PLANNING FOR OPTIMAL TRANSPORTATION SYSTEM IN BANGALORE CITY, INDIA

A THESIS

Submitted in partial fulfilment of the requirements for the award of the degree

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by

MOHAN KUMAR CHAVAN

DEPARTMENT OF ARCHITECTURE AND PLANNING
INDIAN INSTITUTE OF TECHNOLOGY ROORKEE
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CANDIDATE'S DECLARATION

I hereby certify that the work which is being presented in the thesis entitled **"PLANNING FOR OPTIMAL TRANSPORTATION SYSTEM IN BANGALORE CITY, INDIA"** in partial fulfilment of the requirements for the award of the Degree of Doctor of Philosophy and submitted in the Department of Architecture and Planning of the Indian Institute of Technology Roorkee, Roorkee is an authentic record of my own work carried out during a period from July 2006 to February 2011 under the supervision of Dr. V. Devadas, Associate Professor, Department of Architecture and Planning, Indian Institute of Technology Roorkee, Roorkee.

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

Date: 14.02.2011

(Mohan Kumar Chavan)

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

Date: 14.02.2011

V. Devadas
(V. Devadas)
Supervisor

The Ph.D. Viva-Voce examination of **Mr. Mohan Kumar Chavan,** Research Scholar, has been held on 23rd Jan, 2012

V. Devadas 23/01/2012
Signature of Supervisor

Signature of External Examiner

ABSTRACT

An urban system comprises of few interacting subsystems, which include physical, social, economic, ecology, environment, infrastructure and institution subsystem and function as an integral whole. All subsystems comprising the urban system are inextricably linked since they are not only interconnected but also interdependent to each other. The present investigation attempts to have a close look at the micro level. Transportation subsystem which is the part of physical infrastructure in an urban system, and undertakes in-depth investigation in it and finally making use of the multiple complex linkages within the urban system, project the future scenarios and arrive at a set of plausible guidelines for promoting the transportation segment of the infrastructure subsystem of the system.

An extensive field survey was conducted to collect the relevant data and suitable quantitative techniques are employed to quantify the features of the system pertaining to physical, social, economic, ecology, environment, infrastructure and institution subsystems of the system. A system dynamic model was developed, validated and employed for projection and developed the projected year model by considering population, population density, household vehicle ownership, vehicular population, modal split, vehicular density, congestion, fuel consumption and vehicular emission load.

The model was also used for generating alternative scenarios for investigating the behavior of the system in several alternative conditions by considering set of certain infrastructure parameters which include changes in two-wheelers, three-wheelers, cars, other vehicles, buses, transportation area, and bicycle trips. The study enables a close examination of the overall implications of several alternative policy options characterized by combination of relevant control parameters.

Bangalore city, one of the fast growing metropolitan cities in India was selected for the purpose of this investigation. This study examined the structure of transportation pertaining to different mode of transportation used and total trips, travel demand by different mode of transportation, fuel consumption and vehicular emission load by different mode of transportation, vehicle density, and congestion which highly influence

the transportation segment of the system. Finally, a set of policy guidelines was developed and recommended for having optimal transportation system in the system.

DEDICATED TO

MY TEACHER

DR. V. DEVADAS SIR

MY PARENTS

SMT. HEERA BAI (LATE) AND SHRI. MAHADEVA RAO CHAVAN (LATE)

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GLOSSARY OF TERMS

AQI	:	Air Quality Index
ATM	:	Air Traffic Movements
BBMP:		Bruhat Bengaluru Mahanagara Palike
BDA	:	Bangalore Development Authority
BESCOM	:	Bangalore Electricity Supply Company
BIAL	:	Bangalore International Airport Limited
BMR	:	Bangalore Metropolitan Region
BMRDA	:	Bangalore Metropolitan Region Development Authority
BMRCL	:	Bangalore Metropolitan Rail Corporation Limited
BMTC	:	Bangalore Metropolitan Transport Corporation
BPS	:	Bangalore Police Service
BR	:	Birth Rate
BRT	:	Bus Rapid Transit
BWSSB	:	Bangalore Water Supply and Sewerage Board
CAGR	:	Compounded Annual Rate of Growth
CBD	:	Central Business District
CDP	:	Comprehensive Development Plan
CMC	:	City Municipal Council
CO	:	Carbon monoxide
CO_2	:	Carbon dioxide
CPCB	:	Central Pollution Control Board
CRR	:	Core Ring Road
CRRI	:	Central Road Research Institute
CT		Census Town
db	:	Decibel
DIC	:	District Industry Centre
FDI	:	Foreign Direct Investments
GDP	:	Gross Domestic Product
GHG	:	Greenhouse Gas

GIS	:	Geographical Information System
Gm/L	:	Grammes per litre
gm/m^3	:	Grammes per cubic metre
GNP	:	Gross National Product
GOI	:	Government of India
GOK	:	Government of Karnataka
h	:	hour
HC	:	Hydrocarbons
HDI	:	Human Development Index
HH	:	Household
HHTWVO	:	Household with Two-wheeler Vehicle Ownership
HHCO	:	Household with Car Ownership
HIG	:	High Income Group
HMT	:	Hindustan Machine Tools
HRDI	:	Human Resource Development Index
HSC	:	Higher Secondary Class
ICT	:	Information and Communications Technology
IL & FS	:	Infrastructure Leasing and Financial Services Limited
IMD	:	India Meteorological Department
IPT	:	Intermediate Public Transport
IRR	:	Intermediate Ring Road
IT	:	Information Technology
ITeS	:	Information Technology enabled Services
ITI	:	Indian Telephone Industries
ITS	:	Intelligent Transport System
JNNURM	:	Jawaharlal Nehru National Urban Renewal Mission
kg	:	kilogram
km	:	kilometer
KIADB	:	Karnataka Industrial Areas Development Board
Km/h	:	kilometers per hour
KPCL	:	Karnataka Power Corporation Limited
KSPCB	:	Karnataka State Pollution Control Board

KSRTC	:	Karnataka State Road Transport Corporation
KTCP Act	:	Karnataka Town & Country Planning Act 1961
KUIDFC	:	Karnataka Urban Infrastructure Development Finance Corporation
KUWS&DB	:	Karnataka Urban Water Supply and Drainage Board
LDA	:	Lake Development Authority Level
LIG	:	Low Income Group
LOS	:	Level of Service
Lpcd	:	Litres per capita per day
LPG	:	Liquefied Petroleum Gas
LRT	:	Light Rapid Transit
m	:	meter
mi	:	mile
MIG	:	Middle Income Group
MLD	:	Million Litres per Day
MRTS	:	Mass Rapid Transit System
NH	:	National Highway
NMT	:	Non-Motorized Transport
NO	:	Nitric Oxide
NO_2	:	Nitrogen Dioxide
NO_x	:	Oxides of Nitrogen
NUTP	:	National Urban Transport Policy
OG	:	Out Growth
ORR	:	Outer Ring Road
PC	:	Practical Capacity
PCTL	:	Per Capita Trip Length
PCTLW	:	Per Capita Trip Length in Work Purpose
PCTLNW	:	Per Capita Trip Length in Non-work Purpose
PCTR	:	Per Capita Trip Rate
PCTRS	:	Per Capita Trip Rate in Shopping Purpose Trips
PCTRR	:	Per Capita Trip Rate in Recreational Purpose Trips
PCTRE	:	Per Capita Trip Rate in Educational Purpose Trips

PCTRSG	:	Per Capita Trip Rate in Social-gathering Purpose Trips
PCTSNM	:	Per Capita Time Spent in Non-motorized Trips
PCTTL	:	Per Capita Total Trip Length
PCTT	:	Per Capita Travel Time
PG	:	Post Graduate
PM	:	Particulate Matter
PPHPD		:Passengers Per Hour in the Peak Direction
PRR	:	Peripheral Ring Road
PUC	:	Pre-University Course
PT	:	Public Transport
RITES	:	Rail India Techno Economic Services Limited
RTO	:	Regional Transport Office
SD	:	System Dynamics
SMS	:	Short Message System
SO_2	:	sulfur dioxide
SO_x	:	sulfur oxides
SPM	:	Suspended Particulate Matter
SPSS	:	Statistical Package for Social Sciences
Sq. m	:	Square meter
STRR	:	Satellite Town Ring Road
SWOT	:	Strength-Weakness-Opportunities-Threat
TDS	:	Total Dissolved Solids
TLWP	:	Trip Length in Work Purpose
TLNWP	:	Trip Length in Non-work Purpose
TSNMP	:	Time Spent for Non-motorized purpose
TT	:	Travel Time
TTL	:	Total Trip Length
TTMNMT	:	Total Time for Motorized and Non-motorized Trips
U A	:	Urban Agglomeration
UG	:	Under-graduate
V/C	:	Volume to Capacity Ratio

CHAPTER-1

INTRODUCTION

1.0 INTRODUCTION

Cities are the engines of economic growth. Urbanization and globalization are the world wide phenomena, today. These two forces are responsible for rapid economic growth and development across the globe. The economic growth and development of the city go hand in glove across the globe since the time immemorial. The rapid growth of population, growth of economic activities, advancement in technologies, tremendous increase of vehicular population, etc., causes for the growth of the towns and cities. The level of urbanization is varying, from country to country, which is not uniform. The rate of urbanization is very high in the advanced countries, whereas it is less in the developing countries. Though half of the World's population lives in the urban areas, the density of the urban population is not at all uniform in across the globe. In European cities, average of 5000 to 5500 persons live per sq.km; in automobile cities, it is 1500 to 2600 persons per sq.km; whereas in Asian cities, it is 1500 persons per sq.km. European and Asian cities still have around 20.00 per cent of jobs in their central business districts, while in US cities the average is less than 10.00 per cent; and in Canadian, Australian and in New Zealand cities it is in between, i.e., 15.00 per cent. In India, the per cent of urbanization was 25.70 in 1991, which grew to 27.80 in 2001. India has an area of 32,87,263 sq.km, which measures 3214 km from North to South and 2933 km from East to West. In terms of area (land), India is the seventh largest country, and the second highest populous country of the World. As per 2001 census, the country's population was 1,028 million accounts for 16.70 per cent of the World Population and the density was 324 persons per sq.km. The cities having a population one million plus are named as 'Metropolis' or 'Million plus' or 'Metropolitan cities/ UAs. In India, the numbers of metropolitan cities were 9 in 1971, 12 in 1981, 22 in 1991 and it increased to 35 in 2001, whereas the Class I cities grew 148, 216, 296 and 393 respectively in the same period.

Rapid growth of population causes numerous kinds of problems in the towns and cities. Of which, shortage in housing, power, health, electricity, domestic water, development of slums, pollution, absence of sewerage facilities, poor road and transportation infrastructure, improper handling of solid waste management, absence of drainage facilities, inadequate quantity of parks and playgrounds, etc., are considered as more important.

Transportation, one of the most important physical infrastructures plays a significant role in economic development of the nation. Urban transportation is the backbone for the development of the cities, and both intra and inter-transportation play a major role in Metropolitan regional development. In transportation system, the following important modes play a significant role, namely, roadways, railways, airways, and waterways. The Public Road Transportation plays a key role in the developed and developing nations. In European countries like France, Germany, United Kingdom and in Spain the percentage of public transport are 86.40, 84.00, 89.00 and 81.50; and in Asian countries like Japan, Hong Kong-China and the Republic of Korea it is 61.90, 22.50, 40.00 [110], and it is about 80.00 per cent of all trips in Bagota, 75.00 per cent in San Jose, 61.00 per cent in Tunis. The cities, which are blessed with rapid rail transit, do not depend much on road transportation and the bus share is lower like London with 23.00 per cent, New York with 14.00 per cent, Paris with 8.00 per cent, and Tokyo with only 6.00 per cent. In India, 17 metropolitan cities are having dedicated Public Transportation- city bus services, and four are having rail transit of the total metropolitan cities.

Asian cities are characterized by heterogeneous traffic (a mix of motorized and non-motorized mode of transport) and mixed land use patterns. Car ownership rates are low in the Asian countries compared to North America. In 1993, car ownership was 29 cars per 1,000 households in East Asian countries, compared to 561 cars per 1,000 households in North America [11]. The World's 5850 million population shares a total vehicle fleet approximately 500 million cars, or 11 people per vehicle on an average. However, the most mobile countries have a ratio of two to three people per vehicle (European Countries, US and Japan). In the rest of the World, the ratio is around 35 people per car, but the figure can be as high as 500 to 1000 people per car in countries such as Malani, Burkina Faso or Ethiopia. In 2001, in India, the car ownership (including jeeps and taxis) was 7 per 1,000. In 2001, 54.99 million vehicles were plying on Indian roads. According to the Government of India, the annual rate of growth of motor vehicle population in India has been about 10.00 per cent during the last decade, while in the same period annual rate of growth of population was 2.15 per cent. The concentration of vehicular population in the metropolitan cities is the major cause for the transportation problem in the cities rather than increase in number of vehicles. It is alarming to note that 32.00 per cent of these vehicles are plying in the metropolitan cities alone. Two-wheelers and cars (including jeeps) account for more than 80.00 per cent of the vehicle population in most large cities. Transportation problems in the cities across the country are rapid growth of population, concentration of vehicular population in the metropolitan cities, high level of air and noise pollution beyond the acceptable limit, long route to reach work, limited road capacity (limited road space), non integration of transportation modes, imbalance in modal split, overcrowding in the buses at the peak hours, non availability of space for parking, improper location of bus stations, long waiting hours, heterogeneous traffic, all vehicles sharing the same road, limited capacity of bus systems, absence of proper foot paths, absence of drainage, poor maintenance of roads, inadequate transportation infrastructural facilities, heavy concentration of population in the central business district and the commercial street, absence of facilities at the vicinity, encroachment of roads by road side hawkers, the street dwellers, informal sector market, etc. As a consequence, the passengers in the city undergo numerous amount of problem, and these problems become daily living affairs.

Concentration of population in the cities results in escalation of travel demand. A variety of transport modes, such as, walking, cycling, two wheelers, para-transit, public transport, cars, etc., meet the travel needs of the people. Public transportation system plays a decisive role to meet the increased travel demand amongst all these modes of transportation. The developed countries use public transportation system significantly as compared to developing countries, and rail is the major Mass Transit transportation system in the developed countries. The public road transportation system is pivotal in developing countries. In Indian mega cities like Greater Mumbai, Kolkata, Delhi, Chennai, Bangalore, and Hyderabad, the rate of bus per 1000 population is 0.94, 0.65, 2.95, 0.69, 1.13 and 0.47 respectively. Further, the availability of buses has increased from 1.40 buses per 1000 in the year 1981 to 3.24 buses per 1000 population in the year 2001 at the national level, whereas, the private vehicles per 1000 has increased three folds during the same period. The transportation study for Indian cities reveals that walking is a predominant mode in smaller cities, whereas the public transport is the prime mode of transport in the bigger cities.

Webber, (1969), Transportation system is the vital medium through which the interdependencies of complex urban societies get satisfaction and societal integration is occurred [217]. A conventional transportation planning process investigates relationship between land use and traffic, and employs a four-stage theory of trip generation – trip distribution – modal split and trip assignment. To arrive at solutions to minimize the transportation problems without understanding the interactions and interrelationships amongst various components of the urban system is impractical. The impracticability of such solutions calls for fresh approach. A holistic approach is very much essential to evolve plausible plans for the development of the transportation system in particular and the urban system as a whole in general.

1.1. LITERATURE REVIEW

The literatures available about transportation in the urban system are voluminous. The Investigator has collected good number of research articles pertaining to transportation system, and their allied sectors. The Investigator has gone through the collected literatures meticulously and grouped them into different segments based on the literature focused on. Further, most important literatures on the important aspects are chosen for in-depth study and their views, methodologies, findings, etc., are presented in the following sections:

1.1.1. Urban Transportation Planning Process
1.1.2. Techniques in Urban Transportation Planning
1.1.3. Public Transportation Systems and Development
1.1.4. System Dynamics Modeling (SDM)

1.1.1. Urban Transportation Planning Process

Various authors elucidated about on urban transportation planning process [7, 33, 42, 57, 60, 106, 116, 138, 204, 207]. Transport planning is a science that seeks to study the problems that arise in providing transportation facilities in the urban, regional or national setting, and to evolve a systematic basis for planning such facilities [116]. Urban transport planning is a continuous process involving interaction between the government and the urban community. Transport-systems planning consider just one activity of the multilevel process of development planning. Transport planning studies have been conducted in larger number of urban areas across the globe during the past half century. A process for conducting these studies has been developed, and is still evolving, which attempts to provide systematic method for solving urban transport problems [106]. Transportation planning is a critical element in evolution and growth of metropolitan regions, such planning must take into account of trip purpose, temporal and spatial distributions of trips, modal splits of travel, and costs [b68]. Transport sector is one of the largest sectors in the process of urban development. The National Commission on Urbanization (NCU) has noted that urban transport is the most decisive single component instrumental in shaping urban development and urban living [91]. The urban transportation planning process developed in the US in 1950s consists of ten steps [66, 79], which include 1) Coding and zoning, 2) Inventory studies, 3) Travel studies, 4) Socio-economic forecasts for the horizon year, 5) Trip-generation analysis, 6) Pre-distribution modal split analysis, 7) Trip-distribution analysis, 8) Post-distribution modal split analysis, 9) Network assignment analysis, and 10) Evaluation. These steps are very much used for travel demand analysis, modal split analysis, analysis of trip generation, analysis of characteristics of the trips, household characteristics, zonal characteristics and network characteristics in transportation planning [116, 187].

There were a lot of criticism about the traditional transportation planning process done by various researchers, policy makers and planners [56, 155, 188, 203]. These criticisms are: existing trends as projected into the future rather than seeing it as a policy question to be addressed by the planning process [102], inaccuracies in the behavioral of variables which include population, employment, and GNP growth [140], the four-step procedure follows a rigid sequence, and does not use interactive procedures or feedback [65], trip distribution and modal split are not integrated [36], the traditional transportation planning process is inadequate, ineffectiveness and lack of appreciation of land use transport interaction [155]. Often it neglects the important role of infrastructure networks play and limits its focus on the efficiency of the transport system itself and argued that a shift needed from planning for mobility to planning for accessibility [188]. Further, the traditional urban transportation planning is not able to explicitly address the broader economic, social, and spatial goals, which can be served or hampered by the transportation developments [84], and struggle to accommodate the complexities of household travel and the effect of land-use factors [46], typically not capable of handling multipurpose trips [125]. As a consequence, in recent years, it has been argued that the time is right for a shift in paradigm towards a new approach in urban transportation planning [19, 61, 84].

1.1.2. Application of Techniques in Transportation Planning

Application of plausible techniques in transportation planning has been giving momentum since 1970s. Application of Geographical Information System (GIS) techniques in transportation planning is very much used in different studies [6, 24, 35, 107, 114, 118, 119, 124, 162, 171, 196, 197, 227], and Information Technology based application was also done in transportation planning [70, 104]. Extensive research has been done by integrating GIS based transportation in the urban system for various applications, which include travel demand modeling, pavement management, road safety, traffic signal coordination, and development of transportation system analysis at zonal level [24, 35, 107, 114, 124, 171, 197, 227]. Application of Geographical Information System (GIS) has given more insight in urban transportation planning in recent years. It has emerged as one of the best techniques in transportation planning since it has more avenues for data storage, and data manipulation; data management; trip travel demand analysis, trip generation, trip distribution, modal split and network assignment pertaining to transportation, etc. Further, the existing transportation system can be analysed by employing Geographical Information System (GIS) techniques, and future demand of transportation system can also be estimated by employing the same [6, 118, 119, 196]. It is interesting to note that spatial information and attribute information were used for developing GIS based transportation data base. The spatial information comprises of digital map showing road network, transportation junctions, aerial photographs, etc., and the attribute information comprises of population, employment, land use activities, traffic counts, etc., are considered for developing GIS-Transportation data based, which can be used for efficient transportation management in the urban system [196]. In addition, simulation techniques have been used by employing Geographical Information System (GIS) models for evolving optimal transportation plans [6, 70, 119, 162, 196].

An attempt was made to integrate the GIS subsystem and the telecommunication subsystem for delivering online passenger information to mobile phones using variety of information, such as Short Message System (SMS), Wireless Application Protocol (WAP), etc. The GIS techniques integrate static urban data, i.e., geographical data with dynamic flows [193, 205]. The GIS techniques help to integrate the traffic data with urban management for the development of efficient visualizations and analysis of urban traffic conditions [69, 205]. Decision Support System (DSS) with the help of GIS techniques for real time transport control was developed. Further, the Development of Decision Support System (DSS) with GIS techniques bring new possibilities for developing geographical traffic and travel information online at any time and anywhere in the urban system for the benefit of the commuters, which in turn help the travelers to minimize the cost and time of travelling [162], and internet based guidelines that allows public transportation users to find routes, and buses between pairs of origin and destination [118]. GIS for transportation have been developed and used in many transportation projects [36, 62, 156, 161, 194, 202, 216] connecting GIS technology with World Wide Web (www).

Internet and intranet (wireless networks), were used in transportation management. In optimal transportation management, both static and dynamic modes were used to compute routes, and new routes needed in the system. Internet based GIS transportation methodology was developed for optimizing bus riding activities in the urban system with transportation planning related options allowing them for better scheduling their activities, in turn it helps the transport authorities to schedule the bus routes dynamically to offer effective bus services to the travelers [118].

GIS techniques has been employed for optimization of transport services in which the optimum roads, the travel timing, the travel distance and travel cost for defined paths and for the optimum paths were determined [159]. An attempt was also done to study the possibility of application of GIS technique for route optimization, and Chennai city has been considered for thorough investigation for finding the optimal route for emergency services by considering time taken for service as the most important parameter. Further, an attempt was done to optimize transport services by employing GIS techniques for the area of a State Transport of Bhavnagar district and observed that the travel distance has come down to 1.77 per cent, and the consumption of oil has also come down to 1.77 per cent per year, which shows that GIS-based technique for deciding the transportation management is the best option [6].

A good passenger information system bridges the information gap by providing the pre-trip and/or en-route information to the travelers about their travel options [119]. This influences the travel behavior with respect to mode choice, travel time, travel cost, route choice and trip making. In most of the Indian cities, passenger information system is absolutely absent and thereby the travelers are tottering and left with chaotic situation in the urban system. A passenger information system model was developed by aiming at minimize the total generalized cost of passenger from their origin to destination, which consists of in-vehicle time, transfer time, waiting time, walking time and the fare is incurred in traveling. It is interesting to note that the developed protocol model for the passenger information system computed the shortest path based on generalized cost and displayed it in an inclusive manner, and the authors concluded that through this model optimum path could be developed for a multimodal transit network based on generalized cost subject to constraints for path-validity with maximum waiting time.

1.1.3. Public Transport Systems and Development

Various authors have done in intensive research on public transportation and published research papers [8, 1037, 115, 129, 151, 164, 170, 177, 179, 199, 209,]. Urban transportation planning is a very complex and specialized subject. It needs a specialized person who knows the subject very well to evolve transportation plans. Further, it also need scientific input while preparing transportation plans. It is unfortunate to state that there is acute shortage of trained technical man power in this particular field in India [8]. Population growth in the urban system, increasing urbanization, rising motorization, low per capita income, inadequate transportation management system, inadequate strategic planning in transportation system, inefficient transport planning and execution, etc., cause tremendous amount of pressure in Indian cities in general, and in transportation segment in particular. It has been observed that population growth and urban form combine together make formidable challenges to the transportation system in Indian cities [151, 179]. Public transportation services has gained more importance in Indian cities because of low per capita income of the citizens, non-availability of suburban rail networks in all million plus cities, prevailing unemployment, under-employment, disguised unemployment, etc. Buses carry over 90.00 per cent of public transport in Indian cities since suburban rail networks are not available in all million plus cities. It is interesting to note that the people rely upon the combination of buses, minivans, auto-rickshaws, cycle-rickshaws, taxis, etc., for satisfying their requirements. In Kolkata city, at least, 80.00 per cent of the transportation services are met by the public transportation services, whereas it is 60.00 per cent in Mumbai, and 42.00 per cent in Chennai and Delhi respectively of the four metropolitan cities [164].

The high percentage of citizens of Indian cities preferred walking and cycling mainly because of their poor economic condition, and they cannot afford any private motor vehicles at all [14, 147, 218]. They are forced to either walk or using bicycles for even long distances, and suffering from all ill-effects of the urban system, which include all kinds of pollution, safety related problems, congestion, etc. In the urban system, the low income residences are generally dependent heavily on non-motorized transport and transit for performing their day-to-day activities. However, using non-motorized transportation services are mainly depends upon the topography, vegetation covers, terrain, etc. It has been observed that if the terrain is flat then non-motorized vehicles and walking may be preferred, whereas if the terrain is undulated, then motorized vehicle is very much essential for travelling. Further, trip time, trip length, mode of choice, trip frequency, route choice, etc., decide the travel behavior [179].

The growth of Indian cities has generated rapid growth in travel demand, whereas available transportation infrastructure is very less. The sharp increase in level of motor vehicle ownership and their use resulted in sharp increase in congestion, air pollution, noise pollution, traffic jam, etc., in the cities, which further led to deterioration of environment. It is painful to note that in Indian cities mobility and accessibility have been declined to most segments of the population [164]. The public transportation system in the urban system in India is not attractive [163]. Most buses and trains in small and medium size cities of India are old, poorly designed, inadequately maintained, dangerous, overcrowded, undependable, and slow [4]. Further, it has been observed that the public transportation system in India is generally inefficient due to employing obsolete technology, inefficient management, corruption, overstaffing, low worker productivity, subsidies, etc [164]. However, it is imperative to have a close look at the public transportation system in India, and evolve plausible public transport policies for strengthening the public transportation system.

Travel demand is decided by few factors, which include residing population, floating population, average number of journeys performed by the residences per day, average trip length, income status of the residents, occupation structure, education status, available infrastructural facilities in the urban system, etc [8, 115, 164, 179]. However, it has been observed that the motorized vehicle trips are increasing whereas non-motorized vehicle trips are decreasing in Delhi city, the capital of India, and it is observed that between the year 1981 and 1994 the non-motorized trips has been declined from 17.00 to 7.00 per cent. Further, it has been observed that more than half (56.00 per cent) of road accidents are met through cyclists, and pedestrians in the city [148].

The population in A class and above cities in India is estimated to grow 2.50 times during 1991 to 2021, whereas the corresponding intra-city travel demand grew by 3.50 time during the same period [8]. The available public transportation infrastructures are very negligible in Indian cities. It is painful to note that two-wheelers and cars (including jeeps) accounts for more than 80.00 per cent of the vehicular population in most larger cities, and the share of public transportation (bus) is negligible in most Indian cities as compared to personal vehicles, for eg. Two-wheelers and cars together constitute more than 90.00 per cent in Kanpur city, 90.00 per cent in both Hyderabad and Nagpur cities, whereas in these cities buses constitute 0.10, 0.30 and 0.80 per cent respectively [177], which shows that the public transport infrastructure is very negligible in the growing million plus cities in India. Further, it has been observed that the number of public transport vehicles increased between the year 1981 and 2002 is very much minimal, i.e., only 1.10 per cent whereas the number of motor cycles increased to 16 fold, the number of cars increased to 7 fold, and the number of goods vehicles increased to 5 fold [164]. In Delhi city, buses constitute less than 1.00 per cent of the vehicles fleet but serve about half of the total travel demand. Sustainable transportation heavily rely on public transport and non-motorized transport modes. The public transports rely upon good amount of transport of infrastructure. It gives me unpleasant to note that the required amount of road infrastructure is not developed fully in any one of the metropolitan cities in India. As a consequence, average speeds of the vehicles have been reduced over the years. In major intersections, traffic hazards are appearing and it is a day-to-day affair in the peak hours, and during the non-peak hours the vehicles are plying with higher speed, which is ranging from 50-90 kmph, which led to higher fatality create among the pedestrians, cyclists, and the two-wheelers in the city. Further, it has been observed that the poor traffic management systems prevail in the metropolitan cities are also adding the fuel to increase the fatality rate in the system [199].

In most of the Indian cities, there is not much availability of dedicated facilities for bicyclists, pedestrians, two-wheelers, cycle-rickshaw personals, public transport (buses), etc. As a consequence, all the motorized vehicles have to travel together on the road which creates lot of traffic problems and increase in number of fatalities on roads. Further, it has been observed that more quantity of fuel is burned on roads due to traffic jams, low speed of vehicles, which in turn create adverse affect in the system [8, 103, 115, 151,164, 170, 177, 179, 199, 209].

