = Indicate mean of importance values assigned at the begining of the game.

b = Indicate mean of importance values assigned at the end of the game.

c = Ranking of importance of various attributes (Ref. b.)

d = Relative importance of various attributes with the most important one having unit value.

e = Number of times attribute was selected for improvement.

f = Ranking of attribute was selected for improvement.

g = Degree of importance desired.

h = Number of times attributes were selected for lowering level of service.

i = Rank order of attributes in terms of least importance based on column h.

j = Degree of lowering desired i.e., value in column h divided by the maximum number any attribute is desired for lowering (From column h = 62).

TABLE 8.3 RESULTS OF ATTRIBUTES CONSIDERED

Important Attributes	Unimportant Attributes
Waiting time, In-vehicle travel time, Travel cost, Access time	Safety during travel, Reliability of arrival of transport, Air pollution and noise, Distance of travel.

TABLE 8.4 RELATIVE IMPORTANCE OF DIFFERENT TRAVEL ATTRIBUTES FOR DIFFERENT INCOME GROUPS (WITHOUT TRADE-OFF)

Sl. No.	Attribute	Relative Levels of Importance for Sample Stratified on Income Basis				
		EWS	LIG	MIG	HIG-I	HIG-II
1.	Waiting time	1.00	0.95	0.86	1.00	0.69
2.	In-vehicle travel time	0.96	0.94	0.84	1.00	0.96
3.	Access time	0.56	0.76	0.55	0.36	0.54
4.	Saving in total Travel time	0.05	0.51	0.28	0.52	0.56
5.	Travel cost	1.00	1.00	1.00	0.85	0.67
6.	Interruption in flow of traffic	0.69	0.58	0.68	0.71	0.32
7.	Convenience during travel	0.89	0.92	0.73	0.65	0.64
8.	Comfort during travel	0.31	0.34	0.62	0.69	0.74
9.	Distance of travel	0.22	0.64	0.66	0.52	0.55
10.	Reliability of arr-ival of transport	0.21	0.26	0.48	0.56	0.32
11.	Safety during travel	0.59	0.56	0.49	0.42	0.39
12.	Air pollution and noise	0.95	1.00	0.68	0.72	0.52

TABLE 8.5 IMPORTANT AND UNIMPORTANT ATTRIBUTES FOR DIFFERENT INCOME GROUPS

Income Groups	Sample Size	Important Attributes	Unimportant Attributes
EWS <=Rs.900 per month	34	Travel cost,waiting time, in-vehicle travel time, air pollution and noise.	Saving in total travel time, reliability of arrival of transport, distance of travel, comfort during travel.
LIG Rs.901 to Rs. 2000 per month	36	Air pollution and noise, travel cost, waiting time In-vehicle travel time	Reliability of arrival of transport, comfort during travel, saving in total travel time, safety during travel.
MIG Rs. 2001 to Rs. 3000 per month	34	Travel cost, waiting time, in-vehicle travel time, convenience during travel	Saving in total travel time, reliability of arrival of transport, access time, comfort during travel.
HIGH-I Rs.3001 to Rs. 5000 per month	36	Waiting time, in-Vehicle travel time, travel cost, air pollution and noise	Safety during travel,distance of travel, access time, saving in total travel time
HIG-II >Rs. 5000 per month	34	In-Vehicle travel time, comfort during travel, waiting time, travel cost	Reliability of arrival of transport, interruption in flow of traffic safety during travel, air pollution and noise.

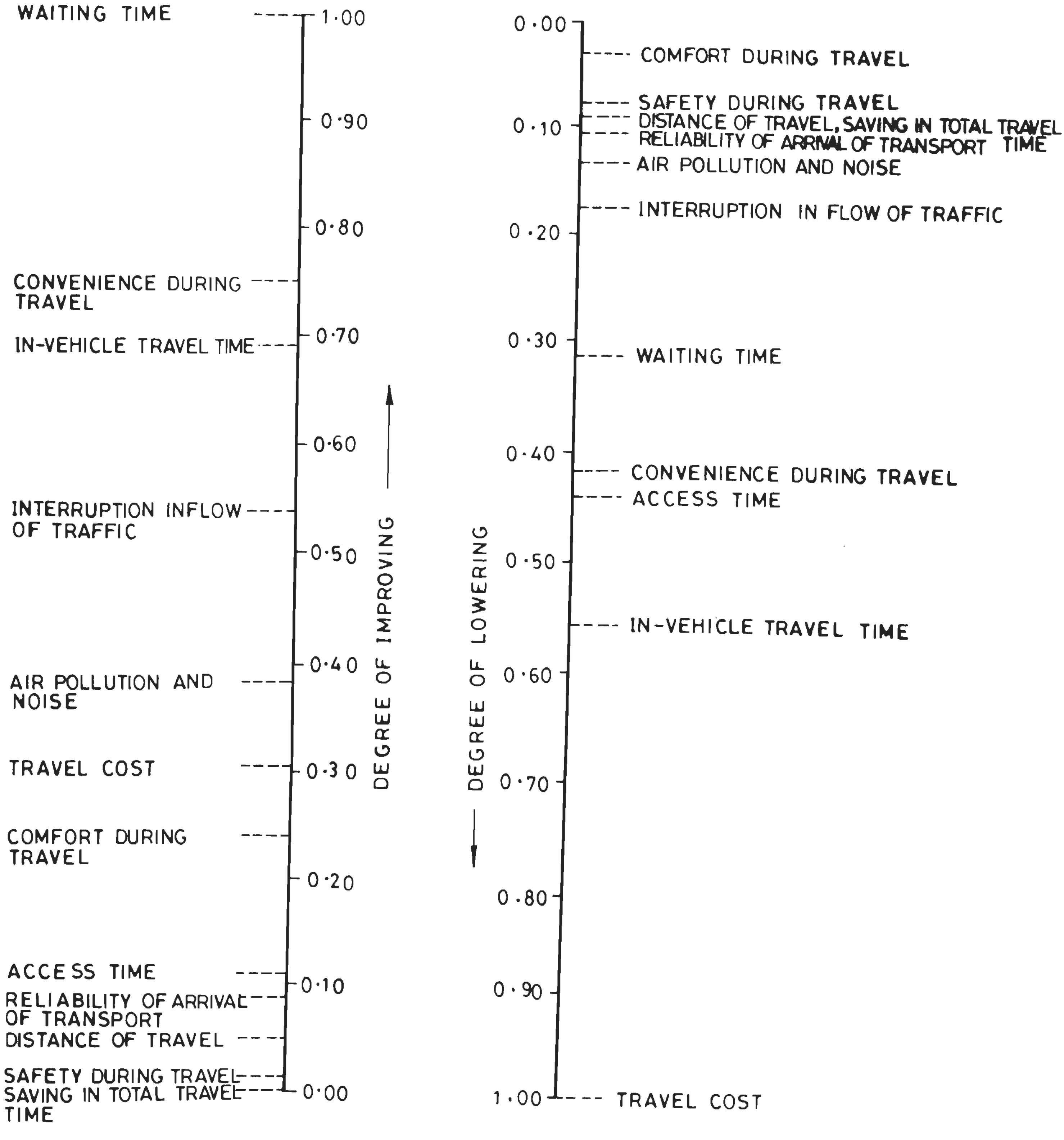
It will be seen that time related and cost related factors are important in all cases. Strangely, pollution is considered important by EWS, LIG, and HIG-I, HIG-II have not considered air pollution and noise as important.

8.4.2 Construction of scale of importance

The trade-off game results are analysed in two ways. The first is to make use of the results of the game to find relative level of importance players attach to various travel attributes in a constrained situation. In this, level of importance is first worked out based on number of times the players select an attribute for improvement. More, it is selected for improvement, more important it is. This level is computed and the attributes are plotted on a vertical scale on one side (left side) with the one not chosen at all at zero level at bottom of the scale, and place the attribute chosen most at top most level at 1.0. Conversely, the attributes chosen for lowering are then considered, and number of times each was chosen for lowering worked out. From this, the relative level of importance computed with o for the one not chosen for lowering at all, and 1.0 for the one chosen maximum number of times for lowering. But while plotting, the scale is reversed with o on top and 1.0 at bottom of the scale and plotted on the right side of scale (Figure 8.4). On a scale of this type, all the items which appear both on left and right sides of scale at top are considered as most important and those which appear on both sides at bottom are considered as having low importance. The mean position (0.5) could be the place for attributes which are neither 'too important' nor 'too unimportant'.

8.4.3 Construction of scale of importance for stratified sample

The results of trade-off for each group stratified on income basis are computed in the same manner as detailed in 8.4.2 and tabulated in Table 8.6 and are also plotted in Figure 8.5 to Figure 8.9. By a careful analysis of trade-off game results, one can list out the attributes into 3 groups. (i) most important attributes (ii) medium important attributes and (iii) least important attributes (Table 8.7).



NOTE : NUMBER OF TIMES EACH ATTRIBUTE IS IMPROVED AND LOWERED HAVE BEEN CONSIDERED

FIG. 8·4 IMPORTANCE OF TRAVEL ATTRIBUTES BASED ON TRADE-OFF GAME RESULT FOR ALL GROUPS TAKEN TOGETHER

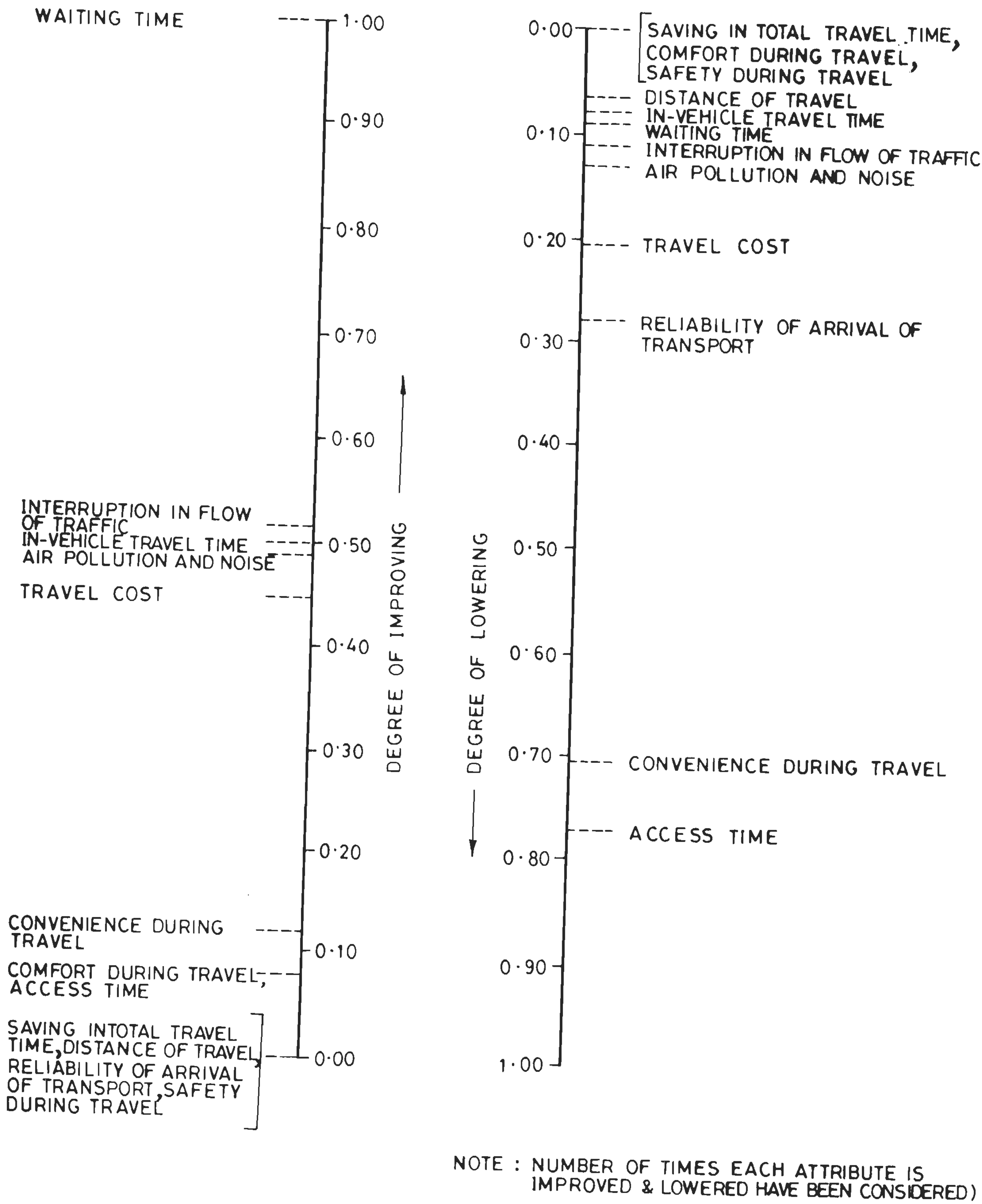


FIG. 8·5 RELATIVE IMPORTANCE OF TRAVEL ATTRIBUTES BASED ON TRADE-OFF FOR EWS

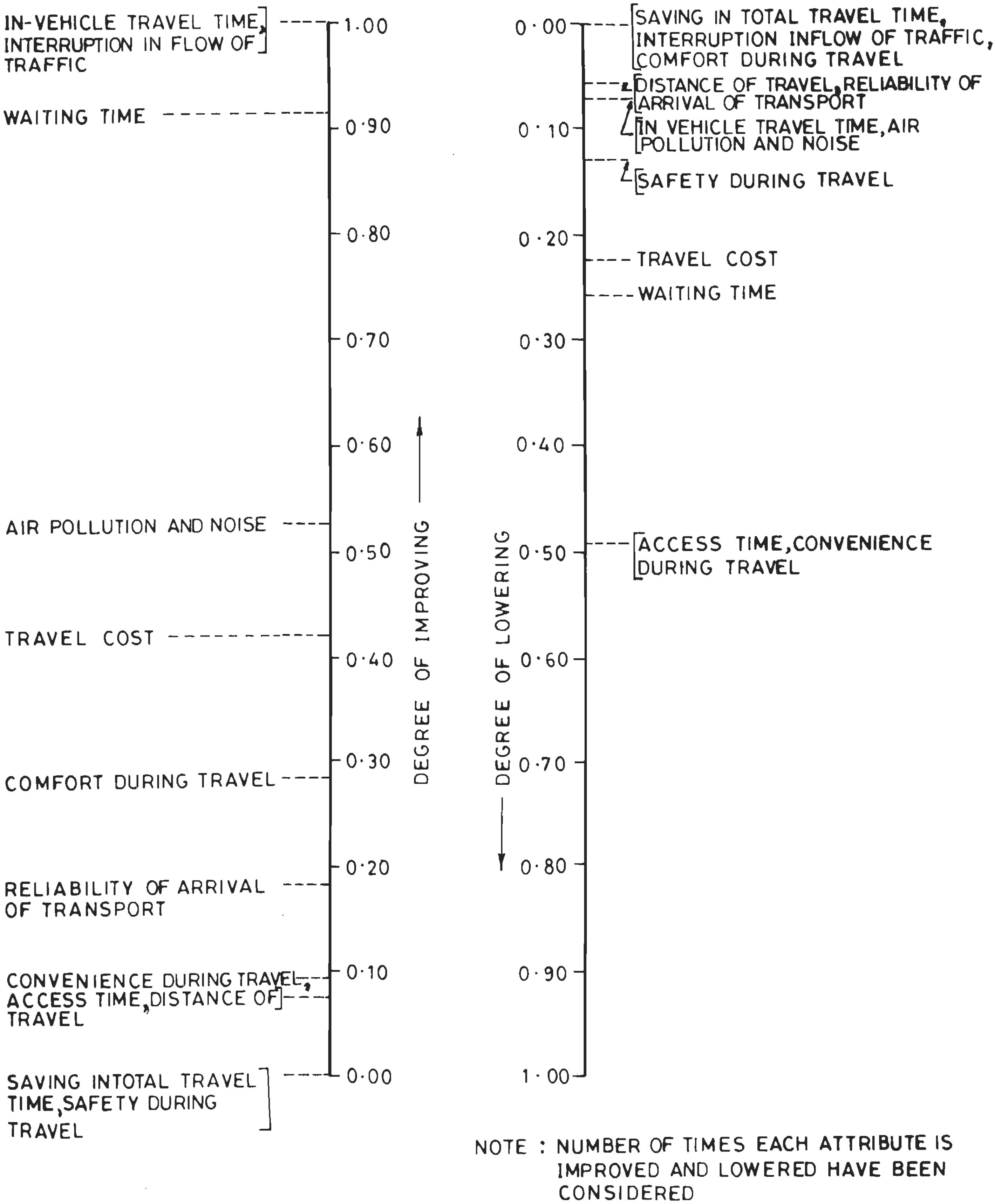
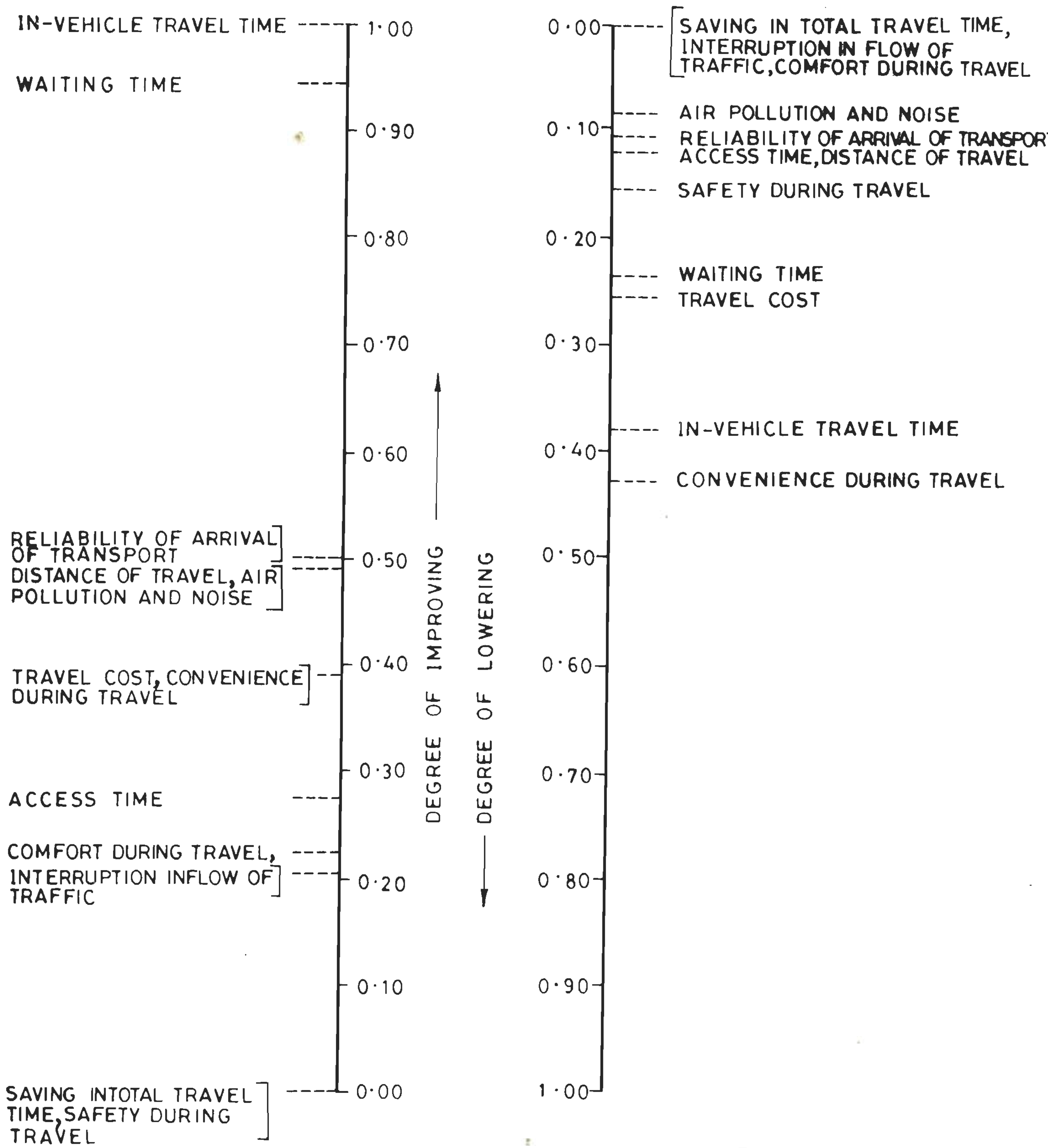
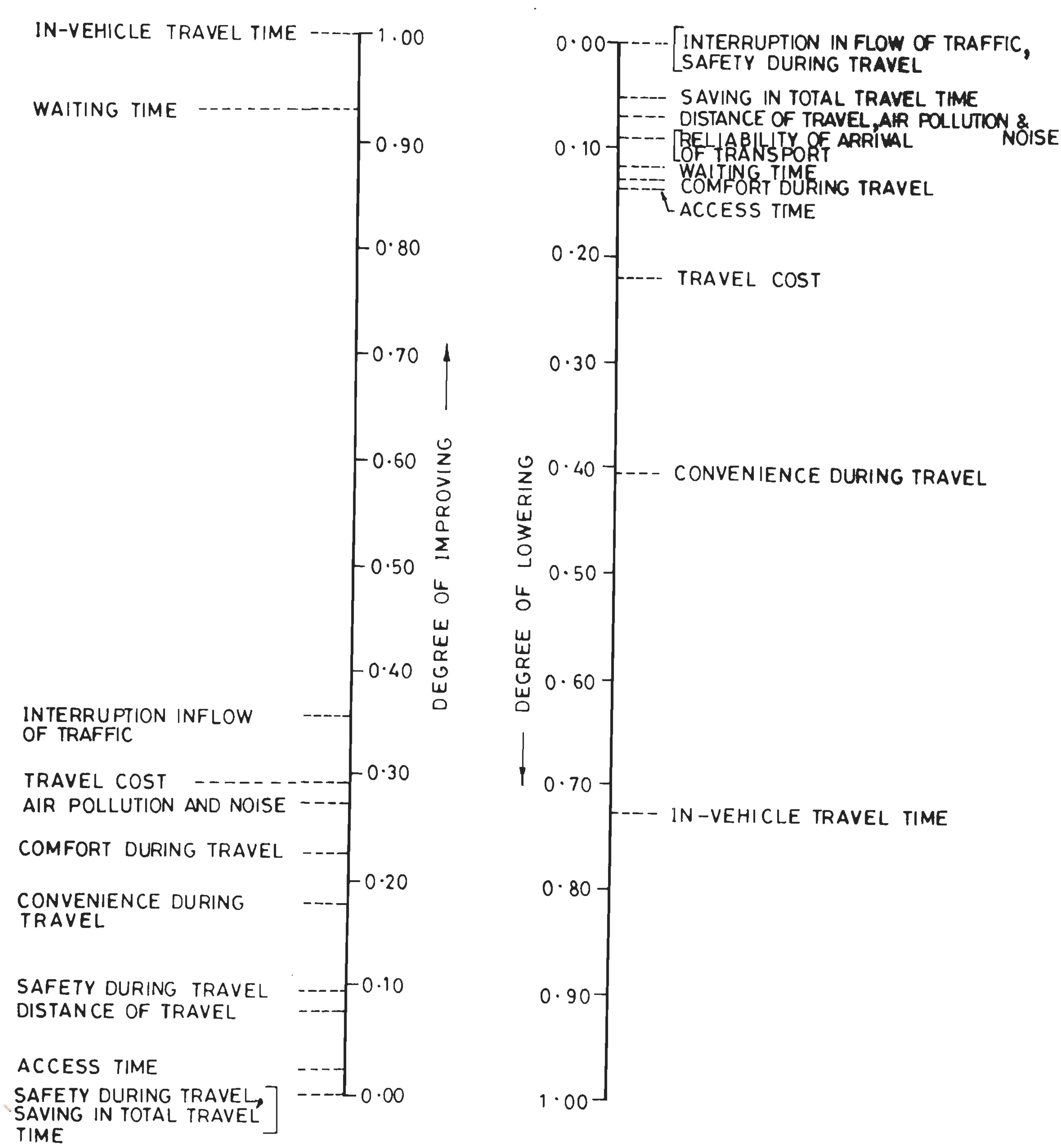


FIG. 8·6 RELATIVE IMPORTANCE OF TRAVEL ATTRIBUTES BASED ON TRADE-OFF FOR LIG



NOTE : NUMBER OF TIMES EACH ATTRIBUTE IS IMPROVED AND LOWERED HAVE BEEN CONSIDERED

FIG. 8·7 RELATIVE IMPORTANCE OF TRAVEL ATTRIBUTES BASED ON TRADE-OFF FOR MIG



NOTE: NUMBER OF TIMES EACH ATTRIBUTE IS IMPROVED AND LOWERED HAVE BEEN CONSIDERED

FIG. 8·8 RELATIVE IMPORTANCE OF TRAVEL ATTRIBUTES BASED ON TRADE-OFF FOR HIG-I

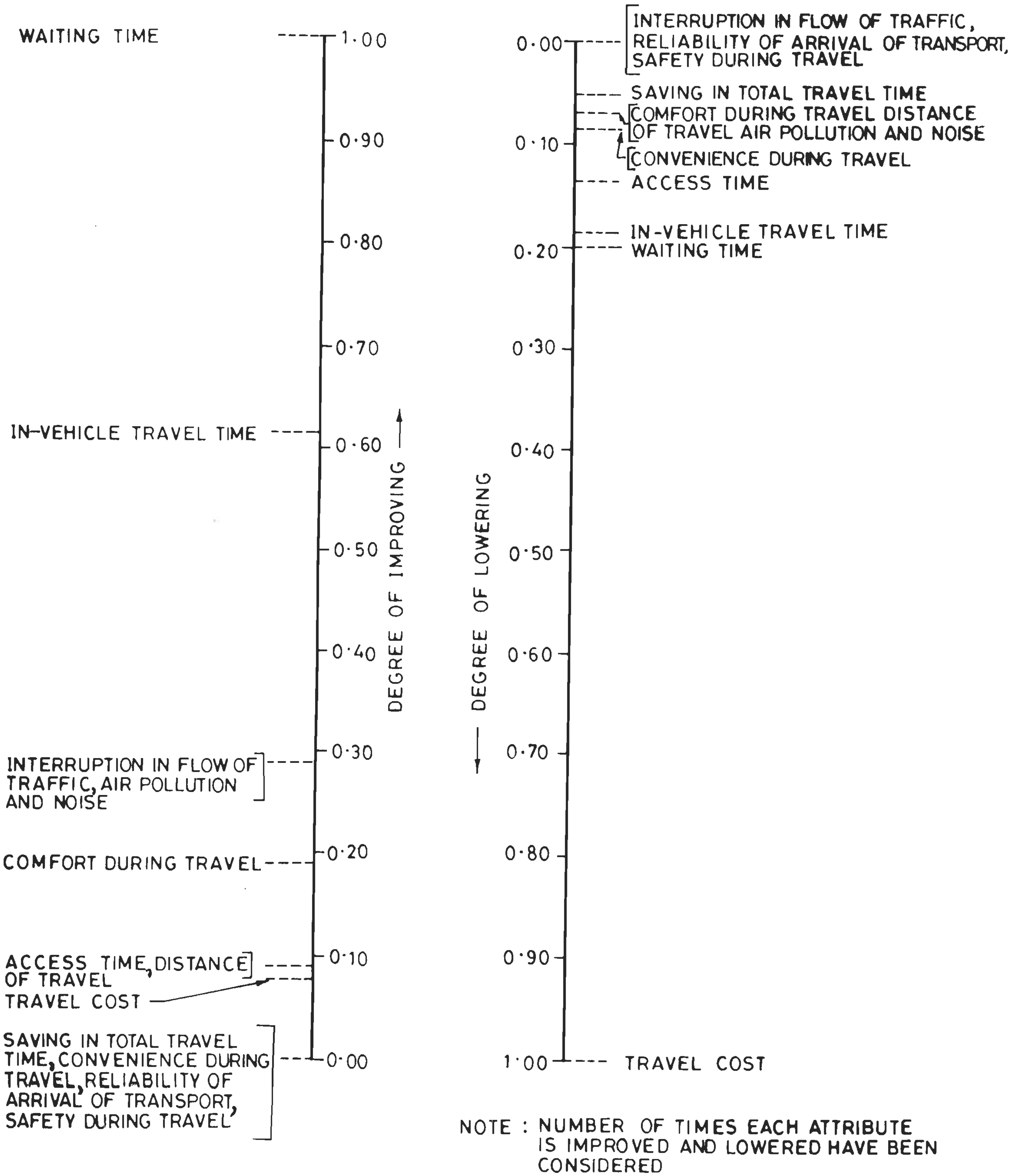


FIG. 8·9 RELATIVE IMPORTANCE OF TRAVEL ATTRIBUTES BASED ON TRADE-OFF FOR HIG-II

TABLE 8.6 RELATIVE LEVELS OF IMPORTANCE AND UNIMPORTANCE BASED ON TRADE-OFF FOR STRATIFIED SAMPLE

Sl. No.	Attribute	Degree of Importance of Attributes Taking the Attributes Considered for Improvement in Level of Service					Degree of Unimportance of Attributes Taking the Attributes Considered for Lowering the Level of Service				
		EWS	LIG	MIG	HIG-I	HIGH-II	EWS	LIG	MIG	HIG-I	HIG-II
1.	Waiting time	1.00	0.92	0.95	0.93	1.00	0.09	0.26	0.24	0.12	0.20
2.	In-vehicle travel time	0.50	1.00	1.00	1.00	0.62	0.08	0.07	0.38	0.73	0.19
3.	Access time	0.08	0.07	0.27	0.03	0.09	0.77	0.49	0.13	0.14	0.14
4.	Saving in total, travel time	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.06	0.06
5.	Travel Cost	0.45	0.43	0.39	0.29	0.08	0.21	0.23	0.26	0.22	1.00
6.	Interruption in flow of traffic	0.52	1.00	0.21	0.35	0.29	0.11	0.00	0.00	0.00	0.00
7.	Convenience during travel	0.13	0.09	0.39	0.17	0.00	0.71	0.49	0.43	0.41	0.08
8.	Comfort during travel	0.08	0.27	0.23	0.23	0.19	0.00	0.00	0.00	0.13	0.07
9.	Distance of travel	0.00	0.07	0.49	0.08	0.09	0.07	0.06	0.13	0.07	0.07
10.	Reliability of arrival of transport	0.00	0.17	0.50	0.00	0.00	0.27	0.06	0.11	0.09	0.00
11.	Safety during travel	0.00	0.00	0.00	0.09	0.00	0.00	0.13	0.15	0.00	0.00
12.	Air Pollution and noise	0.49	0.53	0.49	0.27	0.29	0.13	0.07	0.09	0.07	0.07

TABLE 8.7 DEGREE OF IMPORTANCE OF DIFFERENT TRAVEL ATTRIBUTES AS REVEALED BY TRADE-OFF GAME

Income Group	Most Important Attributes	Medium Important Attributes	Least Important Attributes
EWS	Waiting time	Interruption in flow of traffic, air pollution and noise, in-Vehicle travel time, travel cost	Access time, comfort during travel, convenience during travel.
LIG	In-vehicle travel time, interruption in flow of traffic, waiting time	Travel cost	Distance of travel, convenience during travel
MIG	In-vehicle travel time, waiting time	Reliability of arrival of transport, distance of travel, air pollution and noise	Interruption in flow of traffic, comfort during travel
HIG-I	In-vehicle travel time, waiting time	Interruption in flow of traffic	Access time, distance of travel, safety during travel
HIG-II	Waiting time, in-vehicle travel time	Air pollution and noise, interruption in flow of traffic	Travel cost, access time, distance of travel
All Groups	In-vehicle travel time, waiting time	Interruption in flow of traffic, air pollution and noise	Access time, distance of travel

It is seen that waiting time is considered as the most important attribute by all the five income groups, irrespective of whether they are rich or poor. Travel cost is considered as important by economically weaker sections (EWS) and low income group (LIG). This clearly shows that any service (Bus/train) to cater for EWS and LIG should consider cost also as an important factor besides improving waiting time scenario, i.e., a lowering of waiting time of EWS and LIG may not necessarily be patronized for high costs. Since, other economically stronger groups do not attach too much importance to cost, they could be served by a mode which reduces the travel and waiting time but involves a higher cost. This shows that these groups could be served by a mode which reduces the travel and waiting time but involves a higher cost.

This shows that these groups could be served by more expensive form of transport system like chartered bus etc. In summary, waiting time is important amongst to all ** and travel cost is not important to all except EWS and LIG.

In terms of policy, this means increasing frequency of buses (and trains) and their overall running time and accurate estimate of stratified passengers through income grouping, as well as, the ones they reside.

8.4.4 Level of satisfaction

Analysis has been done to establish relationship between level-of-service and level of satisfaction using data collected in trade-off game for 8 attributes out of the total 12 attributes.

Models derived are listed below :

Models	Coefficient of Correlation	Sample size
$y_1=12.8-6.67 \log x_1$	r = -0.87	S = 105
$y_2=17.25-0.49\ x_1$	r = -0.76	S = 105
$y_3=7.89-0.14\ x_1$	r = -0.82	S = 128
$y_4=15.28-5.2 \log x_2$	r = -0.78	S = 131

$y_5=9.28-7.76 \log x_3$	$r = -0.86$	$S = 132$
$y_6=9.86-0.95\ x_4$	$r = -0.87$	$S = 115$
$y_7=6.84-7.82 \log x_5$	$r = -0.84$	$S = 139$
$y_8=12.27-2.16\ x_6$	$r = -0.88$	$S = 136$

Where,

y_1 = Level of satisfaction of waiting time.

y_2 = Level of satisfaction of access time.

y_3 = Level of satisfaction of travel time.

y_4 = Level of satisfaction of travel cost.

y_5 = Level of satisfaction of interruption in flow of traffic

y_6 = Level of satisfaction of comfort during travel.

y_7 = Level of satisfaction of reliability of arrival of transport

y_8 = Level of satisfaction of air pollution and noise.

x_1 = Level-of-service in terms of In-vehicle travel time/Access time/waiting time in minutes.

x_2 = Level-of-service in terms of travel cost in paise.

x_3 to x_6 = Level-of-service for different attributes as given in Tables 8.8 to 8.11.

S = Sample size of the considered attribute.

These models can be used to determine the level of satisfaction that will be derived by a population from different attributes of any existing transport system and also determine the change in level of satisfaction that would be brought about by any improvement of level-of-service of the attributes.

TABLE 8.8 LEVEL-OF-SERVICE DETAILS FOR Y_5

(Interruption in Flow of Traffic)

X_3	Level-of-Service
1	Free Flow
2	Occasional Stops
3	Frequent Stops
4	Crowded Traffic
5	Very Congested and Crowded traffic

TABLE 8.9 LEVEL-OF-SERVICE DETAILS FOR Y_6

(Comfort During Travel)

X_4	Level-of-Service
1	Riding Alone
2	Shared Travel in Hired/Private Vehicle
3	Seated Comfortably in Public Transport
4	Seated in Crowded Public Transport
5	Seated Part Length in Public Transport
6	Standing for Most Length in Public Transport
7	Travelling in Crush load condition

TABLE 8.10 LEVEL-OF-SERVICE DETAILS FOR Y_7

(Reliability of Arrival of Transport)

X_5	Level-of-Service
1	Punctual and Regular
2	Often Missing of Time
3	Often Not in Time
4	Very Irregular
5	Can not be Relied upon at all

TABLE 8.11 LEVEL-OF-SERVICE DETAILS FOR Y_8

(Air Pollution and Noise)

X_6	Level-of-Service
1	Neither (Pollution or Noise)
2	Exhaust pollution, Engine and Body noise
3	Exhaust pollution, No Engine and body noise
4	Both (Exhaust pollution, Engine and Body noise) moderate
5	Very Smoky
6	Very Smoky and Noisy

8.4.5 Quantifying level-of-service

The greatest advantage of the trade-off game is that it helps to quantify many attributes by considering the trade-off results. Between waiting time (WT) and in-vehicle travel time (IVTT) of bus/train system, it is revealed that, one minute of in-vehicle travel time=0.50 minute of waiting time. Similarly, by comparing the trade-off between comfort during travel and travel cost, it is revealed that provision of assured seat in public transport = 150 paise. Thus, these results give lot of useful information to the transport planner. If for example, one can design a public transport system which will ensure passengers to be seated, he could be charged 50 paise extra. Again, for example, if in a trip of average length an in-vehicle travel time of 10 minutes can be saved by a passenger, he can be charged (10 * 1.5) = 15 paise extra for the trip. This supports the argument to charge extra for level-of-service provided to the commuters over an existing comparable system of lower level-of-service. This can be successfully applied in many situations.

8.5 Application of Trade-Off Game Results for Assessing Possible Changes in Selecting Modes

Results of the trade-off game are presented in the form of a matrix in Table 8.12. It lists out all the 12 attributes in both x and y axis directions grouped in 8 categories. Attributes considered by the players for improvement in their level-of-service are listed in y axis and attributes considered for trade-off by lowering their level-of-service are listed in x axis. The Table 8.12 presents clearly, while trading - off how many times each attribute was considered for lowering in its level-of-service. For example, in order to improve the attribute 'cost of travel' , other attributes which are traded-off are - 4 times the attribute 'waiting time', 3 times ' in-vehicle travel time', 1 time 'saving in total travel time', 2 times 'interruption in flow of traffic', 2 times 'convenience during travel', 1 time 'comfort during travel', 1 time 'reliability of arrival of transport', 1 time 'safety during travel', 1 time 'air pollution and noise', (total 16 trade-offs).

This type of matrix can be used for assessing the likely shift from one mode to another, when the travel attributes of latter are improved or a new mode with some improved travel attributes is introduced.

For example, it is possible to determine what would be the likely shift ;

(a) If a Mass Rapid Transit System (MRTS) service is made available within about a kilometer of reach for those who do not have such access facilities now and,

(b) If a special bus service at fixed time intervals with seats assured is made available at extra travel cost. It could be done by extracting data from relevant cells for related attributes from the trade-off matrix (Table 8.12). On similar lines, trade-off matrix could be constructed for each group of mode users from the data available similar to Table 8.12.