Interlinking of land use planning and transportation planning is very much essential for the development of the region. Transportation system forms the basics, and through this segment resource mobilization takes place, which leads to economic development of the region. The transportation plays a major role, and also functions as a catalyst for regional development where the society and the economy interact. Lack of effective land use planning, land use controls, and population explosion, etc., together resulted into rampant urban sprawl in all directions of the cities, which is far beyond the city boundaries towards the country side. The density of the population in these areas are lower than the core area of the city, and this area people are in need of public transport facilities since usage of walking, cycling, non-motorized rickshaws, etc., are very much minimal because of higher distance. The public transportation system in this area also would not gain momentum among the organization side because the revenue is much lesser compare to the core area of the city. As a consequence, public transport system suffers in this particular locality [115, 151, 164, 179]. Most of the public transportation planning in the urban system in India do not have link with land use planning which led to total chaos in the transportation segment. It is very much essential to have the interaction between the land use planning and the transportation system to have optimal transportation system in the urban system. The public transportation access could be implemented by incorporating dynamics of proximity measures, service considerations, demographic and socio-economic factors, land use for different purposes, etc [151, 179]. Integration of land use and transportation planning is the best option for minimizing the transportation problems in Indian cities [8, 115, 179], since transportation is the function of land use, socio-economic condition of the people, and the transportation infrastructure available in the system [129]. Public transportation planning must be interlinked with land use planning of city [8, 115, 129, 151, 179, 199, 209].

Integrated approach linking transportation planning and the land use planning is very much essential for the country like India for effective use of resources and also to provide better services to the resident population along with the floating population. In India, most of the transportation related problems are met with short term solutions, which include construction of flyovers, widening of the roads, etc., whereas the long term solutions are not much emphasized. Transportation planning has been done in Indian cities unscientifically even without integration of land-use-transportation system [8, 115, 129, 151, 179].

1.1.4. System Dynamics Modeling (SDM)

System Dynamics presents a systems approach and prescribes a rational set of steps for carryout a system inquiry. System Dynamics (SD) is a methodology whereby complex, dynamic and nonlinear interactions in social systems can be understood and analysed, and new structures and policies can be designed to improve the system behavior [149]. Few authors have employed system dynamics techniques in transportation studies [96, 122, 175, 178, 203, 210]. Employing system dynamics technique for sustainable land use and urban development has been attempted. In this investigation, an integrated model was developed by considering five subsystems, which include population, economy, housing, transportation and urban land use, along with environmental-social-economic subsystem to assess the impact of Government policies on sustainable land use in Hong Kong. The model examined the interaction between the aforesaid five subsystems with different population densities, and the results were directly used for planning and policy making [175].

An attempt was made to assess the air pollution and energy consumption in Delhi city between the period 2006 and 2020 [96]. The urban motorized passenger transport is considered as a complex system in which the dynamic change can be occurred by having the interaction between population growth, economic development, policy influence, passenger mobility demand, modal split, environmental impact, etc. This investigation aimed at reducing the energy consumption and air pollutant emissions in an urban motorized transport system. To achieve this goal six policy instruments, which include increasing more efficient number of vehicles, extension of traffic network, increase of rail stations and mass rapid transit system (MRTS) passenger capacity, levy of fuel taxes, and reduction of fuel intensity are considered to optimize the factors affecting the modal share in the passenger mobility. This investigation concluded that implementation of mass rapid transit system (MRTS) would be the best option for reducing energy consumption and air pollution in the city. Further, it suggested to develop of rail network, for reducing energy consumption and air pollution [175].

An attempt was made to understand the relation between land use dynamics and transportation. A system dynamics model was developed by considering the following subsystems such as population, land use, and transportation. A causal loop diagram was developed to understand the interrelationship between different subsystems of the model. In population segment, three groups of population, which include Low Income Group (LIG), Middle Income Group (MIG) and Higher Income Group (HIG) were considered along with their affordability characteristics. The income affordability characteristics are decided by the population grouping, vehicle ownership and trips performing characteristics. The relationship between land use and transportation was established along with the population segment. Land use for different purposes along with transportation related parameters, which include travel demand, road network, public transport trips, level of service, volume capacity ratio, etc., were considered in land use-transportation segment in the modeling purposes. Chennai city has been considered for taking up investigations and for arriving at policy decisions [203].

A systems dynamics model was developed to understand the dynamic relation between the travel demand and the emissions arising out of transportation system. The modal captures the behavior response of transportation users to alternative policies. Congestion index, supply induced travel index, vehicle travel index, vehicle size index, road capacity index have been defined and empirical relation between these parameters were analysed. Further, simulation works have been attempted to analyse effective emission and traffic congestion with respect to travel demand management. Finally, the results were used for evolving policies for having efficient urban transportation system [210].

An attempt was made to integrate the dynamic function of the urban transportation subsystem, which include urban area, the socio-economic activities, highway construction, passenger transportation, transportation fuel consumption and air pollution subsystems in order to understand their interaction and to evolve certain transport policies. The policies were intended to reduce fuel consumption, to reduce the road congestion and thereby to reduce the environmental deterioration in the urban system along with improving the return (benefits) while operating the public transportation system. Causal loop diagrams for socio-economic subsystem, transportation subsystem, transportation fuel consumption and pollution generation, etc., were developed. Further, population and socioeconomic activities subsystem, urban land growth, transportation fuel consumption, air pollution subsystems were developed and put together for developing integrated transportation model for Delhi urban region. The integrated transportation model explained the dynamics behavior of the system, which includes urban area, socio-economic, highways construction, passenger transportation, fuel consumption for transportation and air pollution. The following scenarios such as reduction in fuel consumption, improving the air quality, improving the bus services, encouraging share ride travel, improving mass transit usage, pressure reduction in road network, improving Delhi Transport Corporations (DTC's) operational economy, encouraging the use of non-motorized means of transport, etc., were tested in the model, and the results of the tested scenarios were discussed thoroughly for arriving at policy decisions for having efficient transport system in Delhi urban region [122].

1.1.5. Gaps in Literature

The Investigator has done thorough literature survey, reviewed the available literature, and observed that there is research gap in this particular field of learning. The existing literature shows that research have been done by considering one or two subsystems of the system, like piecemeal manner but not at the comprehensive and integrated manner. In this present investigation, the Investigator considers city as a system and all major subsystems of the system, which include physical, social, economic, ecology, environment, infrastructure and institution are considered, in which transportation is considered as catalyst for realistic development. Having the above in mind, the Investigator has chosen this particular field of investigation as the area of research, and Bangalore City- a Metropolitan city in India is selected for this present investigation. A set of objective are framed to carry out this present investigation and are presented as below:

1.2. OBJECTIVES

The following objectives have been framed for this present Investigation. They are:

1. To assess the existing physical, socio-economic, ecology and environmental conditions of the urban system (study area).
2. To assess the existing transportation system in the system.
3. To identify the control parameters pertaining to transportation, which decide the functions of the system.
4. To quantify the functions of the system.
5. To forecast the demand and supply of transportation infrastructure for the year 2031 A.D., *and quantify the functions of the system in different alternative* conditions.
6. To evolve a set of policy guidelines for transportation system in the system.

1.3. HYPOTHESIS

A plausible hypothesis is framed based on the analytical work and is tested in this present investigation, i.e., a Transportation System brings about a total development of the system. In the development process, Transportation System functions as a catalyst for Integrated Development of the city.

1.4. SCOPE

The study area suffers from lack of coordination among the available modes of transportation, which include public road transportation, rail and air transportation. The traffic in the city is heterogeneous, and is comprised of slow vehicles, medium speed vehicles and high speed vehicles; there are no dedicated lanes available according to vehicle, and its functions; absence of mass transportation system; inadequate and inefficient public transportation system, inadequate road space, narrow roads, traffic congestion, traffic chaos, traffic jam, overcrowding of public transportation buses in peak hours, inadequate infrastructures for non-motorized transportation, e.g. lack of pedestrian paths, no dedicated lane for bicyclists; breakdowns, traffic accidents, etc. The problems and prospectus of transportation system shall be studied with regard to their provision, operation and maintenance, management and financing, and plausible recommendations shall be given. The study aims at to evolve a set of policy guidelines to have efficient transportation system in the study area with environmental considerations. The Investigator hopes that if the recommendations are implemented properly in time, sustainable, people and environmentally friendly transportation shall be anticipated in the system.

1.5. CONCEPT

In this present Investigation, systems concept is employed. A system functions as a whole with the interaction of several sub-systems. All the sub-systems are inter-linked and interdependent to each other and functions as a whole. If one of the subsystems of the system or combination of few subsystem defunct or function with advance level (taking lead roles) during its functions, its effects can be seen in the entire system over the period of time. An urban system is one of such complex, soft, social system with dynamic characteristics. Transportation forms part of the infrastructure subsystem of the urban system. To understand the significance of the urban transportation, it is very much essential to study the system as a whole with more emphasize on transportation.

Over the years, drastic changes occurred in the study area particularly with respect to all the sectors of the economy, structural, physical, social, environment, infrastructure, institutional changes, etc. It has been observed that the city has been transformed its function from one point to another, i.e., from 'Pensioners Paradise' to the 'Silicon Valley of India'; In this situation, it is imperative to have a close look at the functions of the system, factors that decide the functions of the system, and further it requires Integrated Planning Approach to improve the quality of life by exploiting the available resources, infrastructure, etc., in the system. Therefore, system concept is employed to analyse the functions of the city for evolving a plausible set of policy guidelines for integrated development of this city.

1.6. RESEARCH DESIGN

Survey research methods have been employed in this present investigation. The methodology, which has been followed to conduct this investigation, is presented in Fig. 1.1.

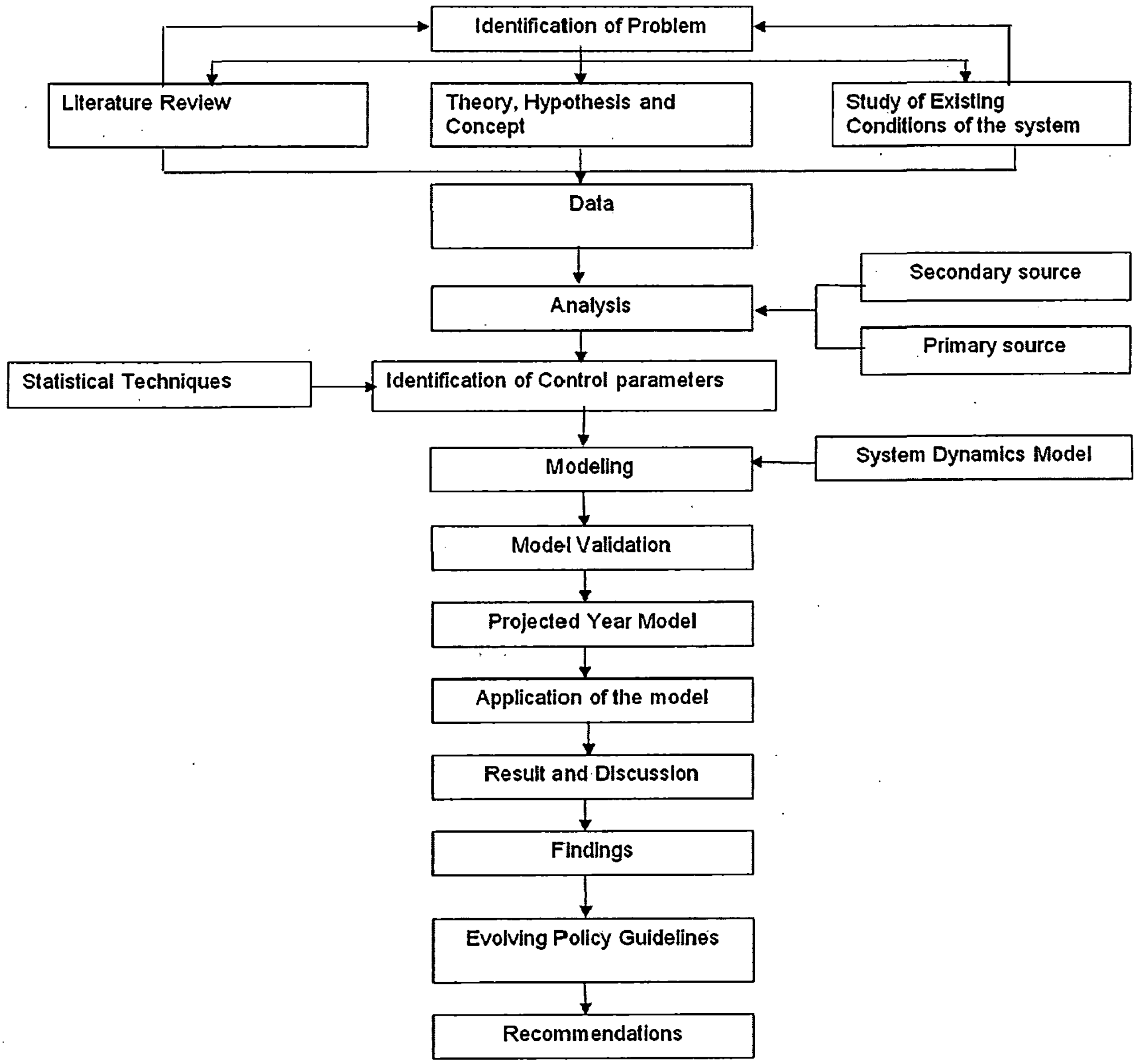


Fig. No. 1.1: Methodology Chart

1.6.1. Methodology

This investigation follows a systematic methodology as shown in Fig. 1.1. The various steps followed in the investigation are identification of problems and formulation of objectives followed by collection of data, analysis and identification of control parameters, which decide the functions of the system, development of model, validating the model, forecasting, simulation, drawing of inferences, policy analysis, and evolving a set of policy guidelines and recommendations.

1.6.1.1. Selection of Sample Households

The study area, i.e., Bangalore City and its Urban Agglomeration is divided into forty seven Planning Districts. These forty seven planning districts are grouped into four categories based on their population density for conducting primary household survey. The population density in these four categories of Planning Districts are grouped into less than 10,000, 10,000-20,000, 20,000-30,000 and above 30,000 persons per Sq. Km. In each population density category, two planning districts were selected. Further, in each planning districts, two planning wards were selected for conducting the primary household survey. Therefore, sixteen planning wards from eight Planning Districts were selected by employing random sampling technique to conduct the primary survey. Then, in each ward, 20 households were selected by employing random sampling technique and finally 320 households were selected to conduct the primary household survey in the study area (system). The sample size was chosen by having the formula of k=N/n represent the total number of households and sample size, respectively. The households selected by Planning District and Planning Ward-wise are presented in Table 1.1, Table 1.2, Fig. 1.2 and Fig. 1.3.

1.6.1.2. Data

There are two types of data have been collected and employed in this investigation. They are secondary and primary sources of data.

Secondary Sources of Data: Required data from the published and unpublished literatures, newspapers, documents, reports, etc., from various sources are collected pertaining to this investigation, and used.

Primary Sources of Data: Survey was done at the selected 320 households for obtaining requisite data at the grassroots level to have firsthand information. The details of data collected are presented in Table No. 1.3.

Table No. 1.1: Planning Districts of Bangalore Metropolitan Area

Sl No.	Name of the Planning District	Population	Area in Sq.km	Density of population (Persons/sq. km)
Planning Districts of Density of Population < 10,000 Persons/ sq. km				
1	Bannerghatta	41129	117.00	352
2	Hesaraghatta	17707	42.29	419
3	Bagaluru	20642	48.44	426
4	Bavalakere	11667	27.31	427
5	Dommasandra	20348	41.69	488
6	Kumbalagodu	10595	19.50	543
7	Bettalasuru	20553	35.30	582
8	Varthur	35330	52.00	679
9	Avahalli	25889	37.70	687
10	Tanisandra	32258	45.83	704
11	Gandhinagar	32451	30.96	1048
12	Electronic city	46570	36.60	1272
13	Sadar Mangala	28978	20.10	1442
14	Begur	162733	73.31	2220
15	White Field	90780	38.84	2337
16	**Yelahanka**	**98450**	**38.71**	**2543**
17	Makali	170639	61.34	2782
18	Anjanapura	220513	71.08	3102
19	Horamavu	123507	37.56	3288
20	**Byatarayanapura**	**145552**	**43.99**	**3309**
21	Kengeri	134242	26.17	5130
22	C.V. Raman Nagar	97876	16.75	5843
23	Baiyyappanahalli	66928	8.92	7503
24	K.R. Puram	131955	17.26	7645
25	Richmond Town	36465	3.65	9990
	Total	**1823757**	**992.30**	**1838**
Planning Districts of Density of Population between 10,000 - 20,000 Persons/ sq. km				
Sl No.	**Name of the Planning District**	**Population**	**Area in Sq.km**	**Density of population (Persons/sq. km)**
26	**Peenya**	**141187**	**12.91**	**10936**
27	Vasanthanagar	37208	3.13	11888
28	Malleshwaram	235918	14.70	16049
29	Indranagar	180000	10.40	17308
30	Kammanahalli	155108	8.92	17389
31	**Jayanagar**	**261695**	**13.98**	**18719**
	Total	**1011116**	**64.04**	**15789**

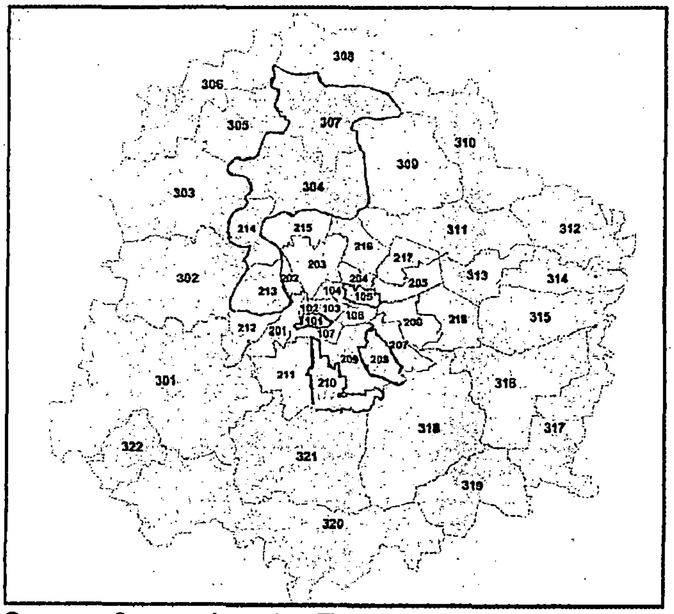
Source: Comprehensive Traffic & Transportation Plan for Bangalore, RITES, 2006.

Contd... in Page No. 20

Table No. 1.1: Planning Districts of Bangalore Metropolitan Area

Sl. No.	Name of the Planning Districts	Population	Area in Sq. km	Density of Population (Persons/Sq. km)
Planning Districts of Density of Population between 20,000 - 30,000 Persons/Sq. km				
32	Shanthinagar	306031	14.00	21859
33	Benson Town	81741	3.70	22092
34	**Shivajinagar**	**70669**	**3.09**	**22870**
35	Vijayanagar	228956	10.00	22896
36	Majestic	32809	1.41	23269
37	**Koramangala**	**178784**	**7.65**	**23370**
38	Banashankari	460726	18.51	24891
39	Kaval Byrasandra	314493	10.90	28853
40	Chamaraj pet	116582	3.89	29970
	Total	**1790791**	**73.15**	**24481**
	Planning Districts of Density of Population > 30,000 Persons/ sq. km			
41	**Rajajinagar**	**425839**	**13.51**	**31520**
42	Herohalli	206263	5.81	35501
43	Kempapura Agrahara	380649	8.77	43404
44	**Petta**	**112076**	**2.24**	**50034**
45	Srirampuram	149638	2.96	50553
46	Unclassified	NA	7.89	NA
47	Mathikere	NA	NA	NA
	Total	**1274465**	**41.18**	**30949**

Source: Comprehensive Traffic & Transportation Plan for Bangalore, RITES, 2006.



Source: Comprehensive Traffic & Transportation Plan for Bangalore, RITES, 2006.

Fig. No. 1.2: Selected Planning Wards for Conducting Primary Household Survey in Bangalore Metropolitan Area

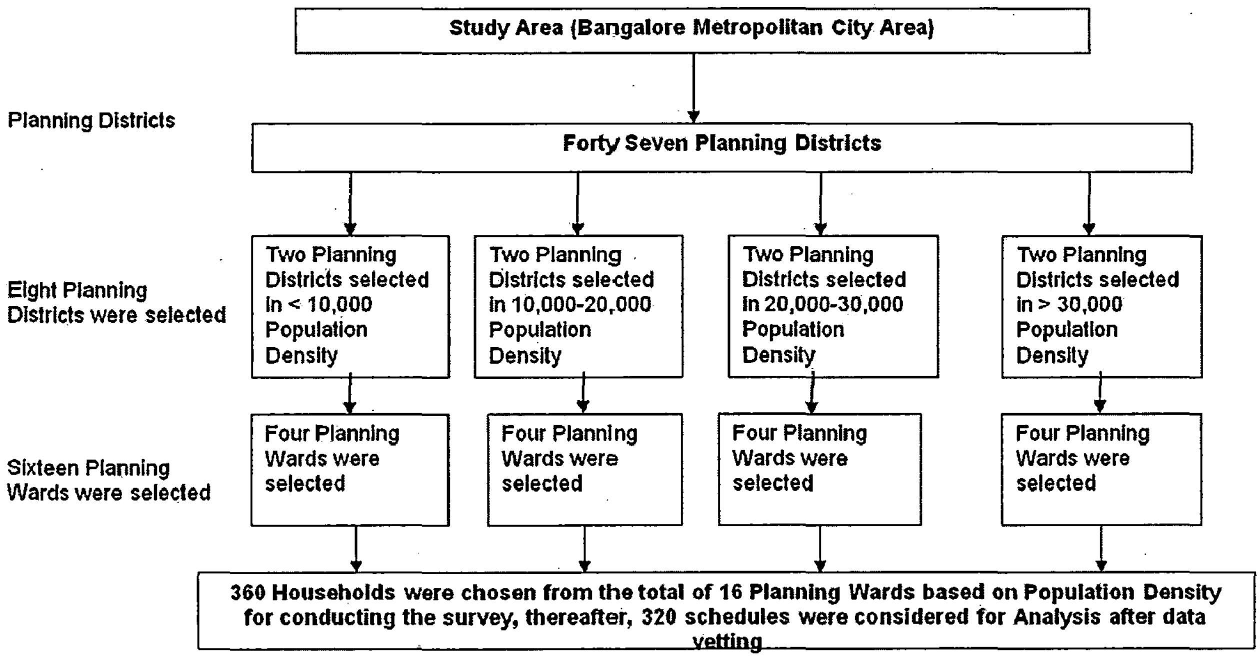


Fig. No. 1.3: Sampling Method

Table No. 1.2: Details of Selected Samples for Primary Household Survey in the Study Area

Sl. No.	Planning Districts	Selected Planning Wards	Civic Status	No. of Selected Samples for Primary Survey
1	Yelahanka	Yelahanka	CMC	20
		K. R. Puram	CMC	20
2	Byatarayanapura	Byatarayanapura	CMC	20
		Mahadevapura	CMC	20
3	Jayanagara	Jayanagara	MC	20
		Visveshwarapuram	MC	20
4	Peenya	Peenya Industrial Area	MC	20
		HMT	MC	20
5	Shivajinagara	Shivajinagara	MC	20
		Ulsoor	MC	20
6	Koramangala	Koramangala	MC	20
		Neelasandra	MC	20
7	Petta	Chikpet	MC	20
		K. R. Market	MC	20
8	Rajajinagar	Rajajinagar	MC	20
		Rajajinagara Industrial Town	MC	20
Total	**8 Planning Districts**	**16 Planning Wards**		**320**

Source: Compiled by the Investigator.

Table No. 1.3: Details of Data Collected

Sl. No.	Levels of Data Collected	Sources of Information/ Persons Concerned	Types of Information/ Data
1	Worldwide Phenomenon	World Transport Policy, Through Internet	Secondary Data
2	National Level	Infrastructure Reports Economic Survey Reports National Level Urban Transport Policy Report	Secondary Data.
3	State Level	Bangalore Development Authority (BDA), Bangalore Metropolitan Transport Corporation (BMTC), Bruhat Bangalore Maha Nagara Palike (BBMP), Transport Authorities, Karnataka Urban Infrastructure Development Finance Corporation (KUIDFC) Economic Survey Reports	Secondary Data
4	Regional Level	Bangalore Metropolitan Region Development Authority (BMRDA)	Secondary Data
5	Study Area Level	District Level Offices, District Level Officers	Secondary Data
6	Household Level	Household Survey	Primary Data
7	Transportation System	Transportation System in the Study Area	Secondary and Primary Data

Source: Compiled by the Investigator

1.6.1.3. Survey Tools

Appropriate survey tools, such as, pre-tested schedules, questionnaires, etc, are employed in this present investigation. They are discussed as below:

1.6.1.3.1. Schedule

Household schedule is used for conducting survey at the grassroots level. The survey schedule consists of two parts. The first part of the schedule comprising of demographic, physical, socio-economic and environmental quality aspects of the households in the system (study area). The details of the first part of the schedule, which include household income from different sources, family size, gender, age, marital status, educational qualification, employment, occupation, ownership of the house, expenditure pattern, drinking water supply, available electricity supply, and waste disposal; environmental quality, which include air quality, noise pollution, land quality, etc. The second part of the schedule comprising of the important parameters pertaining to transportation system or travel characteristics of the households, which include vehicle ownership, purpose of journey, mode of travel, walking distance, waiting time, trip distance, travel time; distribution of trips, trip distances and travel time by the surveyed households in the study area; and road condition, road maintenance, available transportation infrastructural facilities, etc. The household schedule used for this investigation is presented in Appendix – 1.

1.6.1.3.2. Methods of Administering the Surveys

The household survey was conducted in the year 2008-09. To conduct the survey, the Investigator contacted the officers in various levels like at Central Government Officers including research and policy making institutions National Institute of Urban Affairs (NIUA), Ministry of Urban Development, Central Road Research Institute (CRRI), Experts in this field. At the State Level the officers including Bruhat Bangalore Mahanagara Palike (BBMP) (Greater Bangalore City Corporation), Bangalore Development Authority (BDA), Bangalore Metropolitan Transport Corporation (BMTC), Bangalore Metropolitan Region Development Authority (BMRDA), Karnataka Urban Infrastructure Development Finance Corporation (KUIDFC), etc. At the grassroots level, administrative ward-level officials were contacted and detailed discussions were held, which gave valuable insight in organizing the survey. Subsequently, the Investigator conducted a pre testing surveys in some of the identified households with the help of the local level officials. The collected data by using the pre-tested schedules were analysed thoroughly to develop the final schedules for conducting the survey.

To conduct the household survey, the Investigator approached the households directly, and held a detailed discussion with the members of the households, after obtaining prior appointments from the respondents for conducting the survey at the household level. The Investigator himself carried out all these surveys. Since the Investigator himself conducted the surveys, he gained a lot of insight about overall functioning of the system, and was able to draw some conclusion based on the observations too.

1.6.1.4. Analysis

The collected data were checked for completeness and correctness, and errors or bias in the returns was eliminated by crosschecking. The extreme low and higher records of facts and figures of the samples are totally eliminated, and subsequently transferred the data into code sheets carefully and then to a computer for analysis. The analysis is done by employing various tools and techniques as described below:

1.6.1.5. Analytical Tools and Techniques

1.6.1.5.1. Analytical Tools

Relevant analytical tools, such as code sheets, software (SPSS, EXCEL, STELLA) etc., were used for data processing, analysts and modeling.

1.6.1.5.2. Analytical Techniques

Relevant statistical techniques, such as tabulation, correlation, multiple regression, and system dynamic techniques, etc., were employed based on the requirement of the present in investigation.

1.6.1.6. Application of Theory/Models

System Dynamics techniques [74] based on systems concept has been employed in this present investigation. In this investigation, the study area has been considered as a system and achieving integrated development is considered as the major objective. A theoretical framework is developed to establish the functions of the system, based on System Dynamic technique in which Transportation has been considered as a catalyst for Integrated Development of the System.

1.6.1.7. Modeling

System Dynamic models were developed and employed to understand the dynamic functions of the system, and for evolving a suitable planning model. STELLA software is employed to develop the System Dynamics Model.

1.6.1.8. Model Validation

The evolved System Dynamics Model is validated to understand the reliability of the model for further investigation.

1.6.1.9. Forecasting

The validated System Dynamics Model is employed to project the control parameters, which decide the functions of the system, and are incorporated in the model for developing the projected year model for the year 2031 A.D.

1.6.1.10. Application of the Model

Alternate plausible scenarios have been developed based on historical development, trend analysis, assumptions, etc., and the same have been tested in the projected year model for arriving at different feasible decisions.

1.6.1.11. Results and Discussion

Results of all types of analysis, which include literature surveys, primary surveys, model results, simulation, etc., have been discussed in detail to draw inferences.

1.6.1.12. Inferences

Plausible findings were drawn for evolving a set of feasible policies.

1.6.1.13. Strategies and Recommendations

A set of policy guidelines is prepared and recommended based on the results, discussions and inferences of this investigation for Optimal Transportation System and total development of the study area.

1.7. NEED FOR THE PRIMARY SURVEY

Plausible research requires two types of data, which includes secondary sources of data and primary sources of data. The primary sources of data are very much essential to have up to date information about the particular system, which is under investigation. In transportation research, certain parameters like mobility of people, their financial condition, occupation, vehicle ownership, standard of living, age-group, educational status, aspirations, expenditure pattern, affordability, etc., which play a major role. Data pertaining to these activities generally not available in the secondary source of data. Further, the available secondary sources of data are minimum a decade old. In planning research, up to date information is very much essential for evolving policies for the future. Further, the available secondary sources of data may not give insight over the system to the Investigator. The secondary sources of data was collected and compiled by someone else, whereas when the Investigator collects the data at the grassroots level by going to the field, he/she will get more insight over the study area. Further, in modeling both secondary and primary sources of data is very much used to arrive at plausible decisions. Having this knowledge in mind, the primary survey was attempted in the system for this present investigation.

1.8. JUSTIFICATION OF THE STUDY AREA

Transportation infrastructures play a significant role in an urban system for its development. Transportation infrastructure is not only used for human resource mobilization but also mobilization of other resources, trade and commercial activities, etc. Different modes of transportation are available in any urban system for the aforesaid purpose. In India, the urban systems are facing numerous amounts of problems due to population explosion. The available transportation infrastructure is very scarce but the needs are many in the urban system due to the population explosion. Different mode of transportation is implemented by the Govt. of India and the respective State Governments to satisfy the requirements, but the efforts have not achieved the desired amount of output. The Investigator had travelled in Bangalore city, the Silicon Valley of India, in several occasions and observed that this city faces numerous amount of problems in resource mobilization. The major Information and Communications Technology (ICT) industries even threaten the State Government stating that if efficient transportation infrastructure is not provided in the city, they would be quitting from the city, would be setting up their industries in other States where required amount of Transportation infrastructure is provided. Subsequently, one of the major Information and Communication Technology (ICT) industries known as Wipro set up the training centres in neighbouring State in Tamil Nadu and started their industries in West Bengal State. It has been observed that this city's contribution to Information and Communications Technology (ICT) is gradually trailing. Having aforesaid knowledge in mind, and also being an Urban and Regional Planner, the Investigator has serious thinking to minimize the transportation related problems by evolving a set of policy guidelines in the city. Therefore, this present investigation is attempted in the study area.

1.9. LIMITATIONS

The following limitations are observed in the study:

1. Ph. D research is time bound; hence road transportation especially public transportation is considered for detailed investigation.
2. Sampling technique is employed since the Investigator himself would conduct the detailed investigation at the grassroots level.

1.10. CHAPTER SCHEME

The thesis is organized in different chapters as follows

Chapter One: Chapter One consists of Introduction, Review of Literature, Statement of Problem, Objectives, Scope, Concept, Research Methods, Limitations, Conclusion.

Chapter Two: Chapter Two deals with the Study Area Profile and Transportation System in the Karnataka State.

Chapter Three: Chapter Three depicts the Transportation System in the Study Area.

Chapter Four: Chapter Four illustrates the analysis of Demographic, Socio-economic, Physical, Environmental conditions, Travel Characteristics of the Surveyed households in weekdays and weekend days of the system (Study area).

Chapter Five: Chapter Five deals with the Control Parameters, which decide the functions of transportation system based on Correlation and Multiple Regression Analysis. Application of System Dynamics Theory, Development of functional models, and its application under various alternative conditions. Forecasting the demand and supply of infrastructure facilities in 2031 AD and the functions of the system in 2031 A.D., under alternative conditions

Chapter Six: Chapter Six deals Findings based on literature Correlation and Multiple Regression Analysis, Primary Survey, Modeling; Results and Discussions with Inferences.

Chapter Seven: Chapter Seven concentrates on evolving a set of Policy Guidelines, Recommendations and Conclusion.

STUDY AREA PROFILE

2.0 INTRODUCTION

Bangalore city is transformed from a hamlet known as 'Begur' to Metropolis and form the largest city of Karnataka State, India. The transformation of metropolis from a tiny village in terms of growth and development is phenomenal. Currently it is one of the fastest growing cities in Asia. The modern Bangalore city was founded by Mr. Kempe Gowda in the year 1537. He had created basic form of the city (pete) and the fort (kote) and also constructed the Sampangi, Dharmamubudhi, and Kempambudhi tanks; Kempe Gowda II (Immadi Kempe Gowda, ca. 1570-1633) established four towers at the four cardinal point of Bangalore to mark the limit up to which the city would extend in course of time. Subsequently, Hyder Ali developed the city in Persian-style in the year 1760; followed by his son Tipu Sultan developed the city in the period of 1753-99. Thereafter, the British occupied the city and ruled over up to the year 1947. In 1950s, the Government of India reorganized the States on linguistic basis and formed Karnataka State. Bangalore city being the largest city under the jurisdiction of Karnataka State and got more importance and became the State capital. The city has started to grow since then and transformed from one stage to another. Today, this city is so popular and put its own identity in the world map of Information and Communication Technology (ICT). This city is popularly known as 'India's Silicon Valley', people from across the globe are living in the city, and further the city transformed in to a 'Cosmopolitan city'. This city has good number of research laboratories in various fields, industries in different segments, educational institutions, health institutions, etc. The growth and development of this city in different period is shown in Fig. 2.1 (A) to 2.1 (M). Growth of urban area of Bangalore city from the year 1889 to 2001 is presented in Table 2.1 and in Fig. 2.2. This table and this figure illustrate that there have been a considerable amount of growth of Bangalore

Table No. 2.1: Growth of Urban Area in Bangalore City

Sl. No.	Year	Area in Sq. Km	Per cent Increase in Area
1	1889	9.98	0.00
2	1901	28.85	189.07
3	1911	60.35	109.18
4	1941	70.00	15.99
5	1961	113.31	61.87
6	1971	174.70	54.17
7	1981	366.00	109.50
8	1991	446.00	21.85
9	2001	531.00	19.05

Source: Compiled by the Investigator based on BWSSB-Hand Book of Statistics,1994-95; 1995-96; 1996-97 and Census of India, series-30, Karnataka.

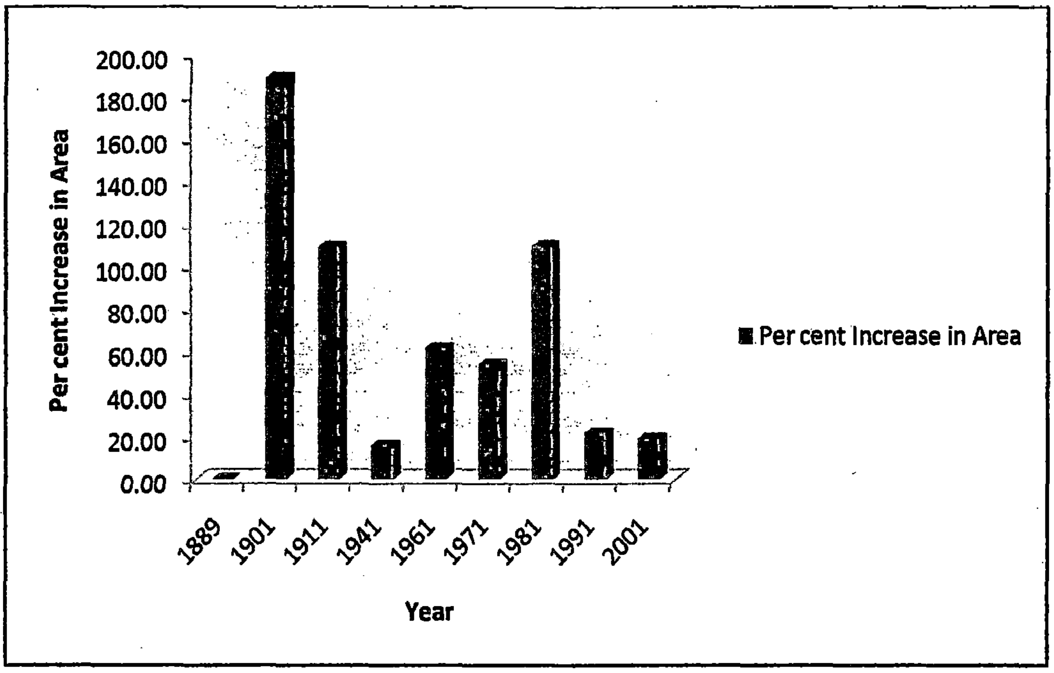


Fig. No. 2.2: Growth of Urban Area in Bangalore City

city in terms of area since the year 1889 to the year 2001. It has been observed that the city had only 9.98 Sq. km in the year 1889 and it is grown up to 531.00 Sq. km in the year 2001. There was an increase of urban area more than 53 times during the same period. The city was the sixteenth biggest city in the country in 1941 and grew rapidly and it was ranked eighth in 1951, and became the sixth largest city in India by the year 1961. Bangalore with a population of 2.91 million became the fifth largest city in the country by the year 1981 [88]. The jurisdictions of Bruhat Bangalore Mahanagara Palike (BBMP), Bangalore Development Authority (BDA) and Bangalore Metropolitan Region Development Authority (BMRDA) are presented in Fig. 2.3.

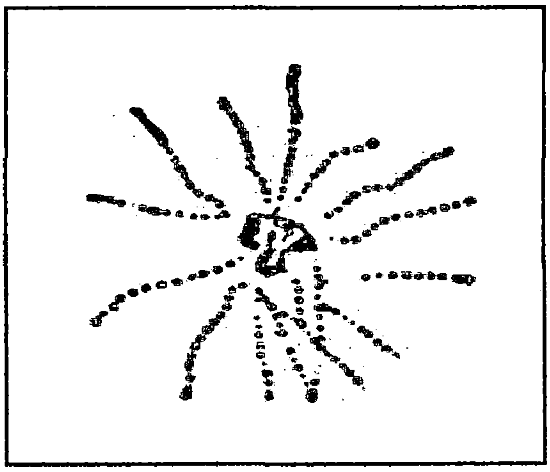


Fig. 2.1 (A): Bangalore in 1537

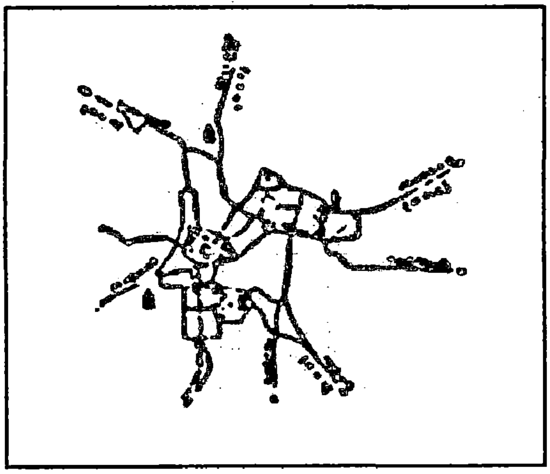


Fig. 2.1 (B): Bangalore in1662

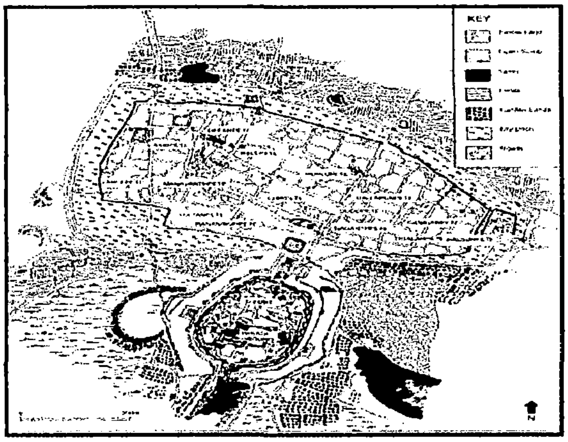


Fig. 2.1 ©: Bangalore in 1791

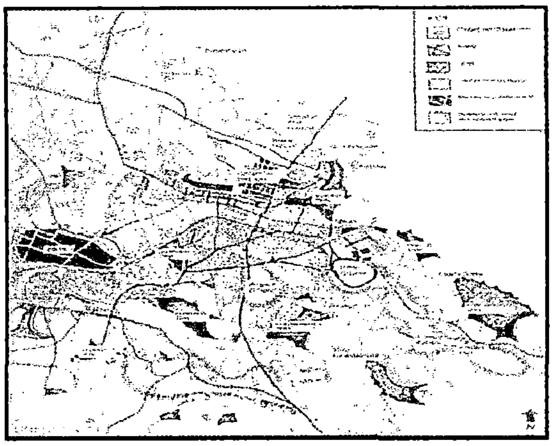


Fig. 2.1 (D): Bangalore in 1850

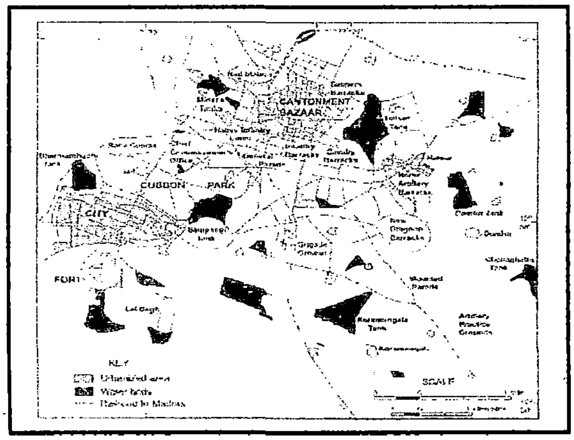


Fig. 2.1 (E): Bangalore City and Cantonment in 1870

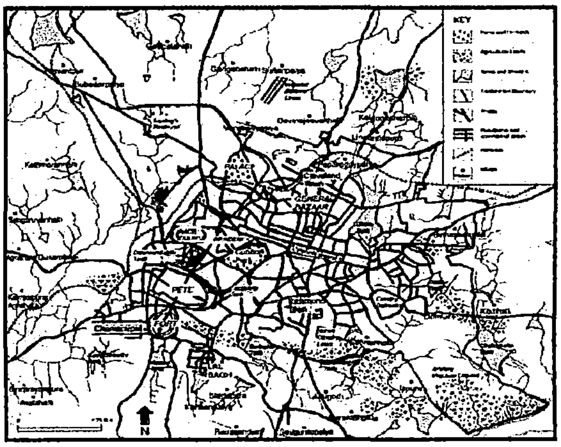


Fig. 2.1 (F): Bangalore in 1897

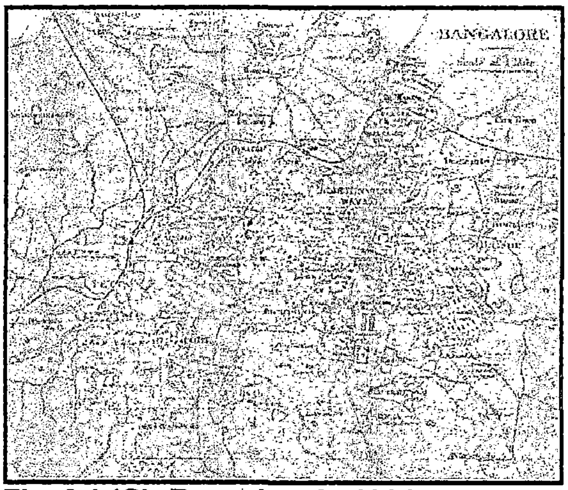


Fig. 2.1 (G): Bangalore in 1924

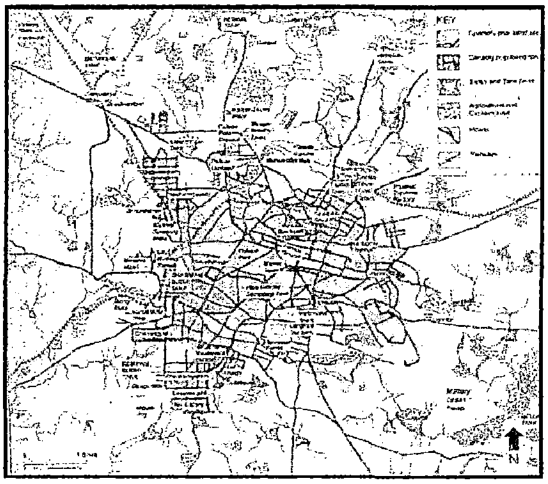


Fig. 2.1 (H): Bangalore in 1935

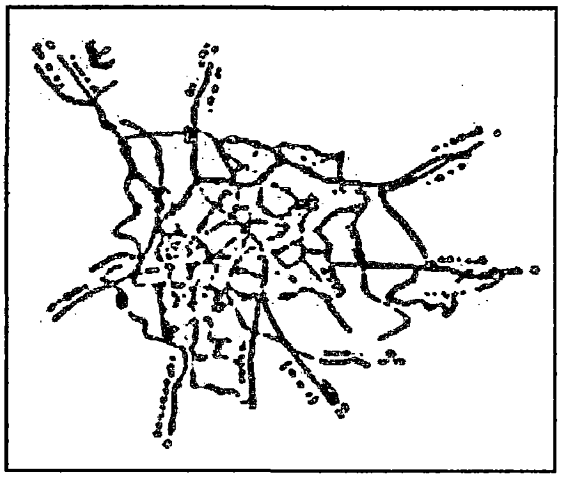


Fig. 2.1 (I): Bangalore in 1949

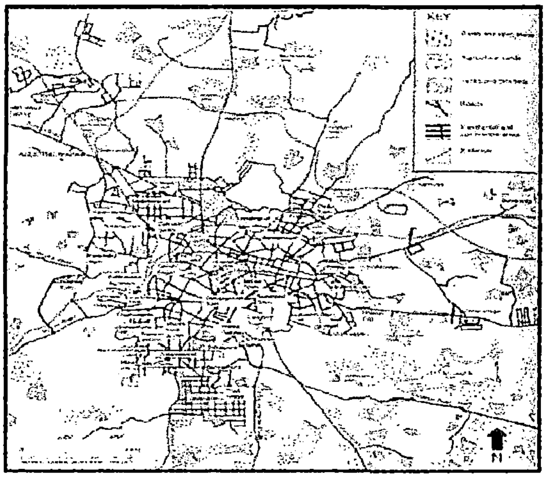


Fig. 2.1 (J): Bangalore in 1960

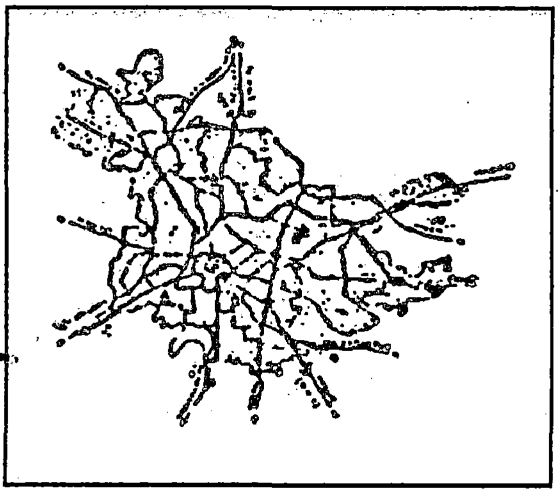


Fig. 2.1 (K): Bangalore in 1972

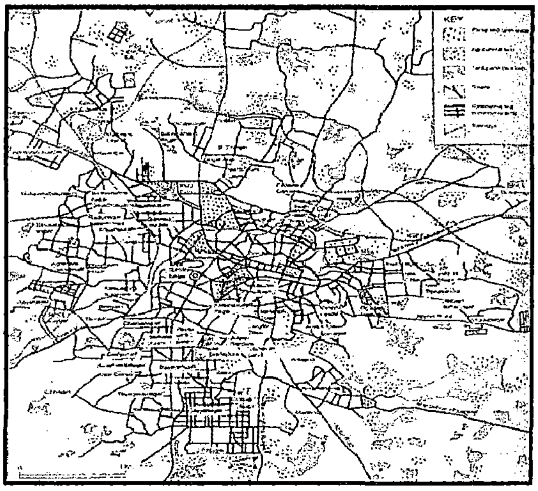
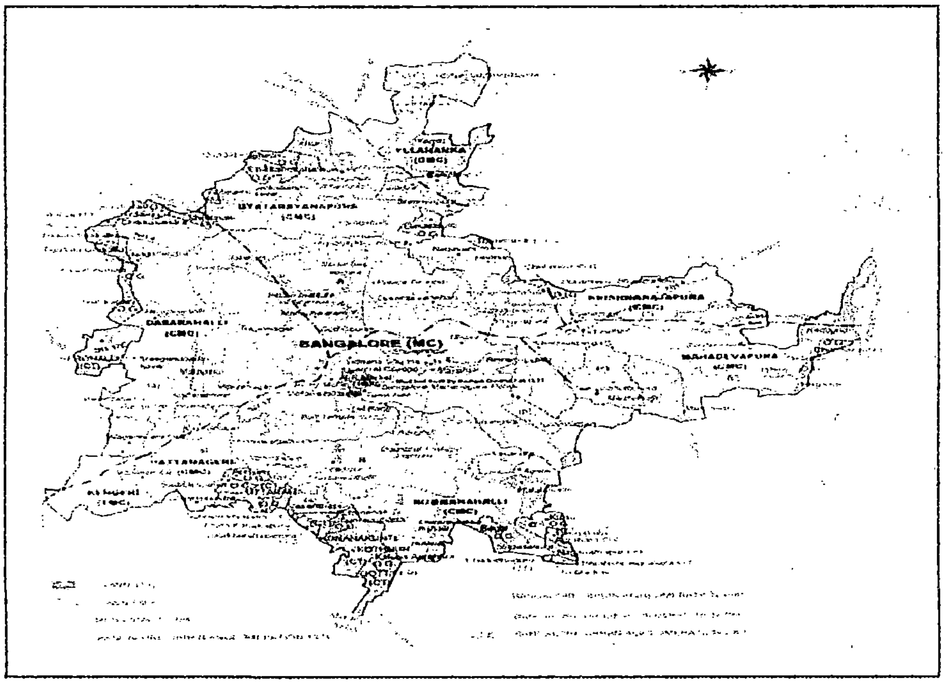


Fig. 2.1 (L): Bangalore in 1980

Source: Heitzman, J., 2004. Network City: Planning the Information Society in Bangalore, Oxford University Press, Oxford; Nair Janaki., 2005. The Promise of the Metropolis: Bangalore's Twentieth Century, Oxford University Press, New Delhi; Gowda, Rame., K. S, 1986. Urban and Regional Planning, PrasarangaPublications, University of Mysore.

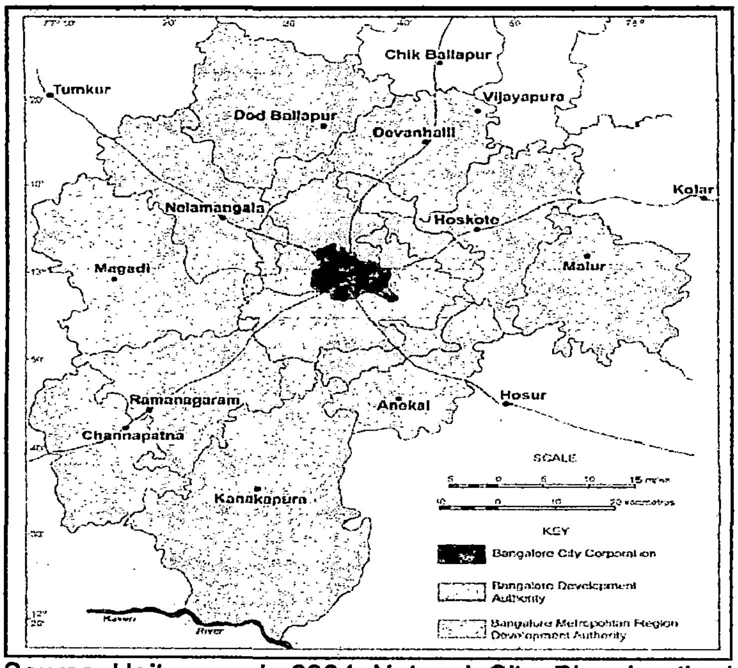
Fig. No. 2.1: Morphological Growth of Bangalore City



Source: State of the Environment Report – 2003

Fig. No. 2.1 (M): Map showing the growth of Bangalore City from the Year 1537 to 2001

Note: Seven Index colours representing the growth during different years in 1537, 1862, 1941, 1971, 1981, 1991, 2001.



Source: Heitzman, J., 2004. Network City: Planning the Information Society in Bangalore, Oxford University Press, Oxford.

Fig. No. 2.3: Map showing the areas of jurisdiction of Bangalore City Corporation-Bangalore Development Authority-Bangalore Metropolitan Region Development Authority

2.1. LOCATION OF BANGALORE CITY AND ITS URBAN AGGLOMERATION

The Bangalore city is situated on the 12° 58′ N latitude and 77° 33′ E longitude, in the heart of South Deccan of Peninsular, India. It has grown on a ridge-top running through the middle of the Mysore plateau from West to East, at an average elevation of 3021 ft (about 1000 m above the mean sea level). As a result, Bangalore city maintains attractive salubrious climate throughout the years. There is no major river flowing near the city. It borders with Kolar District in the northeast, Tumkur District in the northwest, Mandya District in the southwest, Chamarajnagar District in the South and the neighbouring State of Tamil Nadu in the southeast. The study area, Bangalore City and its Urban Agglomeration is chosen in this investigation is an important vibrant and dynamic city of Karnataka State, which is also the State Capital. The location of Bangalore City and its Urban Agglomeration is presented in Fig. 2.4.

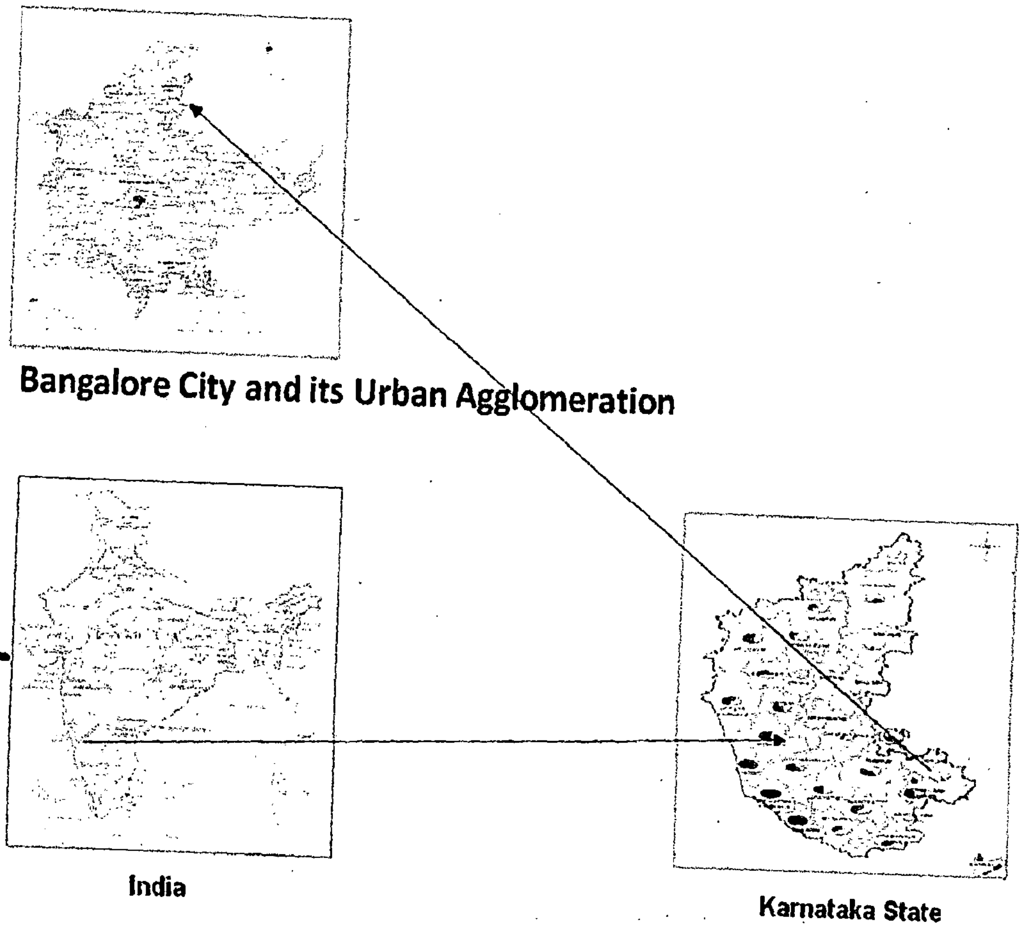


Fig. No. 2.4: Location Map of Bangalore City and its Urban Agglomeration

2.2. CLIMATE

The city enjoys a very agreeable climate free from all extreme weather condition. The climate of Bangalore is classified as the tropical wet and seasonally dries with four seasons. The dry season with clear bright weather is from December to February. The summer season from March to May is followed by the South-West monsoon from June to September. The temperature varies from a mean minimum of 15° C in December/January to mean maximum of 33.4° in April/May. The mean monthly relative humidity ranges from 44.00 % (min) in March to 85.00 % (max) in October. This city is blessed with both monsoons, e., South-West and North-East monsoon. The site meteorology has an important influence on the buildup, diffusion, and transportation of atmospheric pollutants, and therefore meteorological data was collected from India Meteorological Department (IMD) for a set of meteorological parameters from the IMD station in Bangalore. During the period May to September, the winds are MSW to W, while during the period November to March they are ENE to ESE. April to October is transition months when changeover from the Easterly to the Westerly wind regime and vice versa takes place.