As an example, consider that a train mode is to be introduced in the area. Let us consider the case of private vehicle users. The use of train over private vehicle is assumed to occur if the actions taken results in improvement in level-of-service with respect to attributes 'interruptions inflow of traffic', 'safety in travel', 'reliability of arrival of transport', and 'air pollution and noise'.

But it will result in lowering the level-of-service in the attributes 'distance of travel', 'access time', 'convenience during travel', and 'in-vehicle travel time'. Table 8.13 has been constructed by extracting relevant data from Table 8.12.

TABLE 8.12 TRADE-OFF PROPENSITIES FOR WORK TRIPS (ALL GROUPS TOGETHER)

Attributes Traded-off	Number of Times the Attribute was Trade-off to Improve the Corresponding Attribute in Y-Axis													
Attributes		A				B	C		D	E	F	G	H	Total
Improved ⟶		1	2	3	4	5	6	7	8	9	10	11	12	
Time of travel	1			11		15	6	14	3		2	1		52
	2			5		18	5	7				1		36
	3	3				1		2						6
	4													
Cost of travel	5	4	3		1		2	2	1		1	1	1	16
Comfort in travel	6	1	5	9	3	4				6				28
	7	6	9	3	2	13					4	2		39
Convenience in travel	8	3	2	5		1		2						13
Distance of travel	9			1		2								3
Reliability of arrivel of transport	10	3	2											5
Safety in travel	11												1	1
Air pollution and noise	12		7			6							7	20
Total		20	28	34	6	60	13	27	4	6	7	5	9	219

A = Time of travel, B = Cost of travel, C = Comfort in travel, D = Convenience in travel, E = Distance of travel, F = Reliability of arrival of transport, G = Safety in travel, H = Airpollution and noise.

Attributes :

1. Waiting time 2. In-vehicle travel time 3. Access time 4. Saving in total travel time 5. Travel cost 6. Interruption in flow of traffic 7. Convenience during travel 8. Comfort during travel 9. Distance of travel 10. Reliability of arrival of transport 11. Safety during travel 12. Air pollution and noise.

TABLE 8.13 ATTRIBUTES TRADED-OFF IN FAVOUR OF TRAIN AND SPECIAL BUS AND PERSONS LIKELY TO SHIFT TO NEW SYSTEMS BY SAMPLE POPULATION

Options in shift Considered	Attributes Desired for Improvement	Number of Times each Attribute is Traded-off Against Improvement on Other Attributes in y-axis					Proportion of Concerned Population Likely to Shift
		2*	3*	7*	9*	Total	
Train over private vehicles	Interruption in flow of traffic	1	-	2	-	3	
	Safety in travel	1	1	3	2	7	
	Air pollution and noise	-	3	-	-	3	5.94%
					Total	13	
Train over Conventional Bus	Comfort in travel	15	2	-	6	23	
	Waiting time	-	9	1	19	29	
	Air pollution and noise	-	-	-	-		23.74%
					Total	52	

Contd...

Contd Table 8.13

Options in shift Considered	Attributes Desired for Improvement	Number of Times each Attribute is Traded-off Against Improvement on Other Attributes in y-axis					Proportion of Concerned Population Likely to Shift
		2*	3*	7*	9*	Total	
Special Bus over private vehicle	Interruption in flow of traffic	16	6	3	-	25	
	Air pollution and noise	-	-	-	2	2	12.33%
					Total	27	
Special Bus over Conventional Bus	Comfort in travel	11	-	-	4	15	
	Waiting time	-	2	-	-	2	7.76%
					Total	17	
Special Bus over Train	Reliability of arrival of transport	3	1	-	-	4	
	Safety in travel	-	-	-	1	1	2.28%
					Total	5	

2* = In-vehicel travel time 3* = Access time.
7* = Convenience during travel 9* = Distance of travel

The first option for shift, 'Train over private vehicles' exhibits totally 13 trade-off cases. There is a total of 219 trade-offs made by the population and hence the proportion of the concerned group which would shift from private vehicle to train will be 13/219 or 5.94%. Similarly, the shift from 'private vehicle' to a special bus with assured seat' has been assessed as 12.33%, from 'conventional bus to train' as 23.74%, 'conventional bus' to 'special bus' as 7.76%. Where, there are already both train and conventional bus available, some train users may shift to special bus. In this case it works out to 2.28%.

The sample population consists of 26 private vehicle (car and motorised two wheeler) users, 98 conventional bus users and 13 train users. The analysis of trade-off propensities made and likely shifts to train and special bus can be applied to the different commuters using Bayesian principle the total shift works out as follows :

Private vehicle to train i e.,	5.94% of 26 = 1.54.
Private vehicle to special bus i e.,	12.33% of 26 = 3.21.
Conventional bus to train i e.,	23.74% of 98 = 23.27.
Conventional bus to special bus i e.,	7.76% of 98 = 7.60.
Train to special bus i e.,	2.28% of 13 = 0.30.

This will result in shift of 4.75 or 5 from private vehicles and 30.87 or 31 from conventional bus to new systems. The gain to train will be 24.81 or 25 and to special bus 10.81 or 11. The 5 private vehicle users can be pro-rata divided as 1 car user and 4 motorised two wheeler users. The resultant shifts from one mode to another and revised modal split for sample population will be given in Table 8.14. The trade-off analysis here is carried out for users of different modes.

TABLE 8.14 LIKELY SHIFT IN MODAL CHOICE AMONG SAMPLE POPULATION ON INTRODUCTION OF NEW SYSTEMS

Mode	Existing Number of Users	Number Likely to Move to New Systems	Expected Number of Users	Modal Split in Percentage	
				1*	2*
Conventional Bus	98	-31	67	58.33	39.88
Train	13	+25	38	7.74	22.62
Car	6	- 1	5	3.57	2.98
Motorised two Wheeler	20	- 4	16	11.90	9.52
IPT	3		3	1.78	1.78
Bicycle	16		16	9.52	9.52
Walk	12		12	7.16	7.16
Special Bus	-	+11	11	-	6.54
Total	168		168	100	100

1*- Existing state

2*- Modified state if changes in modal state are made.

8.6 Application of Trade-Off Game Results in Shahdara Area of Delhi

The trade-off game results analysed as above, can be used to work out the percentage of commuters using a particular mode that would shift to an improved or a new form of transport when level-of-service of certain attributes are improved. The various steps involved are indicated in Figure 8.10. Mass Rapid Transit System (MRTS) is being proposed for Delhi metropolis. It is in this context, that Shahdara in Delhi has been chosen to study the applicability of trade-off game results.

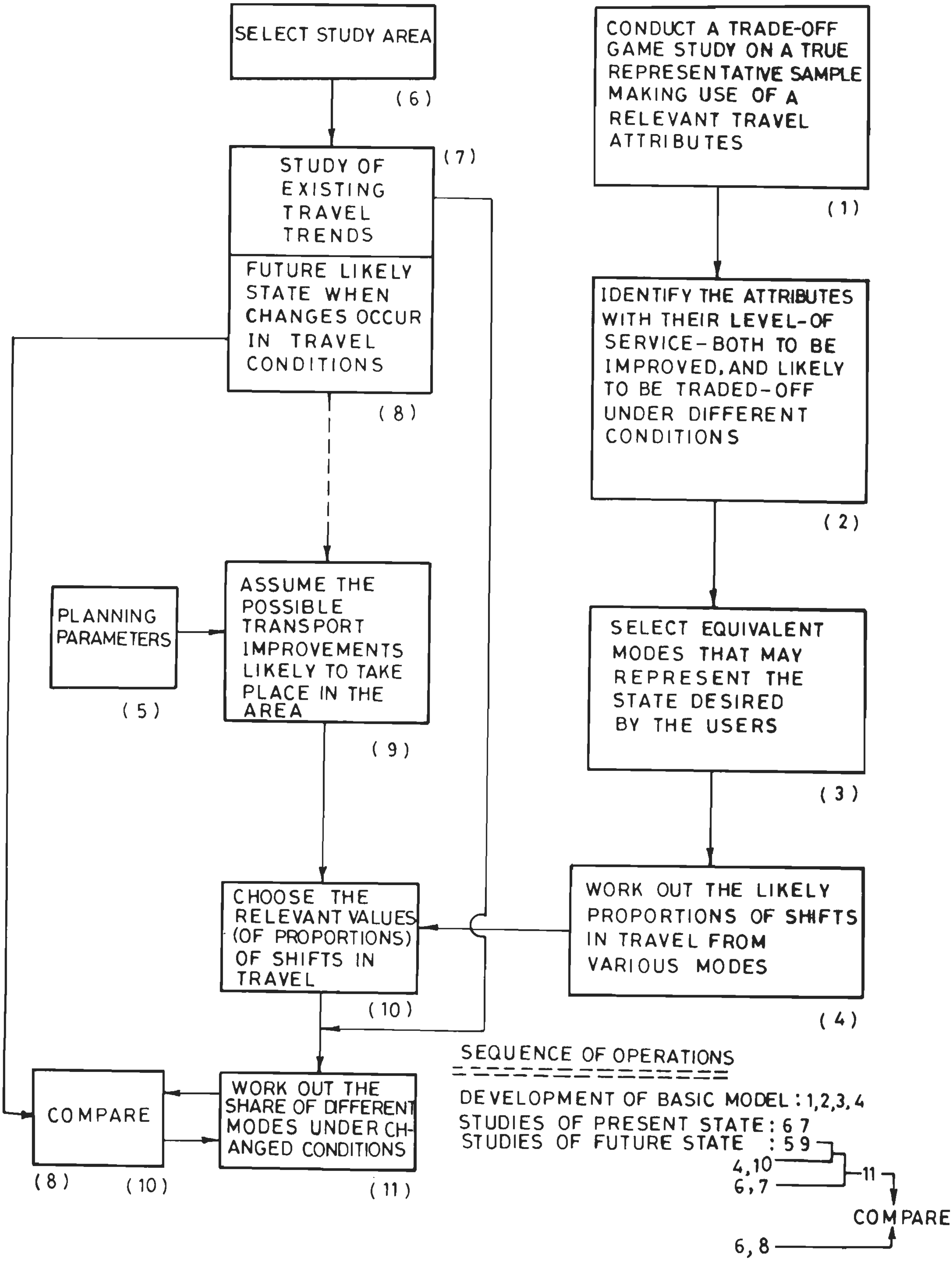


FIG. 8·10 USE OF TRADE-OFF GAME RESULTS FOR A STUDY AREA

The area selected has access to both road and rail facility. the proposed Mass Rapid Transit System (MRTS) in Delhi will pass through this area by 2001 AD, which has been described in Chapter 4 and would link this area directly to CBD and a number of other important work centres. The study area has been so chosen that the samples fall on both sides of the proposed railway station.

For the sample population the two cases viz, introduction of a train service in an area where there is none and introduction of a special bus service with assured seat at an extra cost are considered. The trade-off study has helped to estimate the possible shifts towards the two systems from different modes. they are abstracted and presented in Table 8.15.

TABLE 8.15 LIKELY SHIFT TO NEW SYSTEMS INTRODUCED

From Mode	Train	Special Bus
Conventional Bus	23.2	11.9
Train	-	5.4
Car	15.6	10.9
Motorised Two Wheeler	14.3	14.6
Bicycle	17.6	Nil
IPT	16.8	13.2

The present state and the future modal split state with introduction of MRTS as computed using trade-off findings are shown in Table 8.16. The share of bus, for example, is likely to decrease from the present 44.2% to 35.2% in future, when MRTS is introduced at Shahdara (Delhi).

TABLE 8.16 LIKELY SHIFT OF MODES AND MODAL CHOICE IN SHAHDARA (DELHI) AREA WHEN MRTS IS AVAILABLE-USING TRADE-OFF MATRIX

Mode of Use	Number of Existing Users		Likely Shift as per Trade-off	Future Modal Split		
	Number	Percentage	Percentage of Trips Shifting to Train as per Trade-off Analysis	Number of Persons Likely to Shift	Number of Persons	Percentage
Conventional						
Bus	54	44.2	23.2	-10	44	35.2
Train	3	2.4	-	+20	23	20.4
Car	16	8.6	15.6	-2	14	6.8
Motorised						
Two wheeler	24	23.4	14.3	-6	18	16.4
IPT	-	-	16.8	-	-	-
Bicycle	28	21.4	17.6	-2	26	21.2
Total	125	100.0			125	100.0

A comparison of column (3) and column (7) clearly indicates as to how changes are likely to take place. It shows an appreciable reduction in bus, motorised two wheeler, and bicycle trips with substantial increase in MRTS/Train trips. Instead of introducing MRTS, if a special bus system is introduced, the same may also bring appreciable changes in modal split. On the similar line, the share for different modes have been worked out when special bus system is introduced (Table 8.17).

TABLE 8.17 LIKELY SHIFT OF MODES AND MODAL CHOICE IN SHAHDARA (DELHI) AREA WHEN SPECIAL BUS IS AVAILABLE -USING TRADE-OFF MATRIX

Mode of Use	Number of Existing Users		Likely Shift as per Trade-off		Future Modal Split	
	Number	Percentage	Percentage of Trips Shifting to Special Bus as per Trade-off Analysis	Number of Persons Likely to Shift	Number of Persons	Percent-age
Conventional						
Bus	54	44.2	11.9	-6	48	39.2
Train	3	2.4	5.4	-1	2	2.4
Car	16	8.6	10.9	-5	11	10.0
Motorised						
Two wheeler	24	23.4	14.6	-	24	17.2
IPT	-	-	13.2	-	-	-
Bicycle	28	21.4	Nil	-	28	21.4
Special Bus	-	-	-	+12	12	9.8
Total	125	100.0			125	100.0

8.7 Summary

(i) The trade-off technique is simple in basic principles, but requires elaborate investigations to select appropriate representative sample. It is expressed that conducting a trade-off game requires careful planning, skilled investigators and willing participants. If all the above are materialised, probably the results of this technique could very well serve as a quick response technique (QRT) for analysis of modal split under different future conditions and scenarios.

(ii) The trade-off game can be used to understand as to what travel attributes should be improved if commuters should be made to prefer a desired mode. How preference changes among different income groups or users of modes, could be studied. The study helps to pin-point the attributes which should be improved to effect a shift in mode users and to what levels.

(iii) It has also been demonstrated that as to how the results of trade-off game could be used to work out future levels of mode choice when desired improvements in level-of-services of transport systems are carried out.

CHAPTER 9
CAPITAL AND OPERATING EXPENSES

9.1 Scope

This chapter gives a description of various components of the Mass Rapid Transit System infrastructure and an estimate of the capital and operating expenses of the three proposed MRTS Corridors of Delhi metropolis.

9.2 Capital Costs

The capital costs estimate of the three proposed MRTS corridors are based on the unit rates for various elements of the project. These have been calculated on the basis of schedule of rates of Indian Railways, Calcutta Metro and Metropolitan Transport project (Railways) Madras (Chennai) and is duly adjusted to the year 1996 AD, so as to represent the cost of facilities, if provided at respective percentage rates as adopted by the Indian Railways.

9.3 Vishwavidyalaya - Central Secretariat Metro Corridor

9.3.1 General

The Vishwa Vidyalaya - Central Secretariat corridor has been proposed as an underground metro corridor. It starts from Vishwavidyalaya in the north and follows Sham Nath Marg upto ISBT. After ISBT, the alignment follows Lothian road for some length and then passed under old Delhi station yard, Chawri Bazar, New Delhi station yard, Connaught place, Parliament street, Rafi marg and terminates near Rail Bhawan where Central Secretariat station has been planned. The total length of the corridor is 11 km and it has 10 stations, which has been described in Chapter 4. The proposed depot for this corridor is located at Khyber pass between vishwavidyalaya and old secretariat stations.

Standards for design of route alignment and schedule of dimensions are based on Calcutta Metro, and high capacity metro systems worldwide [60].

Continuously welded 60 kg rails on ballastless track, with elastic fastenings have been proposed.

The proposed gauge for metro corridor is BG.

Three-phase AC induction motor drive with variable voltage variable frequency (VVVF) control and light weight coaches have been planned for BG (Broad gauge) metro corridor.

Continuous Automatic Train Control (CATC), comprising of Cab signalling and Automatic Train protection system (ATP), has been proposed along with Automatic Train operation (ATO) and Automatic Train Supervision (ATS) for station to station signalling. At stations with points and crossings, relay based Route Interlocking systems have been proposed. Optical fibre based telecommunication facilities have been proposed. The telecom facilities would include real time radio communication between moving trains and the operational control centre. CCTV system has been provided for monitoring strategic locations.

Fare collection will be through microprocessor based ticketing machines operated by staff as well as passengers. Computer printed paper tickets are also provided. Manual checking of tickets at entry and exit gates at random has been envisaged [132]. The capital costs estimate of the Vishwavidyalaya-Central Secretariat BG metro corridor (North - South Corridor) at 1996 AD price level is given in table 9.1.

9.4 Shahdara - Nangloi MRTS Corridor

9.4.1 General

Shahdara - Nangloi BG mass rapid transit system with a route kilometreage of 25 is proposed to be operated with EMUs on 25 KV AC overhead traction. Shahdara - Nangloi MRTS section which is 17.7 km an elevated and 7.3 km at-grade has 19 stations, has been described in chapter 4. 25 KV AC single phase 50 Hz simple polygonal OHE system has been proposed. Special fixation and termination arrangements have been planned for OHE on elevated alignment and at stations with property development. Supervisory Control and Data Acquisition (SCADA) system has been planned for remote control and supervision of power supply and current collection system signalling facilities contemplated are same as for Vishwa vidyalaya - Central Secretariat metro corridor except that ATO has not been provided and a truncated ATS, only with train describer - cum passenger information system, has been provided.

TABLE 9.1 CAPITAL COST OF VISHWAVIDYALAYA - CENTRAL SECRETARIAT BG METRO CORRIDOR

Sl.No.	Description	Cost per Km. in 1996 AD (Rs. million)	Cost per Km. in 2001 AD (Escalated) (Rs. million)
1.	Preparatory and Infrastructure	4.4.	6.0
2.	Land	16.5	24.0
3.	Diversion System	101.0	147.0
4.	Support System	151.8	221.0
5.	Earth Work	50.6	74.0
6.	R.C.C. box	242.0	352.0
7.	Ballastless Track	26.4	38.0
8.	Station Finishes	36.5	53.0
9.	Fire Fighting and Water Supply	8.8	13.0
10.	Compensation and repair to buildings	16.5	24.0
11.	Service buildings	40.7	59.0
12.	Staff quarters	9.5	14.0

Contd...

Contd.. Table 9.1

Sl.No.	Description	Cost per Km. in 1996 AD (Rs. million)	Cost per Km. in 2001 AD (Escalated) (Rs. million)
13.	Pumping	25.0	37.0
14.	Grout	18.7	27.0
15.	Power installation	60.5	88.0
16.	Air Conditioning	33.0	48.0
17.	Ventilation and false Ceiling	38.5	56.0
18.	Pump and lighting	13.0	19.0
19.	Escalator	27.5	40.0
20.	C.A.T.C.	75.5	110.0
21.	A.F.C.	62.7	91.0
22.	Telecom	15.0	22.0
23.	Conventional Signal	4.4	6.0
24.	Maintenance and POH Depot	55.0	80.0
25.	Rolling Stock-Considering 8 coach per-km.	137.5	200.0
26.	General charges and Establishment	132.0	192.0
	Grand Total	1403	2041

Source : Estimated cost based on Data collected from Calcutta Metro and Metropolitan Transport Project (Railways) Chennai (Madras).

Telecom facilities contemplated will be similar to those for metro corridor except that redundancy in cables has not been catered for and also no CCTV system has been envisaged at stations. Fare collection system will be identical to that of metro corridor (Vishwavidyalaya-Central Secretariat metro corridor), Repair facilities will be provided at Nangloi depot [132].

The Capital costs estimate at grade MRTS Corridor and at an elevated MRTS corridor are given in Table 9.2 to Table 9.3.

The capital cost of Shahdara - Nangloi MRTS corridor is estimated to be Rs. 18512.6 million at 1996 AD price level.

TABLE 9.2 CAPITAL COST OF AT-GRADE MRTS CORRIDOR

Sl.No.	Description	Cost per Km. in 1996 AD (Rs. million)	Cost per Km. in 2001 AD (Escalated) (Rs. million)
1.	Preparatory and Infrastructure	4.40	6.00
2.	Land	16.50	24.00
3.	Diversion System	90.20	131.00
4.	Earth Work	14.30	21.00
5.	Ballast Track	13.20	19.00
6.	Station Finishes	30.80	45.00
7.	Fire Fighting and Water Supply	4.40	6.00
8.	Compensation and repair to buildings	13.20	19.00
9.	Service buildings	33.00	18.00
10.	Staff quarters	9.90	15.00
11.	Power installation	55.00	80.00
12.	Ventilation and false Ceiling	33.00	48.00
13.	Pump and lighting	11.00	16.00
14.	C.A.T.C.	75.90	111.00
15.	Telecom	15.40	22.00
16.	Conventional Signal	4.40	6.00

Contd...

Contd Table 9.2

Sl.No.	Description	Cost per Km. in 1996 AD (Rs. million)	Cost per Km. in 2001 AD (Escalated) (Rs. million)
17.	Maintenance and POH Depot	55.00	80.00
18.	Rolling Stock-Considering 8 coach per-km. (BG, EMUs)	41.25	60.00
19.	General charges and Establishment	51.15	75.00
	Grand Total	572	832

Source : Estimated cost based on Data colleced from Metropolitan Transport Project (Railways) Chennai (Madras).

TABLE 9.3 CAPITAL COST OF ELEVATED MRTS CORRIDOR

Sl.No.	Description	Cost per Km. in 1996 AD (Rs. million)	Cost per Km. in 2001 AD (Escalated) (Rs. million)
1.	Preparatory and Infrastructure	4.40	6.00
2.	Land	16.50	24.00
3.	Diversion System	101.60	147.00
4.	Support System	117.70	171.00
5.	Earth Work	28.60	42.00
6.	Ballastless Track	26.40	39.00
7.	Station Finishes	36.30	53.00
8.	Fire Fighting and Water Supply	8.80	13.00
9.	Compensation and repair to buildings	16.50	24.00
10.	Service buildings	40.70	60.00

Contd...

Sl.No.	Description	Cost per Km. in 1996 AD (Rs. million)	Cost per Km. in 2001 AD (Escalated) (Rs. million)
11.	Staff quarters	9.90	14.00
12.	Power installation	60.50	88.00
13.	Ventilation and false Ceiling	38.50	56.00
14.	Pump and lighting	11.00	16.00
15.	Escalator	27.50	40.00
16.	C.A.T.C.	75.90	110.00
17.	Telecom	15.40	22.00
18.	Conventional Signal	4.40	6.00
19.	Maintenance and POH Depot	55.00	80.00
20.	Rolling Stock-Considering 8 coach per-km. (BG, EMUs)	41.25	60.00
21.	General charges and Establishment	73.15	106.00
	Grand Total	810	1177

Source : Estimated cost based on Data collected from Metropolitan Transport Project (Railways) Chennai (Madras).

9.5 Subzi Mandi - Holambi Kalan MRTS Corridor

9.5.1 General

Subzi Mandi - Holambi Kalan BG mass rapid transit system with a route kilometreage of 19.3 is proposed to be operated with EMUs on 25 KV AC overhead traction. Subzi Mandi-Holambi Kalan MRTS section which is 4.45 km an elevated and 14.58 km at-grade has 16 stations, has been described in Chapter 4. The alignment for this corridor takes off from pul Bangash and runs parallel to Railway alignment upto Holambi Kalan. 25

KV AC single phase 50 Hz simple polygonal OHE system has been proposed. Special fixation and termination arrangements, have been planned for OHE on elevated alignment and at stations with property development. Two precast prestressed concrete box girders, generally of 20 metre effective span, will support track on elevated segments. They shall span single - column pedestals, with columns of diameter between 1.50 m to 2.0 m, resting on a group of 4 or 6 piles. On at-grade segments 60 kg/m continuous welded rails will be laid on monoblock prestressed concrete sleepers with elastic rail clip and rubber pads on a 250 mm cushion of ballast. On elevated stretches, ballastless track comprising of a rail seat assembly with cast iron bearing plates, elastic rail clips and rubber pads, resting on concrete pedestals has been proposed. Conventional 25 KV AC wide bodied EMU Rolling stock has been proposed. All coaches will have only one class of accommodation. Motorman and conductor/Guard will have facility of communication with operations control centre (OCC).

Signalling facilities contemplated are same as for metro corridor except that ATO has not been provided and a truncated ATS, only with train describer - cum passenger information system, has been provided. Telecom facilities contemplated will be similar to those of metro corridor except that redundancy in cables has not been catered for and also no CCTV systems has been envisaged at stations. Fare collection system will be identical to that of metro corridor [132].

The capital cost of Subzi mandi-Holambi Kalan MRTS corridor is estimated to be Rs. 12098.7 million at 1996 AD price level.

9.6 Capital Cost Model

Capital costs of transit systems vary significantly and are influenced by design standards, type of equipment, quantity of purchase, local conditions of climate and terrain, and other factors. There is no formula approach to capital cost. Each component of a planned new system or for renovation of an existing system should be subjected to a careful engineering analysis that flows from the functional characteristics of the proposed system and estimates of demand for that system. For example, the typical planning process produces modal split data assigning trips to projected alternative. These trips, in turn, determine the number of vehicles required on the system, the optimum spacing of stations, fixed - facility type, and other elements.

While gross unit statistics can be used for very preliminary estimates of the magnitude of expenditure, decisions on implementation of a system require careful engineering analysis [11].

As this engineering analysis proceeds, typically alternative systems will be examined so that the planned improvement, expansion,or new system construction can be assessed in light of cost effectiveness and other criteria. This analysis is performed by postulating modal options for a given corridor, costing those options, comparing that to the resultant demand and other impacts on the community, and combining all statistics in a cost - benefit or other type of comparative analysis to decide on the appropriate mode.

Based on different components of capital cost, the capital cost model has been developed, which is described below .

$$Y = 15.14 + 0.86X_1 + 1.79X_2 + 0.054X_3 + 1.87X_4 \quad (9.1)$$

Where

y = Total capital cost in Rs. million per km.

X_1 = Capital cost of Civil Engineering items in Rs. Million per km.

X_2 = Capital cost of Electrical Engineering items in Rs. million per km.

X_3 = Capital cost of signal and Telecommunication items in Rs. million per km

X_4 = Capital cost of rolling stock in Rs. million per km.

Coefficient of determination, $R^2 = 0.96$

9.7 Operating Expenses and Depreciation

9.7.1 Operating expenses for Vishwavidyalaya - Central Secretariat metro corridor

The operating expenses estimate of the vishwa vidyalaya - central secretariat metro corridor has been worked out using the data collected from various departments of Southern Railway and metropolitan transport project (Railways) Madras (Chennai) in the year 1993 AD and using prevalent rates of payment. The operating expenses are duly adjusted in the year 1996 AD, so as to represent cost of facilities if provided now. The total strength of staff for Vishwavidyalaya - Central Secretariat metro corridor is estimated at 1184, which includes station staff, workshop staff and infrastructure maintenance staff. All the staff expenses are estimated based on the staff scales of pay, house rent allowance, city compensatory allowance, dearness allowance, provident fund and pension at 1996 AD price level. The operating expenses for vishwa vidyalaya - central secretariat metro corridor are given in Table 9.4. Cost per passenger-km versus passengers carried per day on Vishwavidyalaya - Central Secretariat metro system of Delhi is shown in Figure 9.1.

9.7.2 Operating expenses for Shahdara - Nangloi MRTS corridor

The operating expenses estimate of the Shahdara - Nangloi MRTS corridor has been worked out using the data collected from various departments of southern Railway and MTP (Railways) Chennai (Madras) in the year 1993 AD and using prevalent rates of payment. The operating expenses are duly adjusted in the year 1996 AD, so as to represent cost of facilities if provided now. The total strength of staff for Shahdara - Nangloi MRTS corridor is estimated at 1669, which includes station staff, workshop staff and infrastructure maintenance staff. The operating expenses for Shahdara - Nangloi MRTS corridor are given in Table 9.5. Cost per passengers-km versus passengers carried per day on Shahdara - Nangloi MRTS corridor of Delhi is shown in Figure 9.2.

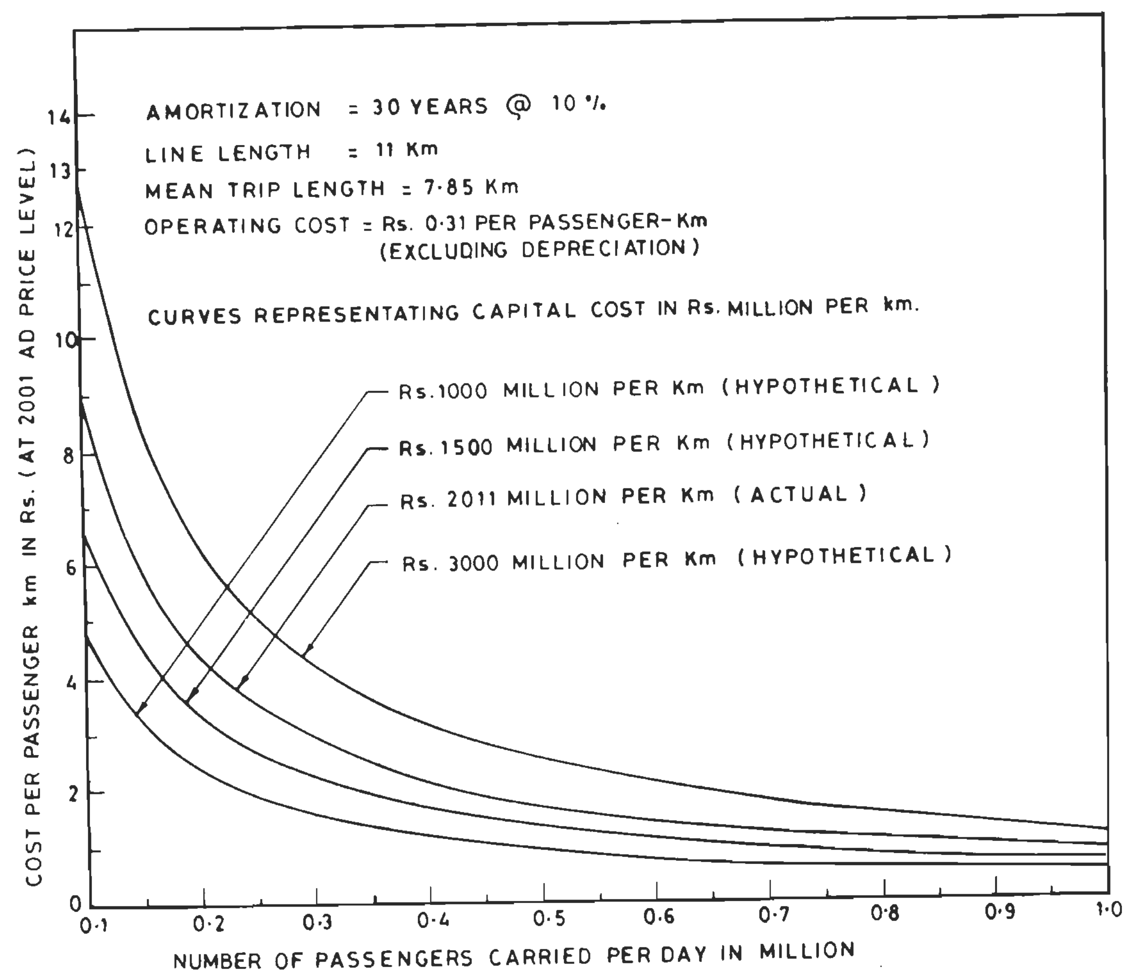


FIG. 9·1 COST PER PASSENGER-KM VERSUS PASSENGERS CARRIED PER DAY ON VISHWA VIDYALAYA-CENTRAL SECRETARIAT METRO CORRIDOR OF DELHI

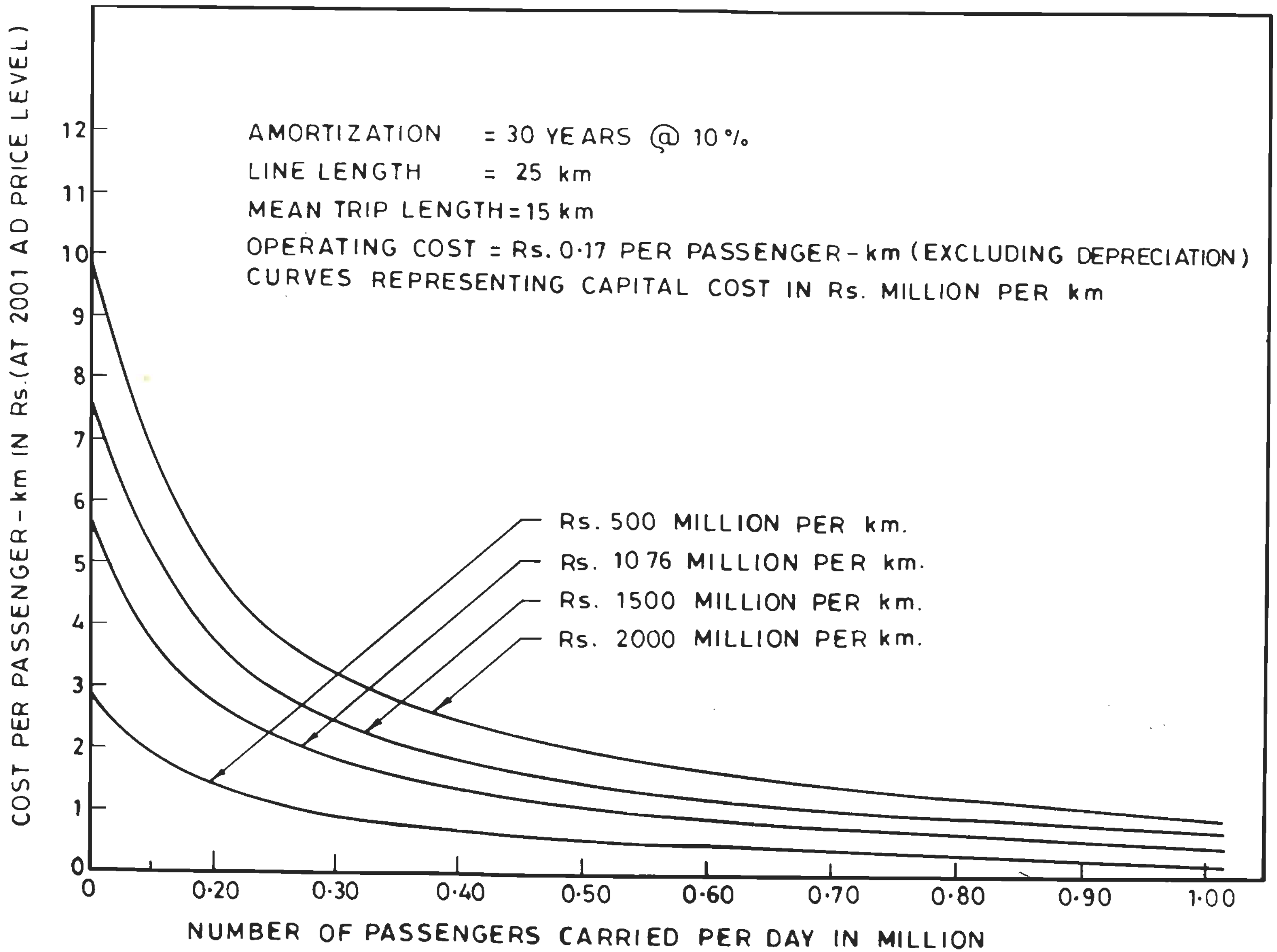


FIGURE 9·2 COST PER PASSENGER-KM VERSUS PASSENGERS CARRIED PER DAY ON SHAHDARA - NANGLOI MRTS CORRIDOR OF DELHI

9.7.3 Operating expenses for Subzi Mandi - Holambi Kalan MRTS corridor

The total strength of staff for Subzi Mandi - Holambi kalan MRTS corridor is estimated at 1292, which includes station staff, workshop staff and infrastructure maintenance staff. The operating expenses for Subzi mandi - Holambi kalan MRTS corridor are given in Table 9.6. Cost per passenger - km versus passengers carried per day on Subzi Mandi-Holambi Kalan MRTS corridor of Delhi is shown in Figure 9.3.

TABLE 9.4 OPERATING EXPENSES FOR VISHWAVIDYALAYA-CENTRAL SECRETARIAT METRO CORRIDOR

Sl.No.	Description	Cost in 1996 AD (Rs. million)	Cost in 2001 AD (Escalated) (Rs. million)
1.	Station Staff	12.53	18.22
2.	Workshop Staff	19.63	28.56
3.	Infrastructure Maintenance staff	9.96	14.48
4.	Maintenance of Permanent way (materials)	4.42	6.43
5.	Maintenance of Rolling Stock	41.36	60.20
6.	Energy Consumption	61.24	89.07
7.	Grand Total	149.14	216.96
8.	Gneral expenses @ 5%	7.46	10.84
9.	Gross total	156.60	227.80

Source : Estimated cost based on data collected from various departments of Madras Division, Southern Railway, Madras (1993 AD).