2.3. RAINFALL

Bangalore city receives an average annual rainfall of 970 mm from southwest monsoon (June to September) and northeast monsoon (November to December) with nearly 70 rainy days spread over the year.

2.4. LAND USE PATTERN IN BANGALORE CITY

Land use is a basic tool for town planners to understand the function and distribution of different categories of existing land uses and for allocation of land for future in the desired and planned manner for the development of the cities. The land uses of the urban system is braodly classified into Residential, Commercial, Industrial, Public and Semi-public, Parks and Openspaces, Transportation, Unclassified uses, Agricultural land, Quarry, Vacant land, Watersheets, etc. The characteristics of land use in the study area is studied carefully, and is presented in Table 2.2 and in Fig. 2.5.

Table No. 2.2: Land Use Pattern in Bangalore City-2003

Sl. No.	Land Use	Area in Sq. km	Per cent
1	Residential	159.76	37.91
2	Commercial	12.83	3.04
3	Industrial	58.83	13.96
4	Public and semipublic	53.32	12.65
5	Parks and Openspaces	13.10	3.11
6	Transportation	88.31	20.96
7	Unclassified	35.26	8.37
	Sub Total	421.41	100.00
8	Agricultural land	649.27	-
9	Lakes and tanks	39.02	-
10	Quarry	9.61	-
11	Vacant	187.72	-
	Total	1307.00	-

Source: Revised Master Plan-2015

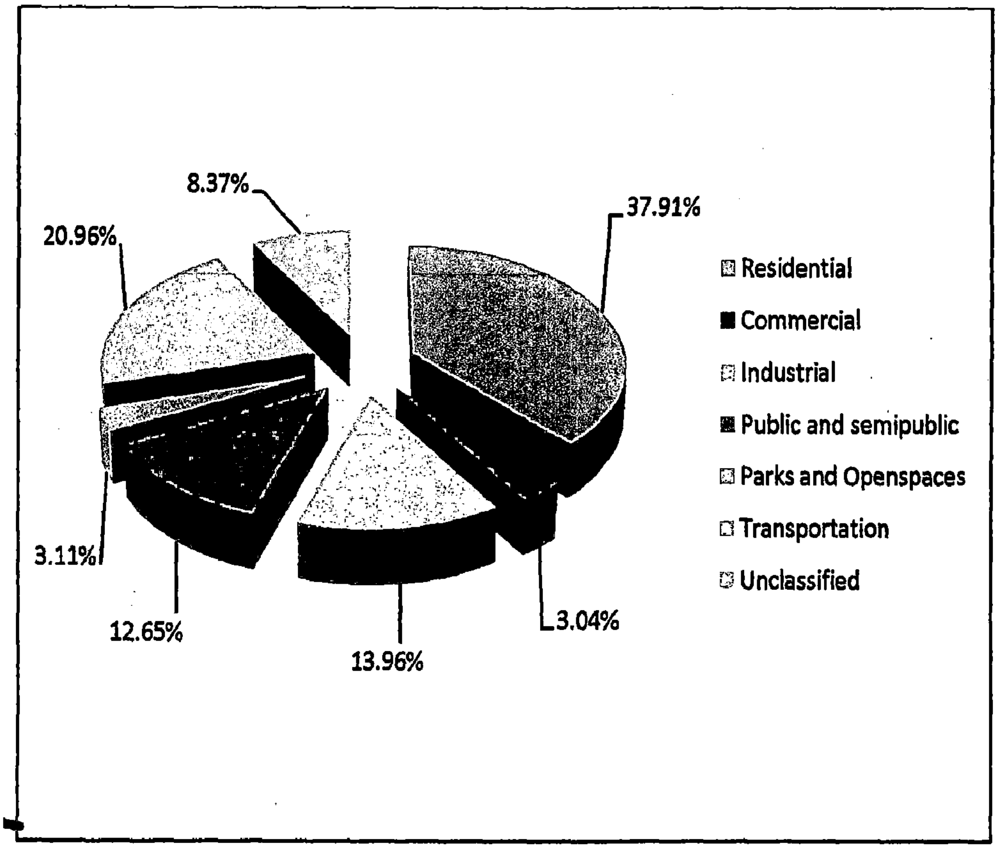
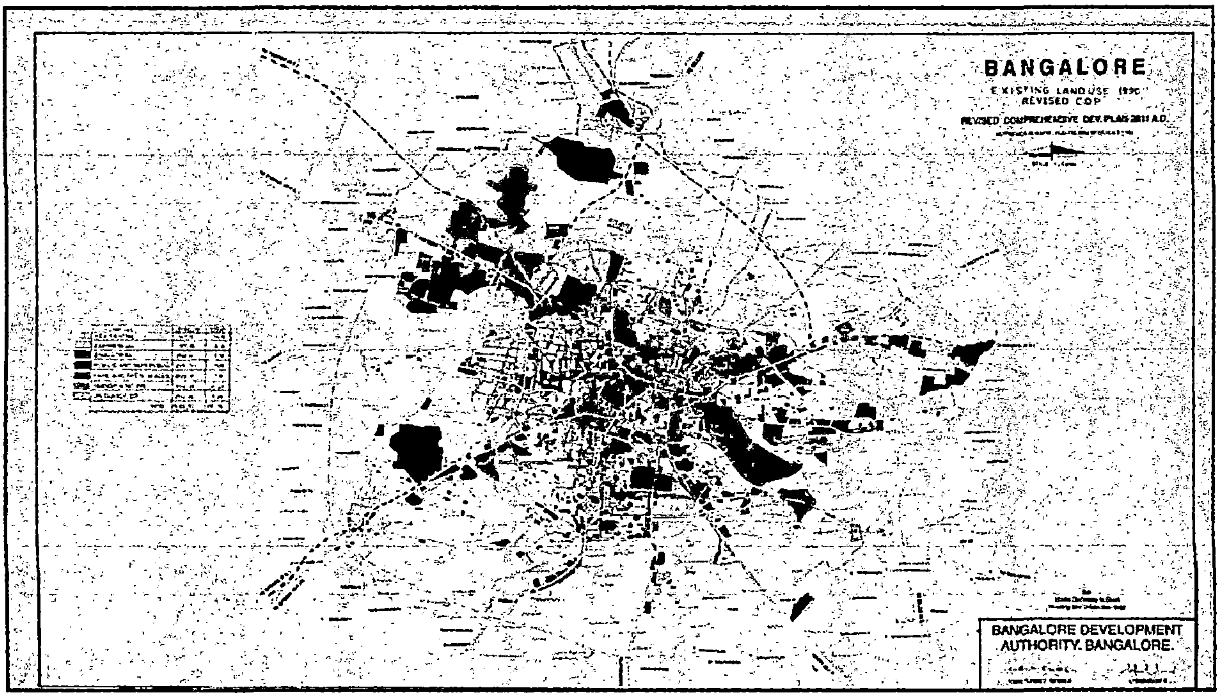


Fig. No. 2.5: Land Use Pattern in Bangalore City-2003

This table and this figure clearly shows that just above one-fifth (20.96 per cent) of the total land was used for transportation purpose. In many developed countries allocation of land for transportation use is between one-fourth to one-third of the total land available in urban areas. Land use in the study area in the year 1990 is presented in Fig. 2.6.

The existing spatial structure of Bangalore city can be classified into five major zones [129]. They are:

1. The Core area, which include traditional business areas, administrative center, and the Central Business District (CBD).
2. The Peri-central area, which include older planned residential areas, and institutional area.
3. The recent extensions, which include on both sides of the outer ring-road.
4. The new layouts, which lies on the outskirts of the city.
5. The greenbelt and the agricultural area, which lies on the city's outskirts.



Source: Comprehensive Development Plan (Revised) Bangalore-Report, Vol. I & II, Bangalore Development Authority, Bangalore, 1995.

Fig. No. 2.6: Existing Land Use Plan of Bangalore City, 1990.

2.5. DEMOGRAPHIC FEATURES

The study area is having a population of 5620139, comprising 10.63 per cent of the total population of the State, and spread over an area of 551.22 Sq. km, bearing a population density of 10710 persons per Sq. km. Population in Bangalore city is presented in Table 2.3.

Table No. 2.3: Demographic Characteristics of Bangalore City -2001

Sl. No.	State	Demographic Characteristics -2001				
		Population	Decadal Growth Rate in per cent	Density of Population (Persons/ sq. km)	Sex ratio	Literacy in per cent
1	Bangalore UA	5620139	37.69	10710	908	87.70

Source: Census of India-2001.

2.5.1. Decadal Growth of Population in the Study Area

The decadal growth rate of Bangalore Metropolitan area was gradually increased from the year 1901 to 1941 whereas there was a sudden increased is observed in it between the year 1941 and 1951, which is due to annexing the neighbouring residential areas and the cantonment along with the metropolitan area. The decadal growth rate of population in Bangalore Metropolitan area is presented in Table 2.4 and in Fig. 2.7, and it has been observed that the population in the study area is increased considerable between 1901 and 2001.

Table No. 2.4: Decadal Growth Rate of Population in Bangalore City

Sl. No.	Year	Bangalore Metropolitan area	
		Population in Million	Per cent Increase
1	1901	0.228	-------
2	1911	0.260	14.500
3	1921	0.311	19.200
4	1931	0.396	27.500
5	1941	0.510	28.900
6	1951	0.991	94.900
7	1961	1.207	21.400
8	1971	1.664	36.700
9	1981	2.913	76.200
10	1991	4.130	41.360
11	2001	5.686	37.690

Source: Census of India-2001

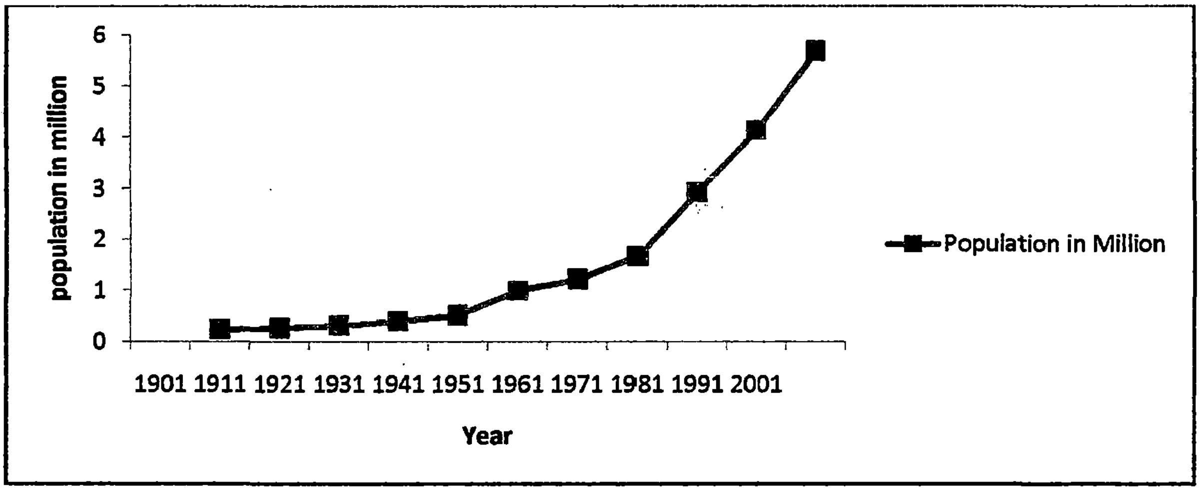


Fig. No. 2.7: Decadal Growth Rate of Population in Bangalore City

2.5.2. Demographic Characteristics in the Study Area

Population of Bangalore City and its Urban Agglomeration is 5701446, which is 10.63 per cent of the total population of the Karnataka State. Population and the literacy rate in the study area is presented in Table 2.5 and it reveals that the male to female population ratio in the study area is 52.41: 47.59 per cent, and the male to female ratio in literacy rate is 89.20: 79.80 per cent.

Table No. 2.5: Demographic Characteristics -2001

Sl. No.	Particulars	Bangalore City and its Urban Agglomeration	
1	Population	5701446	-
	i) Male	2988561	52.41
	ii) Female	2712885	47.59
2	Literate	5000168	87.70
	i) Male	5085689	89.20
	ii) Female	4549754	79.80

Source: Census of India-2001

2.5.3. Population Density

The study area is having the population of 5701446 and the geographical area of 551.22 Sq. km., with population density of 10710 persons per Sq. km. In the study area, Bangalore City Corporation is having the highest contribution of 76.75 per cent in terms of population and 40.15 per cent in terms of area. At the same time, Kengeri Town Municipal Council is having the lowest contribution of 0.76 per cent in terms of population and

Krishnarajapura is having the lowest contribution of 3.86 per cent in terms of area. The overall population density of the study area is 10710 persons per Sq. km.

This population density also varies among the various settlements of the study area. It ranges from 19489 persons per Sq. km in Bangalore City Corporation limit to 1249 persons per Sq. km in Kengeri Town Municipal Council limit as presented in Table 2.6. The higher concentration of population in Bangalore City Corporation areas may be due to high degree of access to bus stations, railway stations to reach work place; concentration of educational institutions, shopping centers, recreational and entertainment facilities; concentration of various economic activities, available job opportunities, commercial and business activities; intensive infrastructural facilities, good connectivity, etc.

The sex ratio in the study area is 908, which is lower than the sex ratio of Karnataka State (965) and India (933). It is observed that in the study area, sex ratio in Dasarahalli is the lowest (844) and in Kengeri Town Municipal Council limit it is the highest (939). In other settlements of the study area, the sex ratio varies marginally. In the study area, low sex ratio is may be due to the higher degree of population, male population belong to lower, middle, economically weaker class of working population migrated to this city in search of job opportunities in skilled and unskilled sectors. The distribution of population, area, population density and sex ratio in the Bangalore city and its Urban Agglomeration is presented in Table 2.6 and distribution of area in Bangalore Urban Agglomeration is presented in Fig. 2.8.

2.5.4. Literacy Rate and Household Size in the Study Area

The literacy rate is considered as one of the major indicators in assessing the quality of life in any system. The study area has the literacy rate of 87.70. In the study area, the Bangalore City Corporation limit is having the highest literacy rate of 85.60 per cent, whereas the Pattanagere City Municipal Council area is having the lowest literacy rate of 78.70 per cent. The male and female literacy rate in Bangalore City Corporation Area is 89.70 and 81.10 per cent, which is higher compared to other parts of the Bangalore City's Urban Agglomeration.

Table No. 2.6: Distribution of Urban Agglomeration Area and Population Density in Bangalore City

Sl. No.	City/Town	Civic Status	Population	Per cent	Area in Sq. Km	Per cent	Population Density in Persons/ Sq. km	Sex Ratio
1	Bangalore (M. Corp. +OG)	MC	4313248	76.75	221.32	40.15	19489	918
2	Dasarahalli (CMC + OG)	CMC	293359	5.22	38.00	6.89	7720	844
3	Pattanagere (CMC + OG)	CMC	105699	1.88	66.00	11.97	1602	881
4	Bommanahalli (CMC + OG)	CMC	230181	4.10	43.60	7.91	5279	870
5	Mahadevapura (CMC + OG)	CMC	154223	2.74	46.20	8.38	3338	865
6	Krishnarajapura (CMC)	CMC	186210	3.31	21.30	3.86	8742	912
7	Byatarayanapura (CMC + OG)	CMC	200530	3.57	47.00	8.53	4267	903
8	Yelahanka (CMC + OG)	CMC	94234	1.68	33.80	6.13	2788	864
9	Kengeri (TMC)	TMC	42455	0.76	34.00	6.17	1249	939
10	**Bangalore Urban Agglomeration**	**City Corporation**	**5620139**	**100.00**	**551.22**	**100.00**	**10196**	**908**

Source: Census of India-2001

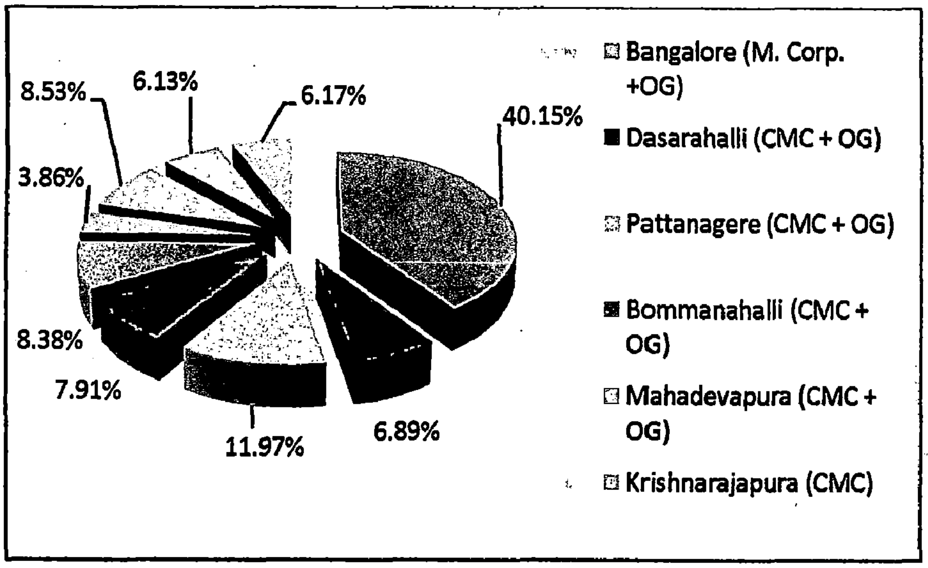


Fig. No. 2.8: Distribution of Area in Bangalore Urban Agglomeration

Bangalore City and its Urban Agglomeration is having the population of 5620139 and are confined in 1258623 numbers of households, and the average household size of 4.46. In the study area, Bangalore City Corporation is having the highest household size of 4.54 persons per household, and Dasarahalli City Municipal Council area is having the lowest household size of 3.93 persons per household. The literacy rate, number of households and household size in Bangalore City and its Urban Agglomeration is presented in Table 2.7.

Table No. 2.7: Literacy Rate and Household Size in the Study Area

Sl. No.	City/Town	Literacy Rate in Per cent			No. of Household	Household size
		Person	Male	Female		
1	Bangalore (M. Corp. +OG)	85.60	89.70	81.10	948918	4.54
2	Dasarahalli (CMC + OG)	82.60	88.50	75.60	74704	3.93
3	Pattanagere (CMC + OG)	78.70	84.50	72.00	24603	4.30
4	Bommanahalli (CMC + OG)	80.80	86.30	74.50	55119	4.18
5	Mahadevapura (CMC + OG)	81.90	88.10	74.70	36945	4.17
6	Krishnarajapura (CMC)	84.80	89.50	79.70	41762	4.46
7	Byatarayanapura (CMC + OG)	81.80	86.70	76.40	44230	4.53
8	Yelahanka (CMC + OG)	83.30	89.20	76.50	21518	4.38
9	Kengeri (TMC)	83.60	89.20	77.70	9824	4.32
10	Bangalore Urban Agglomeration	87.70	89.20	79.80	1258623	4.46

Source: Census of India-2001

2.6. ECONOMY

Bangalore city is turned into an engine of economic growth not only in Karnataka State but also in India since 1970s. Information and Communications Technology (ICT) industries started to function since 1970s in the city. This city has larger number of Information and Communications Technology (ICT) industries besides other types of industries, which include manufacturing industries, construction based industries, biotechnology based industries, etc. it has been observed that about half (47.00 per cent) of the biotechnology based companies confined in the city of the total biotechnology based companies in India. The Bangalore Metropolitan Region (BMR) has about 70,000 industries of which about 10.00 per cent of them are confined in the study area (Bangalore Metropolitan Area). This city gives employment opportunities to the larger size of the population and it has been observed that the organized sector itself gives employment opportunities to 2.40 million people and approximately 1.00 lakh unorganized small industries also provide about 10 employees each which accounted for about 1.00 million employees in the unorganized sector [192]. The rapid growth of information technology sector in the city not only attracts the people from within the country but also from across the globe. Larger number of multinational companies have come to the city and started their operations. As a consequence, larger size of resource mobilization took place and has been functioning, which strengthen the economy further in the city. By and large, the city turned into a vibrant city in terms of technology development and adoption, industrial growth, and growth in tertiary sectors of the economy. The employment opportunities in the organized sector in the city are presented in Table 2.8 and in Fig. 2.9.

Table No. 2.8: Distribution of Employment in Different Segments

(Number/ Per cent)

Sl No.	Category	No. of workers in lakhs	Per cent
1	Primary sector	0.05	0.85
2	Manufacturing	2.54	43.42
3	Electricity, gas and water supply	0.08	1.37
4	Construction	0.06	1.03
5	Transport, storage and communication	0.43	7.35
6	Banking and insurance	0.65	11.11
7	Trade and business	0.21	3.59
8	Services	1.84	31.45
	Total	**5.85**	**100.00**

Source: JNNURM - City Development Plan for Bangalore-2006.

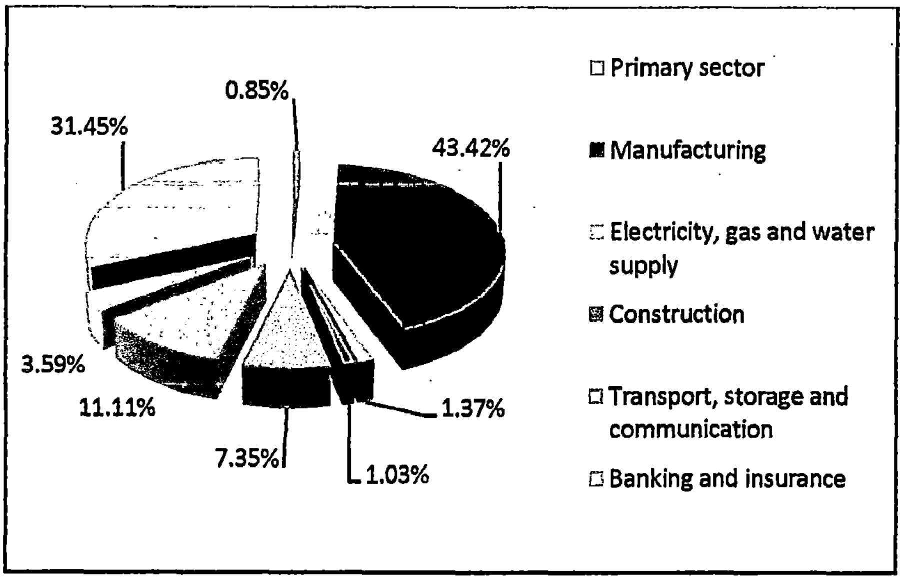


Fig. No. 2.9: Distribution of Employment in Different Segments

It has been observed that there is a great disparity in income, socio-economic status and the standard of living between the employees of Information and Communication Technology companies and the employees of the rest of the companies. The Information and Communications Technology companies pay much more to its employees whereas the rest of the industries/companies pay very less to their employees. The higher disposable income of Information Technology sector influence the rest of the parameters which are functioning in the city and noted among them are real estate, transportation, recreation and entertainment, etc. As a consequence, the land values are skyrocketed in the city. Cost of living is increased manifold in the city, the rental values increased manifold in the city and so on whereas the poor and the middle income group people started to go to the periphery of the city and settle over there after selling their belonging which are confined in the core area of the city.

2.6.1. Bangalore City's Contribution to Karnataka's Economy:

The Bangalore city is the key contributor to the economic growth of the State. Its contributions are substantial and it has more potential to contribute more and more for not only the development of the State, but also to the country. Salient features of Bangalore's economy are given below:

- This city contributes about one-fourth (22.00 per cent) of the State's economy.
- This city and its Urban Agglomeration accounts for less than 0.50 per cent of the State area, but it contributes three-fourth (75.00 per cent) of the corporate tax collections, four-fifth (80.00 per cent) of sales tax collections, and nine-tenth (90.00 per cent) of luxury tax collections in the State.
- This city attracts more than one-tenth (11.00 per cent) of the FDI in the country, which ranks next to Delhi and Mumbai as an investment destination.
- In 2004-05, more than 110 new multinational firms were established in the city. At present, total 512 multinational companies were established in the city.
- This city has seen a five-fold growth of state tax revenues during the period 1990-2003, which is unparalleled in the country. While tax revenues, as a ratio to GDP of most States has remained constant.
- This city plays a prominent role in international electronics, telecommunications, and information technology industries contributing about two-fifth (40.00 per cent) of India's production in high-technology industrial sectors (Madon, 1997).
- The city has around 1550 information technology companies (BangaloreIT.co.in).
- This city accounts for almost one-third of the software employment and exports of the country.

2.7. ECOLOGY

The ecology subsystem consists of area under forest, flora and fauna, lakes, ponds, and the greenbelt. The ecology subsystem plays a significant role in the functions of this urban system. Constructive interaction between built and natural environment results in healthy community and high quality of life. In the study area, the land under parks and open spaces has decreased by 2.21 per cent in last three decades; on the other hand, land under transportation network has increased three and half times during the same period. It implies that transportation network has been adversely affecting the ecological subsystem of the system (Study area). Water bodies like lakes and tanks act as soothing spaces in the city and also acts as open spaces, which is a bare necessity in aesthetic view point, and also these spaces functions as recreational points, and most of the time they are fulfilling the requirement of domestic water supply to the growing population. Bangalore has a water-spread area of 2.50 Sq. km. Water bodies in this city accounts for 0.47 per cent of the geographical area of the city. This city was blessed with good number of tanks, lakes, and water steams. Though this city is blessed with 390 tanks within the jurisdiction of Bangalore Development Authority (BDA) in the year 1987, it is shrunken into 262 in 1990s, and only 81 remain today. The larger lakes in Bangalore city are namely, Ulsoor lake, Sankey tank, Hebbal lake, Yelahanka lake, Bellandur lake, Madivala lake, and Lalbagh garden space. Most of the important tanks and lakes have been lost due to rapid growth of urbanization, unplanned growth and development of extensions, rapid development of housing construction activities, absence of urban planning, public policies, absence of concerned authorities to preserve the tanks and lakes in the study area. The lakes in the study area which were converted into different purposes are presented in Table 2.9., the existing lakes with their extent of the area in this city is presented in Table 2.10., and the distribution of water bodies in Bangalore Development Authority jurisdiction is presented in Table 2.11, and it reveals that there are 608 lakes exist in the study area, which consists of minor, small, medium, large and very large lakes with the total spread over area of 4572.80 hectares.

Table No. 2.9: List of Lakes Converted for Different Purposes

Sl. No.	List of Lakes	Present Use in the Lake Area
1	Akkithimmanahalli tank	Housing Layout and Hockey stadium
2	Binny Mill Tank	Commercial use
3	Challaghatta Tank	Golf Course
4	Dasaiahnakere Tank	Residential use
5	Dharmambudhi Tank	Bangalore City Bus Stand
6	Domlur Tank	BDA Layout
7	Kadugondanahalli Tank	Dr. Ambedkar Medical College
8	Koramangala Tank	Sports Complex
9	Kodihalli Tank	Housing Layout
10	Kurubarahalli Tank	Housing Layout
11	Millers Tank	Housing Layout
12	Nagashettyhalli Tank	Space Department Building
13	Sampangi Tank	Kanteerava Stadium
14	Sholay Tank	Football Stadium
15	Srinivagilu Tank	Housing Layout
16	Subhash Nagar Tank	Housing Layout

Source: Seethalakshmi, S., Preservation of lakes towards sustainability in Fringe areas of Bangalore, MURP Thesis, University of Mysore, 2005.

Table No. 2.10: Existing Lakes in Bangalore City

Sl. No.	Name of the Lake	Area in Hectare
1.	Varthur Lake	180.40
2.	Vibhuthipura Lake	30.20
3.	Doddanakkundi Lake	23.07
4.	Kundalahalli Lake	10.48
5.	Kaikondanahalli Lake	7.47
6.	Chinnappanahalli Lake	56.80
7.	Kasavanahalli Lake	8.91
8.	Haralur Lake	5.16
9.	Bantkondanahalli Lake	42.00
10.	Bheemanakuppe Lake	39.60
11.	Byappanahalli Lake	3.23
12.	Yellamalappa Chetty Lake	110.00
13.	Basavanapura Lake	56.60
14.	Kalkere Lake	75.00
15.	Rachenahalli Lake	60.00
16.	Yelahanka Lake	135.68
17.	Gramada Lake, Allalasandra	16.84
18.	Kacharakanahalli Lake	22.57
19.	Jakkur Lake	50.00
20.	Amruthahalli Lake	9.35
21.	Rampura Lake	5.00
22.	Seegehalli Lake	5.00
23.	Kodigehalli Lake	21.00
24.	Kattigenahalli Lake	2.50
25.	Kogilu Lake	180.00

Source: Seethalakshmi, S., Preservation of lakes towards sustainability in Fringe areas of Bangalore, MURP Thesis, University of Mysore, 2005.

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Table No. 2.10: Existing Lakes in Bangalore City

Sl. No.	Name of the Lake	Area in Hectare
26.	Amani Lake, Singanayakanahalli	178.00
27.	Chikkamaranahalli Lake	10.00
28.	Madhavara Lake	24.00
29.	Dasarahalli Lake	21.00
30.	Doddabidarakallu Lake	18.40
31.	Hosa Lake, Shivapura	49.00
32.	Andralli Lake	46.70
33.	Narasappa Lake, Kario banahalli	7.75
34.	Herohalli Lake	13.49
35.	Hosa Lake, Nallkadarenahalli	8.10
36.	Chikkabanavarahalli Lake	27.52
37.	Laxmipura Lake	4.00
38.	Byramangala Lake	350.00
39.	Bovibassappana Lake, Malathahalli	27.10
40.	Dodda Lake, Hosahalli	24.16
41.	Gangondanahalli Lake	15.00
42.	Hala Lake, Nayandahalli	5.80
43.	Dore Lake, Uttarahalli	11.57
44.	Subramanyapura Lake	11.00
45.	Kombgatta Lake	15.00
46.	Moga Lake, Uttarahalli	6.24
47.	Maragondanahalli Lake	56.80
48.	Puttenahalli Lake	32.00
49.	Lalbagh Lake	12.90
50.	Yediyur Lake	6.45
51.	Byarasandra Lake	6.19
52.	Sarakki Lake	0.81
53.	Hulimavu Lake	50.47
54.	Ara Lake	15.16
55.	Jigani Lake	120.00
56.	Alahalli Lake	7.69
57.	Gottegere Lake	2.00
58.	Begur Lake	39.69
59.	Agrahara Lake, Begur	165.00
60.	Govindashetty Lake, Kondappanna Agrahara	4.00
	Total	2552.85

Source: Seethalakshmi, S., Preservation of lakes towards sustainability in Fringe areas of Bangalore, MURP Thesis, University of Mysore, 2005.

Table No. 2.11: Distribution of water bodies in Bangalore Development Authority Jurisdiction

Sl. No.	Type of lakes and Area in Hectares	Number of Lakes	Water Spread Area in Hectare
1	Minor (less than 2 hectare)	285	194.00
2	Small (between 2 and 8 hectare)	185	833.10
3	Medium (between 8 and 25 hectare)	94	1220.00
4	Large (between 25 and 50 hectare)	29	1003.40
5	Very large (more than 50 hectare)	15	1322.30
	Total	608	4572.80

Source: Lake Development Authority, Bangalore -2003.

2.8. ENVIRONMENT

The term 'environment' in a collective sense ordinarily means the surroundings, the circumstances in which human beings live or the surroundings and circumstances which influence their lives. The term environment can also define as "the sum of the total elements, factors, and conditions of the surroundings, which may have an impact on the development action or survival of an organism or group of organisms". The environmental subsystem plays a major role in the urban system; better environmental quality is a precondition for healthy living of the people. Traffic congestion, slow traffic speed, poor maintenance of vehicles, redundant technology, high traffic density, traffic noise, etc., deteriorates the environment. It has been observed that air and noise pollution level in the city are far beyond the acceptable limit.

The study area is having various highly polluting industries, which include Aluminium smelting, Basic drugs and pharmaceuticals, Caustic soda, Cement (200 tons per day and above), Copper smelting, Distilleries, Dyes and dye intermediates, Fertilisers, Integrated iron and steel plants, Leather tanning and processing, Oil refinery, Pesticide formulation and manufacturing, Pulp and paper (30 tons per day and above), Petrochemicals, Sugar (excluding distilleries), Thermal power plants and Zinc smelting, etc [181]. In the process of rapid urbanization quality of environment has been degraded to the larger extent in the study area, since it has all kinds of pollution.

2.8.1. Air Pollution

The quality and quantity of air is one of the most important aspects for maintaining good health, and economic prosperity of the nation. Population explosion, rapid growth and concentration of motorized vehicles, intensive increased in industrial and commercial activities, and progressive decline of green space are responsible for air pollution in the urban areas. The Karnataka State Pollution Control Board (KSPCB) has constantly measuring the air pollutants in different strategic points across the city and observed that vehicle emissions from the transport sector contribute 51221 tonnes of carbon monoxide (CO) and about 2467 tonnes of particulate matter (PM) annually. The pollution load in Mt/day in Bangalore city is presented in Table 2.12.

Table No. 2.12: Pollution Load in Bangalore City

Sl. No.	Pollutant Load in Mt/day			
	CO	NOx	HC	PM
1	207.00	29.70	117.40	8.10

Source: State of Environment Report,Bangalore-2008

The details of Air Quality Index values and quality criteria along the proposed metro corridors conducted by the Bangalore Metro Rail Corporation Limited in the year 2003 is presented in Table 2.13. This table reveals that the main pollutants like NOx, SPM, RSPM and CO are contributing above permissible limits in terms of Air Quality Index (AQI) values, in all stations except one displayed severe air pollution (>100) situation in the study area. The air index values and the criteria for the same are presented in Table 2.14.

Table No. 2.13: Details of Air Quality Index and Criteria at Metro Corridors

Sl. No.	Name of Stations	AQI Values	Air Quality Criteria
1	Yeshwanthpur	256	Severe Air Pollution
2	Navarang Junction (Rajajinagar)	148	Severe Air Pollution
3	Seshadripuram/ Swastik Circle	140	Severe Air Pollution
4	Anand Rao Circle	189	Severe Air Pollution
5	National College/ Vanivilas Circle	238	Severe Air Pollution
6	South End Circle	173	Severe Air Pollution
7	KIMS Circle	146	Severe Air Pollution
8	Sri Aurobindo Cirlce (Jayanagar 5th block)	178	Severe Air Pollution
9	KIMCO Junction Vijay Bus Depot Mysore Road	256	Severe Air Pollution
10	Vijayanagar Tollgate (Magadi Junction)	140	Severe Air Pollution
11	Okalipuram	310	Severe Air Pollution
12	Anil Kumble Circle	76	Heavy Air Pollution
13	Shanthala Silks (Majestic)	314	Severe Air Pollution
14	Trinity Circle	232	Severe Air Pollution
15	Cauvery Bhavan (Mysore Bank Circle)	241	Severe Air Pollution
16	Old Madras Road	194	Severe Air Pollution

Source: Detailed Project Report-2006, BMRCL, Bangalore

The Air Quality Index (AQI) in different strategic points which include industrial areas, residential areas and sensitive areas of Bangalore city is presented in Table 2.15. This table reveals that the Graphite India Industrial area is affected by severe air pollution as indicated by very high air quality indices. Peenya Industrial area marginally better, showing average quality levels of heavy air pollution. The situation in KHB Industrial area, which is moderately polluted, and also is better compared to other industrial areas. Only in residential and sensitive areas the air quality level is better but slightly polluted.

Table No. 2.14: Air Quality Index Values and Criteria

Sl. No.	AQI Values	Air Quality Criteria
1	0 – 25	Clean Air
2	26 – 50	Light Air Pollution
3	51 – 75	Moderate Air Pollution
4	76 – 100	Heavy Air Pollution
5	> 100	Severe Air Pollution

Source: Detailed Project Report of Bangalore Metro Rail Corporation Limited, Bangalore, 2005.

Table No. 2.15: Air Quality Index in Strategic Locations of Bangalore City-2006-07

Sl. No.	SPM	SO_2	NO_x	AQI	Rank	SPM	SO_2	NO_x	AQI	Rank	SPM	SO_2	NO_x	AQI	Rank
	Graphite India (Industrial Area)					KHB Industrial Area					Peenya Industrial Area				
1	398	23.4	31.4	124.3	SAP	160	22.1	31.0	68.5	MAP	210	21.0	31.0	79.5	HAP
2	328	22.9	31.8	108.2	SAP	173	20.7	30.3	70.4	MAP	196	20.5	29.0	74.9	MAP
3	222	22.4	32.2	83.7	HAP	99	19.9	19.9	46.9	LAP	227	18.8	29.0	81.2	HAP
4	204	19.7	34.0	79.1	HAP	102	17.5	22.4	47.7	LAP	336	18.0	23.6	103.0	SAP
5	332	23.8	39.1	113.5	SAP	129	20.5	28.8	59.2	MAP	293	18.2	27.4	95.3	HAP
6	525	28.9	24.8	152.7	SAP	192	15.1	22.8	67.7	MAP	290	9.9	18.7	85.4	HAP
7	647	15.7	31.6	176.9	SAP	144	14.9	32.0	61.4	MAP	171	11.7	21.1	60.0	MAP
8	900	13.8	31.5	232.7	SAP	236	15.3	32.1	83.1	HAP	174	13.4	29.6	66.3	MAP
9	1004	13.8	30.1	255.2	SAP	209	12.1	30.8	74.4	MAP	179	12.5	30.0	67.2	MAP
10	590	14.0	32.9	163.8	SAP	230	14.0	32.3	81.1	HAP	169	13.6	29.4	65.1	MAP
11	455	14.2	37.3	135.6	SAP	219	13.8	35.5	80.2	HAP	208	14.7	32.6	76.5	HAP
	AMCO Batteries Residential Area					**Victoria Hospital (Sensitive)**					**Yeshwanthpur Residential Area**				
1	160	22.1	31.0	38.2	LAP	255	24.1	31.1	47.8	LAP	218	21.0	29.3	29.3	42.4
2	173	20.7	30.3	38.5	LAP	225	19.4	26.8	41.3	LAP	162	21.6	31.2	31.2	38.3
3	99	19.9	19.9	26.9	LAP	130	15.9	27.6	31.4	LAP	123	19.8	30.0	30.0	33.4
4	102	17.5	22.4	27.3	LAP	141	18.3	22.3	31.2	LAP	151	17.0	20.8	20.8	31.0
5	129	20.5	28.8	33.7	LAP	165	12.3	25.5	32.3	LAP	163	21.6	37.2	37.2	40.8
6	192	15.1	22.8	34.8	LAP	144	17.5	33.1	35.7	LAP	165	20.0	25.6	25.6	35.5
7	144	14.9	32.0	34.1	LAP	184	11.4	29.3	35.2	LAP	136	16.8	29.2	29.2	33.0
8	236	15.3	32.1	42.8	LAP	167	14.2	27.5	34.1	LAP	131	13.4	38.5	38.5	35.0
9	209	12.1	30.8	38.5	LAP	192	13.6	31.3	37.7	LAP	158	13.4	34.7	34.7	35.9
10	230	14.0	32.3	41.8	LAP	260	12.8	33.4	44.6	LAP	248	13.5	32.2	32.2	43.2
11	219	13.8	35.5	42.1	LAP	245	12.4	33.5	43.0	LAP	187	14.2	37.8	37.8	40.2

Source: State of Environment Report Bangalore-2008.

2.8.2. Water Pollution

The availability of quality and quantity of surface and groundwater plays a significant role for providing domestic water to the growing population of larger cities with the limited resources. Over exploitation of water, poor sewerage system, frequent blockages, and rainwater stagnation, untreated and unplanned sewage treatment in industrial activities causes water pollution in the urban areas. Water is an important component in human life and it is used for all development purposes and any loss of beneficial use of water due to pollution amounts to deterioration of economic, ecological and human health.

Vrishabhavathi River, the erstwhile drinking water supply lifeline of the city has virtually been turned into a sewerage that carries highly polluted domestic and industrial wastes. According to Latha (2003) the surface quantity of Vrishabavathi river and lakes in and around this city including Vengaiahnakere, Benniganahalli, Kempambudi, Karithimmanahalli, Nyandahalli, Yediyur, Nagavara, Begur, Yellamallappa, Jakkur, Agaram and Bellandur lakes are highly contaminated with organic and inorganic pollutants [128]. Of the 1000 MLD sewage generated in the city, only 400 MLD or 40.00 per cent of it is collected and treated by the Bangalore Water Supply and Sewerage Board (BWSSB) and the remaining sewage is let out into storm water drains, which finds its way into lakes, tanks, and the groundwater. The surface water quality of selected localities of this city is presented in Table 2.16. This table reveals that the observed values of Fe, HCO_3, and TDS are far beyond the desired limits in the catchment areas of Vrishabhavathi River. The value of Ca is higher than the desired value in Nagarabhavi Ist stage. It has been observed that the value of Mg is higher than the desired value in Kamakshipalya industrial area and Nagarabhavi area. Further, the value of Cl and SO_4 is higher than the desired value in Nandini Layout; the value of TH is higher than the desired value in Kamakshipalya Industrial area and Nagarabhavi area; the value of pH is higher than the desired value observed in the Nandini Layout in the study area.

Table No. 2.16: Surface Water Quality in Vrishabhavathi River Catchment Area

Sl. No.	Parameter	Desirable limits	Peenya Industrial Area	Nandini -Layout	Kamakshipalya Industrial Area	Rajaji-nagar Industrial Area	Mysore Road	Nagarab-havi Ist Stage
1	Ca mg/l	75	67	61	72	54	66	78
2	Mg mg/l	30	20	22	34	24	30	41
3	Na mg/l	-	130	549	162	161	140	154
4	K mg/l	-	17	13	20	19	26	23
5	Fe mg/l	0.30	1.40	3.00	0.68	1.20	1.95	0.38
6	HCO_3 mg/l	200	412	436	490	441	466	529
7	Co_3 mg/l	-	Nil	83	Nil	Nil	Nil	Nil
8	Cl mg/l	250	140	372	148	123	115	140
9	No_3 mg/l	45	11	43	25	30	26	23
10	So_4 mg/l	200	10	383	64	47	62	74
11	TDS mg/l	500	630	1780	800	750	730	830
12	SC µhmos/cm	-	1100	2900	1390	1210	1250	1450
13	TH mg/l	300	248	240	316	232	284	360
14	pH	6.5-8.5	7.68	9.03	7.81	7.28	7.71	7.81
15	F mg/l	1.0	0.24	0.34	0.26	0.29	0.22	0.25

Source: Lata, 2003.

2.8.2.1. Groundwater Pollution

Rapid urbanization, the poor sewerage system and improper disposal of waste have caused heavy groundwater pollution in the study area. Overexploitation of groundwater has also resulted in high concentration of pollutants such as hardness, iron, pH, nitrate and total dissolved solids (TDS) in the study area. It has been observed that 58.00 per cent of groundwater in the study area is not potable due to contamination with nitrates, phosphates, iron and the high hardness values. The groundwater quality in Vrishabhavathi river catchment area is presented in Table 2.17. Industries which are confined in the study area is more or less responsible for pollute water with a wide range of contaminants. This includes toxic chemicals, lubricants, pathogens, hazardous compounds, oil and grease, dyes, suspended solids, and non-biodegradable matter.

Table No. 2.17: Groundwater Quality in Vrishabhavathi River Catchment Area

Sl. No.	Parameter	Desirable limits	Peenya Industrial Area	Nandini -Layout	Kamakshipalya Industrial Area	Rajaji-nagar Industrial Area	Mysore Road	Nagarab-havi Ist Stage
1	Ca mg/l	75	173	51	83	94	122	134
2	Mg mg/l	30	49	36	33	24	45	43
3	Na mg/l	-	187	67	117	151	125	165
4	K mg/l	-	2	1	8	1	16	9
5	Fe mg/l	0.30	0.55	0.45	0.698	0.25	0.17	0.025
6	HCO_3 mg/l	200	549	287	456	529	407	508
7	Co_3 mg/l	-	Nil	Nil	Nil	Nil	Nil	Nil
8	Cl mg/l	250	316	76	98	109	190	207
9	No_3 mg/l	45	54	18	27	1	66	71
10	So_4 mg/l	200	98	64	69	69	122	104
11	TDS mg/l	500	1190	490	700	750	920	1020
12	SC µhmos/cm	-	2080	840	1210	1320	1560	1740
13	TH mg/l	300	628	272	340	332	484	508
14	pH	6.5-8.5	7.03	7.83	7.46	7.78	7.44	7.08
15	F mg/l	1.0	0.24	0.37	0.22	0.37	0.28	0.29

Source: Lata, 2003.

2.8.3. Noise Pollution

Absence of regular vehicle inspection, routine maintenance, usage of outdated vehicles, intensive increase in vehicular movements, regular traffic jams, traffic congestions, movement of vehicles like bumper-to-bumper, overcrowding of buses, prevailing inefficient traffic management system, etc., cause for high level of noise pollution in urban areas. There are numerous effects on the urban environment due to increase in noise levels. The increasing ambient noise levels in public places from various sources, inter-alias, construction and other commercial activities, generator sets, loud speakers, public address systems, music systems, vehicular horns, and other mechanical devices have harmful effects on civic health and the psychological well-being of the people. It is observed that the noise levels in the city are found to be much higher than the permissible limit which is prescribed by the Central Pollution Control Board (CPCB). It is also generally observed that the noise levels during the festivals are above the permissible limits, especially during the festival season. Noise levels in the study area in the year 2007 are presented in Table 2.18, and this table reveals that the noise levels are above the permissible limits prescribed by the authorities.

Table 2.18: Noise Pollution in Bangalore City-2007

Sl. No.	Noisiest Spots	Permissible Level in dB	Noise Levels in dB in 2007
1	Queen's Circle	65	87-91
2	Kempegowda junction	65	89-94
3	Gandhi Bazaar	65	79-85
4	St. John's Hospital	50	87-95
5	Martha's Hospital	50	88-96
6	Anand Rao Circle	65	82-87
7	West of Chord Road	65	83-87
8	MG Road	65	87-95

Source: Times of India: July 2007. Noise Levels in Day Time.

2.9. INFRASTRUCTURE

Infrastructure is one of the most important parameters, which decides the functions of the system. The quality and quantity of available physical, social, and economic infrastructures in the study area clearly establishes the level of development of the system. Adequate, modern, efficient and economic infrastructure facilities are the essential pre-requisite for day-to-day smooth functioning of economic activities in the system, and also for its future expansion. Improved infrastructure and services make good living environment, improvement in the quality of living, etc. The available infrastructure facilities have been classified into physical, social and economic infrastructure, and are presented as below:

2.9.1. Physical infrastructure

The available physical infrastructure in terms of quality and quantity is having significance to create competitiveness over the others. The more important physical infrastructure services, such as transportation and communication, power, water supply, sewage, etc., are briefly discussed as below: However, the transportation infrastructure is presented in the next Chapter.

2.9.1.1. Water Supply

The study area receives water from two important rivers namely, Arkavathi and Cauvery. The treated water from both sources is distributed by the Bangalore Water Supply and Sewerage Board (BWSSB). The main sources of surface water of Arakavathi are TG Halli reservoir and Hesaraghatta Lake. Bangalore City Corporation's required 1464 MLD (Million Litres per Day), of water by the year 2007, which is siphoned from Hesaraghatta reservoir, Arkavathi Tributory, and river Cauvery. The available quantity of water during the same year was 923 MLD, the gap between the demand and supply was 541 MLD. The water supply and the gap between the demand and supply for different periods is presented in Table 2.19 and the surface water sources available in the study area is presented in Table 2.20. To fulfill the growing demand of domestic water, the Bangalore Water Supply and Sewerage Board (BWSSB) and the private agencies are drawing ground water. The number of bore wells and the drawing ground water capacity by the above agencies are presented in Table 2.22. Bangalore Water Supply and Sewerage Board (BWSSB) is unable to meet the WHO water requirement standard of 150-200 litres per capita per day (LPCD) The quantity of drinking water supplied has declined from 145 LPCD in 1995 to 76 LPCD in 2007 in the study area [181] and the per capita consumption of water in Bangalore city from 1910 to 2007 is presented in Table 2.21.

Table No. 2.19: Water Demand and Supply in Bangalore City

Sl. No.	Parameter	1991	2001	2007
1	Population in lakhs	40.80	58.00	65.26
2	Water demand in MLD	924	1433	1464
3	Available Supply of water in MLD	372	647	923
4	Supply gap in MLD	552	786	541

Source: State of Environment Report Bangalore-2008

Table No. 2.20: Surface water sources of Bangalore City

Sl. No.	Sources	Commissioned	Distance in km	Installed Capacity in MLD	Availability in MLD
1	Hesaraghatta	1896	18	36	0
2	Arkavathi (TG Halli)	1933	28	148	58
3	Cauvery Stage I	1974	100	135	145
4	Cauvery Stage II	1982	100	135	146
5	Cauvery Stage III	1993	100	270	324
6	Cauvery Stage IV Phase I	2002	100	270	250
7	Cauvery Stage IV Phase II*	2011	100	(500)	0
	Total			994	923
8	BWSSB bore wells	7000			282
9	Private bore wells	80000			120
	Grand Total				1325

Source: State of Environment Report Bangalore-2008: BWSSB

*Under Development since 2007, installed capacity is proposed

Table No. 2.21: Per Capita Consumption of Water in Bangalore City

Sl. No.	Year	Liters per Capita per Day (LPCD)
1	1910	47.70
2	1921	67.05
3	1933	82.00
4	1951	48.15
5	1958	58.05
6	1967	90.00
7	1982	72.00
8	1991	80.00
9	2000	72.02
10	2001	73.03
11	2007	76.00

Source: BWSSB, Govt. of Karnataka, Bangalore City Indicator Programme Report- 2000 and 2006.

2.9.1.2. Solid Wastes Management

The generation of solid wastes is directly proportional to the growth of population and the population density of the city. Government of India has published Municipal Solid Wastes (Management & Handling) Rules, 2000 for controlling pollution by the Municipal Solid Waste (MSW). As per the Rules, it is necessary to form a committee for selection of sites for solid waste disposal and the Municipal Corporation, the Municipal Councils, and the Cantonment Boards have to take effective steps for processing of municipal wastes/ land filling on the sites, etc.

The Bangalore City is generating Municipal Solid Waste (MSW) to the tune of 3395 tonnes/day. Besides these, a total of 1366.70 MT/a bio-medical waste are also generated in this city. The Greater Bangalore City Corporation has taken all initiatives for deploying adequate manpower for collection, segregation, storage, transportation, processing and safe disposal of sewage for the specific area to the larger extent.

2.9.1.3. Sewage Waste

Bangalore City generates about 721.00 MLD sewage water. Bangalore City Corporation has constructed Sewage Treatment Plants for the treatment of sewage. Some of the Sewage Treatment Plants are in operation, and the construction work of the other Sewage Treatment Plants is in progress. Of the 721.00 MLD sewage, only 408.00 MLD sewage is being treated and the rest is directly discharged into the field. The Municipal Corporation has also not provided drainage network for collection and treatment of sewage for the entire area. As a result, about 313.00 MLD sewage quantities is still goes through open gutters and field without treatment that has caused backwash effects pertaining to environment in the surrounding area. The Present operating capacity of the sewage is 306 MLD, which is very low compared to the generated wastes per day in the study area.

2.9.1.4. Power

The unprecedented growth on population, the rapid development of economic activities, change in lifestyle, requirement of efficient transport, etc., demands huge quantity of energy in the study area. Power generation in the study area is minimal, and this city is receiving more quantity of power supply from the neighbouring States. This city is blessed with a power station, which produce 128 MW power and is supplying to the study area. Besides this, Bangalore Electricity Supply Company (BESCOM) collects electricity from various sources, and supply the same to satisfy the requirement. The increase in demand of power supply in Bangalore city alone by 600.00 megawatts annually [98].

2.9.2. SOCIAL INFRASTRUCTURE

Social infrastructure plays a significant role at the individual level, in societal level, city level, state and national level. Availability of quality and the quantity of social infrastructures plays a major role in the system, as it improves the quality of life. Good quality of social infrastructure attracts people from even across the globe. The most important social infrastructures, such as education and health services are considered for analysis and are presented as below:

2.9.2.1. Education

Education plays a very major role to mould the people into great human resources. It is an indispensable requirement to develop the human resources for inclusive development of the system. It is used as a tool to measure the social development of the Country. The available strong network of educational institutes produce a pool of qualified professionals, to and are working in various industries available in the study area. The Bangalore Urban District comprising of 3994 Primary Schools with 922781 students; 1573 High Schools with 301842 Students; 580 Pre-University Colleges with137610 students; 57 Polytechnic Colleges with 10223 students; 58 Engineering Colleges with 22503 students; 8 Medical (Allopathy) Colleges with 880 students; 8 Indian System of Medicine Colleges with 1689 students; 16 Dental colleges with 1020 students and 6 Universities. Educational facilities in Bangalore Urban District in the year 2006-07 are presented in Table 2.22, and the table depicts that the study area is blessed with larger number of educational institutions.

Table No. 2.22: Educational Facilities in Bangalore Urban District: 2006-07

Sl. No.	Educational Parameters	Number	Number of Students
1	Primary Schools	56441	922781
2	High Schools	1573	301842
3	Pre-University Colleges	580	137610
4	Polytechnic Colleges	57	10223
5	Engineering Colleges	58	22503
6	Medical (Allopathy) Colleges	8	880
7	Indian System of Medicine	8	1689
8	Dental Colleges	16	1020
9	Universities	6	

Source: Directorate of Economics and Statistics, Karnataka at a Glance, 2006-07, Bangalore.

2.9.2.2. Medical Facilities

The National Health Policy aims at providing universal health care and access to medical services, covering preventive and curative measures to all sections to have a healthy and prosperous society. Having the above in mind, the Karnataka State Government implemented several family welfare programs in this State.

The Bangalore Urban District has good number of health institutions comprising of 12 State Government Hospitals with 4327 beds; 41 private hospitals with 3992 beds; 6 Indian system of medicine hospitals with 396 beds; 31 Primary health centres with 566 beds; 42 Primary health units with 35 beds and 65 dispensaries with 4 beds each respectively. The available health facilities in Bangalore Urban District are presented in Table 2.23., and this table reveals that the Bangalore Urban District has good number of health institutions.

Table No. 2.23: Health Facilities in Bangalore Urban District: 2006-07

Sl. No.	Health Facilities	Number	Number of Beds
1	State Government Hospitals	12	4327
2	Other Agencies	41	3992
3	Indian System of Medicine	6	396
4	Primary Health Centres	31	566
5	Primary Health Units	42	35
6	Dispensaries	65	4

Source: Directorate of Economics and Statistics, Karnataka at a Glance, 2006-07, Bangalore.

2.9.3. ECONOMIC INFRASTRUCTURE

The strong, vibrant and efficient economic infrastructure plays a significant role in terms of growth and inclusive development of any system. It has been observed that the affluent families investing their savings in various banks and other financial institutions. In 2005, the Bangalore Urban District had 46 rural, 40 semi-rural, 8 urban banks; whereas the Bangalore Metropolitan area had 928 banks (bank branches). The amount deposits in Bangalore Urban District were 6511101 lakhs in the year 2005 whereas the amount of credit outstanding in Bangalore Urban District was 5034684 lakhs in the same year.