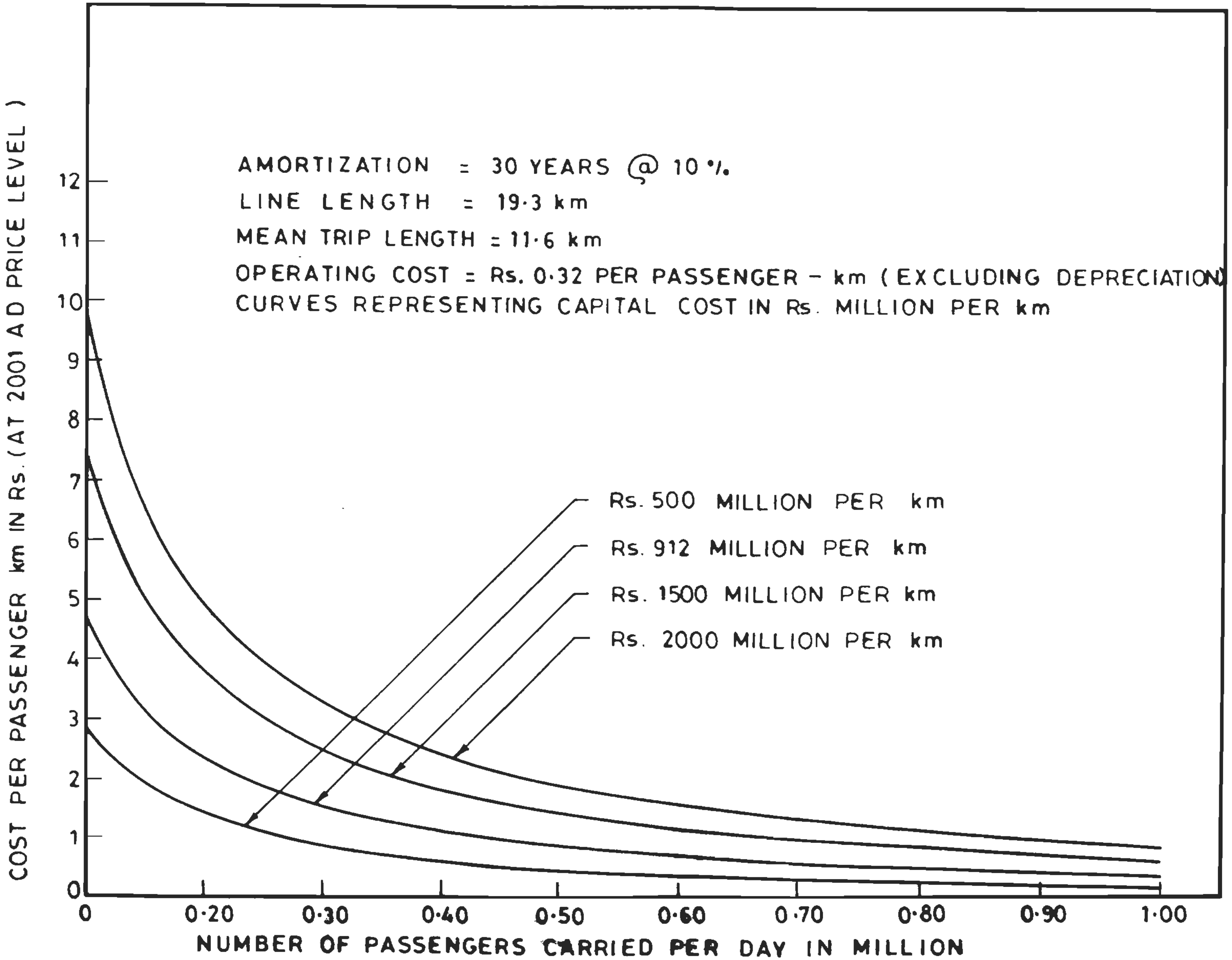


FIGURE 9·3 COST PER PASSENGER-KM VERSUS PASSENGERS CARRIED PERDAY ON SUBZI MANDI-HOLAMBI KALAN, MRTS CORRIDOR OF DELHI

TABLE 9.5 OPERATING EXPENSES FOR SHAHDARA - NANGLOI MRTS CORRIDOR

Sl.No.	Description	Cost in 1996 AD (Rs. million)	Cost in 2001 AD (Escalated) (Rs. million)
1.	Station Staff	20.60	29.97
2.	Workshop Staff	21.98	31.98
3.	Infrastructure Maintenance staff	19.18	27.91
4.	Maintenance of Permanent way (materials)	10.27	14.93
5.	Maintenance of Rolling Stock	58.19	84.65
6.	Energy Consumption	51.93	75.54
7.	Grand Total	182.15	264.98
8.	General expenses @ 5%	9.11	13.25
9.	Gross total	191.26	278.23

Source : Estimated cost based on data collected from various departments of Madras Division, Southern Railway, Madras (1993 AD).

TABLE 9.6 OPERATING EXPENSES FOR SUBZI MANDI-HOLAMBI KALAN MRTS CORRIDOR

Sl.No.	Description	Cost in 1996 AD (Rs. million)	Cost in 2001 AD (Escalated) (Rs. million)
1.	Station Staff	15.89	23.14
2.	Workshop Staff	16.97	24.69
3.	Infrastructure Maintenance staff	14.82	21.55
4.	Maintenance of Permanent way (materials)	7.92	11.53
5.	Maintenance of Rolling Stock	44.93	65.35
6.	Energy Consumption	40.10	58.32
7.	Grand Total	140.63	204.58
8.	General expenses @ 5%	7.03	10.22
9.	Gross total	147.66	214.80

Source : Estimated cost based on data collected from various departments of Madras Division, Southern Railway, Madras (1993 AD).

9.7.4 Depreciation for Vishwavidyalaya - Central Secretariat metro corridor

Depreciation has been computed by the straight line method of dividing the cost of assets, less their residual/ salvage value by their respective life in years. Life of assets on Rail transit is given in the Appendix 8.

The total depreciation for Vishwavidyalaya - Central Secretariat metro corridor is estimated at Rs. 666.79 million in the year 2001 AD.

9.7.5 Depreciation for Shahdara - Nangloi MRTS corridor

The total depreciation for Shahdara - Nangloi MRTS corridor is estimated at Rs. 799.12 million in the year 2001 AD.

9.7.6 Depreciation for Subzi Mandi - Holambi Kalan MRTS corridor

The total depreciation for Subzi Mandi - Holambi Kalan MRTS corridor is estimated at Rs. 522.51 million in the year 2001 AD.

9.8 Operating Expenses Model

Transit operations can be viewed as an economic input - output model. Money is supplied to the system and transit resources (for example Car-km, peak Car needs and track-km) are output by the transit system. Mathematically, this economic relationship can be stated as shown in equation (9.2).

$$O_t = f\,(R_1, R_2, R_3 \,........., R_n) \tag{9.2}$$

where,

O_t =total cost of transit services (input),

R =transit resources provided (output),

n =number of resources provided.

Normally, the cost of providing transit services is presented in a standard list of expense accounts. The cost of each expense account can be denoted O_i, which is the cost of expense account i. The total cost of operations, O_t, for all m expense accounts can be mathematically defined as shown in Equation (9.3).

$$O_t = \sum_{i=1}^{m} O_i \tag{9.3}$$

Where,

O_i =Cost of expense account i,

O_t =total cost,

m =number of expense accounts.

Equation (9.3) represents the input side of transit operations in terms of total cost and the individual cost components. From equations (9.2) and (9.3), it is clear that the input-output relationship for costs and resources can be stated for individual expense accounts as shown in Equation (9.4).

$$O_i = f(R_1, R_2, R_3, \ldots\ldots R_n) \tag{9.4}$$

The primary assumption of the cost allocation model is that each expense account can be attributed to one or more resources. Thus, for each expense account i, a proportion of cost allocated to each resource can be specified. For the most part, this assignment or allocation is a subjective process; however, other research has demonstrated the relationship between certain cost accounts and resource levels.

Mathematically, the assumption regarding assignment of cost to one or more resources can be stated as shown in Equation (9.5).

$$\sum_{j=1}^{n} P_{ij} = 1 \tag{9.5}$$

Where,

p_{ij} = Proportion of cost for expense account i allocated to resource j.

Based on Equation (9.5), the cost for each expense account can be allocated to each resource as shown in Equation (9.6).

$$O_{ij} = O_i \, p_{ij} \tag{9.6}$$

Where,

O_{ij} = Cost allocated to resource j for expense account i.

By summing all the expense account amounts by resource, the total cost can be stratified by resource as shown in Equation (9.7)

$$O_j = \sum_{i=1}^{m} O_{ij} \tag{9.7}$$

Where,

O_j =Cost allocated to resource j.

Thus, the sum of costs allocated to each resource is a rearrangement of cost by resources provided rather than expense accounts and will equal the total system cost, as shown in Equation (9.8).

$$O_t = \sum_{j=1}^{n} O_j \tag{9.8}$$

The development of the cost allocation model is the computation of unit cost factor as shown in Equation (9.9)

$$U_j = \frac{O_j}{R_j} \tag{9.9}$$

Where,

U_j = unit cost for resource j.

The multi-variable cost allocation model can be defined as shown in Equation (9.10).

$$O_t = U_1R_1 + U_2R_2 + U_3R_3 + \ldots\ldots\ldots + U_nR_n \tag{9.10}$$

Given a set of resource levels for a particular transit route or line, the unit cost can be applied to compute the cost of the particular transit services comprising the transit system. Thus, the cost allocation model is quantified from overall system statistics but is applied on individual components that comprise the system. Based on this the operating expenses model has been developed, which is shown in Equation (9.11).

$$O_t = -6550 + 999897\ C_m + 100074\ C_p + 1000181\ C_t \qquad (9.11)$$

Where,

O_t = Total operating expenses including depreciation in Rs. thousand.

C_m = Total operating expenses based on Car - km in Rs. thousand.

C_p = Total operating expenses based on Peak - Car needs in Rs. thousand.

C_t = Total operating expenses based on track - km in Rs. thousand.

Coefficient of determination $R^2 = 0.98$.

Basis for allocation of operating expenses is given in Appendix 9.

9.9 Summary

This Chapter gives the idea of various components of the proposed mass rapid transit system infrastructure and an estimate of the capital costs and operating expenses of the proposed three MRTS corridors of Delhi metropolis.

CHAPTER 10
FARE STRUCTURE AND EARNINGS OF THE SELECTED CORRIDORS

10.1 Fare Structure

10.1.1 General policy of railways

The policy of fixing passenger fares and freight rates on railways is based both on commercial and social considerations. Since the Railway Budget is formulated and presented separately, the aim is to balance the revenue and expenditure, including dividend liability and replacement needs of assets. There is also effort to leave a small surplus to provide for a development head from which other necessary unremunerative works, staff and users amenities, safety works, etc., can be financed. At the same time, it has a social responsibility to see that traffic which can not economically bear the freight expenditure like coal, foodgrains, etc., are not overcharged.

Similarly, passenger fares have to be kept as low as possible, and generally even less than the direct costs involved, in their carriage. In fact on the basis of present fare structure, if a line is meant principally or solely for passengers traffic, the net returns will be far less than the dividend liability.

The loss is made good by higher charging of freight rate on other goods(mostly manufactured) whose price structure is such that the freight element will be only a small proportion of the price.

10.1.2 Concessional fare on urban system

Urban Traffic has one more concession in the form of season tickets which are based on fares for far less number of tips than normally made on the ticket. For single journey tickets, the policy in urban and non-urban section are same and fares are based on a slab system. But for season tickets, the equated number of single journey fares were also on a slab system. The fare structure for season tickets works out to about 60 to 70% of concession. It is this fact that diverts more long distance commuters to rail and results in very low income for a urban Railway system in India.

10.1.3 Relevance of fare policy to urban rail transit

Urban Rail system should be an independent unit and hence need not be linked with the fare policy of the main Railways.

IT brings in many tangible and intangible, direct as well as indirect, benefit to the city and is a necessary liability. Large differential between rail and bus fare also cause unbalanced demand and utilisation of services, particularly non-peak period which is the rest period for 'other' into the performed. Once this fact is accepted as also need for fixing fare on a basis of what the urban community can bear and at the same time it is not normally subsidised. The need for assessing viability of urban rail system project will be realised. The very idea of nationalising bus transport in cities and fixing low fares emphasises this point.

10.2 Projection of Fare Structure for Proposed MRTS of Delhi in the Year 2001 AD

The fares for daily ticket and monthly season ticket have been given in Tables 10.1 and 10.2 respectively.

Fare structures have been projected in the year 2001AD, by using linear regression models for daily ticket and monthly season ticket at different distances. In this study for monthly season ticket, three different scenarios of fare structures have been considered which is given in Table 10.3

TABLE 10.1 DAILY TICKET FARE FOR DIFFERENT DISTANCES

Distance (in km)	Year						Model y=fare in Rs. x=number of years	Correlation Coefficient (r)
	1991	1992	1993 (Fare in Rs)	1994	1995	2001 (Projected)		
1 to 10	1.50	1.50	2	2	2	3	y=1.35 + 0.15x	r = 0.87
11 to 15	2	3.50	4	4	4	7	y=2.15 + 0.45x	r = 0.81
16 to 25	3	4	4	4	4	10	y=0.8x + 1.6	r = 0.71

TABLE 10.2 MONTHLY SEASON TICKET FARE FOR DIFFERENT DISTANCES

Distance (in km)	Year						Model y=fare in Rs. x=number of years	Correlation Coefficient (r)
	1991	1992	1993 (Fare in Rs)	1994	1995	2001 (Projected)		
1 to 5	24	28	33	35	40	63	y=3.9x + 20.3	r = 0.99
6 to 10	30	35	40	45	50	80	y=5.0x + 25	r = 1
11 to 15	36	53	58	60	70	115	y=7.5x + 32.9	r = 0.95
16 to 20	42	69	74	75	85	140	y=9x + 41	r = 0.90
21 to 25	46	74	79	80	90	150	y=9.4x + 45.6	r = 0.90

Note : Monthly season ticket fare per trip is obtained by dividing the 50 trips.

TABLE 10.3 MONTHLY SEASON TICKET FARE FOR THREE DIFFERENT SCENARIOS IN THE YEAR 2001 AD

Distance	Year - 2001 AD					
	Scenario - 1 (Projected)		Scenario - 2 (Assumed)		Scenario - 3 (Assumed)	
	Season ticket fare per month (in Rs.)	Season ticket fare per trip (in Rs.)	Season ticket fare per month (in Rs.)	Season ticket fare per trip (in Rs.)	Season ticket fare per month (in Rs.)	Season ticket fare per trip (in Rs.)
1 to 5	63	1.25	75	1.5	100	2
6 to 10	80	1.60	100	2	150	3
11 to 15	115	2.30	150	3	200	4
16 to 20	140	2.80	200	4	250	5
21 to 25	150	3.00	250	5	300	6

10.3 Earnings on Vishwavidyalaya - Central Secretariat Metro Corridor in the Year 2001 AD

Earnings on Vishwavidyalaya-Central Secretariat metro section in the year 2001 AD at different scenarios of monthly season ticket fare and at projected daily ticket fare are given in Tables 10.4 and 10.5 as well as in Figures 10.1 and 10.2 respectively.

In this study it is considered that the work trips and education trips are performed by monthly season ticket users as practiced in other metropolitan cities of India [60]. In Delhi work trips and education trips constitute around 70% and remaining are other trips [60].

So it is considered that the other trips are performed by daily ticket users. The total earnings on Vishwavidyalaya-central secretariat metro corridor in the year 2001 AD at three different scenarios are estimated at Rs 654.09 million, Rs. 729.10 million and Rs. 896.37 million respectively.

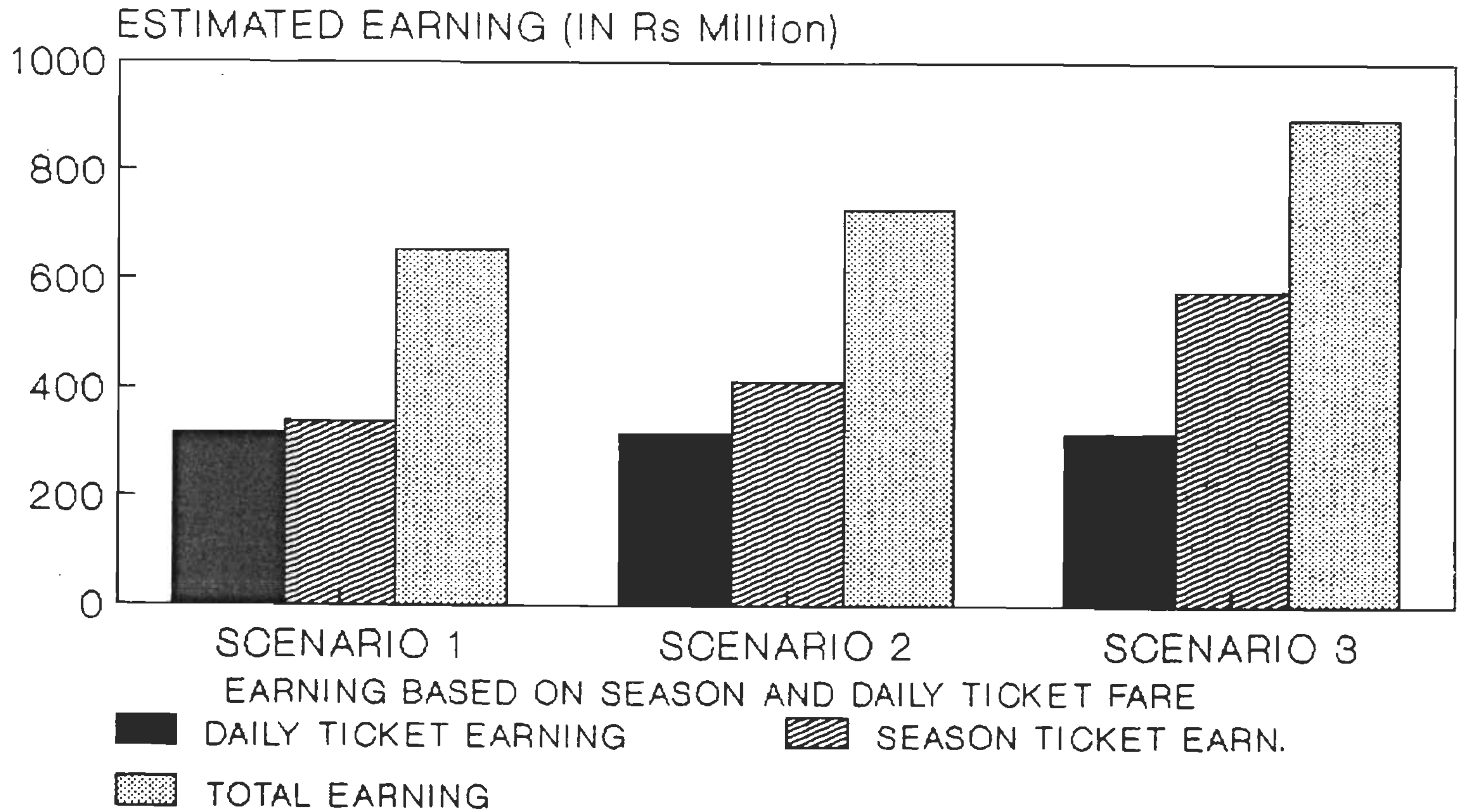


FIG 10.1 EARNING ON VISHWAVIDYALAYA - CENTRAL SECRETARIAT METRO SECTION IN 2001 AD AT DIFFERENT FARE SCENARIOS

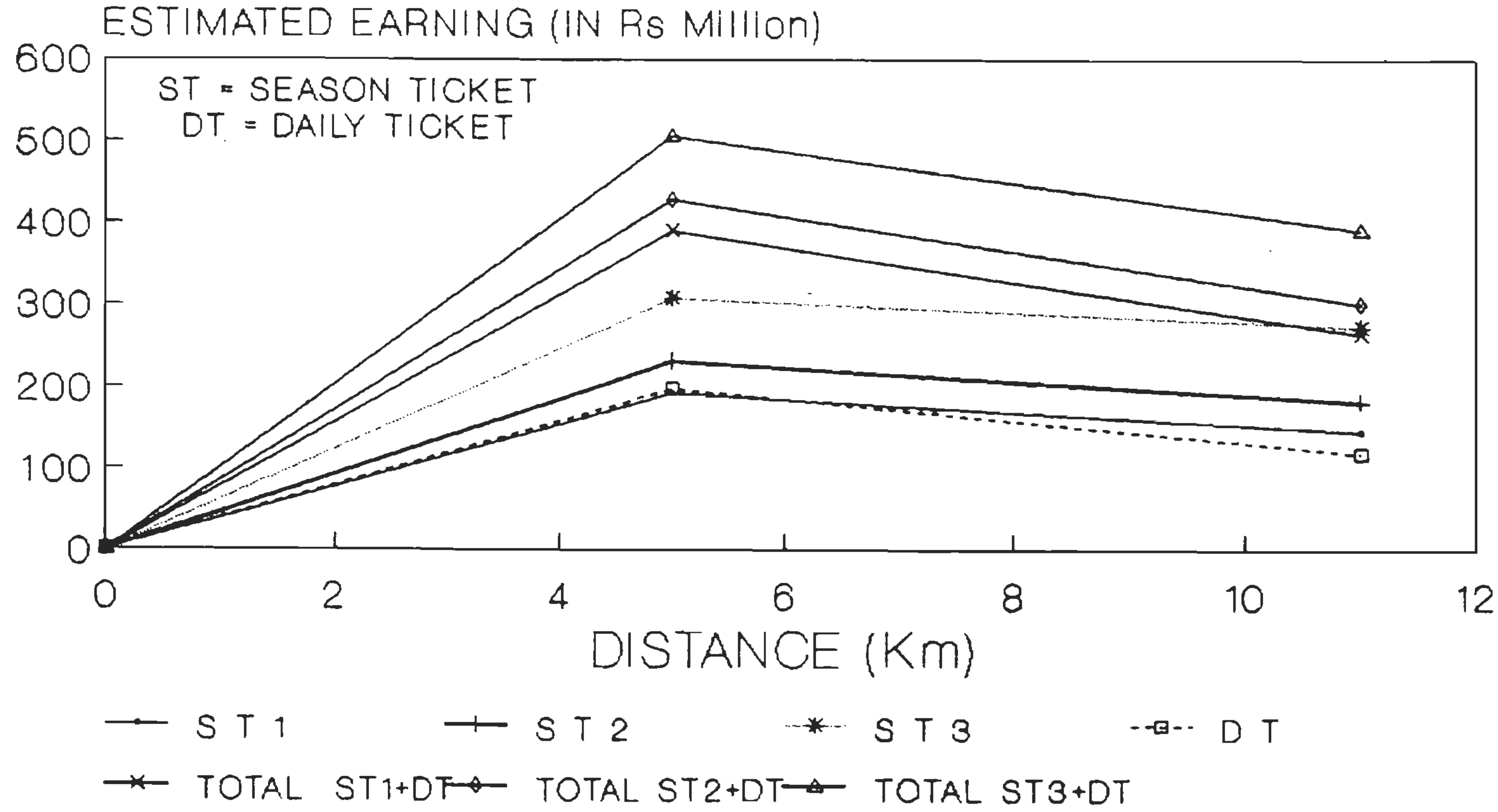


FIG. 10.2 EARNING ON VISHWAVIDYALAYA CENTRAL SECRETARIAT METRO SECTION IN 2001 AD AT DIFFERENT DISTANCES

TABLE 10.4 EARNINGS ON VISHWAVIDYALAYA-CENTRAL SECRETARIAT METRO CORRIDOR IN THE YEAR 2001 AD BY SEASON TICKET

Distance in km	Earning by season ticket fare in 2001 AD			
	Passengers Carried Per Annum in million	Earning per Annum in Rs. million		
		Scenario - 1	Scenario - 2	Scenario - 3
1 to 5	153.85	192.31	230.78	307.70
6 to 11	90.35	145.51	182.05	272.40
Total	244.20	337.82	412.83	580.10

TABLE 10.5 EARNINGS ON VISHWAVIDYALAYA-CENTRAL SECRETARIAT METRO CORRIDOR IN THE YEAR 2001 AD BY DAILY TICKET

Distance in km	Earning by Daily Ticket Fare in 2001 AD	
	Passengers Carried per Annum in million	Earning per Annum in Rs. million
1 to 5	65.93	197.97
6 to 11	39.72	118.48
Total	104.65	316.27

10.4 Earnings on Shahdara - Nangloi MRTS Corridor in the Year 2001 AD.

Earnings on Shahdara-Nangloi MRTS corridor in the year 2001 AD at different scenarios of monthly season ticket fare and at projected daily ticket fare are given in Tables 10.6 and 10.7 as well as in Figures 10.3 and 10.4 respectively. The total earnings on Shahdara-Nangloi MRTS corridor in the Year 2001 AD at three different scenarios of fare structures are estimated at Rs. 1229.28 million, Rs. 1428.23 million and Rs. 1658.22 million respectively.

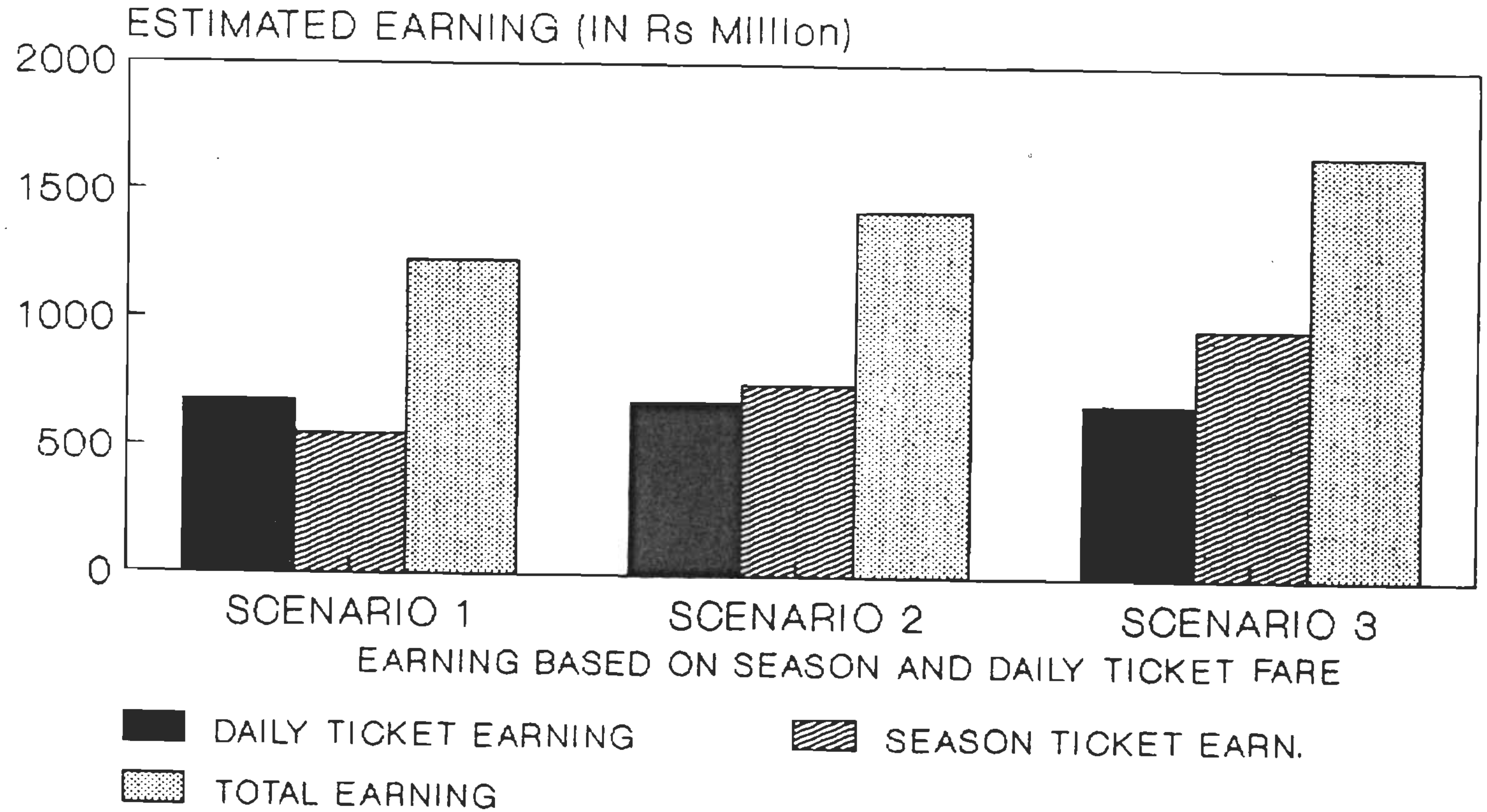


FIG 10.3 EARNING ON SHAHDARA -NANGLOI MRTS SECTION IN 2001 AD AT DIFFERENT FARE SCENARIOS

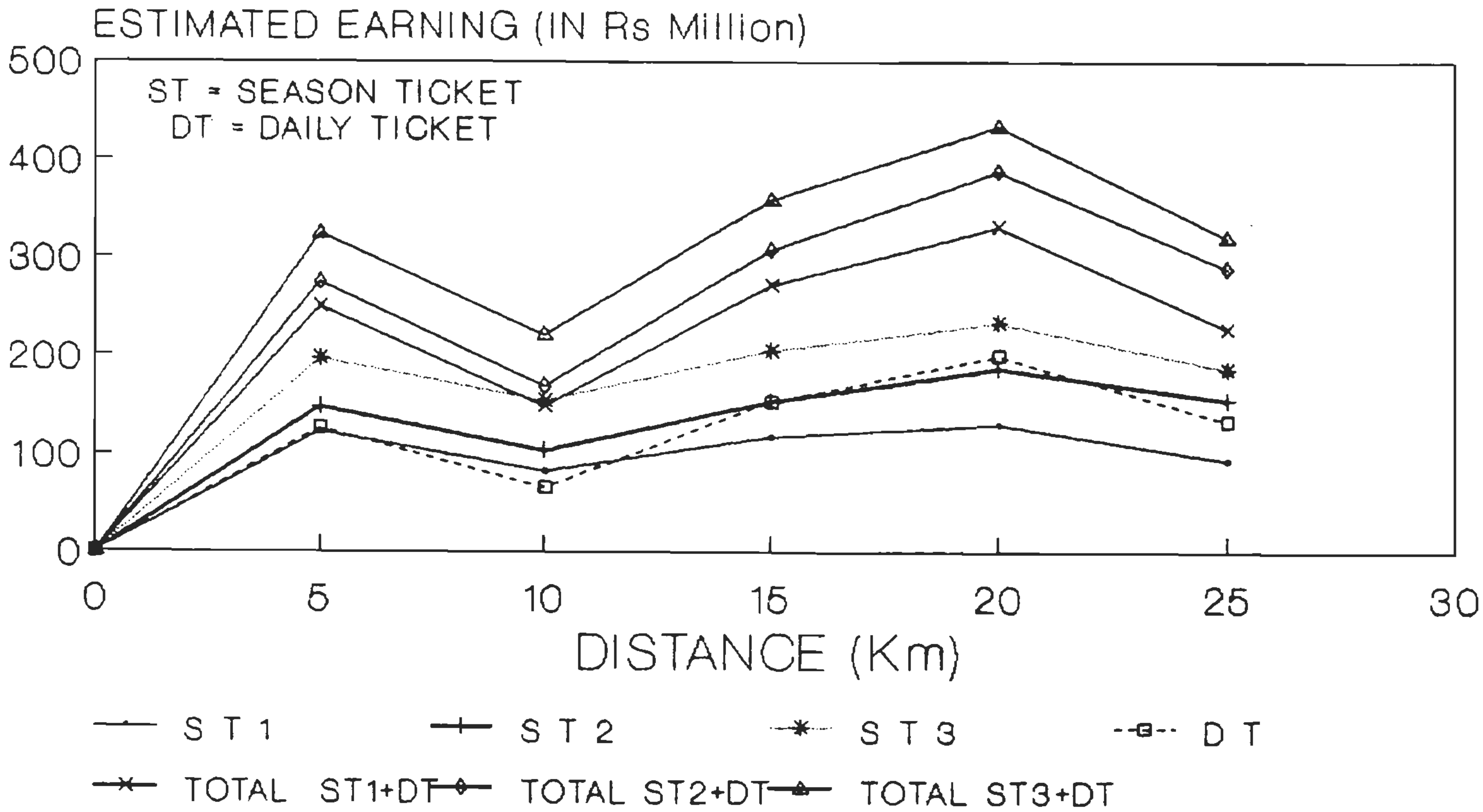


FIG. 10.4 EARNING ON SHAHDARA- NANGLOI MRTS SECTION IN 2001 AD AT DIFFERENT DISTANCES

TABLE 10.6 EARNINGS ON SHAHDARA-NANGLOI MRTS CORRIDOR IN THE YEAR 2001 AD BY SEASON TICKET

Distance in km	Earning by season ticket fare in 2001 AD			
	Passengers Carried Per Annum in million	Earning per Annum in Rs. million		
		Scenario - 1	Scenario - 2	Scenario - 3
1 to 5	98.59	123.24	147.89	197.18
6 to 10	51.53	82.45	103.06	154.59
11 to 15	51.25	117.88	153.75	205.00
16 to 20	46.78	130.98	187.12	233.90
21 to 25	31.14	94.02	155.70	186.84
Total	279.29	548.57	747.52	977.51

TABLE 10.7 EARNINGS ON SHAHDARA-NANGLOI MRTS CORRIDOR IN THE YEAR 2001 AD BY DAILY TICKET

Distance (in km)	Passengers Carried per Annum in million	Earning by Daily ticket fare in 2001AD
		Earning per annum in Rs. million
1 to 5	42.25	126.75
6 to 10	22.08	66.24
11 to 15	21.96	153.72
16 to 20	20.05	200.50
21 to 25	13.35	133.50
Total	119.69	680.71

10.5 Earnings on Subzi Mandi - Holambi Kalan MRTS Corridor in the Year 2001 AD

Earnings on Subzi Mandi - Holambi Kalan MRTS corridor in the year 2001 AD at different scenarios of monthly season ticket fare and at projected daily ticket fare are given in Tables 10.8 and 10.9 as well as in Figures 10.5 and 10.6 respectively.

TABLE 10.8 EARNINGS ON SUBZI MANDI-HOLAMBI KALAN MRTS CORRIDOR IN THE YEAR 2001 AD BY SEASON TICKET

Distance in km	Earning by season ticket fare in 2001 AD			
	Passengers Carried Per Annum in million	Earning per Annum in Rs. million		
		Scenario - 1	Scenario - 2	Scenario - 3
1 to 5	59.55	74.44	89.33	119.10
6 to 10	29.51	47.22	59.02	88.53
11 to 15	25.18	57.91	75.54	100.72
16 to 20	17.22	48.22	68.88	86.10
Total	131.46	227.79	292.77	394.45

TABLE 10.9 EARNINGS ON SUBZI MANDI - HOLAMBI KALAN MRTS CORRIDOR IN THE YEAR 2001 AD BY DAILY TICKET

Distance (in km)	Passengers Carried per Annum in million	Earning by Daily ticket fare in 2001AD
		Earning per annum in Rs. million
1 to 5	25.52	76.56
6 to 10	12.65	37.95
11 to 15	10.79	75.53
16 to 20	7.38	73.80
Total	56.34	263.84

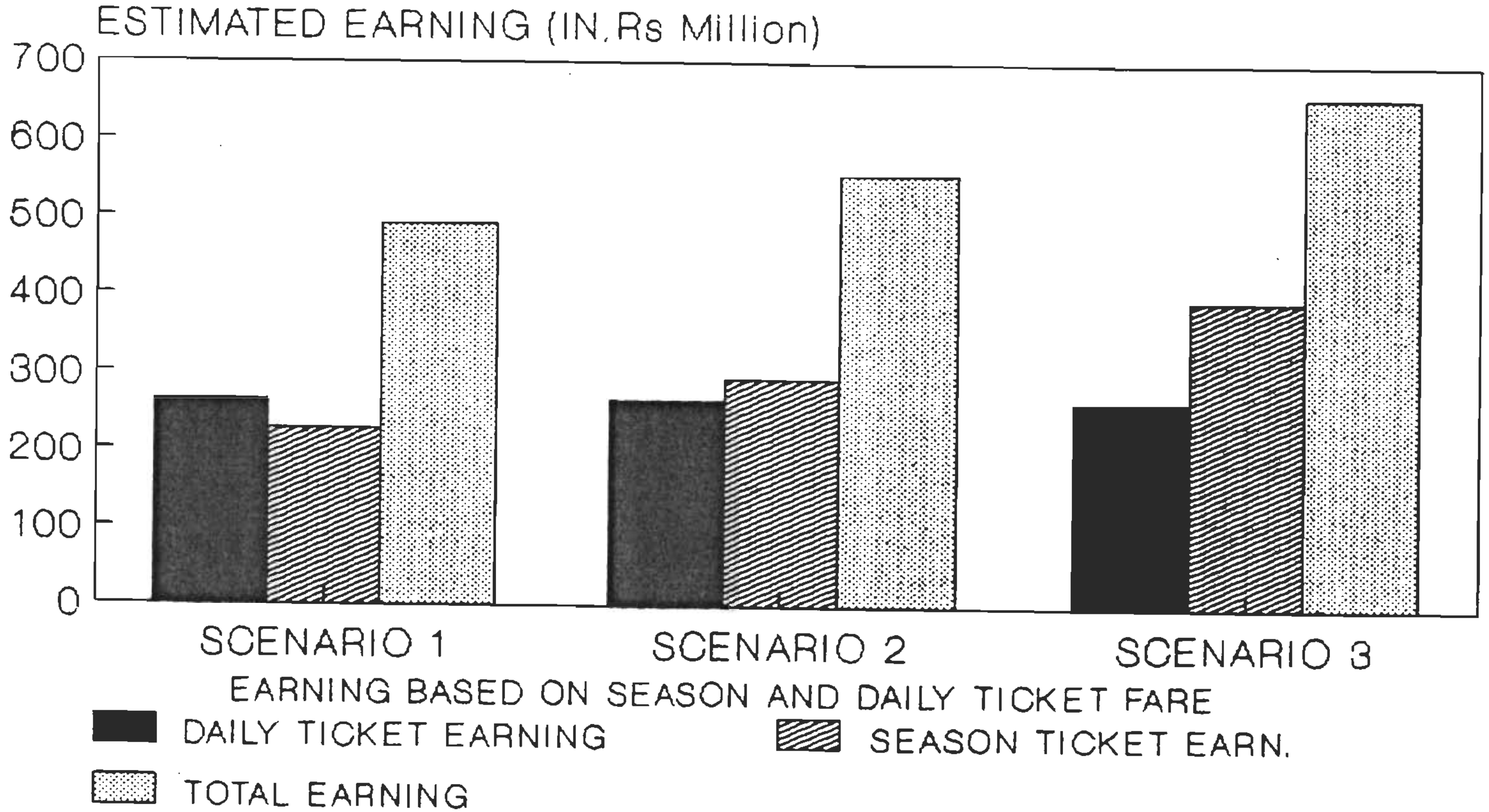


FIG 10.5 EARNING ON SUBZIMANDI - HOLAMBI KALAN MRTS SECTION IN 2001 AD AT DIFFERENT FARE SCENARIOS

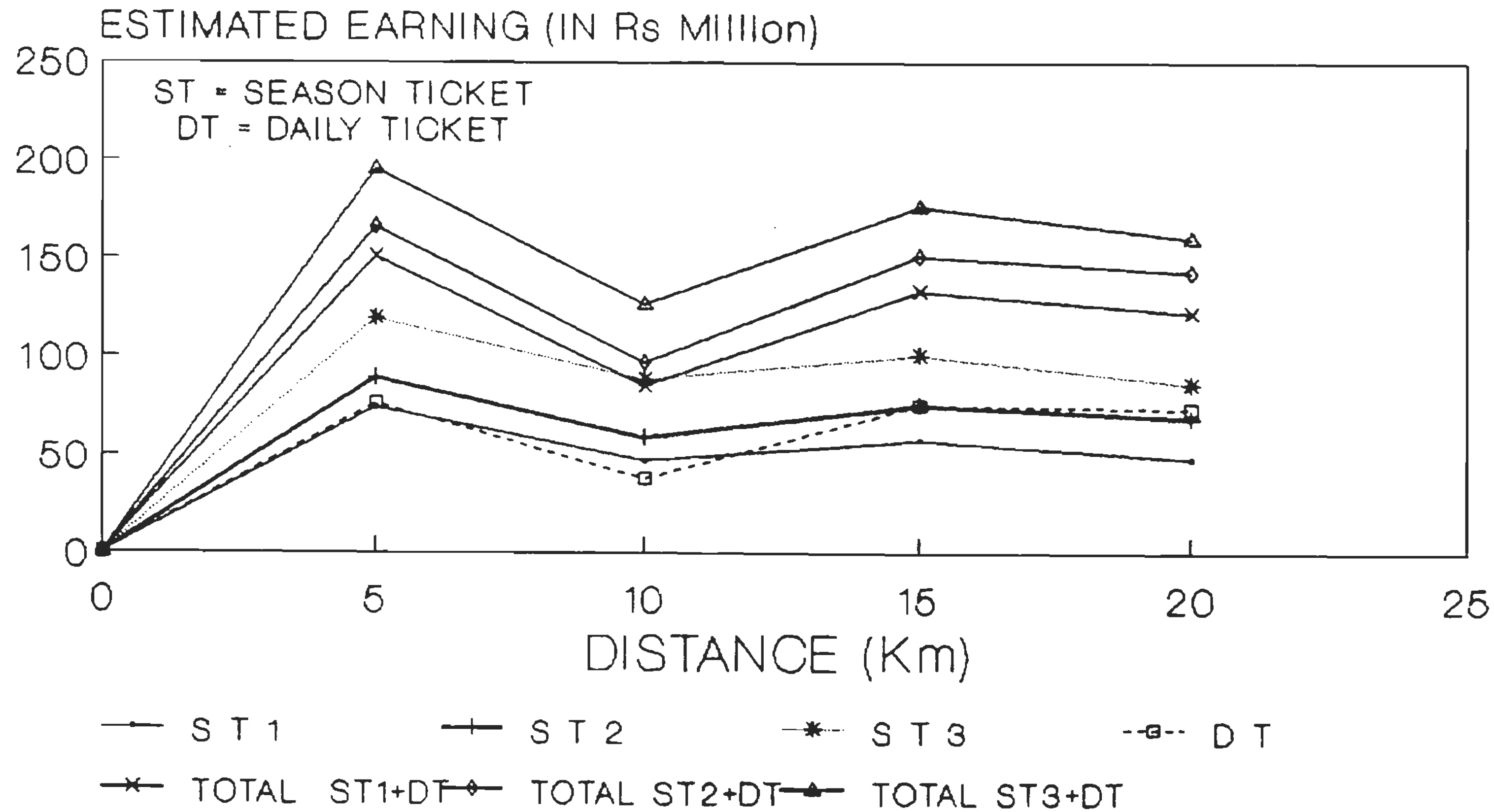


FIG.10.6 EARNING ON SUBZI MANDI -HOLAMBI KALAN MRTS SECTION IN 2001 AD AT DIFFERENT DISTANCES

The total earnings on Subzi Mandi - Holambi Kalan MRTS corridor in the year 2001 AD at three different scenarios of fare structures are estimated at Rs. 491.63 million, Rs. 556.61 million and Rs. 658.29 million respectively.