Table No. 2.24: Economic Infrastructures and their Transactions in Bangalore Urban District

Sl. No.	Parameters	Quantity
1	Regional Rural Banks: Number	12
2	Commercial Banks: Number	1045
3	Cooperative Banks: Main Offices: No.	50
3.1	Cooperative Banks: Branches: No.	140
4	Other Cooperative Banks: No.	48
5	P.L.D. Banks	3
6	Credit Co-operative Societies: Agricultural	51
6.1	Credit Co-operative Societies: Non-Agricultural	565
6.2	Total Agricultural and Non-Agricultural	616
7	Non-credit co-operative societies	
7.1	Marketing: No.	4
7.2	Housing: No.	322
7.3	Milk: No.	382
7.4	Others: No.	29
7.5	Total: No.	737
8	Liquidated Co-operative Societies	
8.1	Credit (No.)	36
8.2	Non-credit (No.)	106
8.3	Total Credit and Non-credit	142
9	Agricultural Regulated Marketing: Main Market (No.)	2
9.1	Sub-market	7
9.2	Total Main and Sub-Market	9

Source: Directorate of Economics and Statistics: Karnataka at a Glance, 2006-07, Bangalore

Table No. 2.25: Financial Transaction in Bangalore Urban District

Sl. No.	Financial Transaction	Unit	Amount in Rs.
1	Regional and Commercial Transactions		
1.1	Total Deposits: Rs. In Crores	In Crores	112343
1.2	Total Credit Rs. In Crores	In Crores	86628
1.3	Credit Deposit Ratio		77.11
2	Co-operative Banks Transactions		
2.1	Deposits (Rs. In lakhs)	In Lakhs	321505.71
2.2	Loan Advanced (Rs. In lakhs)	In Lakhs	358324.00
3	Other Co-operative Banks and PLD Banks		
3.1	Total Loans (Rs. In lakhs)	In Lakhs	1723.30
4	Credit and Non-credit Societies		
4.1	Loans given by agricultural credit co-operative societies: Short tem (Rs. In crores)	In Crores	9.88
5	Market and Sub-market transactions		
5.1	Turnover (Rs. In lakhs)		200778.13

Source: Directorate of Economics and Statistics: Karnataka at a Glance, 2006-07, Bangalore.

Bangalore city is also blessed with good number of trade and commercial institutions, etc. At present, Information and Communications Technology Industries, Information Technology Enabled Services (ITeS), Biotechnology and manufacturing industries, etc., play a significant role in the development of economy of the city. The available economic infrastructures and their transactions for the year 2007 are presented in Table 2.24 and Table 2.25.

The available infrastructural facilities in the study area is summarized, and are presented in Table 2.26.

Table No. 2.26: Summary of Infrastructure Status in Bangalore City

Sl. No.	Sector	Parameters	Service Delivery Levels
1	Water	Coverage	100 per cent BMP area
			CMCs & TMC 20 per cent
		Quantum of water supply available	995 mld
		Available daily per capita water supply	73 lpcd
		Frequency of water supply	3-5 hrs on alternate days
2	Sewerage and Sanitation	Coverage	BMP area 40 per cent of total area
		Disposal of sewerage capacity	408 mld
		Present operating capacity	306 mld (three-fourth of the capacity)
		Wastewater generated daily	721 mld
3	Municipal Solid Waste Management	Coverage	100 per cent BMP area
		Waste generated	3395 TPD
		Waste collected	2715 TPD
		Collection Efficiency	80 per cent
		Segregation	10 per cent (practiced in few locations)
		Treatment and disposal facilities	Treatment facilities for 1000 TPD/landfill facilities being constructed
4	Roads	Quality	80 per cent tarred
		Length of roads in BMP area	3500 km
		Length of arterial roads	250 km
		Length of NH and SH	100 km
		Length of roads in ULBs	2400 km
		No. of streetlights	2.5 lakh
5	Transport	No. of registered vehicles	23 lakh
		No. of buses (BMTC owned)	3300
		Daily passenger trips	32 lakh
		Congestion	Exceeds 1 in 52 corridor/links
		Noise in decibels	Above 80 in most areas (beyond permissible levels
		Average speed of vehicles	12-18 kmph
		No. of accidents	7575 in 2005 3654 up to 20-06-2006
6	Parks	Coverage area	14 per cent
		Four Important Parks	Lalbagh
			Cubbon park
			Bannerghatta National park
			Dhanvantarivana
		Small parks	365
		Well developed parks	55
		Partially developed	105
		Not developed	180
7	Lakes	Coverage area	3.00 per cent of the total CDP area

Source: JNNURM-City Development Plan for Bangalore, 2006.

2.10. INSTITUTION

It consists of administrative institutions confined in the city exclusively for city development starting from the local self-government to the Greater Bangalore City Corporation (GBCC). The development authorities, corporations and various departments are involved in providing facilities and services to the people, which include, Bangalore Development Authority (BDA), Bruhat Bangalore Mahanagara Palike (BBMP), Bangalore Metropolitan Transport Corporation (BMTC), Bangalore Water Supply and Sewerage Board (KWSSB), Public Works Department (PWD), Motor Vehicles Department, Police Department, etc., The Institution subsystem plays a major role in policy planning, evolving developmental plans, annual plans, programs, schemes, their implementation and evaluation, etc., however, overlapping of jurisdictions, multiplicity of work, and lack of coordination among these institutions are big hurdles in efficient functioning of these institutions.

The following statutory authorities are responsible for providing urban infrastructural facilities to the general public. The objectives and functional responsibilities of various agencies in Bangalore city is presented in Table 2.27.

2.11. HUMAN RESOURCE DEVELOPMENT INDICATORS

Human Development Index (HDI) is an average of three different indicators which include longevity, as measured by life expectancy at birth; educational attainment, as measured by combination of adult literacy and combined gross primary, secondary, and tertiary enrollment; and standard of living as measured by real per capita GDP. The indexes for longevity and educational attainment are computed relative to fixed minimum and maximum values. The minimum and maximum values for life expectancy in the HDI are 25 years and 85 years. In 2001, the top-ranked countries in the world according to the GDI were Norway, Australia, Canada, Sweden, and Belgium.

The Gross Domestic Income (GDI), Human Development Index (HDI), Health Index, Gender Index, Education Index and Income Index for the year 1991 and 2001 is presented for the study area in Table 2.28. This table reveals that all the listed variables values are increased between 1991 and 2001 period, which shows that the study areas is developed considerably during this period.

Table No. 2.27: Objectives and Functions of Key Stakeholders in Bangalore City

Sl. No.	Agency	Objective	Functions performed
1	Karnataka State Pollution Control Board (KSPCB)	KSPCB was established to regulate the discharge of sewage, effluents, air emissions, hazardous and biomedical waste under the Water (Prevention and Control of pollution) Act, Air (Prevention and Control Pollution) Act, Hazardous Waste (Management and Handling) Rules and Biomedical Waste (Management and Handling) Rules. KSPCB is the primary agency responsible for safeguarding the environment in consonance with the existing legislation	A central function is the management of constant for establishment and operation of industries, offices, and healthcare establishment to ensure compliance with environmental legislation. Further functions include monitoring of environmental performance of industries, offices and other establishments as well as periodical analysis of water bodies, effluents discharged and air emitted.
2	Bangalore Metropolitan Region Development Authority (BMRDA)	BMRDA plans, coordinates and supervises the orderly development of areas within the jurisdiction of BMR. It was created with the purpose of being the central coordinating agency among all the concerned agencies and corporations including BDA, BWSSB, KIADB, KPTCL, and KSRTC, BMTC, etc.	The authority plans and develops new urban blocks, townships and roads within BMR. It identifies infrastructure requirements and formulates schemes to raise finance and extends assistance to other agencies.
3	Department of Industries and commerce	The objective of the department is to recognize and address the needs of industries and catalyse industrial development. Its key objective is strengthening of industrial base to harness its potential as driver for socio-economic development	Key functions of the department include formulation and implementation of state policies, facilitation of dialogue between entrepreneurs and the government, enhancing competitiveness of the through modernization, technology up gradation and adoption of best practices through its specialized agencies.
4	District Industry Centres (DICs)	It was created with the objective to further registration of micro and small-scale industries and to act as decentralized interface between industries and the department. DIC is a specialized agency of the Department of Industries and Commerce	The centre is issuing provisional registration certificates before the start of production and permanent certificates after commencement of production on voluntary basis. DIC also acts as facilitator of entrepreneurship development programmes of the Department of Industries and Commerce.
5	Karnataka Council for Technological Upgradation (KCTU)	Primary objective of the council is to enhance the competitiveness of micro and small enterprises (MSEs) though assisting entrepreneurs in the upgradation of technology, facilitation of diversification, cost reduction and quality enhancement. KCTU is a specialized agency of the Department of Industries and Commerce.	The council organizes workshops and seminars for industries on emerging topics such as quality management and certifications. It provides testing and calibration facilities, offers assistance in patent registration and guidance in modernization, plant design, product diversification and technology transfer.

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Table No. 2.27: Objectives and Functions of Key Stakeholders in Bangalore City

Sl. No.	Agency	Objective	Functions performed
6	Karnataka Udyog Mitra	Karnataka Udyog Mitra's objectives include the acceleration of industrial growth, attraction of investment, increase of exports and employment and reduction of regional imbalance. Karnataka Udyog Mitra is a specialized agency of the Department of Industries and Commerce.	The agency guides potential investors on government policies and infrastructural considerations and acts as facilitator in the establishment of new industrial projects and clearance procedures.
7	Bangalore Development Authority (BDA)	Bangalore Development Authority (BDA) is entrusted with the task of preparing a Comprehensive Development Plan (CDP) that is subject to revision every 10 years. The Bangalore Development Authority (BDA) is responsible for planning, implementation and monitoring of plans in the Bangalore Metropolitan Area (BMA), whereas Bangalore Metropolitan Regional Development Authority (BMRDA) is responsible for the surrounding region.	
8	Bangalore Metropolitan Regional Development Authority (BMRDA):	BMRDA is mainly responsible for developing outer regional development (areas outside the responsibility of BDA),	BMRDA also has an overseeing role over BDA, with authority to control and reject plans; in fact, there are recent examples of this being done. BMRDA also creates local planning authorities; for the Bangalore International Airport Planning Area (BIAPA), the local areas of Anekal, Hosakote, Kanakapura, Nelamangala and Magadi, the Bangalore-Mysore Infrastructure Corridor Planning Area (BMICA) and the Ramanagaram-Channapatna Urban Development Authority (RCUDA); and prepares "Structure Plans" for the planned development of the BMR Region.
9	Bangalore Metropolitan Transport Corporation (BMTC):	BMTC is responsible for inter-city bus operations and management, and is making substantial efforts to improve the bus network of the city. BMTC is the only pubic transport organization in any of the metropolitan regions in India that has succeeded in running at a profit.	
10	Bangalore Police Service (BPS)	Bangalore Police Service (BPS) is responsible for maintaining law and order, traffic management, and the implementation of social legislation.	In order to facilitate law enforcement and provide citizens of Bangalore with the different services offered by BPS, the department has integrated certain citizen-specific services.

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Table No. 2.27: Objectives and Functions of Key Stakeholders in Bangalore City

Sl. No.	Agency	Objective	Functions performed
11	Bangalore Electricity Supply Company (BESCOM)	BESCOM is responsible for power distribution in the six districts of Karnataka. BESCOM covers an area of 41092 Sq. km with a population of over 168 lakhs.	In order to facilitate use by the citizens of Bangalore of the different services provided by BESCOM, the department has integrated the citizen-specific services with BangaloreOne.
12	Bruhat Bangalore Mahanagara Palike (BBMP):	Bangalore has been expanding its jurisdictional limits so as to take in more peripheral areas. Bangalore Mahanagara Palike (BMP) became Bruhat Bangalore Mahanagara Palike (BBMP); in English Greater Bangalore City Corporation (GBCC) by absorbing seven City Municipal Councils (CMC) and one Town Municipal Councils (TMC).	BBMP is mainly responsible for urban amenity developments (education, health, road connectivity, sanitation, etc).
13	Regional Transport Office (RTO):	The Transport Department is one of the largest revenue earners in the state of Karnataka.	It deals with various transport-related matters including driving licenses, motor vehicle registration, granting and renewal of permits, and other regulatory and enforcement functions. *In order to facilitate* access to its various services, the department has integrated certain citizen-specific services with BangaloreOne.
14	Bangalore Water Supply and Sewerage Board (BWSSB)	The BWSSB is responsible for providing water to the city and drainage out sewerage.	It maintains about 6000 km of existing water distribution lines and 4000 km of underground sewerage lines. Its aim is to ensure 24-hour water supplies. In order to facilitate access by the citizens of Bangalore to the different services provided by BWSSB, the department has integrated certain citizen-specific services with BangaloreOne.
15	Lake Development Authority (LDA)	Lake Development Authority (LDA) is an autonomous body established in July 2002. The LDA's main objectives were Resuscitation of lakes to boost aquifers, diversion and treatment of sewage to generate alternative sources of raw water, improving sanitation and health conditions and preserving the habitat of aquatic life.	Its task was to function as an important axis in the drive for lake restoration and management programme by acting as a nodal agency for conservation of all responsible agencies such as the BWSSB, BDA, BMRDA, BMP, Zilla Panchayat and the Forest Department. Jurisdiction of LDA extends over the entire BMR. The LDA has identified about 60 lakes from six different series of cascades for immediate restoration soon after it was established.

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Table No. 2.27: Objectives and Functions of Key Stakeholders in Bangalore City

Sl. No.	Agency	Objective	Functions performed
16	Departments of Urban Development and Transport		Policies and framework affecting transport sector
17	Bangalore Metro Rail Corporation Limited (BMRCL)		Public transport system-Metro rail
18	Indian Railways		Construction and operation of rail system
19	National Highway Authority of India (NHAI)		Construction and maintenance of National Highways
20	Karnataka Urban Infrastructure Development and Finance Corporation Limited (KUIDFC)		Infrastructure and finance

Source: Compiled by the Investigator

2.12. CITY DEVELOPMENT INDEX

"The City Development Index (CDI) is a broad policy-based indicator system, it is holistic, or intended to look at the health of cities or sectors as a whole, inclusive, covering area beyond the realm of a single management structure, and pluralist, intended to foster or inform a dialogue between the different parties involved in urban development. It is largely driven or integrated with the process of establishing urban strategies and policies".

City Development Index (CDI) is an index to compare the performance of the city. It is considered to be the best single measure of the development in cities. It is a composite index made of five sub-indices for infrastructure, waste management, health, education, and city product. The sub-index infrastructure depends on the number of water connections, sewage, electricity and telephone connections. The rest of the sub-indices have been normalized to give a value between 0 and 1. It is defined at the city level and could also be taken as a measure of average well-being and access to urban facilities by individuals and it is a proxy for the capital and physical capital assets of the city.

Table No. 2.28: Human Resources Development Indicators of Bangalore Urban Between 1991-2001

Sl. No.	Indicators	Bangalore Urban		
		1991	2001	Increase/Decrease
1	**Population Characteristics**			
1.1	Rural population in per cent	14	12	-2.00
1.2	Urban population in per cent	86	88	2.00
1.3	Population density (persons/km^2)	2210	2979	769.00
1.4	Sex Ratio (females/1000 males)	903	906	3.00
1.5	Total literacy rate in per cent	76	83	7.00
1.6	Male literacy rate in per cent	83	88	5.00
1.7	Female literacy rate in per cent	69	77	8.00
2	**Health Characteristics**			
2.1	Life expectancy in years	65	67	2.00
2.2	Crude birthrate	26	20	-6.00
2.3	Crude death rate	7	6	-1.00
2.4	Infant mortality rate	64	45	-19.00
2.5	Fertility rate	3	1.9	-1.10
2.6	Population served per medical institution	26,589	37,185	10,596
2.7	Access to safe drinking water in per cent	82	96	14.00
2.8	Toilet facility in per cent	73	85	12.00
3	**Economic characteristics**			
3.1	Incidence of poverty	3	10	7.00
3.2	Per Capita GDP (1993-94 prices, in INR)	9816	24774	14958
3.3	Per worker GDP (estimate in INR)	32961	63641	30950
3.4	Work participation rate in per cent	34	39	5.00
3.5	Work participation male in per cent	53	58	5.00
3.6	Work participation female in per cent	13	19	6.00
3.7	Primary share in per cent	4	2	-2.00
3.8	Secondary share in per cent	45	38	-7.00
3.9	Tertiary share in per cent *	51	60	9.00
4	**Human resource indices**			
4.1	GDI	0.592	0.731	0.139
4.2	HDI	0.623	0.753	0.130
4.3	Health index	0.663	0.705	0.042
4.4	Gender index	0.592	0.731	0.139
4.5	Education index	0.757	0.887	0.130
4.6	Income index	0.449	0.666	0.217

Source: Human Resources Development Report-2005, Government of Karnataka.

*Shift in workers participation in different sectors of the economy is observed.

The formulae used for calculating City Development Index (CDI) are as below:

Infrastructure = 25 * Water Connections + 25 * Sewage + 25 * Electricity + 25 * Telephone

Waste = Wastewater treated * 50 + Formal Solid Waste Disposal * 50

Health = (Life expectancy – 25) * 50/60 + (32 – Child Mortality) * 50/31.92

Education = Literacy * 25 + Combined enrolment * 25

Product = (log City Product – 4.61) * 100/5.99

City Development Index (CDI) = (Infrastructure Index + Waste Index + Education Index + Health Index + City Product Index)/5.

The City Development Index of Bangalore city is 58.00, City product is 51.10, Infrastructure is 82.70, Waste is 31.30 and Health is 76.50; Whereas the City Development Index of Stockholm is 97.40, City product is 93.50, Infrastructure is 99.50, Waste is 100.00 and Health is 94.00. The City Development Index (CDI) for few cities in the World is presented in Table. 2.29 and it shows that Bangalore city stands at 15 among the listed cities.

Table No. 2.29: City Development Index for Selected Cities in the World

Sl. No.	City	CDI	City Product	Infrastructure	Waste	Health
1	Stockholm	97.40	93.50	99.50	100.00	94.00
2	Melbourne	95.50	90.00	99.80	100.00	93.70
3	Singapore	94.50	91.60	99.50	100.00	92.70
4	Hong Kong	92.00	89.40	99.30	99.00	90.90
5	Moscow	89.90	81.00	98.70	86.80	83.80
6	Seoul	86.00	65.30	98.40	100.00	88.70
7	Rio de Janeiro	79.40	82.30	86.20	62.60	81.90
8	Sofia	79.10	70.90	93.70	58.50	86.20
9	Hanoi	74.20	59.60	72.00	90.00	80.60
10	Havana	71.00	65.00	74.80	50.00	80.70
11	Jakarta	69.20	66.20	57.30	46.70	80.20
12	Ulaanbaatar	68.40	53.70	59.00	90.00	72.50
13	Lahore	61.10	71.10	78.50	50.00	64.90
14	Colombo	58.40	46.90	68.60	45.00	86.20
15	Bangalore	58.00	51.10	82.70	31.30	76.50
16	Dhaka	48.40	55.60	45.30	27.50	64.60
17	Vientiane	47.10	44.00	58.00	-	62.30
18	Accra	46.60	49.40	50.00	-	71.40
19	Phnom Penh	43.50	40.20	33.00	27.00	47.20
20	Port Moresby	39.30	69.00	18.10	10.00	59.10
21	Lagos	29.30	42.10	29.50	2.00	44.00
22	Niamey	21.70	40.00	22.00	-	78.30

Source: Epilogue: The City Development Index (CDI).

2.13. STRENGTH-WEAKNESS-OPPORTUNITIES AND THREATS (SWOT) ANALYSIS

The system (urban system) has its own merits and demerits. Basically the urban system is very complex in nature. It is interwoven with the human population and available basic resources for survival. Further, this is percolated into deeper level in terms of interdependency among the subsystems of the urban system. The analysis of functions of the all subsystems and their interdependency gives little knowledge about the urban system. Therefore, the urban system has its own strengths, weaknesses, opportunities and threats. The strength-weakness-opportunities-threats (SWOT) analysis on Bangalore city is presented in Table 2.30. This SWOT analysis could be used to further strengthening various fields and to achieve better performance in long-range planning, and to minimize the adverse effects in the urban system.

Table No. 2.30: SWOT Analysis of Bangalore's Position

Strengths	**Weaknesses**
• Salubrious climate • Water availability in Cauvery basin • Presence of rich bio-diverse lakes/tanks • Academic Institutions • Availability of a pool of talent/skill base • Cosmopolitan culture • Diverse and balanced industrial base-manufacturing to high-end services • Experience in building large infrastructure projects on PPP formats.	• Land use/ Planning issues-absence of clear CBD, locked up land (defence and railways) • Infrastructure "shadow areas" and under equipped outskirts. • Increasing economic disparity in the society. • Shortage of middle and low income housing stock. • Administrative and structural differences between BMP (the core city) and CMCs.
Opportunities	**Threats**
• Continuing upwards on the value curve – in academics and in eco-friendly, high-technology industries and R & D. (biotechnology, nano-technology, high end outsourcing, logistics) • Capacity for planned unlocking of land in the city and its periphery. • Utilizing the citizen's/ NGOs willingness and ability in participate governance of the city. • Building upon experience gained in formulating infrastructure projects on a PPP format.	• Population explosion • Infrastructure deficiency • Competition from other cities (both metropolises and tier 2 cities), especially from those in Southern India. • Delays in policy formulation and implementation in the area of urban governance/ management.

Source: JNNURM-City Development Plan for Bangalore, 2006.

2.14. CONCLUSION

In this Chapter, the Investigator has attempted to have an in-depth knowledge about various aspects of the study area, like climatological factors, meteorological factors, physiography, historical growth, dynamics of growth and development pattern, demographic characteristics, various infrastructure including housing, water supply, sewerage, education facilities, objective and functional responsibilities of various government agencies involved in the planning and management of city. The available different modes of transportation, their characteristics and the problems of transportation system in the study area are presented in the subsequent Chapter-3.

CHAPTER-3

TRANSPORTATION SYSTEM IN BANGALORE METROPOLITAN AREA

3.0 INTRODUCTION

Bangalore city is one of the largest cities in Karnataka State and the capital city of Karnataka State. This city has been undergoing tremendous amount of pressure due to population explosion, unprecedented growth of vehicular population, especially proliferation of personalized two-wheeler mode of vehicles, increase in rate of vehicle ownership, heterogeneous traffic, narrow roads, grossly inadequate road network capacity, inadequate and inefficient public transportation system, absence of mass transportation system, disproportionate modal split, absence of dedicated lane based on type of vehicles, increase in high rate of environmental degradation which include air pollution, noise pollution, water pollution and land pollution; absence of integrated land use and transportation planning, urban sprawl, increase in use of fossil fuel consumption, long distance journeys, long journey hours, over crowding of public transport buses in peak hours, inadequate transportation infrastructure for pedestrians and non-motorized transport users; lack of parking areas, delays, severe congestion in peak hours, traffic chaos, movement of vehicles like bumper-to-bumper, road accidents, breakdowns; absence of urban transport policies, absence of coordination among the authorities; wide gap in terms of mobility and income level between the rich and poor, etc. The study area has the worst road traffic in India considering the few factors, which include motorization index of 362, about 800 road accidental deaths per year with Accident Severity Index of 11.85, about 4500 official traffic violations per day, the majority of strategic locations indicating the Air Quality Index (AQI) is more than 75 and noise level is more than 9-decibels [9], congestion cost of Rs. 208 million per day in terms of lost time [190], about 30 vehicles stolen per day, overcrowded buses with average loading of 57 passengers with average distance between bus shelters of 2.69 km [9]. As a consequence, the economy of the city suffers to the larger extent. Detailed analysis has been done about the transportation problems and its prospectus in the study area, and is presented as below:

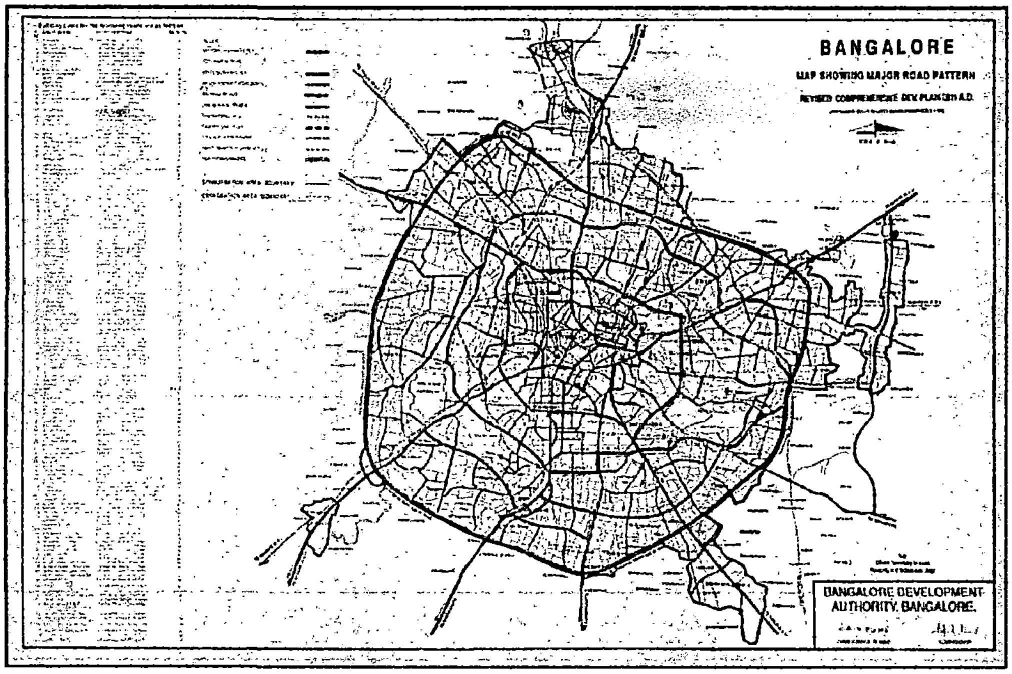
3.1. ROAD NETWORK IN BANGALORE METROPOLITAN AREA

Efficient and well-planned Road network plays a significant role for the greater mobility of the people and goods, and leads to economic prosperity of the urban system. The study area, Bangalore city, is blessed with a radial pattern of road network converging towards the core area of the city. The older parts of the city including the Central Business District (CBD) were developed organically with inadequate rights-of-way and very narrow roads. The study area road is blessed with different kinds of roads, which include ring roads, i.e., Core Ring Road (CRR), Outer Ring Road (ORR), Peripheral Ring Road (PRR), Intermediate Ring Road (IRR), Satellite Township Ring Road (STRR); Expressways; Airport Link Road; National Highways, State Highways; Arterial Roads, Sub-arterial roads, and other link roads. The total road network of the city is 5900 km after merging seven city municipalities, one town municipal council areas and 111 surrounding villages with existing City Corporation then named Bruhat Bangalore Mahanagara Palike (BBMP). The available road length in the study area is presented in Table 3.1, and this table reveals that above nine-tenth (93.00 per cent) of the total road lengths are ordinary roads, above one-twentieth (5.94 per cent) is arterial and sub-arterial roads, and a very meager of 1.06 per cent of them are outer ring road in the study area. The National highways (NH) and State highways (SH) are passing through the city, and are account for about 100 km of the total city roads. The road network of the Bangalore city is presented in Fig. 3.1 and in Fig. 3.2.

Table No. 3.1: Road Length in Bangalore Metropolitan Area

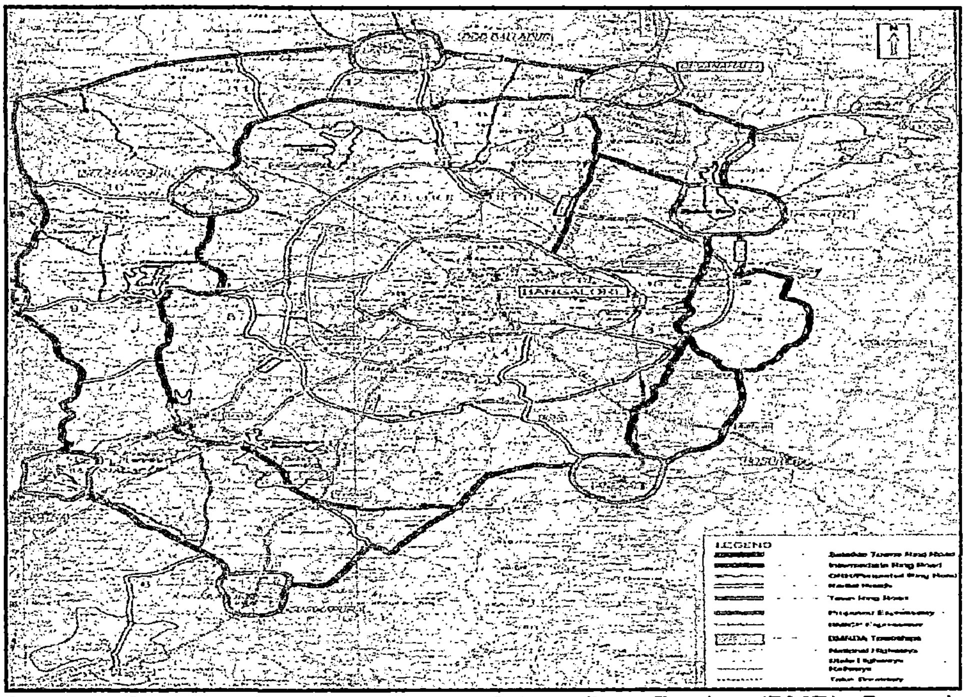
Sl. No.	Particulars	Road Length in Kms	Per cent
1	Ordinary Road Length (Others)	5488	93.00
2	Arterial/Sub-arterial Road Length	350	5.94
3	Outer Ring Road Length	62	1.06
	Total Road Length	**5900**	**100.00**

Source: Compiled by the Investigator.



Source: Comprehensive Development Plan (Revised) Bangalore-Report, Vol. I & II, Bangalore Development Authority, Bangalore, 1995.

Fig. No. 3.1: Bangalore City Road Network.



Source: Structure Plan, Bangalore Metropolitan Region (BMR), Bangalore Metropolitan Region Development Authority, Government of Karnataka, 2006.

Fig. No. 3.2: Satellite Town Ring Road-Intermediate Ring Road-Peripheral Ringoad

The Bangalore city road network is characterized by poor structure, improper continuity and connectivity. Most of the roads are inadequate rights-of-way to cater to growing traffic at an acceptable level of service. Most of these roads are not possible to widen in future to accommodate the growing traffic demand in the city since ribbon development took place both sides of the road and also these roads are illegally occupied by the informal sectors like vegetable vendors, hawkers, road side sellers, street dwellers, etc. Further, these roads are also used for on-road parking, which in turn reduces the effective width of the roads. It has been observed that about four-fifth (80.00 per cent) of the road network has a Right of Way (ROW) of less than 30 m, thereby limiting the road widths in the study area. The increase in road area and road length is not commensurate with the increase in vehicular growth in the study area, which in turn reduces the traffic speed. The average speed of traffic in Bangalore city was decreased from 15-18 kmph to less than 10 kmph between 1990 and 2006 [158].

The distribution of roads with different carriage-widths in the study area is presented in Table 3.2, and this table reveals that about three-fourth (70.11 per cent) of the total road length are confined in the ordinary roads. Followed by, about one-fourth (23.38 per cent) of them confined to two-lane undivided two-way. The road length confined among them are four-lane divided two way, two-lane undivided one-way, four-lane undivided two-way, three-lane, six-lane divided, four-lane undivided one-way and six-lane undivided one-way are very little and their corresponding values are 3.36, 1.05, 0.84, 0.54, 0.53, 0.17, 0.008 per cent respectively.

Table No. 3.2: Distribution of Roads with Carriage Widths in Bangalore Metropolitan Area

Sl. No.	Type of Road	Road Length in km	Per cent
1	Ordinary Roads (Others)	4136.50	70.11
2	Two Lane Undivided Two Way	1379.20	23.38
3	Four Lane Divided Two Way	198.50	3.36
4	Two Lane Undivided One Way	62.30	1.05
5	Four Lane Undivided Two Way	49.70	0.84
6	Three Lane	31.60	0.54
7	Six Lane Divided	31.40	0.53
8	Four Lane Undivided One Way	10.30	0.17
9	Six Lane Undivided One Way	0.50	0.008
	Total	**5900.00**	**100.00**

Source: Compiled by the Investigator from Comprehensive Traffic & Transportation Plan for Bangalore, Rail India Technical Economic Service Ltd, 2006.

3.2. GROWTH OF AREA-POPULATION-VEHICULAR POPULATION

The concentration of vehicular population is the root cause of transportation problem in the study area which results into traffic congestion, environmental degradation, health problems, road accidents, etc. The per cent and cumulative per cent increase in area, total population and total vehicular population in the study area between the year 1971 and 2006 is presented in Table 3.3. This table reveals that the cumulative per cent of area has been increased by 150.42 per cent between the year 1971 and 2001. Further, it has been observed that the cumulative per cent increase in population and total vehicular population between the year 1971 and 2006 were 177.62 and 739.82 per cent respectively in the study area. It has also been observed that the total area has been increased above three times from 1971 to 2001; the total population and the total vehicular population have been increased about 4.20 and 57 times between the year 1971 and 2006 respectively. This table clearly shows that the growth of urban area is not commensurate with increase in population, and also increase in vehicular population in the study area. It is interesting to note that the ratio of total vehicle to total population was 1:32 in the year 1971, 1:14.80 in the year 1981, 1:6.88 in the year 1991, 1: 3.7 in the year 2001 and 1: 2.35 in the year 2006, which also shows that the number of vehicular population is increasing in the study area over a period of time.

3.2.1. GROWTH OF DIFFERENT MODE OF TRANSPORTATION IN THE STUDY AREA

The study area is blessed with different mode of transportation which includes two-wheelers, three-wheelers, cars, jeeps, taxis, buses, trucks, tractors, trailers, maxi cabs and others. The available mode of vehicles in the study area between the year 1976 and 2006, and their growth are presented in Table 3.4. This table depict that the cumulative per cent increase of two-wheelers, three-wheelers, cars, jeeps, taxis, buses, trucks, tractors, trailers, maxi cabs and others are 493.07, 327.33, 384.54, 122.01, 420.10, 354.16, 390.00, 835.00, 863.85, 311.24, and 836.95 per cent respectively in the study area.

Table No. 3.3: Decadal Percentage Increase in Area - Population and Vehicular Population in Bangalore Metropolitan Area from 1971-2006

Sl. No.	Year	Area in sq. km	Per cent increas e	Cumulative Per cent increase	Total Population in Lakhs	Per cent increase	Cumulative Per cent increase	Total Vehicular Population	Per cent increase	Cumulative Per cent increase
1	1971	174.70	-	-	1664000	-	-	51987	-	-
2	1981	366.00	109.50	109.50	2913000	75.06	75.06	196969	278.88	278.88
3	1991	446.00	21.86	131.36	4130000	41.78	116.84	601059	205.15	484.03
4	2001	531.00	19.06	150.42	5686000	37.68	154.52	1687728	180.79	664.82
5	2006	NA	NA	NA	7000000	23.10	177.62	2967701	75.00	739.82

Source: Compiled by the *Investigator*.
Note: NA: Not Available

Table No. 3.4: Vehicular Population in Bangalore Metropolitan Area

(Number/ Per cent)

Sl. No.	Year	Two-wheelers			3 wheelers			Cars		
		Number	Per cent Increase	Cumulative Per cent Increase	Number	Per cent Increase	Cumulative Per cent Increase	Number	Per cent Increase	Cumulative Per cent Increase
1	2	3	4	5	6	7	8	9	10	11
1	1976	62199	0.00	0.00	8699	0.00	0.00	21760	0.00	0.00
2	1981	125600	101.93	101.93	10355	19.04	19.04	32429	49.03	49.03
3	1986	236726	88.48	190.41	10524	1.63	20.67	54885	69.25	118.28
4	1991	502707	112.36	302.77	23350	121.87	142.54	91883	67.41	185.69
5	1996	736798	46.57	349.34	46674	99.89	242.43	133540	45.34	231.03
6	2001	1162111	57.72	407.06	64001	37.12	279.55	221508	65.87	296.90
7	2006	2161663	86.01	493.07	94587	47.78	327.33	415645	87.64	384.54

Source: Compiled by the Investigator

Table No. 3.4: Vehicular Population in Bangalore Metropolitan Area

(Number/ Per cent)

Sl. No.	Year	Jeeps			Taxies			Buses		
		Number	Per cent Increase	Cumulative Per cent Increase	Number	Per cent Increase	Cumulative Per cent Increase	Number	Per cent Increase	Cumulative Per cent Increase
1	2	12	13	14	15	16	17	18	19	20
1	1976	2048	0.00	0.00	1045	0.00	0.00	3487	0.00	0.00
2	1981	3570	74.32	74.32	1171	12.06	12.06	5090	45.97	45.97
3	1986	5122	43.47	117.79	1717	46.63	58.69	5704	12.06	58.03
4	1991	6819	33.13	150.92	2783	62.09	120.78	4775	-16.29	41.74
5	1996	6245	-8.42	142.50	4239	52.32	173.10	12145	154.35	196.09
6	2001	6934	11.03	153.53	7062	66.60	239.70	22841	88.07	284.16
7	2006	6280	-31.52	122.01	19802	180.40	420.10	38835	70.00	354.16

Source: Compiled by the Investigator

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Table No. 3.4: Vehicular Population in Bangalore Metropolitan Area

(Number/ Per cent)

Sl. No.	Year	Trucks			Tractors			Trailers		
		Number	Per cent Increase	Cumulative Per cent Increase	Number	Per cent Increase	Cumulative Per cent Increase	Number	Per cent Increase	Cumulative Per cent Increase
1	2	21	22	23	24	25	26	27	28	29
1	1976	6081	0.00	0.00	1419	0.00	0.00	1121	0.00	0.00
2	1981	8545	40.52	40.52	1781	25.51	25.51	1637	46.03	46.03
3	1986	11366	33.01	73.53	496	-72.15	-46.64	446	-72.76	-26.73
4	1991	21758	91.43	164.96	2217	346.98	300.34	1915	329.37	302.64
5	1996	31238	43.57	208.53	4277	92.92	393.26	3778	97.28	399.92
6	2001	47683	52.64	261.17	6743	57.66	450.92	6100	61.46	461.38
7	2006	109114	128.83	390.00	32642	384.08	835.00	30651	402.47	863.85

Source: Compiled by the Investigator

Table No. 3.4: Vehicular Population in Bangalore Metropolitan Area

(Number/ Per cent)

Sl. No.	Year	Maxi Cabs			Others			Total		
		Number	Per cent Increase	Cumulative Per cent Increase	Number	Per cent Increase	Cumulative Per cent Increase	Number	Per cent Increase	Cumulative Per cent Increase
1	2	30	31	32	33	34	35	36	37	38
1	1976	NA	NA	NA	578	0.00	0.00	108437	0.00	0.00
2	1981	NA	NA	NA	475	-17.82	-17.82	190653	75.82	75.82
3	1986	NA	NA	NA	2269	377.68	359.86	329255	72.70	148.52
4	1991	NA	NA	NA	3941	73.69	433.55	684497	107.89	256.41
5	1996	2464	0.00	0.00	11852	200.74	634.29	993250	45.11	301.52
6	2001	4723	91.68	91.68	16436	38.68	672.97	1566142	57.68	359.20
7	2006	15093	219.56	311.24	43389	163.98	836.95	2967701	89.49	448.69

Source: Compiled by the Investigator

Further, it has been observed that the cumulative per cent growth of trailers, other and tractors are higher among the available mode of vehicles in the study area. Further, it has also been observed that other category vehicles, two-wheelers, trailers, tractors, cars, taxis, trucks, buses, three-wheelers and jeeps were increased about 75, 35, 28, 23, 19, 19, 18, 11, 11 and 3 times respectively between the year 1976 and 2006, whereas the maxi cabs were introduced in the year 1996 and it was increased about 6 times between the year 1996 and 2006 in the study area.

3.3. CONSUMPTION OF FOSSIL FUEL IN BANGALORE METROPOLITAN AREA

The unplanned, uncontrolled growth of cities and piecemeal approach of planning measures led to urban sprawl, horizontal expansion, low density development, imbalanced growth of new extensions, slum developments, illegal constructions, etc., in the study area. As a consequence, the consumption of fossil fuel in the transport sectors has been increased over a period of time. The consumption of fossil fuel in Bangalore urban area for the year 1998-99 and 2002-2003 is presented in Table 3.5. This table reveals that the cumulative per cent increase in petrol and diesel consumption in the study area are 35.27 and 24.96 per cent between the year 1998-1999 and 2002-2003 respectively. It has been observed that the cumulative per cent increase in petrol consumption is more that the diesel consumption in the same period which may be due to unprecedented growth of personalized two-wheelers and cars in the study area.

Table No. 3.5: Consumption of Fossil Fuel in Bangalore City

(Kilolitres/ Per cent)

Sl. No.	Year	Petrol in Kilolitres			Diesel in Kilolitres		
		Bangalore Urban	Per cent Increase	Cumulative Per cent Increase	Bangalore Urban	Per cent Increase	Cumulative Per cent Increase
1	1998-1999	225,566	-	-	274,339	-	-
2	1999-2000	239,964	6.38	6.38	291,850	6.38	6.38
3	2000-2001	273,649	14.03	20.41	301,340	3.25	9.63
4	2001-2002	310,151	13.34	33.75	320,434	6.33	15.96
5	2002-2003	314,852	1.52	35.27	349,284	9.00	24.96

Source: Indian Oil Corporation Limited.

3.4. DISTRIBUTION OF TRIPS BY PURPOSE IN BANGALORE METROPOLITAN AREA

The people's mobility invariably depends on few factors, which include the status of the head of the household, the vehicle ownership, family size, dependability, educational background, occupation pattern, financial status, standard of living, drastic change in socio-economic structure of the family, cultural background, religious activities, etc. The trips made for work purpose is dominant in any system whether it is urban or rural system. The per cent of trips by purpose in different periods of the study area is presented in Table 3.6, and this table reveal that the per cent of trips made for work purpose was reduced from 81.80 per cent to 58.50 per cent between 1965 and 2006, whereas for education purpose, it is increased from 4.20 to 23.50 per cent, and for other category purpose is almost constant.

Table No. 3.6: Percentage of Trips by Purpose

Sl. No.	Purpose	Per cent in 1965	Per cent in 1984	Per cent in 2006
1	Work	81.80	79.73	58.50
2	Education	4.20	3.73	23.50
3	Shopping – Retail	N.A.	5.31	N. A.
4	Shopping - Wholesale	N.A.	1.00	N. A.
5	Recreation	N.A.	6.49	N. A.
6	Health	N.A.	1.16	N. A.
7	Non-Home Based	N.A.	N. A.	2.94
8	Employer Business	N.A.	N. A.	0.38
9	Others	14.00	2.58	14.68
	Total	**100.00**	**100.00**	**100.00**

Source: (a) Central Road Research Institute, New Delhi
(b) Gowda, Rame., (1984), Urban and Regional Planning, Prasaranga, Mysore.
(c) Comprehensive Traffic & Transportation Plan for Bangalore, Rail India Technical Economical Service Ltd, 2006.

3.5. DISTRIBUTION OF TRIPS BY MODE AND TRIP LENGTH

The distribution of trips with different range of trip length performed by different mode of transport in the study area is presented in Table 3.7. This table illustrated that the total trips performed by the public transport buses are 2634471. Of which, above half

(54.27 per cent) of them covered maximum trip length in the range of 10-15 km; the total trips performed by car are 416304. Of which, above one-third (36.61 per cent) of them covered trip length in the range of 10-15 km; the total trips performed by two-wheeler are 1845476. Of which about two-fifth (39.29 per cent) of them covered trip length in the range of 5-10 km; the total trips performed by three-wheeler are 726425. Of which about two-fifth (38.53 per cent) of them covered trip length in the range of 2-5 km. The total trips covered by the bicycle are 139407. Of which above two-fifth (42.42 per cent) of them covered trip length in the range of 0-2 km; the total trips performed by walking are 523597.Of which, about cent per cent (99.52 per cent) of them covered the trip length in the range of 0-2 km in the study area. This table concludes that the maximum trips made by the public transport buses and car were covered the trip length of between 10-15 km; whereas maximum trips made by the two-wheeler covered the trip length of between 5-10 km; maximum trips made by the three-wheeler covered the trip length of between 2-5 km; the maximum trips made by the bicycle and walking mode of transport covered trip length of between 0-2 km respectively in the study area.

Table No. 3.7: Distribution of Trips by Mode and Trip length

(Number (Nos.)/ Per cent (%))

Sl. No	Trip length in km	Bus		Car		Two-wheeler		Three-wheeler		Cycle		Walk	
		Nos.	Per cent	Nos.	Per cent	Nos.	Per cent	Nos.	Per cent	Nos.	Per cent	Nos.	Per cent
1	00 - 02	197	0.01	46	0.01	142633	7.73	0	0.00	59137	42.42	521061	99.52
2	02 - 05	117434	4.46	27809	6.68	482306	26.13	279891	38.53	45390	32.56	2536	0.48
3	05 - 10	134333	5.10	151603	36.42	725082	39.29	165814	22.83	25509	18.30	0.00	0.00
4	10 - 15	1429620	54.27	152409	36.61	316173	17.13	192265	26.47	6560	4.71	0.00	0.00
5	15 - 20	612694	23.26	65318	15.69	135503	7.34	82399	11.34	2811	2.02	0.00	0.00
6	20 - 35	329555	12.51	17627	4.23	43779	2.37	5675	0.78	0.00	0.00	0.00	0.00
7	> 35	10639	0.40	1492	0.36	0.00	0.00	381	0.05	0.00	0.00	0.00	0.00
8	**Total**	**2634471**	**100.00**	**416304**	**100.00**	**1845476**	**100.00**	**726425**	**100.00**	**139407**	**100.00**	**523597**	**100.00**
9	**Per cent of trips**	**41.92**		**6.62**		**29.36**		**11.55**		**2.22**		**8.32**	

Source: Comprehensive Traffic & Transportation Plan for Bangalore, Rail India Technical Economical Service Ltd, 2006.

3.5.1. PER CAPITA TRIP RATE BY PURPOSE IN BANGALORE METROPOLITAN AREA

The trips by purpose with their corresponding percentages and per capita trip rate in the study area are presented in Table 3.8, and this table and figure reveal that the per capita trip rate of total trips is 0.924. The per capita trip rate for work, education, others, non-home based and employer business purpose trips are 0.542, 0.218, 0.122, 0.014 and 0.002 respectively in the study area. It has been observed that the per capita trip rate in work purpose is 0.542, which is higher among the other purpose trip rates.

Table No. 3.8: Per Capita Trip Rates by Purpose in Bangalore Metropolitan Area

Sl. No.	Trip Purpose	Total Trips	Per cent	PCTR
1	Work	3679636	58.54	0.542
2	Education	1477598	23.50	0.218
3	Others	922737	14.68	0.122
4	Non-home based	184799	2.94	0.014
5	Employer Business	20910	0.34	0.002
	Total Trips with Purpose	**6285680**	**100.00**	**0.924**

Source: Compiled by the Investigator based on Comprehensive Traffic & Transportation Plan for Bangalore, Rail India Technical Economical Service Ltd, 2006.

3.6. NON-MOTORIZED TRANSPORTATION

Non-motorized transportation plays a crucial role in mobility pattern of the urban system. The mobility pattern is widened between the rich and the poor. Inefficient and unaffordable public transportation and non-availability of cheap mode of transportation within the reachable limit causes for movement of people by foot. The pedestrian traffic volume on major junctions in Bangalore city is presented in Table 3.9. This Table and this figure reveal that the minimum and maximum pedestrian volume are 2114 to 19168 in different major junctions of the Bangalore city. Therefore, it is very much necessary to provide adequate pedestrian infrastructures in the city for safe movement of the pedestrians and also non-motorized infrastructure also necessarily integrate with the different mechanized mode of transportation infrastructure. In the year 2006, the modal split of the study area reveal that about 8.32 and 2.22 per cent of the total travel demand of the city was fulfilled by walking and bicycle mode of transportation in the study area.

The modal split of the different mode of transport vehicles in the study area is presented in Table 3.12 (c.ref).

Table No. 3.9: Pedestrian Traffic Volume on Major Junctions of Bangalore City

Sl. No.	Name of the Junctions	Peak Hour Pedestrian Traffic
1	Mysore Bank Circle	19168
2	K. G. Circle	10761
3	Ananda Rao Circle	9002
4	Yeshwantpur Circle	5475
5	South End Circle	4870
6	Malleswaram Circle	3579
7	Toll Gate Junction	2937
8	K. R. Cirlce	2778
9	Prof. Shivashankar Circle	2114

Source: Comprehensive Traffic and Transportation Plan for Bangalore-2006, RITES Ltd.

3.7. INTERMEDIATE PUBLIC TRANSPORTATION (IPT)

The Intermediate Public Transportation (IPT) plays a significant role in the towns and cities in Urban India and it has already penetrated to rural areas because of vehicles size, cheap mode of transport compare to car and other luxurious personalized vehicles. The Intermediate Public Transportation (IPT) is plying between the urban centre and the rural areas and vice-versa, where the frequency of public transportation is low or poor. The Intermediate Public Transportation refers to auto rickshaws and city taxis in the urban system. The floating population, the majority of the non-resident city population, and those who are not having access to public transportation nearby their localities are using auto rickshaws are maximum used for their mobility in the study area. In the study area, the Intermediate Public Transportation (auto-rickshaws) is used for education, shopping and other purposes. It has been observed the concentration of auto-rickshaws and taxis are very less in the study area in the year 2006 (c.ref. table 3.3). The annual rate of growth of auto-rickshaws and taxis in the study area are about 9.55 and 36.08 per cent between the year 2001 and 2006 respectively.

3.8. ADVANTAGES OF PUBLIC TRANSPORTATION

Public transportation plays a significant role in the urban system since it has high carrying capacity, occupies less road space, low consumption of fuel, environmental pollution level is within the acceptable limits, accident and breakdown rates are low, high level of safety and security, cost per kilometer is low compared to other modes of transportation, etc. Public transportation carries more number of people with less energy requirement. It has been observed that to transport 10,000 people for one kilometer in regular bus needed about 125 buses, if it is car needed 3333 cars (1:26.66); area about 3900 Sq. m is needed for buses, whereas for cars 48000 Sq. km area is needed (1:12.30); regular buses are consuming 40 litres of fuel, whereas cars consumes 400 litres for the same (1: 10). Buses are carrying 80 passengers, whereas car carrying capacity is 3 (1:26.67). Further, it has been observed that articulated and bi-articulated buses are more advantages than the regular buses in above all mentioned modes. To transport 10,000 people for one kilometer with different mode of transportation is presented in Table 3.10.

Table No. 3.10: To Transport 10,000 People for One Kilometre

Sl. No.	Parameters	Car	Minibus	Regular bus	Heavy bus	Articulated bus	Bi-articulated bus
1	Persons/vehicles	3	25	80	105	180	270
2	Vehicles needed	3333	400	125	95	55	37
3	Area occupied (m^2)	48000	8800	3900	3260	2600	2370
4	Fuel consumption (Litres)	400	120	40	38	31	34

Source: State of the Environment Report and Action Plan – 2003, Department of Forest, Ecology and Environment, Government of Karnataka.

3.9. PUBLIC TRANSPORT INFRASTRUCTURE

Bangalore Metropolitan Transport Corporation (BMTC) is the sole provider for public transport services to the general public. The public transport buses are operated within the city and also suburban area in the study area. The Bangalore Metropolitan Transport Corporation buses are providing the services for entire Bruhat Bangalore Mahanagara Palike area (BBMP) and also about 25 km beyond its jurisdiction (Mobility for Development, Bangalore-2007). The operational characteristics of the Bangalore Metropolitan Transport Corporation (BMTC) are presented in Table 3.11, and this table reveals that the Bangalore Metropolitan Transport Corporation (BMTC) operates 3531 schedules per day with 4812 buses covering the 1726 routes in the study area. The total services operated by the Bangalore Metropolitan Transport Corporation (BMTC) are 3957. Of which, about two-third (64.24 per cent) of them are suburban services and more than one-fourth (27.84 per cent) of them are city services. Followed by about 7.92 per cent of the total services are Pushpak and Volvo services in the study area. The Bangalore Metropolitan Transport Corporation was operating about 65,121 trips per day and carried about half of the total population, i.e., 37.00 lakh passengers per day in the study area. The Bangalore Metropolitan Transport Corporation (BMTC) buses alone fulfill above two-fifth (41.92 per cent) of the travel demand in the study area (c.ref. table 3.12). The daily average schedule kilometers operated by the Bangalore Metropolitan Transport Corporation buses were 9.33 lakhs in the year 2006-07. The accident rate in Bangalore Metropolitan Transport Corporation buses were 0.16 per lakh km coverage. The other characteristics of Bangalore Metropolitan Transport Corporation (BMTC) buses are average 4.47 years; fuel efficiency is 4.66 litres per km, staff/bus ratio is 4.78, vehicle productivity was 218 km/bus/day, total gross revenue Rs. 687 crore, and net profit was 113 crore in the year 2006 [31].

Table No. 3.11: Operational Characteristics of Bangalore Metropolitan Transport Corporation (BMTC)

Sl. No.	Particulars	Units	2006-07
1	Schedule Operations	Number	3531
2	Fleet	Number	4812
3	Daily Average Scheduled km	In Lakhs	9.33
4	Routes	Number	1726
5	City Services	Number	1102
6	Suburban Services	Number	2542
7	Pushpak Services	Number	313
8	Trips per day	Number	65,121
9	Passengers carried per day	In Lakhs	37.00
10	Accidents	Per Lakh km	0.16

Source: Compiled by the Investigator based on Bangalore Metropolitan Transport Corporation Report, 2006-07.

3.10. MODAL SPLIT IN BANGALORE METROPOLITAN AREA

Modal split refers to the process of separating person-trips by the mode of travel. It is usually expressed as a fraction, ratio or percentage of the total number of trips. An understanding of the modal split is one of the important stages of transport planning. The modal split depends on broadly few factors, which include characteristics of the trip, household characteristics, zonal characteristics, and network characteristics. The change in modal split between 1994 and 2006 and the available fleet strength in the year 2006 in the study area are presented in Table 3.12, Fig. 3.3 and Fig. 3.4. This table reveals that there was a drastic change in use of different mode of transport in the study area. It has been observed that the walking mode of transport was totally ignored by the concerned authorities in 1994 and in 2002. In 2006, walking mode of transport shares about 8.32 per cent of the total travel demand of the study area. The bicycle mode of transport was shared about one-tenth (9.05 per cent) of the total travel demand in the year 1994 and further it was gradually declined to 2.22 per cent of the total travel demand in the year 2006. The two-wheeler mode of transport accounts for above one-fifth (22.45 per cent) of the total travel demand in the year 1994, and it was further increased to more than one-third (36.31 per cent) of the total travel demand in the year 2002. Further, it has also been observed that the travel demand by two-wheeler gradually declined from 36.31 per cent to 29.36 per cent between the year 2002 and 2006, whereas the two-wheelers accounts for about three-fourth (72.83 per cent) of the total vehicular population in the study area. The Intermediate Public Transport (auto-rickshaws) shared about 5.28 per cent of the total travel demand in the year 1994. Further, it was observed that the travel demand was increased from 5.28 to about 11.55 per cent between the year 1994 and 2006, whereas the fleet strength of three-wheelers accounts for about 3.18 per cent of the total vehicles in the year 2006. The car mode of transport shared about 2.38 per cent of the total travel demand in the year 1994 and gradually increased travel demand by cars from 2.38 to 5.44 per cent between the year 1994 and 2002. Further it has also been observed that the travel demand by car increased from 5.44 to 6.64 per cent between the year 2002 and 2006, whereas the available total fleet strength of cars was 14.00 per cent of the total vehicles in the year 2006. The public transport buses shared more than three-fifth (60.19 per cent) of the total travel demand in the year 1994. It has been observed that there was a declining trend from 60.19 per cent to 48.91 per cent between the year 1994 and 2002. Further, it has also been observed that there was a decrease from 48.91 per cent to 41.91 per cent between the year 2002 and 2006. It is interesting to note that public transport buses accounts for about 1.32 per cent of the total vehicles, but fulfills more than two-fifth (41.91 per cent) of the total travel demand in the study area.

The Government of India has recommended the modal split based on the size of the population and the modes of transportation, which include mass transportation, bicycles and other modes, and their values are presented in Table 3.13, and this table reveals that the ideal transportation in a million city with population of 5.00 million plus should have a share of mass transportation between 70-85 per cent, bicycles share between 15-20 per cent, and the other modes of transportation would have a share of between 10-15 per cent of the total travel demand. In the study area, the public transportation shared just more than two-fifth (41.92 per cent) of the total travel demand, and the bicycles shared a very meager 2.22 per cent of the total travel demand in the year 2006. These statistics revealed that the study area is facing acute shortage of public transportation service and the availability of non-motorized vehicles is also negligible.