10.6 Summary

Urban traffic has one more concession in the form of season tickets which are based on fares for far less number of trips than normally made on the ticket. For single journey tickets, the policy in urban and non-urban section are same and fares are based on a slab system. Urban Rail system should be an independent unit and hence need not be linked with the fare policy of the main railways.

It brings in many tangible and intangible, direct as well as indirect, benefit to the city and is a necessary liability. Large differential between rail and bus fare also cause unbalanced demand and utilisation of services, particularly during non-peak period which is the rest period for 'other' into the performed. Once this fact is accepted as also need for fixing fare on a basis of what the urban community can bear and at the same time it is not normally subsidised. The need for assessing viability of urban rail system project will be realised. The very idea of nationalising bus transport in cities and fixing low fares emphasises this point.

CHAPTER 11
FINANCIAL ANALYSIS OF THE SELECTED CORRIDORS

11.1 General

Financial analysis is generally carried out to assess the financial viability of the projects. Even after the financial viability has been established for the project, the government may not take up the project due to lack of funds or because of the fact that the financial analysis has indicated that the returns are not attractive for funding. So financial analysis is a must for any project.

11.2 Financial Viability

Consideration on development of any rail transit has for long been based on the viability of the project in financial terms. Urban traffic has more concession in the form of season tickets which are based on fares for far less number of trips than normally made on the ticket. Due to concessional fare on urban system, it is very difficult to achieve the financial viability [58].

11.2.1 Philosophy

Railway transport projects in India have been assessed on the basis of rate of return and a project is considered viable if it can give a rate of return higher than the dividend rate the Railway has to pay to the central government general budget, from which the capital is provided. The rate fixed for this has been periodically revised by the Railway convention committee. It used to be 4% at the time of independence [1947 AD] but now it is fixed at 6.5%. When D.C.F. method is used the lowest IRR has been fixed at 10% for a project to be considered viable. While this is the minimum required when a number of alternatives are considered for same end use, the one giving the highest return is chosen. If any project or improvement is necessary for better operation but at the same time, it is not in a position to yield the minimum return, the funds for executing the same have to be found from the Railways own annual earnings or reserve funds created over the years out of surplus over and above the dividend paid. This is known as "Development Fund". The expenditure incurred on such projects are not added on to the capital at charge. Essential lines of strategic importance and in backward areas an exception to the role in that they are funded by the general revenues with no dividend liability. But urban lines do not come under this category normally.

11.3 Methods of Financial Analysis

11.3.1 Annual rate of return method

The traditional approach adopted on the Railways has been to work out the viability of any project based on a commercial basis. In the rate of return method, the total input required for providing the infrastructure including right-of-way, formation, bridges, the railway track, terminal stations, and intermediate yards, signalling and electrical installations, maintenance (depot) facilities and rolling stock requirements are taken as the initial capital investment. The annual cost of maintaining these, depreciation on same as well as cost of maintaining these necessary services in terms of labour and materials used are taken as the annual cost. The fare collected from the users and any revenue by way of conveyance of goods and parcels as well as any incidental services from the components of income.

The net income/return is worked out, in the traditional method, by forecasting the traffic over the first year of the opening of a line, 6th year of the opening of a line and 11th year of the opening of a line.

The percentage of the net return over the capital cost invested in the initial stage is worked out. If this equals or exceeds the borrowing rate of capital from the general revenues of the country (at present taken as 6.5%), the project is treated as viable and if not, it is treated as non-viable. While considering the depreciation, the life of assets are taken differently based on past experience. For estimating the working expenses the statistical parameters arrived at in terms of unit cost per tonne-Km for goods or cost per passenger-Km for passengers. these are taken from the previous annual report of the parent working railway system and is duly escalated for the first assessment year for use in calculation of earnings. It is generally seen that in this system of working, the proportionate expenses on predominantly passenger carrying lines are higher.

In this study the working expenses are estimated based on the actual number of staff employed and their current scales of pay, house rent allowance, city compensatory allowance, dearness allowance, provident fund and pension and other costs of value as per actual.

The percentage of the net annual earnings (after deducting working expenses and depreciation) bears to initial investment cost is the annual rate of return.

This method does not take into consideration the present value of the future investment or income based on borrowing rates. It does not also take into consideration a realistic pattern with regard to the maintenance and replacement expenditure.

11.3.2 Internal rate of return (IRR) method using discounted cash flow.

This method aims at computing the discounted rate of return of net income over expenditure. In other wards, it is a discounting rate at which the total present value of expenses over a period equals the total present value of income over the same period. In this case, the initial investment costs as well as replacement costs over the years are reduced to its present day value. The net income, i.e. gross fares and other revenues collected less the working expenses for each year is worked out and its present value is discounted and totaled. In either case, effect of inflation is not taken into consideration. The discounting is done by trial and error assuming different interest rates and the rate at which discounted cash out-flow (NPV of expenses) and discounted cash in-flow of net annual income (NPV of net revenues) at which the NPVs equal is interpolated. Since NPV of cash spent or earned over a distant period tends to become very small, on the railways a period of 30 years is taken into account for working this out. There is a disadvantage in applying this method to urban transport projects. Most of them are intensively utilised towards the latter part of the project with more cash in-flow only at that time. But, since the discounting fraction becomes very low for that period the NPV of the income becomes low and does not really represent the utility of the project.

11.4 Financial Analysis

11.4.1. Financial analysis by annual rate of return method on Vishwavidyalaya - Central Secretariat metro corridor in the Year 2001 AD

Financial analysis by annual rate of return method has been done for Vishwavidyalaya-Central Secretariat metro corridor in the year 2001 AD at three different scenarios of monthly season ticket fare and at projected daily ticket fare, is given in Table 11.1.

At scenario 1 fare structure and at scenario 2 fare structure the net loss for Vishwavidyalaya-Central Secretariat metro corridor in the year 2001 AD are estimated at Rs. 240.5 million and Rs. 165.49 million respectively. At scenario 3 fare structure the net benefit for Vishwavidyalaya-Central Secretariat metro corridor in the year 2001 AD is estimated at Rs. 1.78 million.

11.4.2 Financial analysis by annual rate of return method on Shahdara - Nangloi MRTS corridor in the year 2001 AD

Financial analysis by annual rate of return method has been done for Shahdara-Nangloi MRTS corridor in the year 2001 AD at three different scenarios of monthly season ticket fare and at projected daily ticket fare, is given in Table 11.2.

TABLE 11.1 FINANCIAL ANALYSIS BY ANNUAL RATE OF RETURN METHOD ON VISHWAVIDYALAYA-CENTRAL SECRETARIAT METRO CORRIDOR IN THE YEAR 2001 AD

Sl.No.	Description	Amount (in Rs. million)
1.	Gross Earnings in Scenario - 1	654.09
2.	- Operating and Maintenance Cost	227.80
	- Depreciation	666.79
	Total Working Expenditure	894.59
3.	Net Result (1 - 2)	-240.50 (Deficit)
4.	Gross Earnings in Scenario - 2	729.10
5.	Net Result (4 - 2)	-165.49 (Deficit)
6.	Gross Earnings in Scenario - 3	896.37
7.	Net Result (6 - 2)	+ 1.78 (Surplus)

TABLE 11.2 FINANCIAL ANALYSIS BY ANNUAL RATE OF RETURN METHOD ON SHAHDARA - NANGLOI MRTS CORRIDOR IN THE YEAR 2001 AD

Sl.No.	Description	Amount (in Rs. million)
1.	Gross Earnings in Scenario - 1	1229.28
2.	- Operating and Maintenance Cost	278.23
	- Depreciation	799.12
	Total Working Expenditure	1070.35
3.	Net Result (1 - 2)	+151.93 (Surplus)
4.	Gross Earnings in Scenario - 2	1428.23
5.	Net Result (4 - 2)	+350.88 (Surplus)
6.	Gross Earnings in Scenario - 3	1658.22
7.	Net Result (6 - 2)	+580.87 (Surplus)

The net benefit for Shahdara-Nangloi MRTS corridor in the year 2001 AD at three different scenarios of monthly season ticket fare and at projected daily ticket fare are estimated at Rs. 151.93 million, Rs. 350.88 million and Rs. 580.87 million respectively.

11.4.3 Financial analysis by annual rate of return method on Subzi Mandi-Holambi Kalan MRTS corridor in the year 2001 AD

Financial analysis by annual rate of return method has been done for Subzi Mandi-Holambi kalan MRTS corridor in the year 2001 AD at three different scenarios of monthly season ticket fare and at projected daily ticket fare, is given in Table 11.3.

TABLE 11.3 FINANCIAL ANALYSIS BY ANNUAL RATE OF RETURN METHOD ON SUBZI MANDI - HOLAMBI KALAN MRTS CORRIDOR IN THE YEAR 2001 AD

Sl.No.	Description	Amount (in Rs. million)
1.	Gross Earnings in Scenario - 1	491.63
2.	- Operating and Maintenance Cost	214.80
	- Depreciation	522.51
	Total Working Expenditure	737.31
3.	Net Result (1 - 2)	-245.68
		(Deficit)
4.	Gross Earnings in Scenario - 2	556.61
5.	Net Result (4 - 2)	-180.70
		(Deficit)
6.	Gross Earnings in Scenario - 3	658.29
7.	Net Result (6 - 2)	-79.02
		(Deficit)

The net loss for Subzi Mandi - Holambi Kalan MRTS Corridor in the Year 2001 AD at three different scenarios of monthly season ticket fare and at projected daily ticket fare are estimated at Rs. 245.68 million, Rs. 180.70 million and Rs. 79.02 million respectively.

11.4.4 Financial analysis using internal rate of return method by discounted cash-flow technique on Shahdara-Nangloi MRTS Corridor

Financial analysis using Internal Rate of Return (IRR) by discounted cash flow technique for Shahdara-Nangloi MRTS corridor has been done at the scenarios 2 and 3 monthly season ticket fare and at daily ticket fare in 2001 AD, which are given in

Tables 11.4 and 11.5 respectively. The total capital cost for Shahdara-Nangloi MRTS corridor in the year 2001 AD is estimated at Rs.26906 million.

TABLE 11.4 INTERNAL RATE OF RETURN (IRR) BY DISCOUNTED CASH FLOW TECHNIQUE ON SHAHDARA-NANGLOI MRTS CORRIDOR IN 2001 AD AT THE TOTAL CAPITAL COST OF Rs. 26906 MILLION AND TOTAL EARNINGS BASED ON 2001 AD PROJECTED DAILY TICKET FARE AND MONTHLY SEASON TICKET FARE IN SCENARIO - 2

Number of years since commencement of the project	Cash flow item	Amount (Rs. million)	Present worth factor @ 0.40%	Discounted amount (Rs. million)	Remark
	Out-flow				
1. Initial borrowing		(-) 3084.00	x 0.9960	(-) 3071.66	
2.		(-) 3586.00	x 0.9920	(-) 3557.31	
3.		(-) 6897.00	x 0.9881	(-) 6814.92	
4.		(-) 7054.00	x 0.9842	(-) 6942.54	
5.		(-) 3542.00	x 0.9802	(-) 3471.87	
6.		(-) 2743.00	x 0.9763	(-) 2677.99	
20 Replacement of signal and telecommunication		(-) 750.00	x 0.9233	(-) 692.47	No investment expected from the year 7 to 19
				(-)27228.76	
	In-flow				
30 Residual value of coaches	(+192.00)	(+) 542.00	x 0.8871	(+) 480.80	
				(-)26747.96	
30 Residual value of Track	(+ 350.00)				
6th to 30th year : Net earnings without deducting depreciation (1428.23-278.23) = 1150.00		(+) 1150.00	x 23.2761	(+)26767.51	
				(+) 19.55	

The IRR is 0.40%

TABLE 11.5 INTERNAL RATE OF RETURN (IRR) BY DISCOUNTED CASH FLOW TECHNIQUE ON SHAHDARA-NANGLOI MRTS CORRIDOR IN 2001 AD AT THE TOTAL CAPITAL COST OF Rs.26906 MILLION AND TOTAL EARNINGS BASED ON 2001 AD PROJECTED DAILY TICKET FARE AND MONTHLY SEASON TICKET FARE IN SCENARIO - 3

Number of years since commencement of the project	Cash flow item	Amount (Rs. million)	Present worth factor @ 1.70%	Discounted amount (Rs. million)	Remark
	Out-flow				
1. Initial borrowing		(-) 3084.00	x 0.9833	(-) 3032.49	
2.		(-) 3586.00	x 0.9668	(-) 3466.94	
3.		(-) 6897.00	x 0.9507	(-) 6556.97	
4.		(-) 7054.00	x 0.9348	(-) 6594.07	
5.		(-) 3542.00	x 0.9192	(-) 3255.80	
6.		(-) 2743.00	x 0.9038	(-) 2479.12	
20 Replacement of signal and telecommunication		(-) 750.00	x 0.7138	(-) 535.35	No investment expected from the year 7 to 19
				(-)25920.74	
	In-flow				
30 Residual value of coaches	(+192.00)	(+) 542.00	x 0.6031	(+) 326.88	
				(-)25593.86	
30 Residual value of Track	(+ 350.00)				
6th to 30th year : Net earnings without deducting depreciation (1658.22-278.23) = 1379.99		(+) 1379.99	x 18.5937	(+)25659.12	
				(+) 65.26	

The IRR is 1.70%

The analysis period has been taken as 30 years.

This gives the Internal Rate of Return (IRR) as 0.40% and 1.70% respectively. Since this corridor which is the intensively used, gives only a low IRR of 0.40% and 1.70% at scenarios 2 and 3, monthly season ticket fare and at projected daily ticket fare in 2001 AD. Similar exercise has not been for the other two corridors. They will be negative at present level-of -service.

11.5 Summary

The analysis indicates that a MRTS corridor is financially justified and viable if it is effectively utilised and if the infrastructure cost is not included. This is comparable with road transport where the infrastructure (road) is provided and even maintained at cost of government and transport operator only pays for his vehicle and meets day-to-day operating cost. If a monthly ticket fare comparable to road transport is charged, it will pay for replacement of assets also. The justification for MRTS should not be looked at merely on the grounds of commercial profitability. In such instances, it is very important to assess also the socio-economic implications of the projects.

CHAPTER 12
ECONOMIC ANALYSIS OF THE SELECTED CORRIDORS

12.1 General

Economic analysis is not concerned with the sources of financing or availability of funds and allocation of funds. In economic analysis one is concerned with costs and benefit to the society and not financial costs and returns on investment. Economic costs are based on the "opportunity cost" of each of the constituents of the cost such as labour, material and machinery.

In a perfectly competitive market, where taxes are not levied, the economic cost is very nearly equal to financial cost. Economic benefits similarly cover value of savings to users in terms of time and cost of alternative provisions required for meeting the purpose of the user.

12.2 Need For Economic Analysis of Rail Facility

With the rapid and continuous increase in traffic on the road system in the country, there has been an ever increasing demand for the improvement of the existing roads on the one hand and expansion of the road network on the other. Similarly railway requires large capital investment.

The capital investment is several times of annual output. As the railway track is made for a specialised use, it can not be used by any other form of transport. If the railway is a failure, it can neither serve any purpose where it is, nor be taken up and employed elsewhere. For any country, it is clear that the resources available are limited and are insufficient to meet all the demands. This compels the government, like an individual, or a businessman, to deploy the resources available as effectively as possible. In this context, an economic evaluation of projects helps to take decision on whether a project should be taken up, and also on 'when' and 'how much' to invest. Thus the economic evaluation study helps to determine not merely the intrinsic worth of a project but also its optimum timing. Both costs and benefits of all reasonable alternatives are considered over the life of the project to determine whether a project should be done as well as whether it can be done. Economic analysis is a convenient procedure to select only those schemes that result in the greatest benefit from the resources available.

12.3 Alternative Methods of Analysis :

After having determined the costs and benefits of a scheme, a method has to be evolved for relating these two, so as to arrive at an assessment of the usefulness of a scheme in economic terms. A number of methods have been developed. The following are the important methods ;

- Benefit - Cost (B/C) Ratio method;
- Net Present Value (NPV) method; and
- Internal Rate of Return (IRR) method.

12.3.1 Benefit - Cost ratio method

The procedure adopted in this method discounts all costs and benefits to their present worth, at cost of capital which is a percentage fixed based on borrowing rates of interest, opportunity cost of money or minimum expected return on equivalent investments and calculates the ratio of the benefits to costs (B/C).

Negative flows are considered as costs and positive flows are benefits. Thus, the savings in alternative transport costs with direct and indirect are treated as benefits. If the (B/C) ratio is more than one, the project is deemed to be worth undertaking. It makes it easy to decide even on a single project in this by comparing it in a 'Do - Nothing' situation.

This method suffers from the following draw backs ;

- It requires an assumption of a discount rate, which should bear a relation to the opportunity cost of capital. It is difficult to know accurately the latter.

- It is also to some extent difficult to decide all such items which should be termed as 'costs' and placed in the denominator, and similarly all such items which should be termed as 'benefits' and placed in the numerator.

12.3.2 Net Present Value (NPV) method

In this method, the stream of costs/benefits associated with the project over an extended period of time is calculated and is discounted at a selected discount rate to give the present value. Benefits are treated as positive and costs as negative, and the summation gives the net present value (NPV). Any project with positive NPV is treated as acceptable. In comparing more than one alternative, the projects with a higher NPV should be selected. The NPV method suffers from the same disadvantages as those of (B/C) ratio method, wherein a rate of discount has to be assumed.

12.3.3 Internal Rate of Return (IRR) method

The Internal Rate of Return (IRR) is the discount rate, which makes the discounted future benefits equal to the initial outlay.

In other wards, it is the discount rate which makes the stream of cash flows zero.

I.R.R. is algebraically expressed as

$$C_o = \frac{B_1 - C_1}{(1+i)} + \frac{B_2 - C_2}{(1+i)^2} + \ldots\ldots + \frac{B_n - C_n}{(1+i)^n}$$

$$= \sum_{t=1}^{t=n} \frac{B_t - C_t}{(1+i)^t} \qquad (12.1)$$

Where,

C_o = Capital cost of the investment in the year 'zero'.

B_t = Value of the benefits which occur in the year 't'.

C_t = Costs which occur in the year 't'.

i = Discount rate per annum.

n = Number of years for which the analysis in made.

t = year from 1 to n.

I.R.R. avoids the necessity for selecting a discount rate initially. The rate which is derived as a result of the computations can be easily compared with the market rate of interest with which economists and financial experts are familiar. Thus, this method is considered to be more meaningful than the others. Also a number of alternative projects can be compared more easily, which choosing the 'best'.

If the Internal Rate of Return calculated from the above formula is greater than the rate of interest obtainable by investing the capital in the open market, the scheme is considered acceptable. This method is popular with international lending agencies like the Asian Development Bank (ADB) and World Bank. More than one alternative project, this calls for a number of trial and error steps or use of a computer programme. It is best suited for comparing. It this study Benefit cost ratio (BCR) method is used due to its simplicity and since there is a single alternative.

12.4 Appraisal of Urban Railway Projects

12.4.1 General approach

A rail transit project generally results in the following direct benefits ;

(i) Reduces congestion on existing roads, reduces need to use other motor vehicles and thus result in;

- Higher speeds resulting in time as well as energy saving to road users.
- Saving in operation cost of reduced number of road vehicles.
- Reduces number of accidents.
- Reduces pollution.

(ii) Saving in time to users of the rail transit.

Alternatively, it precludes the need to provide an alternative highway/expressway fully or partially and running additional vehicles which result in;

- Avoiding capital expenditure.
- Avoiding recurring expenditure.
- Saving in time to user, as even the alternative, (highway) can not provide as fast a service as the railway. Thus, in this case, the costs and benefits have to be individually worked out.

12.4.2 Costing rail transit facility

The initial costs cover the following :

(i) Preliminary expenses - Investigation costs.

(ii) Right-of-way - Cost of land and buildings to be acquired, stations and terminals and depots.

(iii) Structural engineering works - Formation, tunnels, bridges, elevated structures, track/surfacing, stations and all buildings in terminals, depots, administrative offices, staff quarters, welfare buildings etc.

(iv) Installations

- All electrical installations including traction lines and other equipment.
- All signalling and control equipment enroute and at stations.
- Machinery and plant.
- Substations and power supply lines from state electricity grid.

(v) Rolling stock

- Both trailing and motorised units.

(vi) General Charges

- Cost of temporary structures, plant, machinery used for construction, administrative expenses including salaries.

(vii) Contingencies

- To cover cost of miscellaneous incidental items.

The capital costs of all the three MRTS corridors of Delhi have been worked out separately and are given in Chapter 9.

12.4.3 Assessing benefits

Benefits do not pertain to the direct income by way of fare collected at all. They cover :

(i) Reduced operating expenses due to relieving congestion on same or alternative route/mode.

(ii) Stimulation of economic development.

(iii) Savings in time for both passengers and freight

(iv) Reduction in accidents and consequent damages.

(v) Less pollution.

(vi) Increased comfort and convenience.

The benefits of rail transit projects needed for increased capacity or for diverted traffic can be measured only in respect of savings in use of other alternative mode (Bus). Benefits will be reduction in travel time which is beneficial both to operator and user, saving in fuel which involves foreign exchange and saving in expenses that may otherwise be needed for small improvements and Transport System Management (TSM) measures that may be needed to manage the increased number of vehicles on the road.

When it is an entirely a new project, where even a road has to be provided new for equivalent traffic or widened/improved that comparable cost can be taken. Cost of acquisition and operation of additional buses can be individually taken or operation cost per passenger taken from a comparable service. To these are added the evaluated value of time saved by passenger as a economic benefit. The sum of annual costs including depreciation are then worked out for both the projects. The difference gives the annual saving or benefit. While working out these, the costs used are normally economic costs, i.e., after adjustment needed in both for arriving at 'shadow prices'.

12.5 Economic Analysis

12.5.1 Cost-Benefit analysis for Vishwavidyalaya-Central Secretariat metro corridor for the year 2001 AD

(a) The tangible benefits from introduction of metro services on this route are :

(i) Time saved by users (Bus) diverting to the system.

(ii) Vehicle operating costs (VOC) saved by users (Bus) diverting to the system.

(iii) Time saved by other road users (other modes) on the corridor due to reduction in traffic.

(iv) Vehicle operating costs saved by other users (other modes) due to less congestion on road and better speeds.

(v) Saving in cost of alternative mode of traffic to carry some traffic, i.e., bus - both capital and operation.

(vi) Saving in cost of maintenance of roads due to less traffic.

(vii) Saving due to less accidents and less pollution.

Here (i),(ii) and (v) only are worked out as adequate data for others is not available. Other will be comparatively low also.

(b) The intangible benefits from introduction of metro services on this route are :

(viii) Better service reliability.

(ix) Better comfort.

In working out these benefits, it is considered that the capital cost for buses will be repeated in every 8 years since life span of buses is 8 years on an average. Residual value has been taken into consideration as 20%. Cost of normal bus is taken as Rs. 1 million (in 2001 AD price level) of which 20% is taken out as tax element. Thus capital cost per bus is Rs. 0.80 million. Life of wasting assets on mass rapid transit system or urban rail transit, i.e. track, coaches, electrification are on an average for 30 years [58]. Some replacements will be done for signalling equipment after 20 years. This is accordingly provided for. Since the B:C ratio is proposed to be worked out over a span of 25 years the outgo in terms of additional vehicles and additional operating costs are proposed to be taken into consideration for that span. the NPVs have been worked out at 12% as rate of interest which was normally adopted by World Bank as the minimum required for viable projects in India and other developing countries [58].

The shadow pricing aspect is covered as follows :

(i) Scarcity for skilled labour will be negotiated by the higher payment to ordinary labour as compared to the market rate.

(ii) Foreign exchange element for metro rail vehicles can be equated to foreign exchange element on fuel used for buses.

- Number of metro rake worked out as follows :

  With the trip length of route 11 Km and average speed of 35 kmph required trip time will be = 18.85 minutes

  Capacity of 8 Car BG metro rake during peak hour on an average = 3000

  Number of Services required during peak hour in 2001 AD =

$$\frac{77841 \times 18.85}{60 \times 3000} = 8.15 \quad \text{say } 8$$

  Metro-trips for 6 hours of peak period =

$$\frac{6 \times 60}{18.85} = 19$$

  Assuming equal number of trips in non-peak hour = 19

  Total trips per day = 38

  Car-Km. per day = (8 x 38 x 11) x 8

  Operating Cost per-car km for metro corridor = Rs. 17.54 (Estimated)

  (Excluding depreciation and tax element)

Operating Cost in the year 2001 AD

$= 350^{*} \times 17.54 \times 8 \times 38 \times 11 \times 8$ = Rs. 164.23 million

(* Considering 350 days working days in one year)

- Number of Buses have been worked out as follows :

  With the trip length of route 11 km and average speed of 19 kmph, required trip time will be = 34.74, say 35 minutes

  Capacity of Buses during peak hour = 60

  Number of services required during peak hour in 2001 AD

$$= \frac{77841 \times 36}{60 \times 60} = 778$$

  Bus trips for 6 hours of peak period

$$= \frac{60 \times 60}{35} = 10.28 \text{ say } 10$$

  Assuming equal number of trips

  in non - peak hour = 10

  Bus-km per day = 778 x 20 x 11

  Operating cost per Bus-km in 2001 AD = Rs. 25.67 (Estimated)

  (Excluding depreciation and tax element)

  Operating cost in a year 2001 AD

  = 350 x 25.67 x 20 x 11 x 778 = Rs. 1537.78 million.

The details about requirement of number of Buses and Metro rake are given in Table 12.1 and Figure 12.1 respectively.

- Value of time

  Average value of time in 2001 AD per person per hour = 10.45

  (Based on estimated value of time in chapter 6) for Delhi

  Taking an average lead of 7.85 km for

  Vishwavidyalaya - Central Secretariat metro corridor.

  Average speed of train = 35 kmph

TABLE 12.1 VISHWAVIDYALAYA - CENTRAL SECRETARIAT METRO SYSTEM

Year (AD)	Number of Passengers per day during peak hour	Requirement of number of BG metro rake (8 Car)	Requirement of number of buses
2001	77841	8	778
2002	79523	8	795
2003	81205	9	812
2004	82887	9	829
2005	84569	9	846
2006	86251	9	863
2007	87933	9	880
2008	89615	10	897
2009	91297	10	914
2010	92979	10	931
2011	94661	10	948
2012	96343	10	965
2013	98025	10	982
2014	99707	11	999
2015	101389	11	1016
2016	103071	11	1033
2017	104753	11	1050
2018	106435	11	1067
2019	108117	11	1084
2020	109799	12	1101
2021	111481	12	1118
2022	113163	12	1135
2023	114845	12	1152
2024	116527	13	1169
2025	118209	13	1186

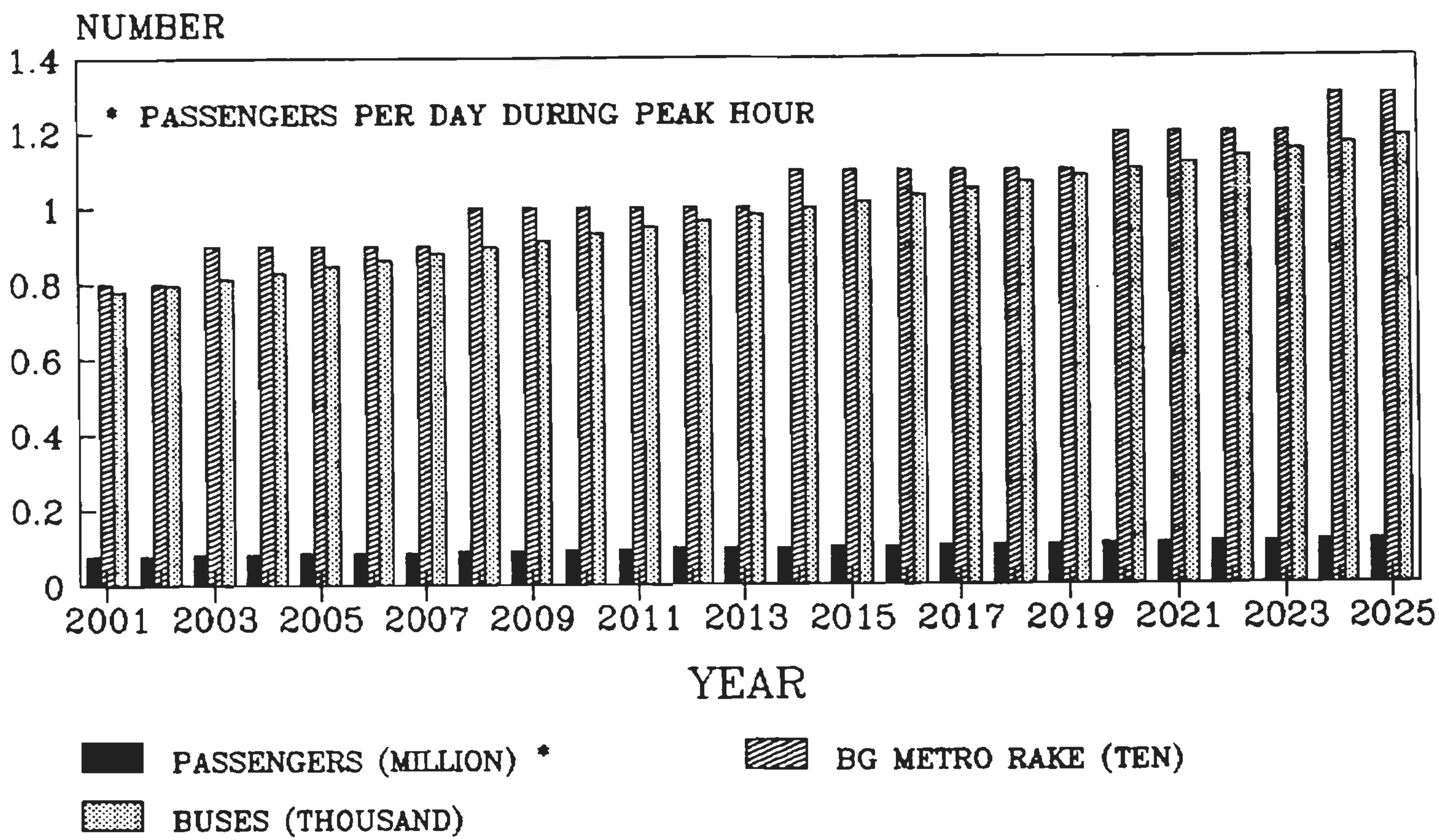


FIG. 12.1 VISHWA VIDYALAYA – CENTRAL SECRETARIAT METRO SYSTEM

Average of speed of bus = 19 kmph

Time saved per person per day

$$= 7.85 \times 60 \times (\frac{1}{19} - \frac{1}{35}) = 11.33 \text{ minutes.}$$

Value of time saved per person per annum

$$= \frac{350 \times 10.45 \times 11.33}{60} = \text{Rs. } 690.66 \text{ say Rs. } 691$$

The values of vehicle operating cost saving due to saving in time for different modes are given in Table 12.2. The details about time values are given in Table 12.3 and Figure 12.2 respectively.

TABLE 12.2 VEHICLE OPERATING COST SAVING FOR DIFFERENT MODES DUE TO SAVING IN TIME

Sl.	Mode	Rate/Vehicle-hour (1989 AD price level) (Rs.)	Rate/Vehicle-hour (2001 AD price level) (Updated) (Rs.)
1.	Car	24.30	58.32
2.	Bus	80.50	192.72
3.	Motorised two wheeler	4.80	11.52
4.	Auto	12.00	28.80
5.	Cycle Rickshaw	0.50	1.20

Source : Gupta, A.K. et al [58].

Tangible benefits will be in terms of savings in purchase of additional buses, operating costs, time costs, and vehicle operating costs saved by the users.

The NPVs of these elements at 12% interest rate have been worked out and are given in table 12.4.

TABLE 12.3 VALUE OF TIME SAVING ON VISHWA VIDYALAYA-CENTRAL SECRETARIAT METRO SYSTEM

Year (AD)	Value of time saved by persons per year (Rs. million)	Value of operating cost saved by buses per year due to saving in time (Rs. million)	Total value of time saving (Rs. million)
2001	537.88	9.69	547.57
2002	549.50	9.91	559.41
2003	561.13	10.13	571.26
2004	572.76	10.35	583.11
2005	584.39	10.57	594.96
2006	596.02	10.79	606.81
2007	607.65	11.01	618.66
2008	619.28	11.23	630.51
2009	630.91	11.45	642.36
2010	642.54	11.67	654.21
2011	654.17	11.89	666.06
2012	665.80	12.11	677.91
2013	677.43	12.33	689.76
2014	689.06	12.55	701.61
2015	700.69	12.77	713.46
2016	712.32	12.99	725.31
2017	723.95	13.21	737.16
2018	735.58	13.43	749.01
2019	747.21	13.65	760.86
2020	758.84	13.87	772.71
2021	770.47	14.09	784.56
2022	782.10	14.31	796.41
2023	793.73	14.64	808.37
2024	805.36	14.86	820.22
2025	816.99	15.08	832.07

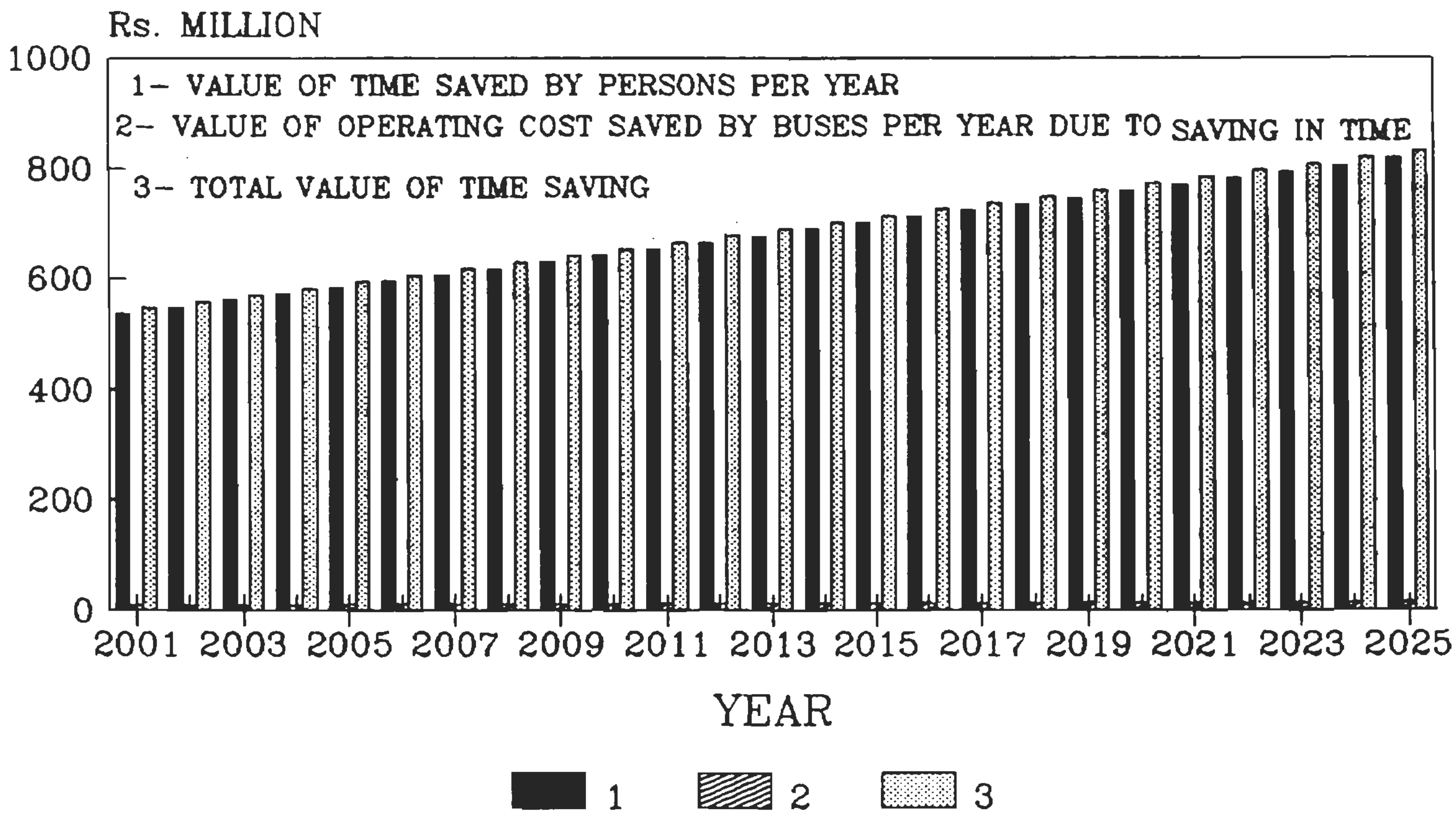


FIG. 12.2 VALUE OF TIME SAVING ON VISHWA VIDYALAYA - CENTRAL SECRETARIAT METRO SYSTEM

TABLE 12.4 BENEFIT COST RATIO @ 12% I.R.R. FOR VISHWAVIDYALAYA-CENTRAL SECRETARIAT METRO CORRIDOR (At 2001 AD price level) ALL FIGURES IN Rs. MILLION

Year (AD)	Out-flow cost for project and equivalent	Cost of equivalent Bus Transit	Value for saving in time	Total Benefit	NPV factor	NPV of	
						Cost(out-flow)	Benefit (In-flow)
2001	2886.00				0.8929	2576.90	
2002	2408.00				0.7972	1919.65	
2003	3189.00				0.7118	2269.93	
2004	3217.00				0.6355	2044.40	
2005	4897.00				0.5679	2781.00	
2006	184.76+5854.00	2396.18+122.5*	606.81	3125.49	0.5066	6038.76	1583.37
2007	184.76	1752.98	618.66	2371.64	0.4523	83.56	1072.69
2008	205.29	1786.58	630.51	2417.09	0.4039	82.91	976.26
2009	205.29	1820.18	642.36	2462.54	0.3606	74.03	887.99
2010	205.29	1853.78	654.21	2507.99	0.3220	66.10	807.57
2011	205.29	1887.38	666.06	2553.44	0.2875	59.02	734.11
2012	205.29	1920.98	677.91	2598.89	0.2567	52.69	667.14
2013	205.29	2472.38	689.76	3162.14	0.2292	47.05	724.76
2014	225.82	1998.38	701.61	2699.99	0.2046	46.20	552.42
2015	225.82	2031.98	713.46	2745.44	0.1827	41.26	501.59
2016	225.82	2065.58	725.31	2790.89	0.1631	36.83	455.19
2017	225.82	2099.18	737.16	2836.34	0.1456	32.88	412.97
2018	225.82	2132.78	749.01	2881.79	0.1300	29.36	374.63
2019	225.82	2166.38	760.86	2927.24	0.1161	26.22	339.85
2020	246.35	2199.98	772.71	2972.69	0.1037	25.54	308.27
2021	246.35	2233.58	784.56	3018.14	0.0926	22.81	279.48
2022	246.35	2267.18	796.41	3063.70	0.0826	20.34	253.06
2023	246.35	2300.78	808.37	3109.15	0.0738	18.18	229.46
2024	266.88	2334.38	820.22	3154.60	0.0659	17.58	207.89
2025	266.88	2367.98	832.07	3200.05	0.0588	15.69	188.16
				Total =		18428.89	11556.86

* Cost of depots and terminal = Rs. 122.5 million

$$\text{B:C ratio} = \frac{11556.86}{18428.89} = 0.63$$

NPV of Cost out-flow or total cost = Rs.18428.89 million

NPV of benefit in-flow or total benefit = Rs. 11556.86 million

B:C ratio = 11556.86 / 18428.89 = 0.63

12.5.2 Cost-Benefit analysis for Shahdara-Nangloi MRTS Corridor for the Year 2001 AD

All the procedures are same as already explained & detailed in the case of Vishwa Vidyalaya - Central Secretariat metro corridor except the average lead of corridor and operating cost per car-km. In this case the average lead of corridor is taken as 15 km and operating cost per car-km is taken as Rs. 17.88 (in 2001 AD price level). The details about requirement of number of buses and EMUs rake are given in Table 12.5 and Figure 12.3 respectively. The details about time value are given in Table 12.6 and Figure 12.4 respectively. Tangible benefits will be in terms of saving in purchase of additional buses, operating costs, time costs, and vehicle operating costs saved by the users. The NPVs of these elements at 12% interest rate have been worked out and are given in Table 12.7.

NPV of cost out-flow or total cost = Rs. 18909.20

NPV of benefit in-flow or total benefit = Rs. 21739.49.

B.C. ratio = 21739.49 / 18909.20 = 1.15.

12.5.3 Cost-Benefit analysis for Subzi Mandi - Holambi Kalan MRTS corridor for the year 2001 AD

All the procedures are same as in the case of Vishwa Vidyalaya - central secretariat metro corridor except the average lead of corridor and operating cost per car-km. In this case the average lead of corridor is taken as 11.6 km and operating cost per car - km is taken as Rs. 18.14 in the year 2001 AD. The details about requirement of number of buses and BG EMUs rake are given in Table 12.8 and Figure 12.5 respectively. The details about time value are given in Table 12.9 and Figure 12.6 respectively.

TABLE 12.5 SHAHDARA - NANGLOI MASS RAPID TRANSIT SYSTEM

Year (AD)	Number of Passengers per day during peak hour	Requirement of number of BG EMUs rake (8 Car)	Requirement of number of buses
2001	60144	14	1504
2002	62151	15	1554
2003	64158	15	1604
2004	66165	16	1654
2005	68172	16	1704
2006	70179	17	1754
2007	72188	17	1804
2008	74193	18	1854
2009	76200	18	1904
2010	78208	19	1954
2011	80216	19	2004
2012	82223	20	2054
2013	84230	20	2104
2014	86237	21	2154
2015	88244	21	2204
2016	90251	22	2254
2017	92258	22	2304
2018	94265	23	2354
2019	96272	23	2404
2020	98279	24	2454
2021	100286	24	2504
2022	102293	25	2554
2023	104300	25	2604
2024	106307	26	2654
2025	108314	26	2704

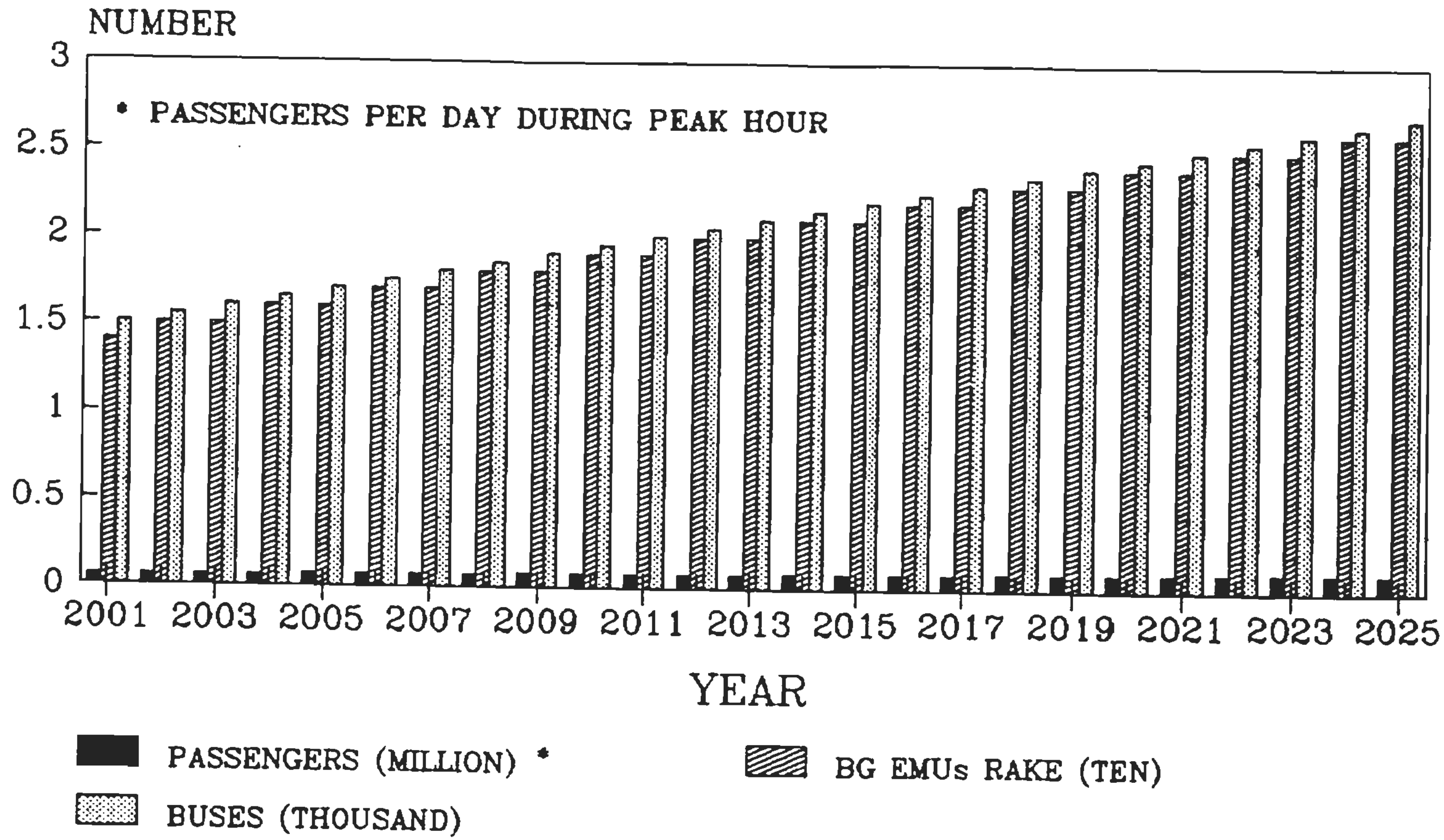


FIG. 12.3 SHAHDARA – NANGLOI MASS RAPID TRANSIT SYSTEM

TABLE 12.6 VALUE OF TIME SAVING ON SHAHDARA - NANGLOI MASS RAPID TRANSIT SYSTEM

Year (AD)	Value of time saved by persons per year (Rs. million)	Value of operating cost saved by buses per year due to saving in time (Rs. million)	Total value of time saving (Rs. million)
2001	793.60	36.60	830.20
2002	820.10	37.82	875.92
2003	846.60	39.04	885.64
2004	873.10	40.26	913.36
2005	899.60	41.48	941.08
2006	926.10	42.70	968.80
2007	952.60	43.92	996.52
2008	979.10	45.14	1024.24
2009	1005.60	46.36	1051.96
2010	1032.10	47.58	1079.68
2011	1058.60	48.80	1107.40
2012	1085.10	50.02	1135.12
2013	1111.60	51.24	1162.84
2014	1138.10	52.46	1190.56
2015	1164.60	53.68	1218.28
2016	1191.10	54.90	1246.00
2017	1217.60	56.12	1273.72
2018	1244.10	57.34	1301.44
2019	1270.60	58.56	1329.16
2020	1297.10	59.78	1356.88
2021	1323.60	61.00	1384.60
2022	1350.10	62.22	1412.32
2023	1376.60	63.44	1440.04
2024	1403.10	64.66	1467.76
2025	1429.60	65.88	1495.48

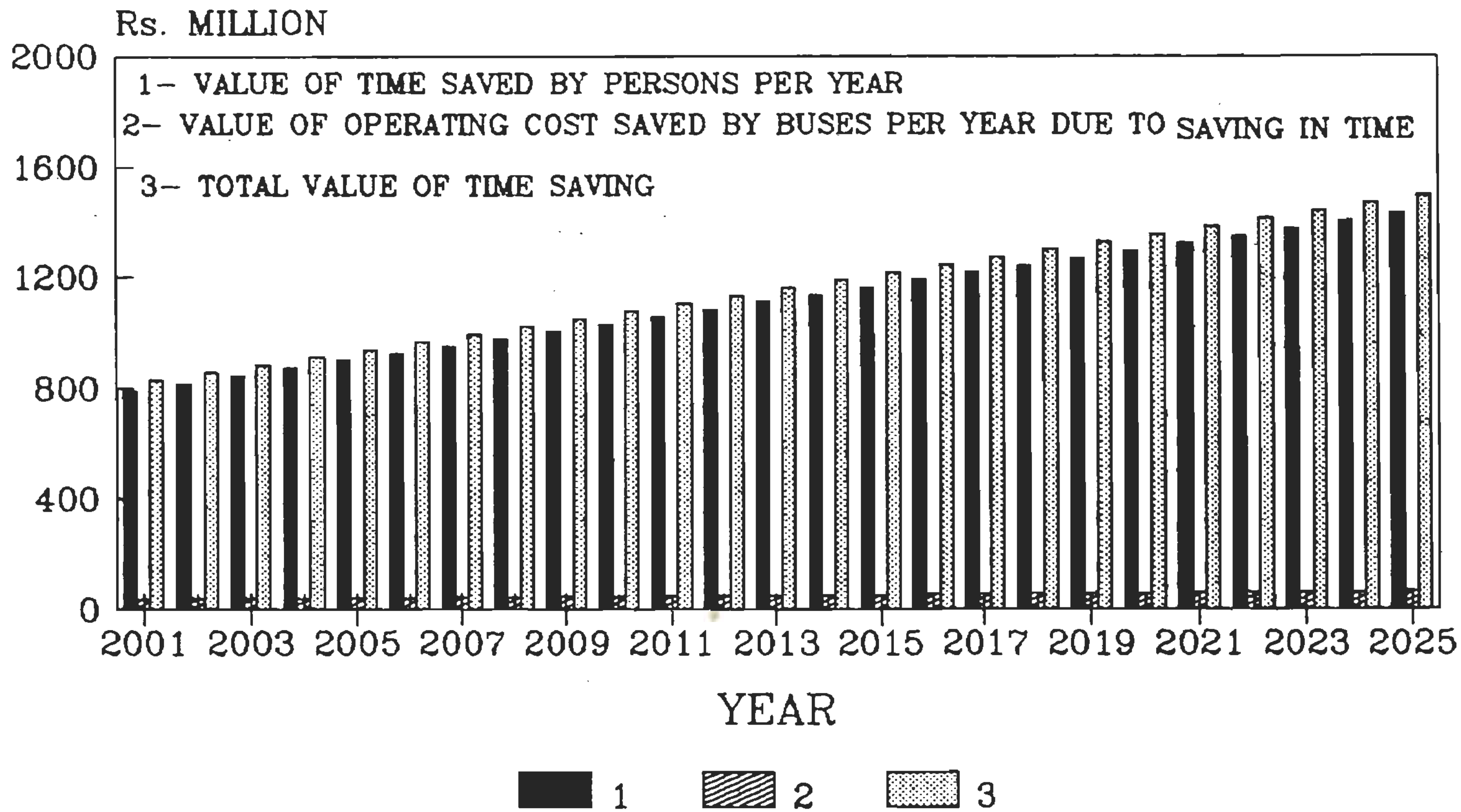


FIG. 12.4 VALUE OF TIME SAVING ON SHAHDARA – NANGLOI MASS RAPID TRANSIT SYSTEM

TABLE 12.7 BENEFIT COST RATIO @ 12% I.R.R. FOR SHAHDARA-NANGLOI MRTS CORRIDOR (At 2001 AD price level) ALL FIGURES IN Rs. MILLION

Year (AD)	Out-flow cost for project and equivalent	Cost of equivalent Bus Transit	Value for saving in time	Total Benefit	NPV factor	NPV of Cost(out-flow)	NPV of Benefit (In-flow)
2001	3084.00				0.8929	2753.70	
2002	2743.00				0.7972	2186.72	
2003	3542.00				0.7118	2521.19	
2004	3586.00				0.6355	2278.90	
2005	6897.00				0.5679	3916.80	
2006	7054+340.44	4554.98+260.58*	968.80	5784.28	0.5066	3746.02	2930.31
2007	340.44	3291.63	996.52	4288.15	0.4523	153.98	1939.53
2008	360.47	3381.48	1024.24	4405.72	0.4039	145.59	1779.47
2009	360.47	3471.33	1024.24	4523.29	0.3606	129.98	1631.10
2010	380.50	3561.18	1079.68	4640.86	0.3220	122.52	1494.36
2011	380.50	3651.03	1107.70	4758.43	0.2875	109.39	1368.04
2012	400.53	3740.88	1135.12	4876.00	0.2567	102.81	1251.67
2013	400.53	4883.13	1162.84	6045.97	0.2292	91.80	1385.74
2014	420.56	3925.38	1190.56	5115.94	0.2046	86.04	1046.72
2015	420.56	4015.23	1218.28	5233.51	0.1827	76.83	956.16
2016	440.59	4105.08	1246.00	5351.08	0.1631	71.86	872.76
2017	440.59	4194.93	1273.72	5468.65	0.1456	64.15	796.24
2018	460.62	4284.78	1301.44	5586.22	0.1300	59.88	726.21
2019	460.62	4374.63	1329.16	5703.79	0.1161	53.48	662.21
2020	480.65	4464.48	1356.88	5821.36	0.1037	49.84	603.68
2021	480.65	4554.33	1384.60	5938.93	0.0926	44.50	549.95
2022	500.68	4644.18	1412.32	6056.50	0.0826	41.35	500.27
2023	500.68	4734.03	1440.04	6174.07	0.0738	36.95	455.65
2024	520.71	4823.88	1467.76	6291.64	0.0659	34.31	414.62
2025	520.71	4878.68	1495.48	6374.16	0.0588	30.61	374.80
				Total =		18909.20	21739.49

* Cost of depots and terminal = Rs. 260.58 million

$$\text{B:C ratio} = \frac{21739.49}{18909.20} = 1.15$$

TABLE 12.8 SUBZI MANDI-HOLAMBI KALAN MASS RAPID TRANSIT SYSTEM

Year (AD)	Number of Passengers per day during peak hour	Requirement of number of BG EMUs rake (8 Car)	Requirement of number of buses
2001	43702	8	740
2002	46790	9	792
2003	49877	9	844
2004	52965	10	896
2005	56053	10	948
2006	59141	11	1000
2007	62229	11	1052
2008	65317	12	1104
2009	68405	12	1156
2010	71493	13	1208
2011	74581	13	1260
2012	77669	14	1312
2013	80757	14	1364
2014	83845	15	1416
2015	86933	15	1468
2016	90021	16	1520
2017	93109	16	1572
2018	96197	17	1624
2019	99285	17	1676
2020	102373	18	1728
2021	105461	18	1780
2022	108549	19	1832
2023	111637	19	1884
2024	114725	20	1936
2025	117813	20	1988

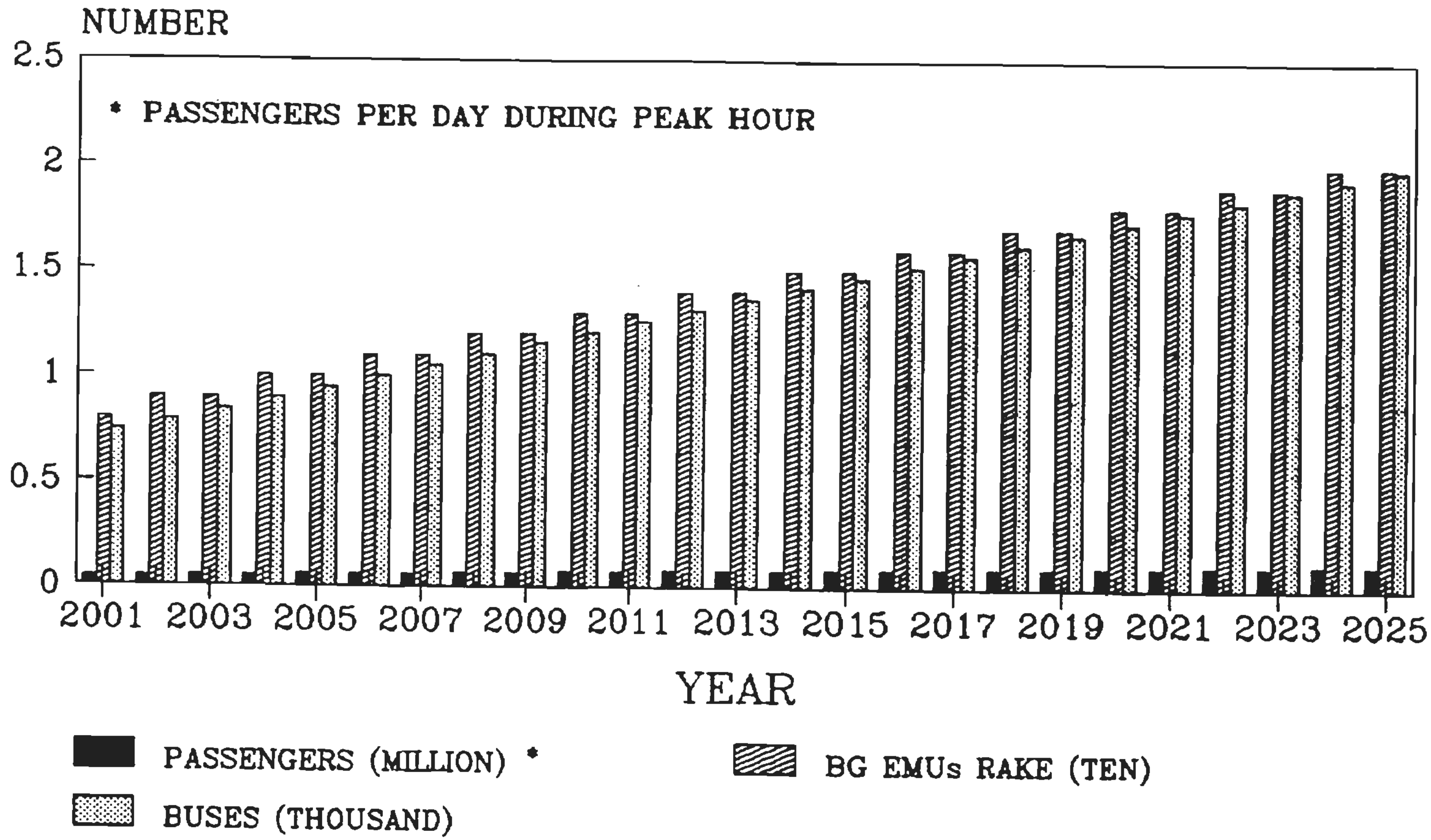


FIG. 12.5 SUBZI MANDI – HOLAMBI KALAN
MASS RAPID TRANSIT SYSTEM

TABLE 12.9 VALUE OF TIME SAVING ON SUBZI MANDI-HOLAMBI KALAN MASS RAPID TRANSIT SYSTEM

Year (AD)	Value of time saved by persons per year (Rs. million)	Value of operating cost saved by buses per year due to saving in time (Rs. million)	Total value of time saving (Rs. million)
2001	446.63	13.93	460.56
2002	478.19	14.91	493.10
2003	509.75	15.89	525.64
2004	541.31	16.87	558.18
2005	572.87	17.85	590.72
2006	604.43	18.83	623.26
2007	635.99	19.81	655.80
2008	667.55	20.79	688.34
2009	699.11	21.77	720.88
2010	730.67	22.75	753.42
2011	762.23	23.73	785.96
2012	793.79	24.71	818.50
2013	825.35	25.69	851.04
2014	856.91	26.67	883.58
2015	888.47	27.65	916.12
2016	920.03	28.63	948.66
2017	951.59	29.61	981.20
2018	983.15	30.59	1013.74
2019	1014.71	31.57	1046.28
2020	1046.27	32.55	1078.82
2021	1077.83	33.53	1111.36
2022	1109.39	34.51	1143.90
2023	1140.95	35.49	1176.44
2024	1172.51	36.47	1208.98
2025	1204.07	37.45	1241.52

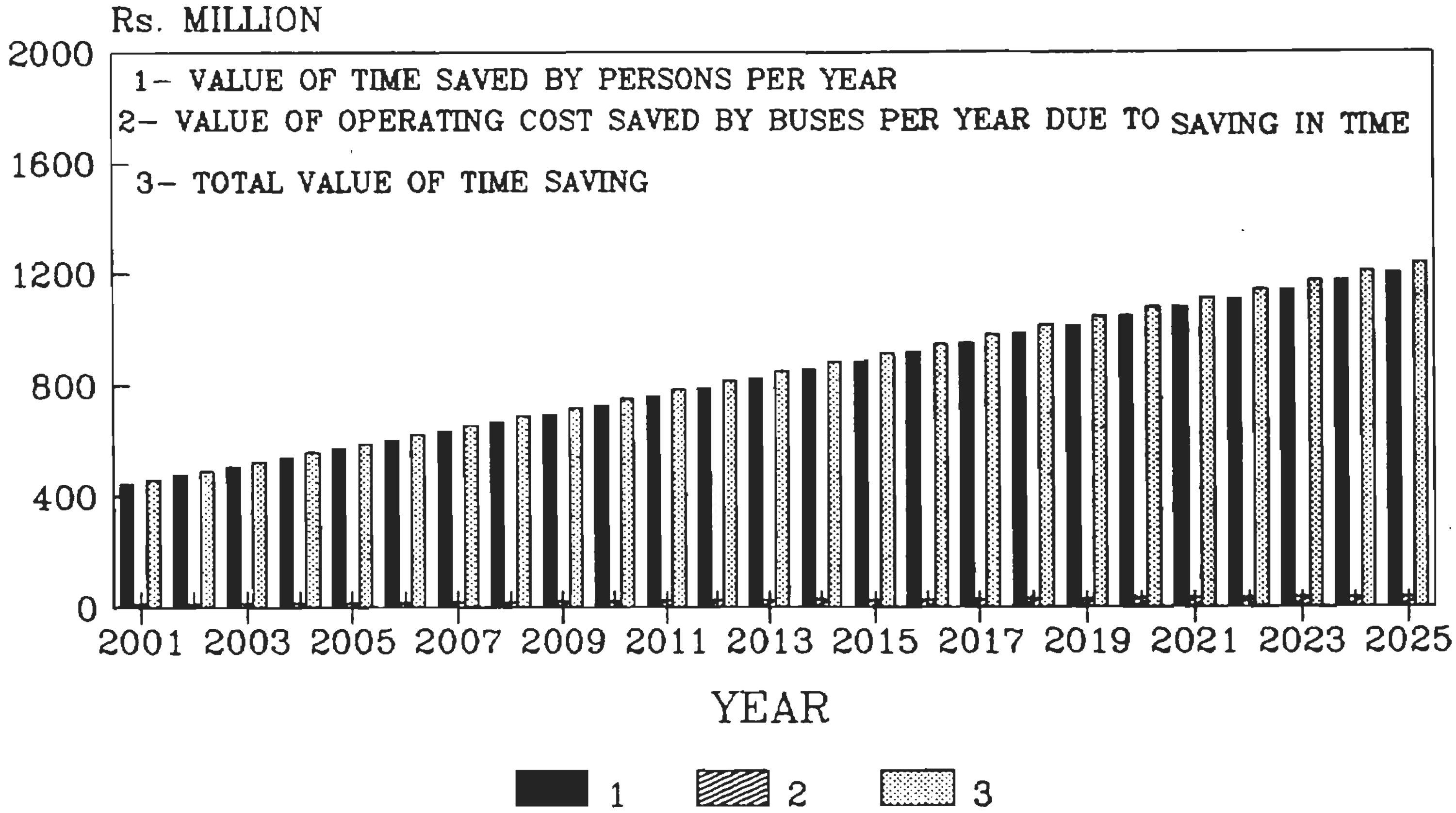


FIG. 12.6 VALUE OF TIME SAVING ON
SUBZI MANDI – HOLAMBI KALAN
MASS RAPID TRANSIT SYSTEM

Tangible benefits will be in terms of savings in purchase of additional buses, operating costs, time costs and vehicle operating costs saved by the users. The NPVs of these elements at 12% interest rate have been are worked out and are given in Table 12.10.

NPV of cost out-flow or total cost = Rs. 12930.87 million.

NPV of benefit in-flow or total benefit = Rs. 15954.74 million .

B : C ratio = 15954.74 / 12930.87 = 1.23.

12.5.4 Other Benefits

The other benefits arising due to mass rapid transit system or urban rail transit over the 'Do nothing' alternative are in terms of :

(i) Less accidents.

(ii) Reduction in pollution levels.

(iii) Better service reliability.

(iv) Improvement in comfort levels.

It is difficult to quantitatively assess these benefits and convert them in financial terms because adequate data are not available.

12.6 Summary

Economic analysis has been done separately for all the three identified MRTS corridors. Economic analysis indicates that the MRTS section will be economically viable if MRTS sections are at grade or an elevated. For the particular case of a Shahdara - Nangloi MRTS section which is 17.7 km an elevated and 7.3 km at-grade the analysis has resulted in B:C ratio of 1.15. Whereas Subzi Mandi - Holambi Kalan MRTS section which is 4.45 km an elevated and 14.85 km at-grade has resulted in B:C ratio of 1.23, Vishwavidyalaya-Central Secretariat Metro section which is fully underground has resulted in B:C ratio of 0.63. The justification for urban railway projects should not be looked at merely on the grounds of commercial profitability. In such instances, it is very important to assess also the socio-economic implications of the projects. Urban

TABLE 12.10 BENEFIT COST RATIO @ 12% I.R.R. FOR SUBZI MANDI-HOLAMBI KALAN MRTS CORRIDOR (At 2001 AD price level) ALL FIGURES IN RS. MILLION

Year (A.D.)	Out-flow cost for project and equivalent	Cost of equivalent Bus Transit	Value for saving in time	Total Benefit	NPV factor	NPV of Cost(out-flow)	NPV of Benefit (In-flow)
2001	2032.00				0.8929	1814.37	
2002	2627.00				0.7972	2094.24	
2003	2939.00				0.7118	2091.98	
2004	3186.85				0.6355	2025.24	
2005	3214.00				0.5679	1825.23	
2006	237.24+3594	2880.84+226.00*	623.26	3730.10	0.5066	1940.90	1889.67
2007	237.24	2230.65	655.80	2886.45	0.4523	107.30	1305.54
2008	258.81	2338.86	688.34	3027.20	0.4039	104.53	1222.69
2009	258.81	2447.07	720.88	3167.95	0.3606	93.32	1142.36
2010	280.38	2555.28	753.42	3308.70	0.3220	90.28	1065.40
2011	280.38	2663.49	785.96	3449.45	0.2875	80.61	991.72
2012	301.95	2771.70	818.50	3590.20	0.2567	77.51	921.60
2013	301.95	3479.91	851.04	4530.95	0.2292	69.21	1038.49
2014	323.52	3019.32	883.58	3902.90	0.2046	66.19	798.53
2015	323.52	3127.53	916.12	4043.65	0.1827	59.10	738.77
2016	345.10	3235.74	948.66	4184.40	0.1631	56.28	682.48
2017	345.10	3343.95	981.20	4325.15	0.1456	50.25	629.74
2018	366.66	3452.16	1013.74	4465.90	0.1300	47.67	580.57
2019	366.66	3560.37	1046.28	4606.65	0.1161	42.57	534.83
2020	388.23	3668.58	1078.82	4747.40	0.1037	40.26	492.31
2021	388.23	3776.79	1111.36	4888.15	0.0926	35.95	452.64
2022	409.80	3885.00	1143.90	5028.90	0.0826	33.85	415.39
2023	409.80	3993.31	1176.44	5169.65	0.0738	30.24	381.52
2024	431.37	4101.42	1208.98	5310.40	0.0659	28.43	349.96
2025	431.37	4209.63	1241.52	5451.15	0.0588	25.36	320.53
				Total =		12930.87	15954.74

* Cost of depots and terminal = Rs. 226.00 million

$$\text{B:C ratio} = \frac{15954.74}{12930.87} = 1.23$$

railway projects have a significant impact on the society which would result into the maximum possible benefit to the present and future generations. In the use of a particular case of fully utilised line the B:C ratio exceeds 1.1 even without considering other benefits. The technique of cost-Benefit analysis is an aid in assessing the desirability and viability of urban railway projects from the point of view of the overall development of the society and the achieving the social, developmental and essential mobility goals.

CHAPTER 13
CONCLUSIONS AND RECOMMENDATIONS

13.1 Background

Based on the detailed study presented in the thesis, the following rational conclusions have been arrived at and are presented under various sub-heads in the following articles.

13.2 Conclusions of the Research Study

The salients conclusions are as under :

13.2.1 Attitude study

Attitudes of users have been measured from two angles i.e. users feelings in terms of importance they attach to different 'travel attributes' and their 'perceptions' in terms of level of satisfaction they derive from use of different modes in respect of different travel attributes. Technique has been devised to estimate a consolidated 'attitude value' for different travel modes making use of the values expressed by the users. The study has revealed the following :

(i) At disaggregate level 'attitude values' are more influenced by accessibility and level-of-service as provided by the concerned mode. Mathematical models for computing users 'attitude values' for different modes have also been developed which would help to predict the attitudes of prospective user under various conditions.

(ii) Private vehicles derive high score only from high income group whereas train receive high score from all income groups.

(iii) Attitude value has noticeable influence on choice of mode only among vehicle owning groups. However, time of travel is valued high by all income groups.

Both MLR and MNL models have been developed taking attitude value as a variable.

Multiple Linear Regression (MLR) models developed using the attitude of users towards different modes and in this the form using log of ratio of proportion of use of different modes to the proportions of use of a base mode (say bus) as dependent variable gives better results. The models developed indicate that attitude has a significant influence on choice by Motorised Two Wheeler, IPT and Train users.

Multi-Nomial Logit (MNL) models developed have led to three important observations.

(a) In a multi-modal environment with wide varying income levels, development of models by disaggregating the population under four groups (NVP, CYP, TWP and COP) result in better understanding of the behaviour of commuters.

(b) Inclusion of attitude value as a variable in addition to time of travel and cost of travel improves reliability of the models.

(c) The attitude value has highly significant impact on choice only amongst car owners, some impact on motorised two wheeler owners and no impact on non-vehicle owners. Between time and cost, time is more significant in all cases.

Application of the developed model to a selected area has been done where MRTS is likely to be introduced. It has shown that the results obtained from the model are fairly close to the desires expressed by the people. This modelling approach is found to be quite suitable for application to a multi-modal environment as we have in Indian cities.

13.2.2 Trade-off game

The Trade-off game study covers 12 attributes. These attributes have been studied under 5 to 7 levels-of-services. The special feature of the Trade-off analysis is that it helps us to understand how people would behave in future when conditions / characteristics of various travel attributes are subjected to changes.

The following are the findings :

(i) The commuters value 'waiting time' as the most important issue.

(ii) The commuters would be prepared to pay more to save travel time.

(iii) The commuters are willing to pay more if an assured seat is made available during their travel.

(iv) A scale of importance for different travel attributes has been constructed.

The results of the Trade-off study have been used to estimate as to how the share of various modes would undergo changes when MRTS is introduced in a selected area. The share of bus, for example, is likely to decrease from the present 44.2% to 35.2% in future, when MRTS is introduced at Shahdara (Delhi).

However the trade-off study calls for a very careful preparation of the study instrument, careful and skilful enquiry by investigators, careful selection of representative sample and willing participants to cooperate. It can not be subjected to any statistical fit test. Thus Trade-off technique could be a quick response technique for modal choice analysis when controlling conditions are likely to change.

13.2.3 Financial analysis

Financial analysis has been done separately for all the three MRTS corridors at three different scenarios of monthly season ticket fare and at projected daily ticket fare in the year 2001 AD. Financial analysis indicates that at the current projected fare structure in the scenario 1, the metro section is not able to meet even, day-to-day expenditure. This indicates that the metro section is not financially viable at three different scenarios of monthly season ticket fare and also at projected daily ticket fare. In the scenario 3, fare structure, the Metro section is able to meet its operating cost including depreciation. The analysis indicates that a Metro system which is fully used would be viable, if the cost of provision of initial infrastructure, and other auxiliary facilities are not considered, as in the case of a road transport facility where cost of provision and maintenance of road is borne by the state government; the other tangible benefits are saving in energy and less pollution.

13.2.4 Economic analysis

Economic analysis has been done separately for all the three proposed MRTS corridors.

Economic analysis indicates that the MRTS section will be economically viable if MRTS sections are at-grade or an elevated. For the particular case of a Shahdara - Nangloi MRTS section, which is 17.7 km an elevated and 7.3 km at - grade has resulted in B:C ratio of 1.15. Whereas Subzi mandi - Holambi kalan MRTS section which is 4.45 km an elevated and 14.85 km at - grade has resulted in B:C ratio of 1.23. Vishwavidyalaya - Central Secretariat Metro section which is fully underground has resulted in B:C ratio of 0.63. The justification for urban railway projects should not be looked at merely on the grounds of commercial profitability. In such instances, it is very important to assess also the socio - economic implications of the projects. Urban railway projects have a significant impact on the society which would result in the maximum possible benefit to the present and future generations, in the use of a particular case of fully utilised line the B:C ratio exceeds 1.1 even without considering other benefits. The technique of Cost-Benefit analysis is an aid in assessing the desirability and viability of urban railway projects from the point of view of overall development of the society and the achieving the social, developmental and essential mobility goals.

13.3 Recommendations for Further Studies

* The study can be extended to cover other types of trips, e.g.. education, shopping, entertainment etc.
* Extension of Trade-off Game technique can be made to estimate value of time for different modes for different income or vehicle owning groups for work trips and for other trips.

* Expanding the sample size in attitude studies and developing models to relate the attitude values to different trips and modal characteristics.
* Urban rail projects should not be looked at only based on 'return on investment' basis. They should be assessed on economic benefit cost basis.
* The fare structure should be such as to meet operational cost of system. It should be delinked from inter-city fare structure. The unified interchangeable travel tickets on a multi-modal urban transport system must be developed with directional constraint or time constraint.
* It is recommended that, wherever possible, the MRTS should be at - grade or an elevated.

REFERENCES

1. Allen,W.B., and Isserman, A., "Behavioural Modal Split", High Speed Ground Transport Journal, Vol.6, pp.179-199, 1972.
2. Algers, Stefan; Hanser, Stein and Tegner, Goran, "Role of Waiting Time, Comfort and Convenience in Modal Choice for Work Trip", Transportation Research Record, 534, USA, pp. 38-51, 1975.
3. Avadhanulu,T.V., and Saxena,R.B., "Rosenbroch's Direct Search Algorithm - A modified version suitable for large scale optimisation problems", Energy-78 Conference Record, I.E.E.E., Region Five Annual Conference, pp. 78-82, September, 1978.
4. Anantharamaiah,K.M.,and Rao,M.S.V., "Bangalore Metropolitan Area : A Simplified Transport Land Use Model for Restructuring the Metropolitan Area and Transport Development for 2000 AD", Indian Roads Congress Paper 363, Indian Roads Congress, New Delhi, 1984.
5. Anantharajan,T., "Trade-off Games in Planning for Residential Area", International Journal for Housing Science and its Application, Vol. 2, pp. 197-208, 1984.
6. Anantharajan,T.,"Residents Participation in Slum Upgrading Through Trade-Off-Games", International journal for Housing Science and its Applications, Vol. 9, No. 4, pp. 325-341, 1985.
7. Anand,Y.P.,"Relevance of Energy and Pricing Issues in Urban Transportation in Developing Countries like India", CODATU VII, New Delhi, Vol. 1, No.2, pp. 49-56, 1996.
8. Blumenfeld, "Are Land use patterns predictable", Journal of American Institute of planners, May, 1959.

9. Bruton,N.J., "Introduction to transportation planning", Hutchinson of London, 1975.

10. Ben-Akiva, Moshe,"Issues in Transferring and updating Travel behaviour Models", in Ed. Stopher, P. et al, New Horizons in Travel Behaviour Research, Lexington Books, Massachusetts, 1981.

11. Booz, Allen, and Hamilton,"Bus Route Costing procedures", Interim Report No.2 : proposed Method, prepared for UMTA, Report No. UMTA-IT-09-9014-81-1, Exhibit 3-2, Following p.8, Urban Mass Transportation Administration, Washington, D.C., 1981.

12. Bourgin,Christian, and Goddard, Xavier, "Structural Threshold Effects in the use of Transportation Modes", in Ed. Stoper P.R., Meigburg, Arnium H. and Werner Brig, 'New Horizons in Travel-Behaviour Research', Lexington Books, Toronto, pp.353-368, 1981.

13. Benjamin,Julian and Sen, Lalita, "Comparison of the predictive Ability of Four Multi-Attribute Approaches to Attitudinal Measurement", Transportation Research Record, No.890, pp. 1-6, T.R.B., Washington, D.C., 1982.

14. Ben-Akiva, Moshe and Lerman, Steven R., "Discrete choice Analysis Theory and Application to Travel Demand", The MIT press, Massachusetts, 1985.

15. Benjamin, Julian, "Utilisation of Attitudinal Measurement Techniques to Analyse Demand for Transportation", in Ed. Methods, Applications and New Directions in Behavioural Research for Transport policy, VNU science press, pp. 383-403, 1986.

16. Clark,C., "Urban population Densities", Journal of Royal Statistical Society, Series A, No. 114, London, 1951.

17. Crecine,J.P., "Time oriented Metropolitan Model", Technical Bulletin No.6, Community Renewal programme, Pittsburg, 1969.

18. Chari,S.R., and Khanna,S.K., "Analysis of Socio-Economic variables in Trip Generation Models", Journal of Indian Roads Congress, New Delhi, Vol. 38, No.1, 1977.

19. Chari,S.R., and Khanna,S.K., "Study of Work trip travel in India", Transportation Engineering journal, ASCE, Vol. 104, No. TE.1, pp. 89-105, 1978.

20. Chari,S.R., "Modal Split Models for work trip travel", Journal of Indian Roads Congress, New Delhi, 1979.

21. Chari,S.R., "Modal Split Models for work trip travel", Indian Highways, Vol.10, No.1, IRC, New Delhi, pp. 18-42, 1982.

22. CRRI, "Road user cost study", Final report, Vol. V, Central Road Research Institute, New Delhi, 1982.

23. CRRI, "Traffic Flow Trends in Delhi", Study Report, Central Road Research Institute, New Delhi, 1984.

24. Chandra, Jag Pravesh, "Delhi is Doomed without Metro", Book Printed by Virendra Printers, New Delhi, 1992.

25. Deen,B.T. and James,D.H., "Relative Costs of Bus and Rail Transit Systems" in Transportation system planning, Highway Research Record 293 (Washington, D.C., Highway Research Board), pp. 33-53, 1969.

26. Demetsky, Michael,J., "Attitudinal Data", Transportation Research Record, Special Report 149, pp. 21-24, T.R.B., Washington, D.C. 1974.

27. Domenich,T., and Mc Fadden,D., "Urban Travel Demand", A Behavioural Analysis, North Holland America Elsevier, New York, 1975.

28. Dajani, Javir S., and Sullivan, Deborah Anne, "A causal Model for estimating public Transit Ridership using Census Data", High speed Ground Transportation, Vol. 10, No.1., pp.47-58, 1976.

29. Donnelly, E.P., Howe, S.M., and Deschamps, J.A.,"Trade - off Analysis : Theory and Applications to transportation policy Analysis", Preliminary Research Report No. 103, New York State Department of Transportation, Planning Research Unit, 1976.

30. Dobson,R., and Tischer,M.L., "Perceptual Market Segmentation Technique for Transportation Analysis", Transportation Research Record No.673, pp. 145-152, T.R.B., Washington,D.C.,1978.

31. Dobson,R., Dunbar,F.,Smith,C., Reibstein,D., and Lovelock, C., "Structural Models for the Analysis of Traveller- Attitude-Behaviour Relationships", Transportation, Vol.7, pp. 351-363, 1979.

32. Dickey,J.W., "Metropolitan Transportation Planning", Tata-McGraw Hill Publishing Company Limited, New Delhi, 1980.

33. DDA, "Travel Survey Data Report", Delhi Development Authority, New Delhi, 1980.

34. DDA, "Travel Survey Data Report", Delhi Development Authority, New Delhi, 1981.

35. Dhir,M.P., Sarin,S.M.,"Some Special Features of Traffic Safety Situations in India", Proc. Int. Conf. on SHRP and Traffic safety on two Continents, Hague, the Neither lands,VIT Conferences 14 Part 1, pp. 17-36, September 22-24, 1993.

36. DTP, "A Diary of Delhi Traffic Police Activities", Delhi traffic police, New Delhi, 1995.

37. Edward,K.M., "The comparison of transport Technologies", in Transportation System Evaluation, Highway Research Record 238 (Washington, D.C, Highway Research Board), pp. 1-22. 1968.

38. Edwin,N.T., and Joseph,L.S., "Strategies for the Evaluation of Alternative Transportation plans", NCHRP Report 96 (Washington, D.C.,Highway Research Board), 1970.

39. Foster,C.D., and Beesley,M.E., "Estimating the Social Benefit of Constructing an underground Railway in London", Journal of the Royal Statistical Society, Vol.126, London, 1963.

40. Fabrycky, W.J., and Thuesen, G.J., "Economic Decision Analysis", Prentice-Hall, Englewood Cliffs, N.J., 1974.

41. Feo, Alberto and Echnique Marcial, "A disaggregated model for Caracas", LUBFS, Conference proceedings on Urban Development Models, The Construction Press, U.K., 1975.

42. Garin,R.A., "A Matrix formulation of Lowry model for Intra Metropolitan Activity Allocation", Journal of American Institute of Planners, Vol. 32, 1966.

43. Golob, Thomas F., "The Survey of user choice of Alternate Transportation Modes", High Speed Ground Transportation Journal, Vol. 4, pp. 103-116, 1970.

44. Goldner,W., "Lowry Model Heritage ", Journal of the American Institute of Planners, Vol. 37, pp. 100-110, 1971.

45. Gustafson, Richard L., Lurd, Harriet N., and Golob, Thomas F., "User Preferences for a Demand Responsive Transportation System - A Case Study Report", Highway Research Record No. 367, pp. 31-45, Highway Research Board, Washington, D.C., 1971.

46. Golob, T.F., Canty, E.T., Gustafson, R.L., and Vitt,J.E., "An Analysis of Consumer Preferences for a public Transportation System", Transportation Research Vol. 6, No. 1, Pergamon Press, 1972.

47. Golob, Thomas F., "Research paper on Attitudinal Models", in Urban Travel Demand Forecasting, Highway Research Record, Special Report 143, pp. 130-147, T.R.B., Washington, D.C. 1973.

48. Golob, Thomas F., and Dobson, Richard, "Assessment of preferences and perceptions towards attributes of Transportation Alternative", T.R.R., Special Report No. 149, T.R.B., Washington, D.C. 1974.

49. Gunn, H., and Bates, J., "Statistical Aspects of Travel demand modelling", Transportation Research, 16A (5/6), pp. 371-382, 1982.

50. Golob,J.M., and Golob, Thomas, F., "Classification of Approaches to Travel - Behaviour Analysis", Transportation Research Record, Special Report No. 201, pp. 83-107, TRB, Washington, D.C., 1983.

51. Gupta,S.D., "Planning and Evaluation of Urban Bus Route Networks based on Origin - Destination Information in Multi-mode Environment" Ph.D. Thesis, Regional Engineering College, Warangal, 1986.

52. Golob,J.M. Schreurs, L.S.M., and Swait, J.G., "The Design and policy Applications of a panel for studying changes in Mobility over time", in Behavioural Research for transport policy, VNU Science Press, pp. 81-95, 1986.

53. Government of India, "Report of the study group of Alternative Systems of Urban transport", Ministry of Development, Government of India, New Delhi, 1987.

54. Government of India, "National Commission on Urbanisation Report of working group on City Transport", Ministry of Urban Development, Government of India, New Delhi, 1988.

55. Gupta,A.K., Jain,S.S., Kumar,Susheel, "Final Report on Research Project, Evaluation of the Existing Mass Transportation System and Suggestions for Requirements in 2001 AD for Delhi Metropolitan Area", R & D Report, Submitted to UGC, New Delhi, 1993.

56. Government of India, "Motor Transport Statistics 1991 - 93", Ministry of Shipping and Transport, Transport Research Division, Government of India, New Delhi, 1994.

57. Gupta,A.K., Singh, Indrasen and Jain,S.S., "Socio-Economic Analysis of Multi-Modal Tansport System in Delhi", The Institution of Engineers (India), U.P. State Center,Lucknow, Annual Technical Volume and Proceedings, Vol. 75, pp. 43-54, December 2-3, 1995.

58. Gupta,A.K., Singh, Indrasen and Jain,S.S.,"Economics of Urban Rail Transport Operation on Madras Beach-Tambaram MG Urban System", Indian Journal of Transport Management, Volume 19, No. 8, pp. 518-531, CIRT, Pune, August, 1995.

59. Gupta,A.K., Singh,Indrasen and Jain,S.S.,"Planning and Management of Urban Transportation System", Policy Seminaron Urban Transport and Mass Transit, HUDCO, New Delhi, pp. 59-71, October 14-17, 1996.

60. Gupta,A.K., Singh Indrasen and Jain,S.S., "Financial Analysis of The Proposed Delhi MRTS Corridor - A case study" Indian Journal of Transport Management,Vol 20, No.12, pp. 705-719, CIRT, Pune, December, 1996.

61. Hamburg,J.R., and Creighton,R.L., "Predicting Chicago's Land use Pattern", Journal of American Institute of Planners, May 1959.

62. Herbert, J.D., and Stevens, B.H., "A Model for the distribution of residential activity in urban areas", journal of Regional Science, USA , Vol. 2 , 1960.

63. Hansen,W.G., "Evaluation of Gravity Model Trip Distribution procedures", H.R.B., Bulletin, No. 347, Highway Research Board, washington, D.C., 1962.

64. Hill, D.M., "A Growth Allocation Model for the Boston Region", Journal of American Institute of Planners, 1965.

65. Hartgen, D.T., and Tanner, G.H., "Individual Attitudes and Family Activities : A behavioural model of traveller mode choice", High Speed Ground Transportation, Vol. IV, No.3, pp. 439-467, 1970.

66. Hoinville,G., "Evaluating Community Preferences", Environment and Planning, Vol. 3, pp. 33-50, 1971.

67. Hartgen, David, T., "A Note on the Ability of Socio-Economic Variables to Explain Attitudinal Bias Towards Alternative Travel Modes", Journal of Advanced Transportation Vol. 6, Summer No.2, pp. 201-212, 1972.

68. Hensher,D.A., "Problem of Aggregation in Disaggregate Behavioural Travel Choice Models with Emphasis on Data Requirements", Transportation Research Record, Special Report No. 149, pp. 85-100, TRB, Washington, D.C., 1974.

69. Hutchinson,B.G., "Tools for Urban Land Use-Transport Strategy Planning", Canadian Journal of Civil Engineering, 1975.

70. Herbert,S. Levinson, "Coordinating Transport and urban Development", ITCC Review, No.4 (10), Tel Aviv Association of Engineers and Architects in Israel, October, 1976.

71. Hutchinson,B.G., "Principles of Urban Transportation Planning", McGraw Hill Book Company, New York, 1976.

72. Hensher,D.A., "Market segmentation as a mechanism in allowing for variability of traveller behaviour", Transportation, 5(3), pp.257-284, 1976.

73. Hensher,D.A, "Review of studies leading to existing values of travel time", Transportation Research Record, 587, USA, pp. 30-41, 1976.

74. Heggle,ian G., "Behavioural Dimensions of Travel Choice", in Ed. Hensher, David A. and Dalvi, Quasim, Determinants of Travel Choice, Saxon House, Westwood, pp. 100-125, 1978.

75. Held,Hostin, "Some Thoughts about the Individual's Choice among Alternative Travel Modes and its Determinants", In Ed. Stopher, Peter R., Meyburg, Arnim H., and Warner Brog, 'New horizons in Travel-Behaviour Research', Livingstone Books, Toronto, pp. 155-188, 1981.

76. Horowitz,J.L.,"Specification tests for probabilistic Choice models", Transportation Research, 16A (5/6), pp. 383-394, 1982.

77. Hauer, E., and Greenough,J.C., "A Direct Method for value of time Estimation", Transportation Research, Volume 16 A, No.3, pp. 163-172, 1982.

78. Ira,M.,Robinson, William,C.,Baer, Tridib K.,Bannerjee and Peter,G., Flagsbert, "Trade-off Games in Ed William Michelson, Behavioural Research Methods in Environmental Design", Dowden, Hutchinson and Ross Inc. Pennsylvania, Stroudsburg, pp. 79-118, 1975.

79. Israel, Exella, Daor, "The Effect of Income on Trip making Behaviour", Traffic, Transportation and Urban Planning, Vol 1, pp. 127-140, 1981.

80. Jeffrey,Ganek and Raymond, Saulino, "Disaggregate Mode Choice models and the Aggregation Issue : Some Empirical Results", Transportation Research, Vol. 19A, No.4, pp. 315-324, Pergamon Press Limited, 1976.

81. Jones, Peter M., "Forecasting Family Response to Changes at School hours", A Exploratory Study using 'HATS' a working paper by Oxford University, T.S.U.P., 1976.

82. Jornstone,K.O., and Lundgen,J.T., "An Entropy Based Modal Split Model", Transportation Research, Vol. 23B, pp. 345-349, 1979.

83. Jones, Peter M., "View Point on Activity, Based Travel Analysis", Transportation, Vol. 15 No.1.2, pp. 49-53, 1988.

84. JORSA, "Urban Transportation Systems in Japan", Japan Overseas Rolling Stock Association, 1994.

85. Knight, Robert and Menchik, Mark,D., "Conjoint Preference Estimation for Residential Land use planning in Ed. Golledge,R.G., and Rushton,G. ", Spatial Choice and Spatial Behaviour, Ohio State University Press,pp. 135-156, 1976.

86. Krishnan,K.S., "Incorporating Thresholds of Indifference in Probabilistic Choice Models", Management Science, Vol. 33, pp. 1224-1233, 1977.

87. Kerlinger,Fred,N., "Foundation of Behavioural Research", Second Edition Holt, Reinhart and Winston Inc,(Indian Educational Subject Publications, New Delhi),1978.

88. Koppelman, Frank S., "Consumer Analysis of Travel Choice Behaviour", Journal of Advanced Transportation, Vol. 14, No.2, pp. 133-160, 1980.

89. Kitamura,R., "A Stratification Analysis of taste variation in work-trip mode choice", Transportation Research, 15A(6), pp. 473-485, 1981.

90. Kadiyali,L.R., Gopalswami,T.V., Laxmikanthan, "Value of Travel Time Savings", Traffic Engineering, Highway Research Bulletin, No. 20, I.R.C., New Delhi, 1983.

91. Koppelman, Frank,S., and Chaushie Chu, "Effect of Sample size on Disaggregate Choice Model Estimation and Prediction", Transportation Research Board No.944, pp. 60-70, 1983.

92. Kirloskar Consultants,"Madras Metropolitan Area Traffic and Transport Study", Report of Kirloskar Consultants Ltd. Madras Metropolitan Development Authority, 1986.

93. Kadiyali,L.R., and Associates, "Updating Road Users Cost Data", Final Report,, New Delhi, 1991.

94. Kadiyali, L.R., Vinod,M.K., Satyanarana,M., and Swaminathan,A.K., "Cost of Road Accidents in India (1990)", Journal of Indian Highways, I.R.C., New Delhi, 1994.

95. Kaura, Girija Shankar, "An Article on Future Shock", The Hindustan Times, April 12, 1995.

96. Lowry,I.S., "A Model of Metropolis", Rand Corporation, Santa Monica, California, RM-4035 - RL, 1964.

97. Leibrand,Kurt, "Transportation and Town Planning", leonard, Hill, London, 1970.

98. Lane, Robert, Powell, Timothy J., and Smith, Paul, Prestwood, "Analytical Transportation Planning", Gerald Duckworth and Company Ltd., London 283 p., 1971.

99. Louviere, Jordan, "Psychological Measurement of Travel Attributes", in Ed. Hensher,D.A. and Dalvi, Q.,Determinants of Travel Choice, Saxon House, Westmead, pp. 148-186, 1978.

100. Levin, Irwin, P., "The Development of Attitudinal Modelling Approaches in Transport Research ", in Ed. Hensher D.A., and Stopher P.R., Behavioural Travel Modelling, Croom Holm, London, pp. 758-781, 1979.

101. Levin, Irwin,P., "New Applications of Attitude Measurement and Attitudinal Modelling Techniques in Transportation Research", in Ed. Stopher P.R., Heyberg A.J., and Werner Brog., New Horizons in Travel Behaviour, Lexington Books, Massachusetts, pp. 171-188, 1981.

102. Levin,Richard I., "Statistics for Management", Fourth Edition, Printice Hall of India, New Delhi, 1987.

103. Meyer,J.R., Kain,J.F., and Wohl,M., "The Urban Transportation Problem", Cambridge, Mass, Harvard University Press, 1966.

104. Morris Hill, "A Method for the Evaluation of Transportation Plans", in Transportation System Analysis and Evaluation of Alternative plans, Highway Research Record 180 (Washington, D.C., Transportation Research Board), pp. 21-34, 1967.

105. Manheim,M.L., "Principles of Transport System Analysis", in Transportation System analysis and Evaluation of Alternative plans, Highway Research Record 180 (Washington, D.C., Transportation Research Board), pp. 11-20, 1967.

106. Muthukumaraswami, A., and Thillainayagam, R., "Road Rail Barrier - A Traffic Study of the railway level crossings of Madras Beach - Tambaram section of Southern Railways ", Journal of the Indian Roads Congress, Volume-30, New Delhi, 1969.

107. McFadden, Daniel, "Conditional Logit Analysis of Qualitative Choice Behaviour", in Ed. P. Zaremka, P. Frontiers in Econometrics, pp. 105-142, Academic Press, New York, 1970.

108. MATSU, "Madras Area Transportation Study ", Department of Town and Country Planning, Madras, 1974.

109. Michaels, Richard M., "Behavioural Measurement : An Approach to Predicting Transport Demand", Transportation Research Record, No. 149, pp. 551-571, T.R.B., Washington, D.C., 1974.

110. Michelson, William, "Behavioural Research Methods in Environmental Design", Dowden, Hutchinson.and Ross Inc. Stroudsburg, 1975.

111. Macket,R.L., "A Dynamic Integrated Activity Allocation Model for West Yorkshire", Working paper 71, Institute of Transport Studies, University of Leeds, 1976.

112. Meyer,Robert J., Levin, Irwin P. and Louviere, Jordan J., "Functional Analysis of Mode Choice", Transportation Research Record 673, pp. 1-6, TRB, Washington, D.C., 1978.

113. MTPR, "Conversion of Madras Beach-Tambaram MG Urban System to BG Transit System", Report Vol.1, Metropolitan Transport Project (Railways), Madras, 1981.

114. Mason, Emmanuel J., and Bramsel, William,j., "Understanding and Conducting Research - Applications in Education and the Behavioural Sciences", Second Edition, McGraw Hill International Edition, 1989.

115. Neveu,A.J.,"Perceptions of Comfort, Convenience and Reliability for the work Trips", M.S. Thesis, North-Western University, Evanston, IL, 1979.

116. Neels,Kelvin and Mather, Joseph, "Modelling Mode Choice in New Jersey", Transportation Research record No. 1139, pp. 20-27, 1987.

117. Nixon,Beverly B., Bolena, Gary D., and Atkinson G.B., "A Handbook of Social Science Research", Oxford University Press, London, 1987.

118. Narsinga Rao, Kolluru,G.N., "Urban Transit System Characteristics", A Seminar Report, University of Roorkee, Roorkee, July, 1993.

119. Pindyck, R.S., and Rubinfeld, "Econometrics Models and Economic Forecasts", McGraw Hill Kogakusha Ltd., Tokyo,1976.

120. Planning Commission, Government of India, "Report of the National Transport Plicy Committee", Planning Commission, Government of India, New Delhi, 1980.

121. Pushkarev,B., and J.Zupan, "Urban Rail in America", Indiana University Press, Bloomington, IN, 1980.

122. Papacostas, C.S., "Fundamentals of Transportation Engineering", Prentice Hall Inc., New York, 1987.

123. Prasad,C.S.R.K., "A Strategy for Improving Mass Transit work trips through Mode Choice Analysis", M.Tech Thesis, Regional Engineering College, Warangal, 1988.

124. Patankar, P.G., "Urban Transport in India (in Distress)", Central Institute of Road Transport, Pune, 1989.

125. Palaniswamy,S.P., and Vatsala Nair, "Behaviour Modelling of Travel Demand : A Case Study of Kanpur", paper presented in National Seminar on Advance in Transport Systems, Planning and Management, Madras, 1992.

126. Quarmby,D.A., "Choice of Travel mode for the journey to work : Some Findings", Journal of Transportation Economics and Policy, Vol. 1, No.3. pp. 273-314. 1967.

127. Quandt, Richard, E., "Estimation of Modal Splits", Transportation Research, 2 Pergamon Press, pp. 41-50, 1968.

128. Row,A., and Jurkat,E., "The Economic Forces Shaping Land use patterns", Journal of American Institute of Planners, May, 1959.

129. Rassam, Paul R., Ellis, Raymond H., and Benner, John C., "The n-Dimensional Logit Model Development and Applications", Highway Research Record No. 369, pp.135-147, 1971.

130. Ragavachari,S., "Disaggregated Transportation Demand Model for Home Based Trip Generation", Ph.D. Thesis, University of Roorkee, Roorkee, 1976.

131. Raina Jay, "An Article on MRTS project to take off by 96", The Hindustan Times, June 10, 1995.

132. RITES, "Integrated Multi-Modal Mass Rapid Transport System for Delhi", Rail India Technical and Economic Services, Modified Phase-I Engineering Report, 1995.

133. Stopher, Peter, R., "Towards the Development of Measures of Convenience for Travel Modes", Transportation Research Record, No. 527, pp. 16-32, T.R.B., Washington, D.C., 1974.

134. Sarna,A.C., "Modal Split Forecasting for Urban Area", Road Research paper 148, Central Road Research Institute, New Delhi, 1977.

135 Spear,Bruce D., "Application of New Travel demand Forecasting Techniques to transportation planning - A study of Individual Choice Models", Staff Research Report, US Department of Transportation, 1977.

136. Sinha,H.K., Khanna,S.K., and Arora, M.G., "Survey on Mode Choice for work trips in Patna", Highway Research Bulletin, No.14, Indian Roads Congress, New Delhi, 1980.

137. Stopher,Peter R., "Data Needs and Data Collection - State of the practice", Transportation Research Record, Special Report No. 201, pp. 63-71, T.R.B., Washington,D.C., 1983.

138. Stopher,Peter R., and McDonald, Kathi G., "Trip Generation by Cross-Classification : An Alternative Methodology", Transportation Research Record No. 944, pp. 84-91, 1983.

139. Sarna,A.C., and Sarin,S.M., "Transportation Planner's Dilemma - Modal Split and its Manipulation", Indian Highways, Vol. 13, No.1, pp. 5-18, Indian Roads Congress, New Delhi, 1985.

140. Stopher,Peter R., Okstrom, Eric G., Kaltenbach, Kenneth D., and Clouse, Donald L., "Logit Mode - Choice Models for Non-work Trips", Transportation Research Record No. 987, pp. 75-81, 1985.

141. Swait, Joffre D., and Ben - Akiva, Moshe, "Constraints on Individual Travel Behaviour in a Metropolitan City", Transport Research Record, No. 1085, pp. 75-85, 1985.

142. Sarna,A.C, Suryanarayana, Y., Rao, S.B.S., Suthar, H.H. and Besant Lal, "An Analysis of Household Travel Survey data for Bombay Metropolitan Region", Journal of Indian Roads Congress, Vol. 47-1, pp. 157-218, 1986.

143. Swait, Joffre and Ben-Akia, Moshe, "Incorporating Random Constraints in Discrete Models of Choice set Generation", Transportation Research, pergamon press, Vol. 21B, No.2, pp. 91-102, 1987.

144. Swait, Joffre and Ben - Akiva, Moshe, "Empirical Test of a Constrained Choice Discrete Model : Mode Choice in Sao Paulo, Brazil " , Transportation Research, pergamon press, Vol. 21 B, No.2, pp. 103 - 115, 1987.

145. Sripathi Rao,S.B., "Community Response to Components of Urban transport for work journeys through Mode Choice Models", Unpublished 1988, Ph.D. Thesis, Regional Engineering College, Warangal, 1988.

146. Satsangi,P.S., "Development of Demand Models for Urban Tansport in India", A paper, IIT, Delhi, 1989.

147. Sivaramakrishnan,K.C., "Urbanisation; No Evidence of Slowdown ", Economic times, Bangalore, September 1, 1991.

148. Sarna,A.C., Marwah, B.R., and Sachdeva, Y.P., "Planning of an Urban Bus System - A case Study of Delhi", Journal of Indian Roads Congress, New Delhi, Volume 55 - 3, pp. 409 - 444, November, 1994.

149. Thurstone,L.L., and Chave, E.J., "The Measurement of Attitude ", University of Chicago Press, 1929.

150. Train, Kenneth and McFadden, Daniel, "The Goods/Leisure Trade-off and Disaggregate work trip Mode Choice Models", Transportation Research Vol. 12, pp. 349-357, 1978.

151. Voorhees,A.M., "A General Theory of Traffic Movement", Proceedings of the Institute of Traffic Engineers, 1955.

152. Vuchic,V.R. and Stanger, R.M., "Lindenwold Rail line and Shirley Busway : A Comparison", in Evaluation of Bus Transit Strategies, Highway Research Record 459 (Washington,D.C., Highway Research Board), pp. 13-28, 1973.

153. Veeraragavan,A., and Simha, N.R.N., "Value of Travel time and Comfort by Willingness to pay Approach", Traffic Engineering Highway Research Bulletin No. 37, (I.R.C. Highway Research Board), pp. 27-42, New Delhi, 1989.

154. Vijayakumar,S., "Model Choice for Work trips in Madras using Multi-Nomial Logit Model", M.E. Thesis, Anna University, Madras, 1990.

155. Venkatraman, T.S., "Traffic Noise and its Effect on Housing", NCOTSS - 90, IIT, Delhi, 1990.

156. Warner,S.L., "Stochastic Choice of mode in Urban Travel" A study in Binary Choice, North-Western University Press, Evanston, III, 1962.

157. Wilson,F.R., "Journey to Work-Modal Split", Maclaren and Sons Ltd., London, 1967.

158. Wright,R.L.D., "Understanding Statistics", Harcourt Brace Jovanovich, Inc, New York, 1976.

159. Williams,H.C.W.L., and Lam, W.M., "Transport Policy Appraisal With Equilibrium Models 1 : Generated traffic and Highway Investment Benefit", Transpn. Res.-B, Vol. 25 B, No. 5, pp. 253 - 279, Great Britain, 1991.

VITAE

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He has been doing this Research work at the University of Roorkee under University Grants Commission Senior Research Fellowship since January 1994. He is the Author of over 25 research papers on Railway and Urban Transportation. A list of papers published/presented relevant to this research is appended.

PUBLICATIONS BY AUTHOR ON THE SUBJECT OF RESEARCH

(1) Gupta,A.K., Singh,Indrasen and Jain,S.S., "Tchno-Economic Analysis of Madras Central - Arakkonam Suburban Rail Transport System", Proceedings of 74th A.G.M., I.E. (INDIA) U.P. State Centre Lucknow, December 2-3, 1994.

(2) Gupta,A.K., Singh,Indrasen and Jain,S.S., "Emerging Trends in High Speed Public Transport Facilities Along Highway Network", Proceedings of National Seminar on Emerging Trends in Highway Engg., Bangalore University, Bangalore, March 11-12, 1995.

(3) Gupta,A.K., Singh,Indrasen and Jain,S.S., "Light Rail Transit for Delhi", Proceedings of Power system World Conference, Intertec International Inc, Ventura, California, U.S.A. September 9-15, 1995.

(4) Gupta,A.K., Singh,Indrasen, Jain,S.S., Chauhan,M.P.S., "Requirement of Mass Transit System for the National Capital Region of a Major Development Country", Proceedings of Power System World Conference, Intertec International Inc, Ventura, California, U.S.A. September 9-15, 1995.

(5) Gupta,A.K., Singh,Indrasen and Jain,S.S., "Economics of Urban Rail Transport Operation on Madras Beach-Tambaram MG Urban System", Indian Journal of Transport Management, Volume 19, No. 8, August, 1995.

(6) Gupta,A.K., Singh,Indrasen and Jain,S.S., "Requirement of Mass Rapid Transit System for Greater Ahmedabad", Proceedings of Dedicated Conference on Advanced Transportation System, 28th, ISATA, Stuttgart, Germany, September 18-22, 1995.

(7) Jain,S.S., Singh,Indrasen and Gupta,A.K., "Advanced Urban Transport System along the Highway Network", Proceedings of Dedicated Conference on Advanced Transportation System, 28th ISATA, Stuttgart, Germany, September 18-22, 1995.

(8) Gupta,A.K., Singh,Indrasen and Jain,S.S., "Measurement of commuter's Mode Choice Attitude and Analysis of Travel Attributes in Delhi, Proceedings of ICORT, Department of Civil Engg. Centre of Transportation Engg., University of Roorkee, December 11-14, 1995.

(9) Gupta,A.K., Singh,Indrasen and Jain,S.S., "Socio-Economic Analysis of Multi-Modal Transport System in Delhi", Platinum Jubilee Seminar on opportunities of Industrial Development in U.P. - Present and Future and 75th Annual Technical Volume, the I.E. (INDIA), U.P. State Centre, Lucknow, December, 2-3, 1995.

(10) Gupta,A.K., Singh,Indrasen and Jain,S.S., "Management of Public Transportation System", Proceedings of National Seminar on Infrastructure-its Importance in the Development of Economy, the I.E.(INDIA), Tenth Indian Engineering Congress, Jaipur, December 20-23, 1995.

(11) Gupta,A.K., Singh,Indrasen and Jain,S.S., "The Role of Public Transportation system in the Future", Proceedings of National Seminar on Infrastructure - its Importance in the Development of Economy, the I.E. (INDIA), Tenth Indian Engineering Congress, December 20-23, 1995.

(12) Singh,Indrasen, Gupta,A.K., and Jain,S.S., "Attitudinal Studies on Modal Choice for Work Trips in Delhi", Proceedings of CODATU-VII, New Delhi, February 11-16, 1996.

(13) Gupta,A.K., Singh,Indrasen and Jain,S.S., "Integrated Development of Public Transport Modes", Proceedings of Perspective Planning for Road Development in India", Indian Roads Congress, New Delhi, October 7-8, 1996.

(14) Gupta,A.K., Singh,Indrasen and Jain, S.S., "Planning and Management of Urban Transportation System", Proceedings of Policy Seminar on Traffic Management and Mass Transit, HUDCO, October 4-17, 1996.

(15) Gupta,A.K., Singh,Indrasen, Jain, S.S. and J, Ashok Babu., "Project Planning and Network Analysis by Computer Simulation Approach", the Journal of the Institution of Engineers (INDIA), Volume 77 pp 156-161, Calcutta, November, 1996.

(16) Gupta,A.K., Singh,Indrasen and Jain, S.S., "Influence of Attitude on Choice of Multi-Modal Transport in Delhi", Proceedings of 76th AGM, The Institution of Engineers (INDIA) U.P. State Centre, Lucknow, November 16-17, 1996.

(17) Gupta,A.K., Singh,Indrasen and Jain, S.S., "Financial Analysis of the proposed Delhi MRTS Corridor - A Case Study", Indian journal of Transport Management, Vol. 20, No.12., pp. 705-719, CIRT, Pune, December, 1996.

(18) Gupta,A.K., Singh,Indrasen and Jain, S.S., "Financial Analysis of an Identified MRTS Corridor-An Approach for Sustainable Public Transport", Proceedings of International Conference on Civil Engg. for Sustainable Development, Department of Civil Engg., University of Roorkee, Roorkee, February 13-15, 1997.

ACCEPTED FOR PUBLICATION

(19) Gupta,A.K., Singh,Indrasen and Jain, S.S., "Application of Attitudinal based Multi-Nomial Logit Model in Estimating Modal Choice in Delhi", the Journal of Transport Research Forum (JTRF), U.S.A.

(20) Gupta,A.K., Singh,Indrasen and Jain, S.S., "Behavioural Simulation Approach in Mode Choice Analysis for work trips in Delhi", Highway Research Bulletin, Traffic Engineering, Indian Roads Congress, New Delhi.

SENT FOR PUBLICATION

(21) Gupta,A.K., Singh,Indrasen and Jain, S.S., "Application of Trade-off Game in Estimating Modal Choice for Work Trips in Delhi", The Journal of Advanced Transportation, U.S.A.

APPENDIX 1 SUMMARY OF ANALYSED TRIPS BY MODE AND PURPOSE

(Rounded off to thousands)

Purpose	One way Trips by Mode					
	Mass	Fast	Slow	Total Vehicular trips	Walk trips	Total Trips vehicular and walk
- Home Based						
Work	439	177	176	792	459	1251
	(56)	(22)	(22)	(100) (63)	(37)	(100)
Education	193	9	26	228	915	1143
	(85)	(4)	(11)	(100) (20)	(80)	(100)
Other	23	4	3	30	24	54
	(77)	(13)	(10)	(100) (56)	(44)	(100)
All	655	190	205	1050	1398	2448
	(62)	(18)	(20)	(100) (43)	(57)	(100)
Non-Home Based	77	15	21	113	79	192
	(68)	(13)	(19)	(100) (59)	(41)	(100)
Total Home based and Non-Home Based	732	205	226	1163	1477	2640
	(63)	(18)	(19)	(100) (44)	(56)	(100)

. Figures in Brackets show percentages
. proportion of Non-Home Based Vehicular tirps to total trips = 10%

Source : Delhi Development Authority (1981 AD) Data.

APPENDIX 2 ROAD NET WORK DETAILS IN 1981 AD

Sl. No.	From Node	To Node	Travel Time (Minutes)	Length (km.)
1	1	363	3.36	1.4
2	1	364	4.32	1.8
3	2	362	3.60	1.5
4	2	363	2.42	0.20
5	2	364	2.16	0.90
6	3	347	2.40	1.0
7	3	348	3.60	1.5
8	4	370	2.64	1.1
9	4	666	0.50	0.20
10	4	346	2.64	1.1
11	4	345	3.84	1.6
12	4	344	3.60	1.5
13	5	404	2.40	1.0
14	5	405	0.75	0.30
15	6	407	3.12	1.3
16	6	408	0.75	0.30
17	6	410	4.80	2.0
18	6	411	2.64	1.1
19	6	412	3.12	1.3
20	7	402	5.52	2.3
21	7	422	2.16	0.90
22	7	672	4.32	1.8
23	8	341	0.50	0.20
24	8	663	1.20	0.50
25	9	308	0.75	0.30
26	9	309	1.00	0.40
27	10	386	0.5	0.20
28	10	390	1.20	0.50
29	11	387	1.68	0.70
30	11	388	3.36	1.4
31	11	394	2.40	1.0
32	11	678	4.10	1.7
33	12	338	4.10	1.7
34	12	382	2.90	1.2
35	12	388	4.80	2.0
36	13	327	1.45	0.60
37	13	328	2.40	1.0
38	13	335	1.92	0.80
39	14	324	3.12	1.3
40	14	682	1.00	0.4
41	15	326	4.80	2.0
42	15	334	2.40	1.0
43	15	376	3.60	1.5
44	16	300	3.85	1.6
45	16	320	6.72	2.8
46	16	322	4.56	1.9
47	17	320	5.76	2.4

Contd....

48	17	325	1.92	0.80
49	17	375	10.80	4.5
50	18	292	6.72	2.8
51	18	293	7.45	3.1
52	18	294	3.85	1.6
53	19	286	6.50	2.7
54	19	288	4.32	1.8
55	19	290	4.32	1.8
56	19	292	6.72	2.8
57	19	294	7.20	3.0
58	20	283	3.84	1.6
59	20	284	3.12	1.3
60	20	285	2.88	1.2
61	20	286	4.80	2.0
62	21	287	1.92	0.80
63	21	290	3.36	1.4
64	21	289	3.36	1.4
65	22	269	3.60	1.5
66	22	657	3.70	1.7
67	22	276	2.88	1.2
68	23	269	2.88	1.2
69	23.	271	2.64	1.1
70	23	274	5.28	2.2
71	24	265	4.10	1.7
72	24	267	1.92	0.8
73	24	270	6.00	2.5
74	24	271	4.10	1.7
75	25	293	200.00	150.0
76	25	683	200.00	150.0
77	26	208	200.00	150.0
78	27	425	200.00	150.0
79	28	420	200.00	150.0
80	29	424	200.00	150.0
81	30	416	200.00	150.0
82	31	361	200.00	150.0
83	296	420	5.28	2.2
84	296	298	5.52	2.3
85	298	658	1.20	0.50
86	298	300	6.00	2.5
87	658	659	13.20	5.5
88	659	660	10.10	4.2
89	659	682	7.92	3.3
90	300	302	6.72	2.8
91	302	304	5.10	2.1
92	302	659	0.50	0.2
93	304	306	5.28	2.2
94	306	418	3.12	1.3
95	296	320	12.96	5.4
96	320	325	6.24	2.6
97	325	375	9.60	4.0
98	325	326	7.68	3.2
99	375	376	6.50	2.7
100	376	377	6.72	2.8

Contd…

101	334	335	8.16	3.4
102	326	327	5.52	2.3
103	327	328	1.92	0.8
104	302	322	5.28	2.2
105	322	326	5.10	2.10
106	322	327	5.76	2.4
107	304	324	4.32	1.8
108	324	328	2.40	1.0
109	328	335	1.92	0.80
110	335	377	4.32	1.8
111	377	385	2.40	1.0
112	385	386	1.92	0.8
113	386	390	2.64	1.10
114	390	392	6.00	2.50
115	392	393	1.20	0.5
116	306	660	1.45	0.6
117	660	682	3.60	1.8
118	681	682	3.00	1.5
119	680	681	3.00	1.5
120	679	680	3.20	1.6
121	678	679	3.40	1.70
122	677	678	3.00	1.5
123	307	418	4.32	1.8
124	307	661	0.50	0.20
125	328	329	5.10	2.10
126	329	330	1.92	0.80
127	330	331	4.32	1.8
128	331	332	2.40	1.0
129	308	332	2.88	1.2
130	307	309	3.85	1.6
131	308	309	1.45	0.60
132	308	662	0.50	0.20
133	332	661	2.16	0.90
134	331	661	2.40	1.0
135	330	660	3.12	1.3
136	329	660	3.36	1.40
137	329	682	1.68	0.70
138	335	681	2.88	1.2
139	331	337	2.40	1.0
140	337	338	2.88	1.2
141	332	338	2.40	1.0
142	338	341	5.28	2.2
143	308	340	3.85	1.6
144	340	662	2.16	0.90
145	377	380	6.00	2.5
146	377	680	3.36	1.4
147	380	680	2.88	1.2
148	338	380	6.96	2.90
149	380	381	1.92	0.80
150	381	382	1.20	0.5
151	381	387	2.64	1.10
152	386	387	7.68	3.2
153	385	679	2.88	1.2

Contd...

154	381	679	4.32	1.8
155	387	679	3.84	1.6
156	338	382	6.72	2.8
157	338	341	6.00	2.5
158	340	341	3.60	1.5
159	382	388	4.32	1.8
160	388	389	5.10	2.1
161	341	389	5.76	2.4
162	388	394	3.36	1.4
163	393	394	4.32	1.8
164	392	677	0.50	0.2
165	394	677	3.60	1.5
166	340	663	2.40	1.0
167	660	661	6.00	3.0
168	661	662	3.00	1.5
169	662	663	3.00	1.5
170	663	664	3.00	1.5
171	664	666	3.00	1.5
172	309	310	3.12	1.3
173	310	311	7.45	3.1
174	310	333	1.68	0.7
175	308	333	3.12	1.3
176	311	333	6.72	2.8
177	341	384	4.32	1.8
178	345	384	1.20	0.50
179	384	401	4.32	1.8
180	389	401	3.12	1.3
181	343	344	1.20	0.50
182	344	345	1.92	0.80
183	345	346	1.68	0.70
184	401	402	1.45	0.60
185	402	422	6.00	2.5
186	408	422	5.10	2.1
187	393	395	3.84	1.6
188	395	397	4.80	2.0
189	395	676	0.50	0.20
190	397	675	0.50	0.20
191	397	399	4.80	2.0
192	399	400	1.68	0.70
193	400	673	2.40	1.0
194	400	403	2.88	1.20
195	403	406	2.64	1.10
196	399	674	1.92	0.80
197	404	406	1.20	0.50
198	403	672	3.60	1.5
199	404	407	2.40	1.0
200	404	405	2.16	0.9
201	406	408	5.52	2.3
202	408	410	5.28	2.2
203	408	671	1.68	0.70
204	346	347	2.88	1.20
205	347	348	2.64	1.10
206	348	368	1.92	0.80

Contd…

207	368	410	3.12	1.3
208	410	411	4.32	1.8
209	411	412	1.44	0.60
210	412	413	2.88	1.2
211	413	416	9.84	4.1
212	413	670	1.68	0.70
213	406	407	3.60	1.5
214	407	412	3.84	1.60
215	676	677	4.10	1.7
216	675	676	4.80	2.0
217	674	675	3.00	1.5
218	673	674	3.00	1.5
219	672	673	3.20	1.6
220	671	672	3.80	1.9
221	669	670	10.40	5.2
222	668	669	2.00	1.0
223	667	668	3.20	1.60
224	666	667	4.40	2.20
225	665	666	5.00	2.50
226	665	667	6.20	3.10
227	368	669	0.50	0.20
228	348	668	0.75	0.30
229	346	369	3.60	1.50
230	369	370	1.45	0.60
231	311	373	1.45	0.60
232	370	373	5.10	2.10
233	369	667	1.45	0.60
234	344	664	1.20	0.50
235	343	664	0.50	0.20
236	333	343	5.10	2.10
237	333	665	5.28	2.2
238	311	665	1.20	0.50
239	373	665	1.20	0.50
240	311	312	2.40	1.0
241	312	370	5.10	2.1
242	312	314	2.88	1.2
243	314	316	8.16	3.4
244	364	412	5.28	2.2
245	363	364	2.40	1.0
246	362	363	3.60	1.5
247	358	362	2.40	1.0
248	357	358	1.00	0.40
249	358	361	4.32	1.8
250	357	370	12.72	5.3
251	314	357	14.40	6.0
252	294	316	5.10	2.1
253	292	294	10.56	4.4
254	292	293	7.20	3.0
255	286	292	6.72	2.8
256	281	283	1.92	0.80
257	283	284	1.20	0.50
258	284	285	1.92	0.80
259	285	286	3.60	1.50

Contd...

260	286	288	2.88	1.2
261	288	290	3.60	1.5
262	290	291	3.12	1.30
263	291	311	3.84	1.6
264	295	300	7.44	3.1
265	251	295	3.84	1.6
266	251	425	7.20	3.0
267	251	252	3.12	1.3
268	252	253	5.10	2.1
269	253	270	6.72	2.8
270	270	272	3.12	1.3
271	267	270	6.48	2.7
272	265	267	5.52	2.3
273	265	271	4.80	2.0
274	271	272	3.84	1.6
275	271	419	2.88	1.2
276	272	419	1.68	0.70
277	274	419	3.84	1.6
278	265	266	2.40	1.0
279	264	266	2.88	1.20
280	266	269	5.10	2.10
281	269	274	7.20	3.0
282	274	309	6.48	2.70
283	272	418	7.68	3.2
284	274	289	8.40	3.5
285	289	291	3.60	1.50
286	269	287	6.24	2.6
287	287	288	2.64	1.1
288	264	657	0.75	0.30
289	264	276	2.64	1.1
290	276	282	2.40	1.0
291	282	283	2.64	1.1
292	281	211	4.80	2.0
293	211	208	7.20	3.0
294	210	281	5.52	2.3
295	210	292	5.10	2.10
296	293	683	3.60	1.5
297	393	424	21.60	9.0
298	326	334	5.10	2.1
299	334	376	1.68	0.70
300	665	684	13.00	6.5
301	683	684	13.40	6.7
302	656	684	4.60	2.3
303	657	661	16.80	8.4
304	209	211	3.36	1.4
305	209	210	4.80	2.0
306	208	211	3.36	1.4

APPENDIX 3 ROAD NET WORK DETAILS IN 2001 AD

ALTERNATIVE - 1

Sl. No.	From Node	To Node	Travel Time (Minutes)	Length (km.)
1	1	363	4.20	1.4
2	1	364	5.40	1.8
3	2	362	4.50	1.5
4	2	363	0.60	0.20
5	2	364	2.70	0.90
6	3	347	3.00	1.0
7	3	348	4.50	1.5
8	4	370	3.30	1.1
9	4	666	0.60	0.20
10	4	346	3.30	1.1
11	4	345	4.80	1.6
12	4	344	4.50	1.5
13	5	404	3.00	1.0
14	5	405	0.90	0.30
15	6	407	3.90	1.3
16	6	408	0.90	0.30
17	6	410	6.00	2.0
18	6	411	3.30	1.1
19	6	412	3.90	1.3
20	7	402	6.90	2.3
21	7	422	2.70	0.90
22	7	672	5.40	1.8
23	8	341	0.60	0.20
24	8	663	1.50	0.50
25	9	308	0.90	0.30
26	9	309	1.20	0.40
27	10	386	0.60	0.20
28	10	390	1.50	0.50
29	11	387	2.10	0.70
30	11	388	4.20	1.4
31	11	394	3.00	1.0
32	11	678	5.10	1.7
33	12	338	5.10	1.7
34	12	382	3.60	1.2
35	12	388	6.00	2.0
36	13	327	1.80	0.60
37	13	328	3.00	1.0
38	13	335	2.40	0.80
39	14	324	3.90	1.3
40	14	682	1.20	0.4
41	15	326	6.00	2.0
42	15	334	3.00	1.0
43	15	376	4.50	1.5
44	16	300	4.80	1.6

Contd...

45	16	320	8.40	2.8
46	16	322	5.70	1.9
47	17	320	7.20	2.4
48	17	325	2.40	0.80
49	17	375	13.50	4.5
50	18	292	8.40	2.8
51	18	293	9.30	3.1
52	18	294	4.80	1.6
53	19	286	8.10	2.7
54	19	288	5.40	1.8
55	19	290	5.40	1.8
56	19	292	8.40	2.8
57	19	294	9.00	3.0
58	20	283	4.80	1.6
59	20	284	3.90	1.3
60	20	285	3.60	1.2
61	20	286	6.00	2.0
62	21	287	2.40	0.80
63	21	290	4.20	1.4
64	21	289	4.20	1.4
65	22	269	4.50	1.5
66	22	657	5.10	1.7
67	22	276	3.60	1.2
68	23	269	3.60	1.2
69	23	271	3.30	1.1
70	23	274	6.60	2.2
71	24	265	5.10	1.7
72	24	267	2.40	0.8
73	24	270	7.50	2.5
74	24	271	5.10	1.7
75	25	293	200.00	150.0
76	25	683	200.00	150.0
77	26	208	200.00	150.0
78	27	425	200.00	150.0
79	28	420	200.00	150.0
80	29	424	200.00	150.0
81	30	434	200.00	150.0
82	31	435	200.00	150.0
83	296	420	6.60	2.2
84	296	298	6.90	2.3
85	298	658	1.50	0.50
86	298	300	7.50	2.5
87	658	659	16.50	5.5
88	659	660	12.60	4.2
89	659	682	9.90	3.3
90	300	302	8.40	2.8
91	302	304	6.30	2.1
92	302	659	0.60	0.2
93	304	306	6.60	2.2
94	306	418	3.90	1.3
95	296	320	16.20	5.4
96	320	325	7.80	2.6
97	325	375	12.00	4.0

Contd…

98	325	326	9.60	3.2
99	375	376	8.10	2.7
100	376	377	8.40	2.8
101	334	335	10.20	3.4
102	326	327	6.90	2.3
103	327	328	2.40	0.8
104	302	322	6.60	2.2
105	322	326	6.30	2.10
106	322	327	7.20	2.4
107	304	324	5.40	1.8
108	324	328	3.00	1.0
109	328	335	2.40	0.80
110	335	377	5.40	1.8
111	377	385	3.00	1.0
112	385	386	2.40	0.8
113	386	390	3.30	1.10
114	390	392	7.50	2.50
115	392	393	1.50	0.5
116	306	660	1.80	0.6
117	660	682	5.40	1.8
118	681	682	4.50	1.5
119	680	681	4.50	1.5
120	679	680	4.80	1.6
121	678	679	5.10	1.70
122	677	678	4.50	1.5
123	307	418	5.40	1.8
124	307	661	0.60	0.20
125	328	329	6.30	2.10
126	329	330	2.40	0.80
127	330	331	5.40	1.8
128	331	332	3.00	1.0
129	308	332	3.60	1.2
130	307	309	4.80	1.6
131	308	309	1.80	0.60
132	308	662	0.60	0.20
133	332	661	2.70	0.90
134	331	661	3.00	1.0
135	330	660	3.90	1.3
136	329	660	4.20	1.40
137	329	682	2.10	0.70
138	335	681	3.60	1.2
139	331	337	3.00	1.0
140	337	338	3.60	1.2
141	332	338	3.00	1.0
142	338	341	6.60	2.2
143	308	340	4.80	1.6
144	340	662	2.70	0.90
145	377	380	7.50	2.5
146	377	680	4.20	1.4
147	380	680	3.60	1.2
148	338	380	8.70	2.90
149	380	381	2.40	0.80
150	381	382	1.50	0.5

Contd…

151	381	387	3.30	1.10
152	386	387	9.60	3.2
153	385	679	3.60	1.2
154	381	679	5.40	1.8
155	387	679	4.80	1.6
156	338	382	8.40	2.8
157	338	341	7.50	2.5
158	340	341	4.50	1.5
159	382	388	5.40	1.8
160	388	389	6.30	2.1
161	341	389	7.20	2.4
162	388	394	4.20	1.4
163	393	394	5.40	1.8
164	392	677	0.60	0.2
165	394	677	4.50	1.5
166	340	663	3.00	1.0
167	660	661	6.00	3.0
168	661	662	3.00	1.5
169	662	663	3.00	1.5
170	663	664	3.00	1.5
171	664	666	3.00	1.5
172	309	310	3.90	1.3
173	310	311	9.30	3.1
174	310	333	2.10	0.7
175	308	333	3.90	1.3
176	311	333	8.40	2.8
177	341	384	5.40	1.8
178	345	384	1.50	0.50
179	384	401	5.40	1.8
180	389	401	3.90	1.3
181	343	344	1.50	0.50
182	344	345	2.40	0.80
183	345	346	2.10	0.70
184	401	402	1.80	0.60
185	402	422	7.50	2.5
186	408	422	6.30	2.1
187	393	395	4.80	1.6
188	395	397	6.00	2.0
189	395	676	0.60	0.20
190	397	675	0.60	0.20
191	397	399	6.00	2.0
192	399	400	2.10	0.70
193	400	673	3.00	1.0
194	400	403	3.60	1.20
195	403	406	3.30	1.10
196	399	674	2.40	0.80
197	404	406	1.50	0.50
198	403	672	4.50	1.5
199	404	407	3.00	1.0
200	404	405	2.70	0.9
201	406	408	6.90	2.3
202	408	410	6.60	2.2
203	408	671	2.10	0.70

Contd…

204	346	347	3.60	1.20
205	347	348	3.30	1.10
206	348	368	2.40	0.80
207	368	410	3.90	1.3
208	410	411	5.40	1.8
209	411	412	1.80	0.60
210	412	413	3.60	1.2
211	413	416	12.30	4.1
212	413	670	2.10	0.70
213	406	407	4.50	1.5
214	407	412	4.80	1.60
215	676	677	4.10	1.7
216	675	676	4.80	2.0
217	674	675	3.00	1.5
218	673	674	3.00	1.5
219	672	673	3.20	1.6
220	671	672	3.80	1.9
221	669	670	10.40	5.2
222	668	669	2.00	1.0
223	667	668	3.20	1.60
224	666	667	4.40	2.20
225	665	666	5.00	2.50
226	665	667	6.20	3.10
227	368	669	0.60	0.20
228	348	668	0.90	0.30
229	346	369	4.50	1.50
230	369	370	1.80	0.60
231	311	373	1.80	0.60
232	370	373	6.30	2.10
233	369	667	1.80	0.60
234	344	664	1.50	0.50
235	343	664	0.60	0.20
236	333	343	6.30	2.10
237	333	665	6.60	2.2
238	311	665	1.50	0.50
239	373	665	1.50	0.50
240	311	312	3.00	1.0
241	312	370	6.30	2.1
242	312	314	3.60	1.2
243	314	316	10.20	3.4
244	364	412	6.60	2.2
245	363	364	3.00	1.0
246	362	363	4.50	1.5
247	358	362	3.00	1.0
248	357	358	1.20	0.40
249	358	361	5.40	1.8
250	357	370	15.90	5.3
251	314	357	18.00	6.0
252	294	316	6.30	2.1
253	292	294	13.20	4.4
254	292	293	9.00	3.0
255	286	292	8.40	2.8
256	281	283	2.40	0.80

Contd...

257	283	284	1.50	0.50
258	284	285	2.40	0.80
259	285	286	4.50	1.50
260	286	288	3.60	1.2
261	288	290	4.50	1.5
262	290	291	3.90	1.30
263	291	311	4.80	1.6
264	295	300	9.30	3.1
265	251	295	4.80	1.6
266	251	425	9.00	3.0
267	251	252	3.90	1.3
268	252	253	6.30	2.1
269	253	270	8.40	2.8
270	270	272	3.90	1.3
271	267	270	8.10	2.7
272	265	267	6.90	2.3
273	265	271	6.00	2.0
274	271	272	4.80	1.6
275	271	419	3.60	1.2
276	272	419	2.10	0.70
277	274	419	4.80	1.6
278	265	266	3.00	1.0
279	264	266	3.60	1.20
280	266	269	6.30	2.10
281	269	274	9.00	3.0
282	274	309	8.10	2.70
283	272	418	9.60	3.2
284	274	289	10.50	3.5
285	289	291	4.50	1.50
286	269	287	7.80	2.6
287	287	288	3.30	1.1
288	264	657	0.90	0.30
289	264	276	3.30	1.1
290	276	282	3.00	1.0
291	282	283	3.30	1.1
292	281	211	6.00	2.0
293	211	208	9.00	3.0
294	210	281	6.90	2.3
295	210	292	6.30	2.10
296	293	683	4.50	1.5
297	393	424	27.00	9.0
298	326	334	6.30	2.1
299	334	376	2.10	0.70
300	665	684	13.00	6.5
301	683	684	13.40	6.7
302	656	684	4.60	2.3
303	657	661	16.80	8.4
304	209	211	4.20	1.4
305	209	210	6.00	2.0
306	208	211	4.20	1.4
307	296	425	30.30	10.10
308	375	425	7.80	2.60
309	376	426	4.20	1.40

Contd...

310	386	426	6.00	2.00
311	426	427	13.20	4.40
312	427	428	4.50	1.50
313	393	428	4.80	1.60
314	424	427	12.90	4.30
315	428	430	24.90	8.30
316	430	431	4.50	1.50
317	431	432	14.40	4.80
318	405	430	10.20	3.40
319	432	434	1.20	0.40
320	416	432	6.00	2.00
321	432	433	30.60	10.20
322	433	435	1.20	0.40
323	316	433	27.90	9.30
324	358	361	10.20	3.40
325	361	433	6.90	2.30

APPENDIX 4 ROAD NET WORK DETAILS IN 2001 AD

ALTERNATIVE - 2

Sl. No.	From Node	To Node	Travel Time (Minutes)	Length (km.)
1	1	363	4.20	1.40
2	1	364	5.40	1.80
3	2	362	4.50	1.50
4	2	363	0.60	0.20
5	2	364	2.70	0.90
6	3	347	3.00	1.00
7	3	348	4.50	1.50
8	4	344	4.50	1.50
9	4	345	4.80	1.60
10	4	346	3.30	1.10
11	4	370	3.30	1.10
12	4	666	0.60	0.20
13	5	404	3.00	1.00
14	5	405	0.90	0.30
15	6	366	5.40	1.80
16	6	407	3.90	1.30
17	6	408	0.90	0.30
18	6	410	6.00	2.00
19	6	411	3.30	1.10
20	6	412	3.90	1.30
21	7	422	2.70	0.90
22	7	672	5.40	1.80
23	7	402	5.10	1.70
24	7	403	2.70	0.90
25	8	340	0.60	0.20
26	8	341	3.00	1.00
27	8	663	0.90	0.30
28	8	796	0.60	0.20
29	9	308	0.60	0.20
30	9	309	0.90	0.30
31	10	386	0.60	0.20
32	10	390	1.50	0.50
33	11	387	2.10	0.70
34	11	388	4.20	1.40
35	11	394	3.00	1.00
36	11	678	5.10	1.70
37	12	338	5.10	1.70
38	12	798	1.80	0.60
39	13	327	1.80	0.60
40	13	328	3.00	1.00
41	13	335	2.40	0.80
42	14	324	3.90	1.30
43	14	682	1.20	0.40
44	15	326	6.00	2.00
45	15	334	3.00	1.00

Contd...

46	15	376	4.50	1.50
47	16	300	4.80	1.60
48	16	301	5.40	1.80
49	16	320	8.40	2.80
50	16	322	5.70	1.90
51	17	320	7.20	2.40
52	17	325	2.40	0.80
53	17	375	13.50	4.50
54	18	292	8.40	2.80
55	18	293	9.30	3.10
56	18	294	4.80	1.60
57	19	286	8.10	2.70
58	19	288	5.40	1.80
59	19	290	5.40	1.80
60	19	292	8.40	2.80
61	19	294	9.00	3.00
62	19	893	7.50	2.50
63	20	283	4.80	1.60
64	20	284	3.90	1.30
65	20	285	3.60	1.20
66	20	286	6.00	2.00
67	21	287	2.40	0.80
68	21	289	4.20	1.40
69	21	892	4.50	1.50
70	22	269	4.50	1.50
71	22	276	3.60	1.20
72	22	657	3.30	1.10
73	23	268	3.60	1.20
74	23	271	3.30	1.10
75	24	265	5.10	1.70
76	24	267	2.40	0.80
77	24	270	7.50	2.50
78	24	271	5.10	1.70
79	25	293	200.00	150.00
80	25	683	200.00	150.00
81	26	208	200.00	150.00
82	27	425	200.00	150.00
83	28	420	200.00	150.00
84	29	424	200.00	150.00
85	30	457	200.00	150.00
86	31	459	200.00	150.00
87	211	281	6.00	2.00
88	208	211	9.00	3.00
89	210	281	6.90	2.30
90	251	425	9.00	3.00
91	251	252	3.90	1.30
92	251	295	4.80	1.60
93	252	253	6.30	2.10
94	253	270	8.40	2.80
95	265	266	3.00	1.00
96	265	267	6.90	2.30
97	265	271	6.00	2.00
98	266	268	3.00	1.00

Contd...

99	267	270	8.10	2.70
100	268	269	3.30	1.10
101	269	274	9.00	3.00
102	269	287	7.80	2.60
103	270	272	3.90	1.30
104	271	272	4.80	1.60
105	271	419	3.60	1.20
106	272	418	9.60	3.20
107	272	419	2.10	0.70
108	274	289	10.50	3.50
109	274	309	8.10	2.70
110	276	282	3.00	1.00
111	280	281	2.40	0.80
112	280	282	4.20	1.40
113	281	283	2.40	0.80
114	282	283	3.30	1.10
115	282	656	2.70	0.90
116	283	284	1.50	0.50
117	284	285	2.40	0.80
118	285	286	4.50	1.50
119	286	288	3.60	1.20
120	286	292	8.40	2.80
121	286	891	0.60	0.20
122	287	288	3.30	1.10
123	287	892	5.40	1.80
124	288	290	4.50	1.50
125	288	684	3.30	1.10
126	288	891	3.60	1.20
127	289	291	4.50	1.50
128	290	291	3.90	1.30
129	290	892	0.60	0.20
130	291	311	4.80	1.60
131	291	893	2.10	0.70
132	292	293	9.00	3.00
133	292	294	13.20	4.40
134	293	683	4.50	1.50
135	294	316	6.30	2.10
136	294	893	12.00	4.00
137	296	298	6.90	2.30
138	296	317	5.40	1.80
139	296	420	6.60	2.20
140	298	300	7.50	2.50
141	300	301	4.50	1.50
142	301	302	3.00	1.00
143	302	304	6.30	2.10
144	302	322	6.60	2.20
145	302	659	0.60	0.20
146	304	305	3.60	1.20
147	304	324	5.40	1.80
148	306	418	3.90	1.30
149	306	660	1.80	0.60
150	307	309	4.80	1.60
151	307	661	0.60	0.20

Contd...

152	307	418	5.40	1.80
153	308	309	1.80	0.60
154	308	333	3.90	1.30
155	308	662	0.60	0.20
156	308	332	3.30	1.10
157	308	340	2.70	0.90
158	309	310	3.90	1.30
159	310	311	9.30	3.10
160	310	333	2.10	0.70
161	311	312	3.00	1.00
162	311	333	8.40	2.80
163	311	373	1.80	0.60
164	311	665	1.50	0.50
165	312	313	1.50	0.50
166	313	314	3.60	1.20
167	314	315	1.50	0.50
168	313	792	0.60	0.20
169	315	791	0.50	0.10
170	315	356	3.00	1.00
171	312	894	0.60	0.20
172	317	320	9.90	3.30
173	317	658	4.80	1.60
174	320	325	7.80	2.60
175	322	326	6.30	2.10
176	322	327	7.20	2.40
177	324	328	3.00	1.00
178	325	326	9.60	3.20
179	325	375	12.00	4.00
180	326	327	6.90	2.30
181	326	334	6.30	2.10
182	327	328	2.40	0.80
183	328	329	6.30	2.10
184	328	335	2.40	0.80
185	329	330	2.40	0.80
186	329	660	4.20	1.40
187	329	682	2.10	0.70
188	330	331	4.20	1.40
189	330	660	3.90	1.30
190	331	332	3.00	1.00
191	331	337	3.00	1.00
192	332	338	3.00	1.00
193	333	343	6.00	2.00
194	334	335	10.20	3.40
195	334	376	2.10	0.70
196	335	374	4.50	1.50
197	374	377	5.40	1.80
198	337	338	3.60	1.20
199	337	379	3.30	1.10
200	338	340	4.20	1.40
201	338	380	8.70	2.90
202	338	799	3.90	1.30
203	340	341	2.70	0.90
204	340	663	1.20	0.40

Contd...

205	341	796	3.00	1.00
206	341	383	3.30	1.10
207	341	384	4.50	1.50
208	343	344	1.50	0.50
209	343	795	0.90	0.30
210	344	345	2.40	0.80
211	344	664	1.50	0.50
212	345	346	2.10	0.70
213	345	384	1.50	0.50
214	346	347	3.60	1.20
215	347	897	4.20	1.40
216	347	348	3.30	1.10
217	347	897	0.90	0.30
218	348	668	1.80	0.60
219	348	368	2.40	0.80
220	348	898	0.60	0.20
221	349	370	0.90	0.30
222	349	910	0.60	0.20
223	349	350	2.40	0.80
224	350	351	3.00	1.00
225	350	911	1.80	0.60
226	351	352	2.40	0.80
227	351	912	1.80	0.60
228	352	353	1.80	0.60
229	352	913	1.50	0.50
230	352	353	2.40	0.80
231	353	354	3.00	1.00
232	353	914	1.20	0.40
233	354	355	2.10	0.70
234	354	915	1.20	0.40
235	355	357	1.50	0.50
236	355	916	0.90	0.30
237	357	358	1.50	0.50
238	356	790	1.80	0.60
239	357	917	0.90	0.30
240	358	359	1.20	0.40
241	358	362	3.00	1.00
242	358	918	1.50	0.50
243	359	360	3.00	1.00
244	359	918	0.90	0.30
245	360	451	3.00	1.00
246	360	919	0.90	0.30
247	362	363	4.50	1.50
248	363	364	3.00	1.00
249	364	365	3.30	1.10
250	365	412	3.60	1.20
251	366	410	1.50	0.50
252	366	411	4.20	1.40
253	366	899	0.60	0.20
254	367	368	1.50	0.50
255	367	410	2.70	0.90
256	367	899	0.60	0.20
257	369	370	1.80	0.60

Contd...

258	370	371	3.30	1.10
259	370	910	1.20	0.40
260	371	372	1.80	0.60
261	371	666	2.10	0.70
262	371	895	0.90	0.30
263	372	373	1.80	0.60
264	372	793	2.10	0.70
265	372	895	0.60	0.20
266	373	793	1.50	0.50
267	373	794	2.10	0.70
268	373	665	3.00	1.00
269	374	378	2.40	0.80
270	374	681	0.60	0.20
271	375	376	8.10	2.70
272	376	377	8.40	2.80
273	377	380	7.50	2.50
274	377	385	3.00	1.00
275	377	680	4.20	1.40
276	378	379	2.70	0.90
277	378	380	5.40	1.80
278	380	381	2.40	0.80
279	380	680	3.60	1.20
280	381	382	1.50	0.50
281	381	387	3.30	1.10
282	381	679	5.40	1.80
283	382	388	5.40	1.80
284	382	798	3.30	1.10
285	383	389	3.30	1.10
286	383	797	1.80	0.60
287	384	401	5.40	1.80
288	385	386	2.40	0.80
289	385	679	3.60	1.20
290	386	387	9.60	3.20
291	386	678	5.10	1.70
292	387	679	4.80	1.60
293	388	389	6.30	2.10
294	388	394	4.20	1.40
295	388	798	4.20	1.40
296	389	401	3.90	1.30
297	389	798	4.50	1.50
298	390	392	7.50	2.50
299	390	678	3.30	1.10
300	392	393	1.50	0.50
301	392	677	0.60	0.20
302	393	394	5.40	1.80
303	393	395	4.80	1.60
304	393	437	5.10	1.70
305	394	677	4.50	1.50
306	395	676	0.60	0.20
307	397	399	6.00	2.00
308	397	675	0.90	0.30
309	399	400	2.10	0.70
310	399	674	2.40	0.80

Contd...

311	400	403	3.60	1.20
312	400	673	3.00	1.00
313	401	402	1.80	0.60
314	402	403	3.00	1.00
315	403	422	4.50	1.50
316	404	405	2.70	0.90
317	404	406	1.50	0.50
318	406	407	4.50	1.50
319	407	412	4.80	1.60
320	408	409	3.00	1.00
321	408	422	6.30	2.10
322	409	410	3.90	1.30
323	409	671	1.50	0.50
324	410	411	5.40	1.80
325	411	412	1.80	0.60
326	411	900	1.20	0.40
327	412	413	3.60	1.20
328	412	900	2.10	0.70
329	412	901	3.30	1.10
330	413	670	2.10	0.70
331	413	901	1.50	0.50
332	422	671	1.50	0.50
333	210	292	6.30	2.10
334	209	210	6.00	2.00
335	209	211	4.20	1.40
336	305	306	3.30	1.10
337	413	442	4.20	1.40
338	442	443	3.60	1.20
339	442	902	1.20	0.40
340	443	444	3.90	1.30
341	443	903	1.20	0.40
342	444	445	3.90	1.30
343	444	904	0.90	0.30
344	445	446	3.90	1.30
345	445	905	0.90	0.30
346	446	447	3.90	1.30
347	446	906	0.90	0.30
348	447	448	3.90	1.30
349	447	907	0.90	0.30
350	448	449	3.90	1.30
351	448	908	0.90	0.30
352	449	441	4.50	1.50
353	449	909	0.90	0.30
354	451	452	3.60	1.20
355	451	920	1.20	0.40
356	452	453	3.60	1.20
357	452	921	1.20	0.40
358	453	454	3.60	1.20
359	453	922	1.20	0.40
360	454	455	3.90	1.30
361	454	923	1.50	0.50
362	455	456	3.90	1.30
363	455	924	1.50	0.50

Contd...

364	456	450	5.40	1.80
365	456	925	1.50	0.50
366	450	459	3.30	1.10
367	441	457	4.50	1.50
368	296	458	30.30	10.10
369	375	458	7.80	2.60
370	376	457	4.20	1.40
371	386	457	6.00	2.00
372	438	457	13.20	4.40
373	437	438	4.50	1.50
374	393	437	4.80	1.60
375	424	438	12.90	4.30
376	437	439	24.90	8.30
377	439	440	4.50	1.50
378	440	441	14.40	4.80
379	405	439	10.20	3.40
380	441	457	1.20	0.40
381	441	449	3.30	1.10
382	441	450	30.60	10.20
383	450	459	1.20	0.40
384	316	450	27.90	9.30
385	450	456	6.00	2.00
386	655	656	9.60	4.80
387	656	684	4.60	2.30
388	657	660	21.00	10.50
389	657	661	16.80	8.40
390	658	659	10.60	5.30
391	659	660	7.60	3.80
392	659	682	6.00	3.00
393	660	661	6.00	3.00
394	661	662	3.00	1.50
395	662	663	3.00	1.50
396	663	664	3.00	1.50
397	664	666	2.60	1.30
398	665	667	6.20	3.10
399	665	684	13.00	6.50
400	666	667	4.40	2.20
401	667	668	3.20	1.60
402	668	669	2.00	1.00
403	669	670	10.40	5.20
404	669	671	5.20	2.60
405	671	672	3.80	1.90
406	672	673	3.20	1.60
407	673	674	3.00	1.50
408	674	675	3.00	1.50
409	675	676	4.00	2.00
410	676	677	3.40	1.70
411	677	678	3.00	1.50
412	678	679	3.40	1.70
413	679	680	3.20	1.60
414	680	681	3.00	1.50
415	681	682	3.00	1.50
416	683	684	13.40	6.70

Contd...

417	790	791	2.10	1.20
418	791	792	2.10	1.20
419	792	793	2.10	1.20
420	793	794	2.10	1.20
421	794	795	2.10	1.20
422	795	796	2.10	1.20
423	796	797	2.20	1.30
424	797	798	2.20	1.30
425	798	799	2.10	1.20
426	891	892	2.70	1.60
427	892	893	2.60	1.50
428	893	894	2.60	1.50
429	894	895	2.40	1.40
430	895	896	2.40	1.40
431	896	897	2.40	1.40
432	897	898	2.40	1.40
433	898	899	2.40	1.40
434	899	900	2.60	1.50
435	900	901	2.60	1.50
436	901	902	2.20	1.30
437	902	903	2.20	1.30
438	903	904	2.20	1.30
439	904	905	2.20	1.30
440	905	906	2.20	1.30
441	906	907	2.20	1.30
442	907	908	2.20	1.30
443	908	909	2.20	1.30
444	910	911	2.10	1.20
445	911	912	2.10	1.20
446	912	913	2.10	1.20
447	913	914	2.10	1.20
448	914	915	2.10	1.20
449	915	916	2.10	1.20
450	916	917	2.10	1.20
451	917	918	2.10	1.20
452	918	919	2.20	1.30
453	919	920	2.40	1.40
454	920	921	2.40	1.40
455	921	922	2.40	1.40
456	922	923	2.40	1.40
457	923	924	2.40	1.40
458	924	925	2.40	1.40

APPENDIX 5 ROAD NET WORK DETAILS IN 2011 AD

ALTERNATIVE - 1

Sl. No.	From Node	To Node	Travel Time (Minutes)	Length (km.)
1	1	363	4.66	1.4
2	1	364	6.00	1.8
3	2	362	4.95	1.5
4	2	363	0.66	0.20
5	2	364	3.00	0.90
6	3	347	3.30	1.0
7	3	348	4.95	1.5
8	4	370	3.63	1.1
9	4	666	0.66	0.20
10	4	346	3.63	1.1
11	4	345	5.28	1.6
12	4	344	4.95	1.5
13	5	404	3.30	1.0
14	5	405	1.00	0.30
15	6	407	4.30	1.3
16	6	408	1.00	0.30
17	6	410	6.60	2.0
18	6	411	3.63	1.1
19	6	412	4.30	1.3
20	7	402	7.60	2.3
21	7	422	3.00	0.90
22	7	672	6.00	1.8
23	8	341	0.66	0.20
24	8	663	1.65	0.50
25	9	308	1.00	0.30
26	9	309	1.30	0.40
27	10	386	0.66	0.20
28	10	390	1.65	0.50
29	11	387	2.33	0.70
30	11	388	4.65	1.4
31	11	394	3.30	1.0
32	11	678	5.60	1.7
33	12	338	5.60	1.7
34	12	382	4.00	1.2
35	12	388	6.60	2.0
36	13	327	2.00	0.60
37	13	328	3.30	1.0
38	13	335	2.65	0.80
39	14	324	4.30	1.3
40	14	682	1.35	0.4
41	15	326	6.60	2.0
42	15	334	3.30	1.0
43	15	376	4.95	1.5
44	16	300	5.30	1.6
45	16	320	9.30	2.8

Contd...

46	16	322	6.30	1.9
47	17	320	7.95	2.4
48	17	325	2.65	0.80
49	17	375	14.85	4.5
50	18	292	9.30	2.8
51	18	293	10.25	3.1
52	18	294	5.30	1.6
53	19	286	8.90	2.7
54	19	288	5.95	1.8
55	19	290	5.95	1.8
56	19	292	9.30	2.8
57	19	294	9.90	3.0
58	20	283	5.30	1.6
59	20	284	4.30	1.3
60	20	285	3.95	1.2
61	20	286	6.60	2.0
62	21	287	2.65	0.80
63	21	290	4.60	1.4
64	21	289	4.60	1.4
65	22	269	4.95	1.5
66	22	657	5.60	1.7
67	22	276	3.95	1.2
68	23	269	3.95	1.2
69	23	271	3.65	1.1
70	23	274	7.25	2.2
71	24	265	5.60	1.7
72	24	267	2.65	0.8
73	24	270	8.25	2.5
74	24	271	5.60	1.7
75	25	293	200.00	150.0
76	25	683	200.00	150.0
77	26	208	200.00	150.0
78	27	425	200.00	150.0
79	28	420	200.00	150.0
80	29	424	200.00	150.0
81	30	434	200.00	150.0
82	31	435	200.00	150.0
83	296	420	7.25	2.2
84	296	298	7.60	2.3
85	298	658	1.65	0.50
86	298	300	8.25	2.5
87	658	659	13.20	5.5
88	659	660	10.10	4.2
89	659	682	7.92	3.3
90	300	302	9.25	2.8
91	302	304	6.95	2.1
92	302	659	0.66	0.2
93	304	306	7.25	2.2
94	306	418	4.30	1.3
95	296	320	17.85	5.4
96	320	325	8.60	2.6
97	325	375	13.20	4.0
98	325	326	10.60	3.2

Contd...

99	375	376	8.90	2.7
100	376	377	9.25	2.8
101	334	335	11.25	3.4
102	326	327	7.60	2.3
103	327	328	2.65	0.8
104	302	322	7.28	2.2
105	322	326	6.95	2.10
106	322	327	7.95	2.4
107	304	324	5.95	1.8
108	324	328	3.30	1.0
109	328	335	2.65	0.80
110	335	377	5.95	1.8
111	377	385	3.30	1.0
112	385	386	2.65	0.8
113	386	390	3.65	1.10
114	390	392	8.25	2.50
115	392	393	1.65	0.5
116	306	660	2.00	0.6
117	660	682	3.60	1.8
118	681	682	3.00	1.5
119	680	681	3.00	1.5
120	679	680	3.20	1.6
121	678	679	3.40	1.70
122	677	678	3.00	1.5
123	307	418	5.95	1.8
124	307	661	0.66	0.20
125	328	329	6.95	2.10
126	329	330	2.65	0.80
127	330	331	5.95	1.8
128	331	332	3.30	1.0
129	308	332	3.96	1.2
130	307	309	5.28	1.6
131	308	309	2.00	0.60
132	308	662	0.66	0.20
133	332	661	2.98	0.90
134	331	661	3.30	1.0
135	330	660	4.30	1.3
136	329	660	4.65	1.40
137	329	682	2.30	0.70
138	335	681	3.96	1.2
139	331	337	3.30	1.0
140	337	338	3.96	1.2
141	332	338	3.30	1.0
142	338	341	7.25	2.2
143	308	340	5.28	1.6
144	340	662	2.98	0.90
145	377	380	8.25	2.5
146	377	680	4.65	1.4
147	380	680	3.95	1.2
148	338	380	9.58	2.90
149	380	381	2.65	0.80
150	381	382	1.65	0.5
151	381	387	3.65	1.10

Contd...

152	386	387	10.60	3.2
153	385	679	3.95	1.2
154	381	679	5.95	1.8
155	387	679	5.30	1.6
156	338	382	9.25	2.8
157	338	341	8.25	2.5
158	340	341	4.95	1.5
159	382	388	5.95	1.8
160	388	389	6.94	2.1
161	341	389	7.92	2.4
162	388	394	4.62	1.4
163	393	394	5.94	1.8
164	392	677	0.66	0.2
165	394	677	4.95	1.5
166	340	663	3.30	1.0
167	660	661	6.00	3.0
168	661	662	3.00	1.5
169	662	663	3.00	1.5
170	663	664	3.00	1.5
171	664	666	3.00	1.5
172	309	310	4.30	1.3
173	310	311	10.25	3.1
174	310	333	2.30	0.7
175	308	333	4.30	1.3
176	311	333	9.25	2.8
177	341	384	5.95	1.8
178	345	384	1.65	0.50
179	384	401	5.94	1.8
180	389	401	4.30	1.3
181	343	344	1.65	0.50
182	344	345	2.65	0.80
183	345	346	2.30	0.70
184	401	402	1.98	0.60
185	402	422	8.25	2.5
186	408	422	6.95	2.1
187	393	395	5.30	1.6
188	395	397	6.60	2.0
189	395	676	0.66	0.20
190	397	675	0.66	0.20
191	397	399	6.60	2.0
192	399	400	2.30	0.70
193	400	673	3.30	1.0
194	400	403	3.98	1.20
195	403	406	3.65	1.10
196	399	674	2.65	0.80
197	404	406	1.65	0.50
198	403	672	4.95	1.5
199	404	407	3.30	1.0
200	404	405	2.97	0.9
201	406	408	7.60	2.3
202	408	410	7.28	2.2
203	408	671	2.30	0.70
204	346	347	3.98	1.20

Contd...

205	347	348	3.65	1.10
206	348	368	2.65	0.80
207	368	410	4.30	1.3
208	410	411	5.95	1.8
209	411	412	1.98	0.60
210	412	413	3.98	1.2
211	413	416	13.55	4.1
212	413	670	2.30	0.70
213	406	407	4.95	1.5
214	407	412	5.28	1.60
215	676	677	3.40	1.7
216	675	676	4.00	2.0
217	674	675	3.00	1.5
218	673	674	3.00	1.5
219	672	673	3.20	1.6
220	671	672	3.80	1.9
221	669	670	10.40	5.2
222	668	669	2.00	1.0
223	667	668	3.20	1.60
224	666	667	4.40	2.20
225	665	666	5.00	2.50
226	665	667	6.20	3.10
227	368	669	0.66	0.20
228	348	668	1.00	0.30
229	346	369	4.95	1.50
230	369	370	1.98	0.60
231	311	373	1.98	0.60
232	370	373	6.95	2.10
233	369	667	1.98	0.60
234	344	664	1.65	0.50
235	343	664	0.66	0.20
236	333	343	6.95	2.10
237	333	665	7.30	2.2
238	311	665	1.65	0.50
239	373	665	1.65	0.50
240	311	312	3.30	1.0
241	312	370	6.95	2.1
242	312	314	3.98	1.2
243	314	316	11.25	3.4
244	364	412	7.26	2.2
245	363	364	3.30	1.0
246	362	363	4.95	1.5
247	358	362	3.30	1.0
248	357	358	1.35	0.40
249	358	361	5.95	1.8
250	357	370	17.50	5.3
251	314	357	19.80	6.0
252	294	316	6.95	2.1
253	292	294	14.55	4.4
254	292	293	9.90	3.0
255	286	292	9.25	2.8
256	281	283	2.65	0.80
257	283	284	1.65	0.50

Contd...

258	284	285	2.65	0.80
259	285	286	4.95	1.50
260	286	288	3.98	1.2
261	288	290	4.95	1.5
262	290	291	4.30	1.30
263	291	311	5.28	1.6
264	295	300	10.25	3.1
265	251	295	5.28	1.6
266	251	425	9.90	3.0
267	251	252	4.30	1.3
268	252	253	6.95	2.1
269	253	270	9.25	2.8
270	270	272	4.30	1.3
271	267	270	8.90	2.7
272	265	267	7.60	2.3
273	265	271	6.60	2.0
274	271	272	5.28	1.6
275	271	419	3.98	1.2
276	272	419	2.30	0.70
277	274	419	5.28	1.6
278	265	266	3.30	1.0
279	264	266	3.98	1.20
280	266	269	6.95	2.10
281	269	274	9.90	3.0
282	274	309	8.90	2.70
283	272	418	10.60	3.2
284	274	289	11.55	3.5
285	289	291	4.95	1.50
286	269	287	8.60	2.6
287	287	288	3.65	1.1
288	264	657	1.00	0.30
289	264	276	3.65	1.1
290	276	282	3.30	1.0
291	282	283	3.65	1.1
292	281	211	6.60	2.0
293	211	208	9.90	3.0
294	210	281	7.60	2.3
295	210	292	6.95	2.10
296	293	683	4.95	1.5
297	393	424	29.90	9.0
298	326	334	6.95	2.1
299	334	376	2.30	0.70
300	665	684	13.00	6.5
301	683	684	13.40	6.7
302	656	684	4.60	2.3
303	657	661	16.80	8.4
304	209	211	4.65	1.4
305	209	210	6.60	2.0
306	208	211	4.65	1.4
307	296	425	33.30	10.10
308	375	425	8.60	2.60
309	376	426	4.65	1.40
310	386	426	6.60	2.00

Contd...

311	426	427	14.50	4.40
312	427	428	4.95	1.50
313	393	428	5.30	1.60
314	424	427	14.20	4.30
315	428	430	27.40	8.30
316	430	431	4.95	1.50
317	431	432	15.85	4.80
318	405	430	11.25	3.40
319	432	434	1.35	0.40
320	416	432	6.60	2.00
321	432	433	33.70	10.20
322	433	435	1.35	0.40
323	316	433	30.70	9.30
324	358	361	11.25	3.40
325	361	433	7.60	2.30

APPENDIX - 6 ROAD NET WORK DETAILS IN 2011 AD

ALTERNATIVE - 2

Sl. No.	From Node	To Node	Travel Time (Minutes)	Length (km.)
1	1	363	4.66	1.40
2	1	364	6.00	1.80
3	2	362	4.95	1.50
4	2	363	0.66	0.20
5	2	364	3.00	0.90
6	3	347	3.30	1.00
7	3	348	4.95	1.50
8	4	344	4.95	1.50
9	4	345	5.30	1.60
10	4	346	3.65	1.10
11	4	370	3.65	1.10
12	4	666	0.66	0.20
13	5	404	3.30	1.00
14	5	405	1.00	0.30
15	6	366	5.95	1.80
16	6	407	4.30	1.30
17	6	408	1.00	0.30
18	6	410	6.60	2.00
19	6	411	3.65	1.10
20	6	412	4.30	1.30
21	7	422	1.00	0.90
22	7	672	5.95	1.80
23	7	402	6.60	1.70
24	7	403	1.00	0.90
25	8	340	0.66	0.20
26	8	341	3.30	1.00
27	8	663	1.00	0.30
28	8	796	0.66	0.20
29	9	308	0.66	0.20
30	9	309	1.00	0.30
31	10	386	0.66	0.20
32	10	390	1.65	0.50
33	11	387	2.30	0.70
34	11	388	4.65	1.40
35	11	394	3.30	1.00
36	11	678	5.60	1.70
37	12	338	5.60	1.70
38	12	798	2.00	0.60
39	13	327	2.00	0.60
40	13	328	3.30	1.00
41	13	335	2.65	0.80
42	14	324	4.30	1.30
43	14	682	1.35	0.40
44	15	326	6.60	2.00
45	15	334	3.30	1.00

Contd...

46	15	376	4.95	1.50
47	16	300	5.30	1.60
48	16	301	5.95	1.80
49	16	320	9.25	2.80
50	16	322	6.30	1.90
51	17	320	7.95	2.40
52	17	325	2.65	0.80
53	17	375	14.85	4.50
54	18	292	9.25	2.80
55	18	293	10.25	3.10
56	18	294	5.30	1.60
57	19	286	8.90	2.70
58	19	288	5.95	1.80
59	19	290	5.95	1.80
60	19	292	9.25	2.80
61	19	294	9.90	3.00
62	19	893	8.25	2.50
63	20	283	5.30	1.60
64	20	284	4.30	1.30
65	20	285	3.95	1.20
66	20	286	6.60	2.00
67	21	287	2.65	0.80
68	21	289	4.65	1.40
69	21	892	4.95	1.50
70	22	269	4.95	1.50
71	22	276	3.95	1.20
72	22	657	3.65	1.10
73	23	268	3.95	1.20
74	23	271	3.65	1.10
75	24	265	5.60	1.70
76	24	267	2.65	0.80
77	24	270	8.25	2.50
78	24	271	5.60	1.70
79	25	293	200.00	150.00
80	25	683	200.00	150.00
81	26	208	200.00	150.00
82	27	425	200.00	150.00
83	28	420	200.00	150.00
84	29	424	200.00	150.00
85	30	457	200.00	150.00
86	31	459	200.00	150.00
87	211	281	6.60	2.00
88	208	211	9.90	3.00
89	210	281	7.60	2.30
90	251	425	9.90	3.00
91	251	252	4.30	1.30
92	251	295	5.30	1.60
93	252	253	6.95	2.10
94	253	270	9.25	2.80
95	265	266	3.30	1.00
96	265	267	7.60	2.30
97	265	271	6.60	2.00
98	266	268	3.30	1.00

Contd...

99	267	270	8.90	2.70
100	268	269	3.65	1.10
101	269	274	9.90	3.00
102	269	287	8.60	2.60
103	270	272	4.30	1.30
104	271	272	5.30	1.60
105	271	419	3.95	1.20
106	272	418	10.55	3.20
107	272	419	2.30	0.70
108	274	289	11.55	3.50
109	274	309	8.90	2.70
110	276	282	3.30	1.00
111	280	281	2.65	0.80
112	280	282	4.65	1.40
113	281	283	2.65	0.80
114	282	283	3.65	1.10
115	282	656	3.00	0.90
116	283	284	1.65	0.50
117	284	285	2.65	0.80
118	285	286	4.95	1.50
119	286	288	3.95	1.20
120	286	292	9.25	2.80
121	286	891	0.66	0.20
122	287	288	3.65	1.10
123	287	892	5.95	1.80
124	288	290	4.95	1.50
125	288	684	3.65	1.10
126	288	891	3.95	1.20
127	289	291	4.95	1.50
128	290	291	4.30	1.30
129	290	892	0.66	0.20
130	291	311	5.30	1.60
131	291	893	2.30	0.70
132	292	293	9.90	3.00
133	292	294	14.50	4.40
134	293	683	4.95	1.50
135	294	316	6.95	2.10
136	294	893	13.20	4.00
137	296	298	7.60	2.30
138	296	317	5.95	1.80
139	296	420	7.30	2.20
140	298	300	8.25	2.50
141	300	301	4.95	1.50
142	301	302	3.30	1.00
143	302	304	6.95	2.10
144	302	322	7.30	2.20
145	302	659	0.66	0.20
146	304	305	3.95	1.20
147	304	324	5.95	1.80
148	306	418	4.30	1.30
149	306	660	2.00	0.60
150	307	309	5.30	1.60
151	307	661	0.66	0.20

Contd...

152	307	418	5.95	1.80
153	308	309	2.00	0.60
154	308	333	4.30	1.30
155	308	662	0.66	0.20
156	308	332	3.65	1.10
157	308	340	3.00	0.90
158	309	310	4.30	1.30
159	310	311	10.25	3.10
160	310	333	2.30	0.70
161	311	312	3.30	1.00
162	311	333	9.25	2.80
163	311	373	2.80	0.60
164	311	665	1.65	0.50
165	312	313	1.65	0.50
166	313	314	3.95	1.20
167	314	315	1.65	0.50
168	313	792	0.66	0.20
169	315	791	0.35	0.10
170	315	356	3.30	1.00
171	312	894	0.66	0.20
172	317	320	10.90	3.30
173	317	658	5.30	1.60
174	320	325	8.60	2.60
175	322	326	6.95	2.10
176	322	327	7.95	2.40
177	324	328	3.30	1.00
178	325	326	10.60	3.20
179	325	375	13.20	4.00
180	326	327	7.60	2.30
181	326	334	6.95	2.10
182	327	328	2.65	0.80
183	328	329	6.95	2.10
184	328	335	2.65	0.80
185	329	330	2.65	0.80
186	329	660	4.65	1.40
187	329	682	2.30	0.70
188	330	331	4.65	1.40
189	330	660	4.30	1.30
190	331	332	3.30	1.00
191	331	337	3.30	1.00
192	332	338	3.30	1.00
193	333	343	6.60	2.00
194	334	335	11.25	3.40
195	334	376	2.30	0.70
196	335	374	4.95	1.50
197	374	377	5.95	1.80
198	337	338	3.95	1.20
199	337	379	3.65	1.10
200	338	340	4.65	1.40
201	338	380	9.60	2.90
202	338	799	4.30	1.30
203	340	341	3.00	0.90
204	340	663	1.35	0.40

Contd...

205	341	796	3.30	1.00
206	341	383	3.65	1.10
207	341	384	4.95	1.50
208	343	344	1.65	0.50
209	343	795	1.00	0.30
210	344	345	2.65	0.80
211	344	664	1.65	0.50
212	345	346	2.30	0.70
213	345	384	1.65	0.50
214	346	347	3.95	1.20
215	347	897	4.65	1.40
216	347	348	3.65	1.10
217	347	897	1.00	0.30
218	348	668	2.00	0.60
219	348	368	2.65	0.80
220	348	898	0.66	0.20
221	349	370	1.00	0.30
222	349	910	0.66	0.20
223	349	350	2.65	0.80
224	350	351	3.30	1.00
225	350	911	2.00	0.60
226	351	352	2.65	0.80
227	351	912	2.00	0.60
228	352	353	2.00	0.60
229	352	913	1.65	0.50
230	352	353	2.65	0.80
231	353	354	3.30	1.00
232	353	914	1.30	0.40
233	354	355	2.30	0.70
234	354	915	1.30	0.40
235	355	357	1.65	0.50
236	355	916	1.00	0.30
237	357	358	1.65	0.50
238	356	790	2.00	0.60
239	357	917	1.00	0.30
240	358	359	1.30	0.40
241	358	362	3.30	1.00
242	358	918	1.65	0.50
243	359	360	3.30	1.00
244	359	918	1.00	0.30
245	360	451	3.30	1.00
246	360	919	1.00	0.30
247	362	363	4.95	1.50
248	363	364	3.30	1.00
249	364	365	3.65	1.10
250	365	412	3.95	1.20
251	366	410	1.65	0.50
252	366	411	4.65	1.40
253	366	899	0.66	0.20
254	367	368	1.65	0.50
255	367	410	3.00	0.90
256	367	899	0.66	0.20
257	369	370	2.00	0.60

Contd...

258	370	371	3.65	1.10
259	370	910	1.35	0.40
260	371	372	2.00	0.60
261	371	666	2.30	0.70
262	371	895	1.00	0.30
263	372	373	2.00	0.60
264	372	793	2.30	0.70
265	372	895	0.66	0.20
266	373	793	1.65	0.50
267	373	794	2.30	0.70
268	373	665	3.30	1.00
269	374	378	2.65	0.80
270	374	681	0.66	0.20
271	375	376	8.90	2.70
272	376	377	9.25	2.80
273	377	380	8.25	2.50
274	377	385	3.30	1.00
275	377	680	4.65	1.40
276	378	379	3.00	0.90
277	378	380	5.95	1.80
278	380	381	2.65	0.80
279	380	680	3.95	1.20
280	381	382	1.65	0.50
281	381	387	3.65	1.10
282	381	679	5.95	1.80
283	382	388	5.95	1.80
284	382	798	3.65	1.10
285	383	389	3.65	1.10
286	383	797	2.00	0.60
287	384	401	5.95	1.80
288	385	386	2.65	0.80
289	385	679	3.95	1.20
290	386	387	10.55	3.20
291	386	678	5.60	1.70
292	387	679	5.30	1.60
293	388	389	6.95	2.10
294	388	394	4.65	1.40
295	388	798	4.65	1.40
296	389	401	4.30	1.30
297	389	798	4.95	1.50
298	390	392	8.25	2.50
299	390	678	3.65	1.10
300	392	393	1.65	0.50
301	392	677	0.66	0.20
302	393	394	5.95	1.80
303	393	395	5.30	1.60
304	393	437	5.60	1.70
305	394	677	4.95	1.50
306	395	676	0.66	0.20
307	397	399	6.60	2.00
308	397	675	1.00	0.30
309	399	400	2.30	0.70
310	399	674	2.65	0.80

Contd…

311	400	403	3.95	1.20
312	400	673	3.30	1.00
313	401	402	2.00	0.60
314	402	403	3.30	1.00
315	403	422	4.95	1.50
316	404	405	2.00	0.90
317	404	406	1.65	0.50
318	406	407	4.95	1.50
319	407	412	5.30	1.60
320	408	409	3.30	1.00
321	408	422	6.95	2.10
322	409	410	4.30	1.30
323	409	671	1.65	0.50
324	410	411	5.95	1.80
325	411	412	2.00	0.60
326	411	900	1.30	0.40
327	412	413	3.95	1.20
328	412	900	2.30	0.70
329	412	901	3.65	1.10
330	413	670	2.30	0.70
331	413	901	1.65	0.50
332	422	671	1.65	0.50
333	210	292	6.95	2.10
334	209	210	6.60	2.00
335	209	211	4.65	1.40
336	305	306	3.65	1.10
337	413	442	4.65	1.40
338	442	443	3.95	1.20
339	442	902	1.35	0.40
340	443	444	4.30	1.30
341	443	903	1.35	0.40
342	444	445	4.30	1.30
343	444	904	1.00	0.30
344	445	446	4.30	1.30
345	445	905	1.00	0.30
346	446	447	4.30	1.30
347	446	906	1.00	0.30
348	447	448	4.30	1.30
349	447	907	1.00	0.30
350	448	449	4.30	1.30
351	448	908	1.00	0.30
352	449	441	4.95	1.50
353	449	909	1.00	0.30
354	451	452	3.95	1.20
355	451	920	1.35	0.40
356	452	453	3.95	1.20
357	452	921	1.35	0.40
358	453	454	3.95	1.20
359	453	922	1.35	0.40
360	454	455	4.30	1.30
361	454	923	1.65	0.50
362	455	456	4.30	1.30
363	455	924	1.65	0.50

Contd...

364	456	450	5.95	1.80
365	456	925	1.65	0.50
366	450	459	3.65	1.10
367	441	457	4.95	1.50
368	296	458	33.30	10.10
369	375	458	8.60	2.60
370	376	457	4.65	1.40
371	386	457	6.60	2.00
372	438	457	14.50	4.40
373	437	438	4.95	1.50
374	393	437	5.30	1.60
375	424	438	14.20	4.30
376	437	439	27.40	8.30
377	439	440	4.95	1.50
378	440	441	15.85	4.80
379	405	439	11.25	3.40
380	441	457	1.35	0.40
381	441	449	3.65	1.10
382	441	450	33.60	10.20
383	450	459	1.35	0.40
384	316	450	30.70	9.30
385	450	456	6.60	2.00
386	655	656	9.60	4.80
387	656	684	4.60	2.30
388	657	660	21.00	10.50
389	657	661	16.80	8.40
390	658	659	10.60	5.30
391	659	660	7.60	3.80
392	659	682	6.00	3.00
393	660	661	6:00	3.00
394	661	662	3.00	1.50
395	662	663	3.00	1.50
396	663	664	3.00	1.50
397	664	666	2.60	1.30
398	665	667	6.20	3.10
399	665	684	13.00	6.50
400	666	667	4.40	2.20
401	667	668	3.20	1.60
402	668	669	2.00	1.00
403	669	670	10.40	5.20
404	669	671	5.20	2.60
405	671	672	3.80	1.90
406	672	673	3.20	1.60
407	673	674	3.00	1.50
408	674	675	3.00	1.50
409	675	676	4.00	2.00
410	676	677	3.40	1.70
411	677	678	3.00	1.50
412	678	679	3.40	1.70
413	679	680	3.20	1.60
414	680	681	3.00	1.50
415	681	682	3.00	1.50
416	683	684	13.40	6.70

Contd...

417	790	791	2.10	1.20
418	791	792	2.10	1.20
419	792	793	2.10	1.20
420	793	794	2.10	1.20
421	794	795	2.10	1.20
422	795	796	2.10	1.20
423	796	797	2.20	1.30
424	797	798	2.20	1.30
425	798	799	2.10	1.20
426	891	892	2.70	1.60
427	892	893	2.60	1.50
428	893	894	2.60	1.50
429	894	895	2.40	1.40
430	895	896	2.40	1.40
431	896	897	2.40	1.40
432	897	898	2.40	1.40
433	898	899	2.40	1.40
434	899	900	2.60	1.50
435	900	901	2.60	1.50
436	901	902	2.20	1.30
437	902	903	2.20	1.30
438	903	904	2.20	1.30
439	904	905	2.20	1.30
440	905	906	2.20	1.30
441	906	907	2.20	1.30
442	907	908	2.20	1.30
443	908	909	2.20	1.30
444	910	911	2.10	1.20
445	911	912	2.10	1.20
446	912	913	2.10	1.20
447	913	914	2.10	1.20
448	914	915	2.10	1.20
449	915	916	2.10	1.20
450	916	917	2.10	1.20
451	917	918	2.10	1.20
452	918	919	2.20	1.30
453	919	920	2.40	1.40
454	920	921	2.40	1.40
455	921	922	2.40	1.40
456	922	923	2.40	1.40
457	923	924	2.40	1.40
458	924	925	2.40	1.40

APPENDIX 7

UNIVERSITY OF ROORKEE, ROORKEE
BEHAVIOURAL ANALYSIS OF MODE CHOICE OF URBAN COMMUTERS
HOUSEHOLD SURVEY QUESTIONNAIRE
(JUNE,1995)

This questionnaire is devised to study your travel habits and preferences. Your response will be used only for academic research purpose in the University of Roorkee and will be kept confidential. Your co-opertion in this survey will help to improve our understanding of urban transportation problems.

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1. AREA OF SURVEY

2. RESPONDENT CHARACTERISTICS

    * Name
    * Address
    * Occupation
    * Sex
    * Income of the respondent

3. FAMILY DETAILS

* No. of persons in family	:	Male	Female
More then 60 years			
16 - 60 years			
5 - 15 years			
Less than 5 years			
* No. of employees	:	Male	Female
* Monthly income of the family			
* No. of Vehicles	:	Owned	Accessible
Car/Van/Jeep/M.cycle/Scooter/			
Moped/Cycle			
Other			

* Approximate Annual Saving
* Approximate Monthly expense on transport
* Rent for Residence per month

4. TRIP PARTICULARS

Please give particulars of all trips made by you and members of your household on the previous working day in the following table. Please include return trip also. If any trip for a single purpose has been made in more than one mode, please give particulars in separate line (one below other for each mode, but bracket all against each purpose.

TRIP DETAILS FOR ______________________ (date) ______________ (day)

Person making the Trip	Age/ Sex	Purpose	From	To	Starting time	Arrival time at Destination	Distance in km.	Mode	Travel time in Minutes					Cost per trip (Rs.)
									Access	Waiting	In Vehicle	Terminal	Total	

5. FACTORS AFFECTING MODE CHOICE

(A) Please indicate in the table below, what is the mode you or your household members use normally for trips for different purposes now. Please also indicate what modes you used previously, in case any of you have made a change within the last five years.

(Certain factors referred in this questionnaire are explained below :

Time of travel : refers to total time taken including waiting time, in-vehicle travel time, transfer and terminal times by using the particular mode (s)

Cost refers to total out-of-pocket expense of user in performing the journey including all travel costs. For private vehicle usage, parking cost, and loss of interest on capital invested, taxes, etc. on vehicle should also be included.

Comfort refers to travel comfort in vehicle with respect to getting a seat or standing comfortably and travelling without strain or tension. For own vehicle user, this will cover congestion and other conditions of roads.

Convenience refers to access distance to and from place of boarding/alighting from vehicle and number of changes to be made enroute and terminal distance. For private vehicle user this will cover parking problems, particularly at destination.

Reliability refers to arrival of vehicles in time and their running to schedule and without breakdown).

Purpose of journey	Mode of use			Reason (s) for change (Tick under one or more as appropriate)					Person concerned
	Present (state)	Previous (state)	Since when changed (months)	Cost	Comfort	Convenience	Reliability	Others if any)	
Work									
Shopping									
Social call									
Entertainment/Recreation									
Education									

(b) Distance to nearest Bus stop

≤ 250m	251 to 500 m	501 to 1000 m	> 1 to 2 km	> 2 km

(c) Distance to nearest subrban Railway/Ring Railway station

≤ 1/2 km	1/2 km to 1 km	1 km to 2 km	> 2 km to 3 km	> 3 km

(d) Frequency of service of Bus normally used (time in minutes)

≤ 5 min	> 5 min to 10 min	> 10 min to 20 min	> 20 min to 30 min	> 30 min

(e) If you are bus or train user how comfortable do you travel

	Bus (Tick in appropriate boxes)	Train (Tick in appropriate boxes)
Seated		
Standing comfortably		
Standing in crush load		

(f) How ofter (in a week) do you find your mode bus/train not keeping to achedule

Bus ______________________

Train ______________________

6. VALUE ATTACHED TO DIFFERENT FACTORS ASSOCIATED IN TRAVEL (TRIP) MAKING

Each person while choosing a method of travel, attaches varying importance to different factors. These may also vary depending on purpose of journey.

In the following table several factors are listed. you may add one or two which you think as important in addition to some factors listed. Please indicate in the table, how you value the factors for each purpose, using a marking system. You have 100 points under each purpose to distribute between the factors, in order to indicate the relative importance. (All factors listed below may please be valued without ommission).

Factors Associated	Trip Purpose				
	Work	Shopping	Social Call	Entertainment/ Recreation	Education
	(No. of points assigned)				
1. Time of travel					
2. Cost of travel					
3. Travel comfort					
4. Convenience in accessing to transport system					
5. Distance of travel					
6. Reliability of the transport system					
7. Safety in travel					
8.					
9.					
Total	100	100	100	100	100

7. LEVEL OF SERVICE

Please indicate how much you are satisfied with respect to various factors in performing a journey by different modes in your city. This judgement is to be made on a 100 point scale, on which 0 refers to a 'completely unsatisfactory' level, 100 to a 'completely satisfactory' level and the mid point 50 to a level neither unsatisfactory nor satisfactory. Please give your opinion for any 3 modes first the one you mostly/always use, second the next best alternative available to you and the third one you have some knowledge of, whether you use it or not by putting a 'x' at appropriate place along scale.

Mode - 1 Name of Mode : ______________________

	Completely unsatisfied		Neither satisfied nor unsatisfied		Completely satisfied
	0	25	50	75	100
1. Time of travel					
2. Cost of travel					
3. Travel comfort					
4. Convenience					
5. Reliability					
6. Distance in travel					
7. safety in travel					
8.					
9.					

Mode - 2 Name of Mode : ______________________

	Completely unsatisfied		Neither satisfied nor unsatisfied		Completely satisfied
	0	25	50	75	100
1. Time of travel					
2. Cost of travel					
3. Travel comfort					
4. Convenience					
5. Reliability					
6. Distance in travel					
7. safety in travel					
8.					
9.					

Mode - 3 Name of Mode : ______________________

	Completely unsatisfied		Neither satisfied nor unsatisfied		Completely satisfied
	0	25	50	75	100
1. Time of travel					
2. Cost of travel					
3. Travel comfort					
4. Convenience					
5. Reliability					
6. Distance in travel					
7. safety in travel					
8.					
9.					

8. CHANGE OF MODE

What different in total cost per trip and total time of travel you would like to agree/permit between your usual mode of travel and alternative mode of travel you would like to choose, if affordable/provided. Please indicate them purpose wise in the following table :

Purpose	Average No. of one way trips made per person	Average trip length	For Present mode of use			For preferred mode			Reason for change preferred (state factor (s))
			Mode used	Cost per trip One-way (Rs.)	Total time taken for one way (minutes)	Mode preferred	Max. price willing to pay for one way (Rs.)	Max. acceptable limit of travel time	
Work									
Shopping									
Social call									
Entertainment/ Recreation									
Education									

9. If the in-bus travel time is reduced by 30%, how much extra fare you are willing to pay ? (As percent of orignal fare) during.

(1) Work trips

(2) Shopping

(3) Social call .

(4) Recreation

(5) Education

10. How much extra fare you are willing to pay if you are granted a seat for every trip as percent of original fare.

11. Do you go to the bus stop with the knowledge of bus timings?

12. Out of 100 points, allot points, 0 to 100, to each of the following items according to the importance you give to them.

Cost :

Walking distance :

Waiting time :

In-Vehicle travel time :

Bus to Bus change over :

Comfort :

Adherence of Buses to the scheduled timing of arrival :

13. Which of the following systems (fare being same would you prefer).

a) Direct route system with less frequency.

b) Changeover system with higher frequency.

14. What are the reasons you are using present mode (give ranking according to importance attached.)

(a) To reduce walking time

(b) To reduce waiting time

(c) To reduce in-vehicle travel time

(d) To reduce over crowding

(e) Economic constraints

15. What are your time savings as compared to DTC ?

(only for train and private mode users)

Trip purpose	Walking		Waiting		In-vehicle travel time time	
Work	Origin	Destination	Origin	Destination	Origin	Destination

16. Working hours per day :

Working hourse Per week :

17. Additional Money One is Ready To Spend for :

	Time in Minutes				
(a) Walking	0 - 5	6 - 10	11 - 15	16 - 30	above 30

Trip purpose

1. Work
2. Education
3. Shopping
4. Social call
5. Entertainment

(b) Waiting
1. Work
2. Education
3. Shopping
4. Social call
5. Entertainment

(c) Waiting at transfer
1. Work
2. Education
3. Shopping
4. Social call
5. Entertainment

(d) Waiting for destination
1. Work
2. Education
3. Shopping
4. Social call
5. Entertainment

(e) In-vehicle travel time
1. Work
2. Education
3. Shopping
4. Social call
5. Entertainment

18. His score for travel time components :

How Long ?	Walk	Wait
(a) For 0-5 minutes of travel		
(b) For 6-10 minutes of travel		
(c) For 11-15 minutes of travel		
(d) For 16-30 minutes of travel		
(e) For above 30 minutes of travel		

APPENDIX 8 LIFE OF ASSETS ON RAIL TRANSIT

Sl. No.	Particulars of Assets	Life Adopted (in Year)
1.	Bridge work - Masonry	60
2.	Overhead Power lines and traction equipment	50
3.	Buildings, machinery and others	60
4.	Tunnels	60
5.	Station Machinery and Electric Equipment	25
6.	Underground Cables and Microwave applicances	30
7.	Domestic and Industrial Electric applicances	25
8.	Signal and Interlocking equipment	20
9.	Train Control equipment and Station/office furniture	20
10.	Telephone exchange equipment	13
11.	Rolling Stock :	
	Locomotives	25
	Coaches	25
	EMU_S	25
12.	Machinery and Plant	20
13.	Permanent way : Rails, points andd Crossings (Average depending on traffic intensity)	30
14.	Sleepers : Concrete	40
15.	Sleepers : Wooden	7
16.	Other Engineering Equipment	10

Source : Metropolitan Transport project (Railways) Chennai (Madras)

APPENDIX 9

Allocation of Operating Expenses	Basis for Allocation		
	Car-km	Peak Car needs	Track-km
1. Maintenance of way. and Structures			
- Superintendence			100%
- Ties and rails	100%		
- Ballast and other track material	50%		50%
- Track laying and surfacing	50%		50%
- Fences			100%
- Station and office buildings			100%
- Water and fuel stations			100%
- Shops and engine houses		100%	
- Communication systems	100%		
- Signals and interlocking		100%	
- Power plants and transmission			100%
- Insurance and injuries to persons			100%
- Stationery and printing		50%	
- Employees health and welfare benefits	50%		
- Other expenses	50%		
2 Maintenance of Equipment			
- Superintendence		100%	
- Shop and power plant machinery		100%	
- Electric locomotives - repairs	100%		
- Passenger train cars - repairs	100%		
- Other equipment - repairs		100%	
- Equipment depreciation		100%	
- Insurance and injuries to persons		100%	
- Stationery and printing	50%	50%	

Contd....

3. Traffic and Transportation			
- Superintendence		100%	
- Advertising, stationery and printing	50%		50%
- Dispatching trains		100%	
- Station employees, supplies and expenses	50%	50%	
- Train supervisors		100%	
- Train fuel and servicing locomotives		100%	
- Train crew			100%
- Train supplies and expenses	50%		
- Singal and interlocking operation	100%		
- Crossing protection			100%
- Communication system	100%		
- Employees health and welfare benefits	50%	50%	
4. General and Miscellaneous			
- Salaries and expenses of general officers		100%	
- salaries and expenses of clerks and attendants		100%	
- General office supplies and expenses		100%	
- Taxes		50%	50%

Source : Booz, Allen and Hamilton, (11).