Table No 3.12: Change in Modal Split and Available Fleet Strength in Bangalore City

(Number/ Per cent)

Sl. No.	Mode of Transport	Modal Split in 1994*		Modal Split in 2002**		Modal Split in 2006***		Available Fleet strength in 2006	
		No. of Trips	Per cent	No. of Trips	Per cent	No. of Trips	Per cent	Nos.	Per cent
1	Walking	-	-	-	-	523597	8.32	-	-
2	Bicycle	355500	9.05	99717	2.00	139407	2.22	-	-
3	Two-wheeler	881550	22.45	1806651	36.31	1845476	29.36	2161663	72.83
4	Three-wheeler	207450	5.28	343153	6.90	726425	11.55	94587	3.18
5	Car	93600	2.38	270862	5.44	416304	6.64	415645	14.00
6	Public Transport buses	2363850	60.19	2433913	48.91	2634471	41.92	38835	1.32
7	Others	25650	0.65	21935	0.44	-	-	256971	8.67
	Total	3927600	100.00	4976231	100.00	6285680	100.00	2967701	100.00

Source: * Infrastructure Leasing and Financial Services Limited (IL & FS-1994)
** Detailed Project Report by Rail India Techno Economic Services Limited (RITES-2002)
*** Comprehensive Traffic and Transportation Plan for Bangalore by RITES-2006.

Table No. 3.13: Desirable Modal Split for Indian Cities

(per cent)

Sl. No.	City Population (In Millions)	Mass Transport	Bicycle	Other Modes
1	0.10 - 0.50	30-40	30-40	25-35
2	0.50 - 1.00	40-50	25-35	20-30
3	1.00 - 2.00	50-60	20-30	15-25
4	2.00 - 5.00	60-70	15-25	10-20
5	5.00 +	70-85	15-20	10-15

Source: Ministry of Urban Development, Government of India, New Delhi, 1998. Traffic and Transportation Policies and Strategies in Urban Areas in India, Final Report.

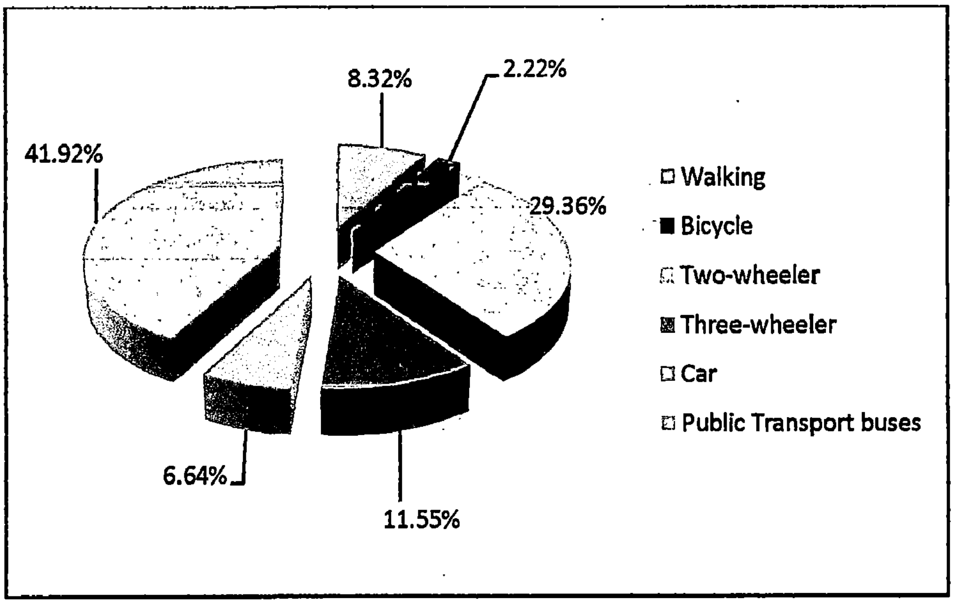


Fig. No 3.3: Modal Split in Bangalore City-2006

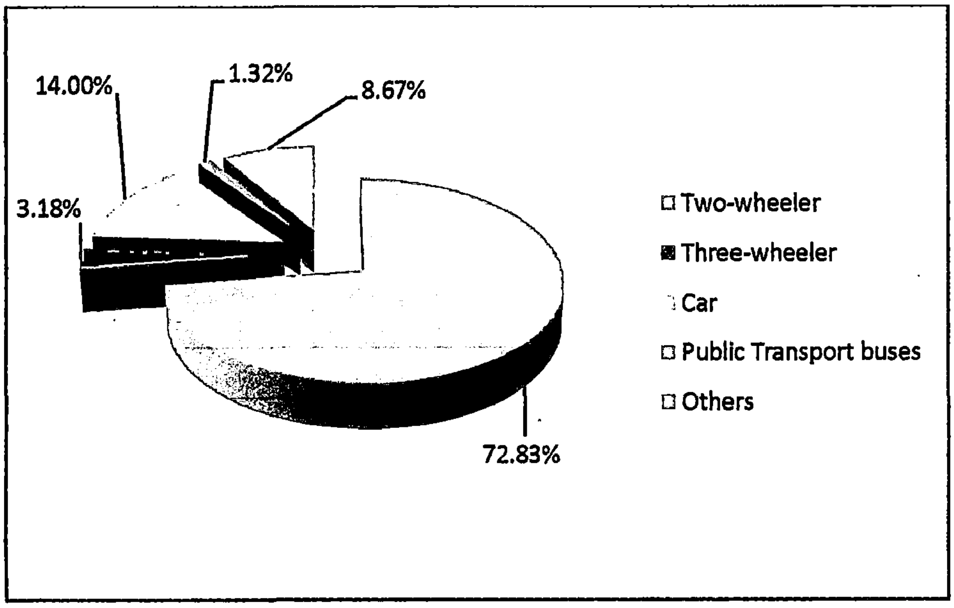


Fig. No 3.4: Available Fleet Strength in Bangalore City-2006

3.11. CONGESTION LEVELS IN BANGALORE METROPOLITAN AREA

The rate of growth of roads in terms of increase in area, length, improved advanced technological solutions and adoptability, etc., is not commensurate with the increase in population as well as vehicular population growth in the study area. As a consequence, the available capacity of roads is insufficient of handling the increased in volume of traffic in the study area. The ratio of peak hour service volume (PSV) to practical capacity is known as Congestion Index (CI). Ideally, the volume to capacity ratio (V/C) should be less than 1.00. The level of service decides based on the ratio of volume to capacity, if the ratio of volume to capacity is 0.20, the level of service (LOS) is excellent; the ratio of volume to capacity is 0.40, the level of service is good; the ratio of volume to capacity is 0.60, the level of service is average; the ratio of volume to capacity is 0.80, the level of service is bad; and the ratio of volume to capacity is 1.00, the level of service is worse; The volume to capacity ratio is more than 1.00 indicating that the high congestion, low speeds and high delay in mobility. The volume to capacity ratio in different important roads in the study area is presented in Table 3.14, and this table reveals that except in three roads, in all other roads the volume to capacity ratio is far above the limit and in some cases the ratio is more than 2.00 and 3.00. This clearly indicates that the exacerbated increase of personalized vehicles, inadequate public transportation system, absence of mass transportation system, inefficient traffic management system, heterogeneous traffic, absence of urban transport policies, lack of planning, etc., in the study area are responsible for peak hours of congested traffic in the study area. The road network of the study area is unable to carry increase in current traffic volume, and mean time it is observed that about 900 new vehicles are registered per day in the study area, which result into the congestion index of selected roads in the study area is beyond the permissible limits and these values in different areas are presented in Table 3.15. This table illustrates that the practical capacity of the selected roads are insufficient of handling the generated volume of traffic in the study area.

Table No. 3.14: Volume-Capacity Ratio in Different Roads of Bangalore Metropolitan Area

Sl. No.	Name of road	Volume/Capacity Ratio
1	Nrupatunga Road	3.62
2	Peenya	2.94
3	M.G. Road	2.76
4	Lalbagh Fort Road	2.67
5	Tumkur Road	2.62
6	Hosur Road	2.62
7	Sampige Road	2.61
8	District office Road	2.51
9	K.G. Road	2.51
10	Chord Road	2.51
11	Race Course Road	2.46
12	Puttanna Chetty Road	2.45
13	Airport Road	2.34
14	Richmond Road	2.26
15	St. Marks Road	2.09
16	Old Madras Road	2.06
17	Richmond Road	2.01
18	Residency Road	1.96
19	Infantry Road	1.88
20	Margosa Road	1.86
21	J. C. Road	1.81
22	Sankey Road	1.52
23	Bull Temple Road	1.36
24	Cubbon Road	0.92
25	Raja Ram Mohan Roy Road	0.80
26	Museum Road	0.69

Source: Jawaharlal Nehru National Urban Renewal Mission -City Development Plan for Bangalore, 2006, Traffic Police Department, Bangalore., 2004 and State Environment Report Bangalore-2008, Department of Forest, Ecology and Environment, Government of Karnataka.

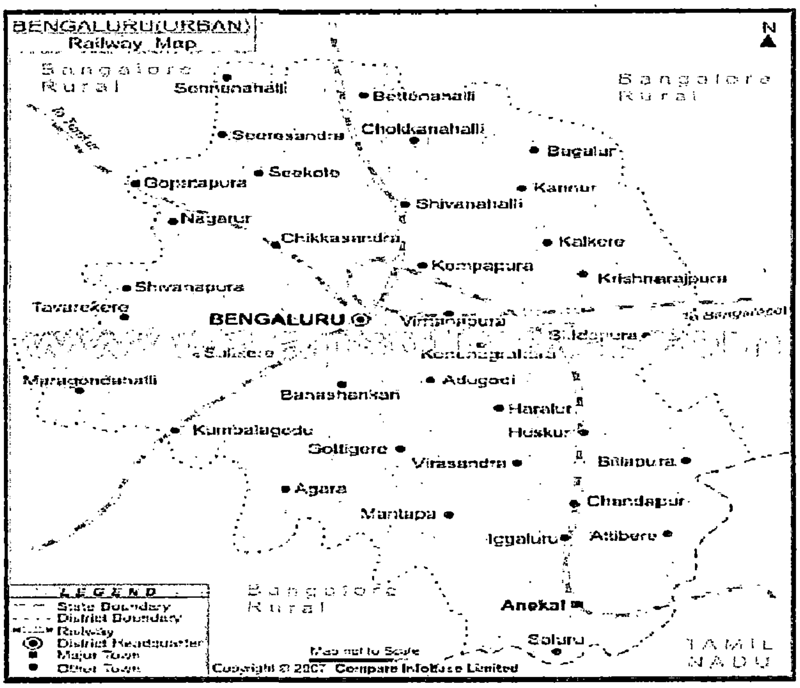
Table No. 3.15: Congestion Index of Selected Roads in Bangalore Metropolitan Area

Sl. No.	Name of the Road	Peak Hour Service Volume (PSV)	Practical Capacity (PC)	Congestion Index (CI)
1	Platform Road	14,375	2,486	5.78
2	Old Mysore Road	16,049	3,492	4.60
3	Seshadri Road	10,105	3,813	2.65
4	Bhashyam Road	4,734	1,791	2.64
5	Tank Bund Road	6,531	2,698	2.42
6	Loop Road	4,958	1,858	2.67
7	Race Course Road	7,375	1,371	5.38
8	Nagappa Road	6,360	1,714	3.71
9	Hare Krishna Road	6,893	2,172	3.17
10	Subedar Chatram Road	5,934	2,057	2.88
11	Okalipuram Main Road	9,848	3,811	2.58
12	District Office Road	9,900	4,647	2.13
13	J.C. Road	11,813	4,971	2.30
14	Lalbagh Road	8,829	4,142	2.13
15	H.Siddaiah Road	5,742	4,004	2.02
16	Lalbagh Fort Road	5,850	1,971	2.97
17	R.V. Road	6,554	2,914	2.25
18	M.N.K. Road	5,009	1,799	2.78
19	Queen's Road	5,266	2,163	2.43
20	Dickenson Road	5,511	1,971	2.80
21	Ulsoor Road	3,897	1,762	2.21
22	Old Madras Road	5,850	2,455	2.38
23	Richmond Road	7,296	2,914	2.50
24	Airport Road	7,767	2,900	2.68
25	Victoria Road	5,394	2,000	2.70

Source: Detailed Project Report of Metro Rail on Bangalore City, 2005.

3.12. RAIL TRANSPORTATION IN BANGALORE CITY

The study area is blessed with five railway lines from five different directions, and has about 62 km length of surface rail track. At present, these railway lines are used for intercity transportation and these lines are well connected and served the commuters of nearby satellite, district and taluk headquarters, which include Tumkur, Chikaballapur, Bangarpet, Hosur and Mandya, etc. The rail network of Bangalore city is presented in Fig. 3.5.



Source: http://www.mapsofindia.com/maps/karnataka/railways/bangalore.htm.

Fig. No. 3.5: Rail Network in Bangalore City

3.13. AIR TRANSPORT IN BANGALORE CITY

The study area is blessed with an International Airport, located at Devanahally from 35 kilometers from the city centre. The Airport is well connected to the city and provided public transportation exclusively for this purpose. The city was earlier served by the HAL airport, which was India's fourth busiest airport. Few private airlines like Air Deccan and Kingfisher Airlines have their headquarters in this city. It is now the fourth busiest airport in India in terms of passenger traffic and the number of air traffic movements (ATMs) with about 280 per day.

3.14. BANGALORE METRO RAIL

The Government of Karnataka has taken initiative to implement Metro Rail in Bangalore city by considering the growth of population, vehicular population and its associated problems. The proposed Bangalore Metro Rail covers North-South corridor 14.90 km. long, East-West corridor will be 18.10 km. long, total metro length in this phase cover 33.00 km and going to operate by 2011. The North-South corridor will begin at

Yeshwantpur Terminal and terminate at R. V. Road terminal; the East-West corridor will starting from Byappanahalli and terminating at Mysore Road terminal. The features of proposed Bangalore Metro Rail which include transport demand projections in the year 2007, 2011 and 2021 will be 8.20, 10.20 and 16.10 lakh passengers per day; passenger km/ km of corridor would be 178839, 228201 and 362828 respectively during the same period; peak hour direction peak direction (PHDPD) would be 22442, 27358, and 39838 PHPDT in E-W direction during the same period; peak hour direction peak direction (PHDPD) would be 19585, 22705, and 31964 PHPDT in N-S direction during the same period; the maximum range of PHPDT (Peak Hour Peak Direction Trips) on the system by 2011 would be 20,000 and further it would be increased to 40,000 by 2021 are presented in Table 3.16 and 3.17. The proposed Bangalore Metro Rail is presented in Fig. 3.6.

Table No. 3.16: Transport Demand Projections-Bangalore Metro

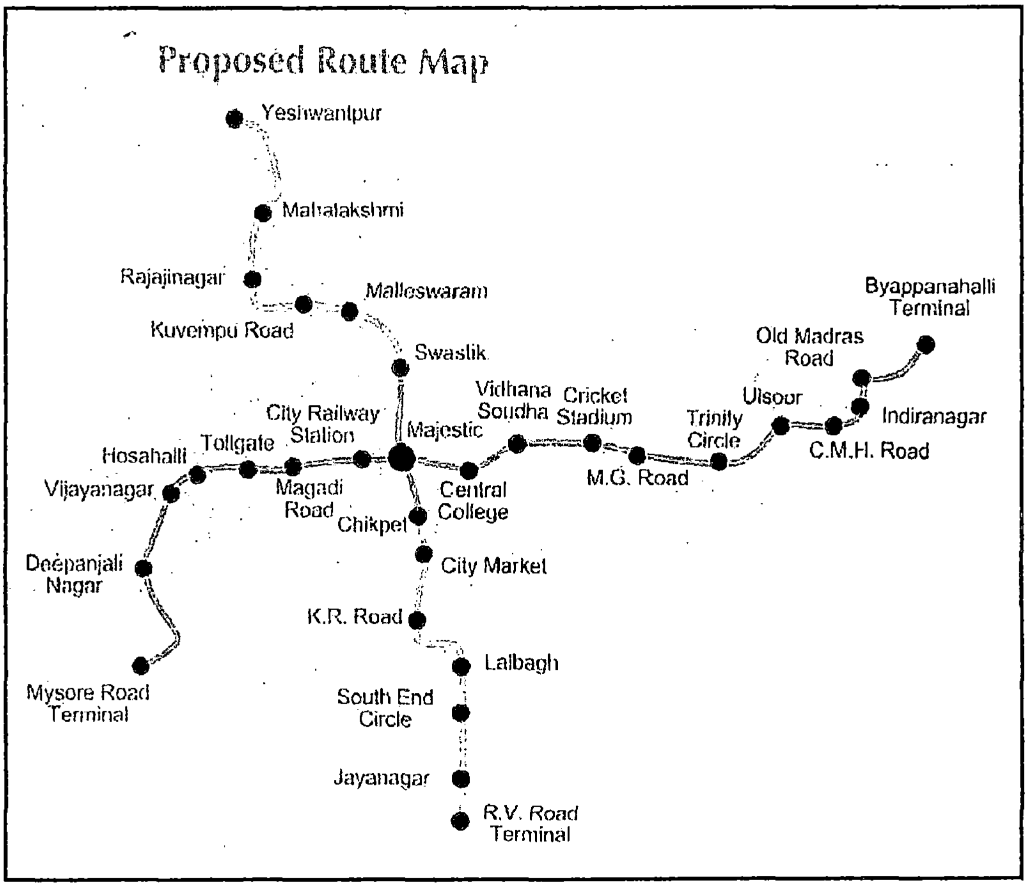
Sl. No.	Year	Number of passengers (Lakhs/day)	Passenger km/km of corridor (Lakhs/day)
1	2007	8.20	178839
2	2011	10.20	228201
3	2021	16.10	362828

Source: Detailed Project Report, Bangalore Metro Rail Corporation Limited.

Table No. 3.17: Peak Hour Peak Direction Trips-Bangalore Metro

Sl. No.	Line	Year		
		2007	2011	2021
1	Line 1: E-W	22442	27358	39838
2	Line 2: N-S	19585	22705	31694

Source: Detailed Project Report, Bangalore Metro Rail Corporation Limited.



Source: Detailed Project Report, Bangalore Metro Rail Corporation Limited.

Fig. No. 3.6: Proposed Metro Rail Route Map

3.14. ACCIDENTS IN BANGALORE METROPOLITAN AREA

The road accidents are grouped into fatal, non-fatal, killed and injured. The road accidents in the Bangalore Metropolitan Area (BMA) are presented in Table 3.18. This table reveals that the total road accidents occurred in the year 2006 was 13093. Of which, about half (46.22 per cent) of them were non-fatal. Followed by, above two-fifth (41.68 per cent) of them were injured, about 6.18 per cent and 5.93 per cent of them were killed and fatal respectively in the study area. The study area ranked fifth among India's fourteen major cities in terms of road traffic injuries (RTI) with annual rate of almost 13 road traffic injury deaths per 100,000 population [77].

Table No. 3.18: Accidents in Bangalore Metropolitan Area-2006

Sl. No.	Particulars	Accidents	
		Number	Per cent
1	Non Fatal	6051	46.22
2	Injured	5457	41.68
3	Killed	809	6.18
4	Fatal	776	5.93
	Total	13093	100.00

Source: Traffic Police Department, Bangalore.

3.15. PARKING

The uncontrolled and unplanned growth of vehicular population demands huge parking facilities in the study area. Vehicle parking is the major problem faced across the city, and street parking space is totally exhausted in the Central Business District (CBD) and the major commercial areas of the city. The major important roads like J.C. Road, Sampige Road, M.G. Road, Brigade Road, Commercial Street, CMH Road, Jayanagar 4th Block, Shivajinagar and K. G. Circle are attracting a large number of vehicles especially during the peak hours, weekends, and holidays. The problems pertaining to transportation subsystem and allied sectors in the study area are presented in Fig. 3.7 (A) to Fig. 3.7 (N).

Fig. 3.7 (A): Overcrowding of passengers

Fig. 3.7 (B): Narrow Roads

Fig. 3.7 © and Fig. 3.7 (D): Two-wheelers are dominant in the Study Area

Fig. 3.7 (E): Another Scene for Narrow Roads Fig. 3.7 (F): Heterogeneous Traffic

Fig. 3.7 (G): Mixed Traffic

Fig. 3.7 (H): Vehicles Parked on Road

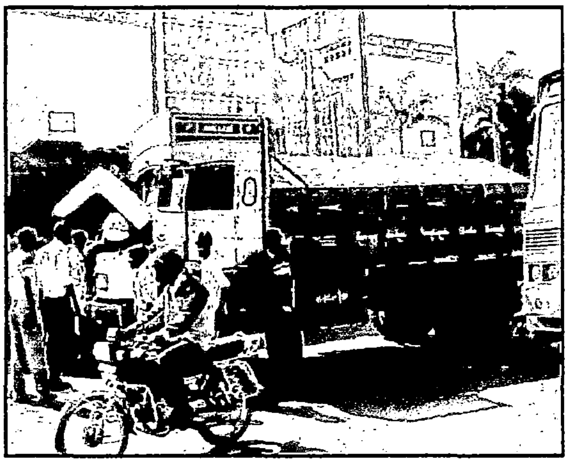


Fig. 3.7 (I): Overloaded Breakdown Vehicle Fig. 3.7 (J): Encroached Footpath

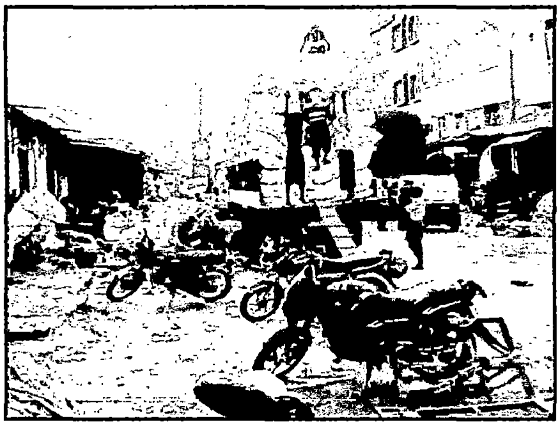


Fig. 3.7 (K): Loading and Unloading of Goods Fig. 3.7 (L): Animals on Footpath

Fig. 3.7 (M): Dumping Waste in Open spaces Fig. 3.7 (N): Drainage in overflow Condition

Fig. No. 3.7: Problems pertaining to Transportation and allied Sectors

3.16. CONCLUSION

In this Chapter, the Investigator has analysed the problems and prospects of the existing urban transportation system in the study area. This analysis covered various aspects of transportation, which include growth of vehicular population; different categories of roads and their road length; per cent of road length in different right-of-way; per cent of trips by purpose; distribution of trips by mode and trip length; distribution of trip length by purpose of travel; per capita trip rate by purpose; transport parameters; available transportation infrastructure and their services; operations which include number of schedules, number of routes, fleet strength, daily average schedule kilometers, passengers carried per day, accidents, etc.,; congestion index of selected roads; modal split in different periods in the study area and desirable modal split for Indian cities based on population; overall accidents; relative characteristics of available public transport technologies, and fossil fuel consumption. A detailed study is done pertain to demographic, socio-economic, infrastructure and environmental aspects, travel characteristics of the households in weekdays and weekend days, at the household level, and the results are presented in the next Chapter-4.

PHYSICAL-SOCIO-ECONOMIC FEATURES AND TRAVEL CHARACTERISTICS IN THE STUDY AREA (SYSTEM)

4.0 INTRODUCTION

A detailed investigation was done pertaining to the socio-economic conditions, available physical infrastructures, travel characteristics, etc., in weekdays and weekend days of the households in the system, at the grassroots level, and the results are presented in this chapter. To understand the features and functions of the system at the grassroots level, survey research was done, and the detailed methodology employed in this investigation is presented in section 1.8.1 and in Fig. 1.1 and Fig. 1.3 in chapter -1 (c. ref.). This chapter is presented under various heads, which include demographic factors, socio-economic conditions of the households, expenditure pattern of the households, vehicle ownership, travel characteristics of the households in weekdays and weekend days pertaining to distribution of trips, trip length, travel time, per capita travel time, per capita trip rate, per capita trip length, modal split, travel speed, etc., in the study area for clarity.

The Investigator had visited the study area in several occasions and observed the functions of the system related to transportation segment. Further, he had visited good number of offices, which are working for the provision of services related to transportation, such as Bangalore Metropolitan Transport Corporation (BMTC), Bruhat Bangalore Mahanagara Palike (BBMP), Bangalore Development Authority (BDA), Bangalore Metropolitan Region Development Authority (BMRDA), Karnataka Urban Infrastructures and Development Finance Corporation (KUIDFC), Rail India Techno Economic Services Limited (RITES), Bangalore Metro Rail Corporation Limited (BMRCL), etc., in the study area, and had detailed discussion with experts and personal who are directly connected with providing transportation services in the study area. Thereafter, the Investigator developed a schedule for conducting the investigation based on the results of the in-depth analysis of the literature surveyed, observation done in the study area, results of the discussion with experts, officials, academicians, policy makers, transportation planners, urban and regional planners, bureaucrats, etc., connected to provision of transportation services in the system, and pretested the schedule in the study area. Subsequently, the schedule was modified in accordance with the requirement; the Investigator himself has done the primary household survey in the selected 360 households by employing the aforesaid pre-tested schedules at the grassroots level to understand the functions of the system. Once the data were collected, the Investigator vetted all the schedules, crosschecked, and found that there were more discrepancies in 40 schedules, so that those schedules were discarded from the list of schedules considered for analysis. Subsequently, the data were transferred into the code sheets to avoid errors. Thereafter, the Investigator fed the data into the computer and used EXCEL software for analysis.

4.1. SOCIO-ECONOMIC CHARACTERISTICS OF THE STUDY AREA

The socio-economic characteristics of the study area are analysed based on the surveyed household schedules. The analysis is done by considering the household income as the dependent variable, and the rest of the other major variables are considered as independent variables, and the results are presented in the sequel. They are:

4.1.1. Income:

Income is the most important parameter, which decides the functions of the system. The household income indicates the status of the family and the status of the family increases with the increase in income and thereby accumulation of wealth. The household income decides the purchasing power of the family in particular, and the system as a whole in general. The increase in income leads to increase of manifold activities in the system including standard of living, increase in using infrastructure services, increase in investment, which also leads to increase in production, trade, and commercial activities, employment opportunities, saving, etc. The higher per cent of saving further leads to increase in capital formation, strengthen the reinvestment in the system, which further helps in increase in production, trade and commerce, employment generation, income earning opportunities, and so on. In this process, a strong dynamic function takes place in the system, which is very much essential for the development of any system.

In order to analyze the surveyed household's data, the collected data have been classified into few income groups. Monthly household income is considered as dependent variable (y), and the rest of the variables in the schedule are considered as independent variables for analysis, and presented in this chapter. Grouping is done after preliminary investigation of the income of the individual households and income range variation among the total surveyed households. Care has been taken to keep the income class interval uniform for easy and error free unambiguous analysis. Accordingly, the entire surveyed households have been classified into five monthly income groups. They are having monthly household income of below Rs. 20,000/-, Rs. 20,000-40,000, Rs. 40,000-60,000, Rs. 60,000-80,000 and above Rs. 80,000/- in ascending order of income. The number of households covered under the survey in various income groups is presented in Table 4.1 and in Fig. 4.1. This Table and this Fig. illustrated that the available number of households are decreasing along with increase in income groups. Further, it has been observed that of the total households, about half (48.13 per cent) of the them are confined in the lowest income group category i.e., below Rs. 20,000/-per month, followed by just above one-fourth of them (27.19 per cent) belong to the next hierarchy, i.e., having monthly income group of Rs. 20,000-40,000, and about one-sixth (15.31 per cent) falls under the next category of income, i.e., Rs. 40,000-60,000, and the rest of them (5.00 per cent) and (4.38 per cent) confined under the monthly income group of between Rs. 60,000-80,000 and above Rs. 80,000 respectively. This table concludes, based on the above analysis, that the people in the study area are living a very moderate life since most of them are confined among the first two income groups, and very less number, i.e., less than even one-tenth of them are confined among the last two higher income group categories.

Table No. 4.1: Distribution of Households by Monthly Income

(Numbers/ Per cent)

Sl. No.	Household Income (Rs. /month)	Total Number of Households	
		Nos.	Per cent
1	< 20,000	154	48.13
2	20,000 - 40,000	87	27.19
3	40,000 - 60,000	49	15.31
4	60,000 - 80,000	16	5.00
5	> 80,000	14	4.38
	Total	**320**	**100.00**

Source: Primary Household Survey-2008

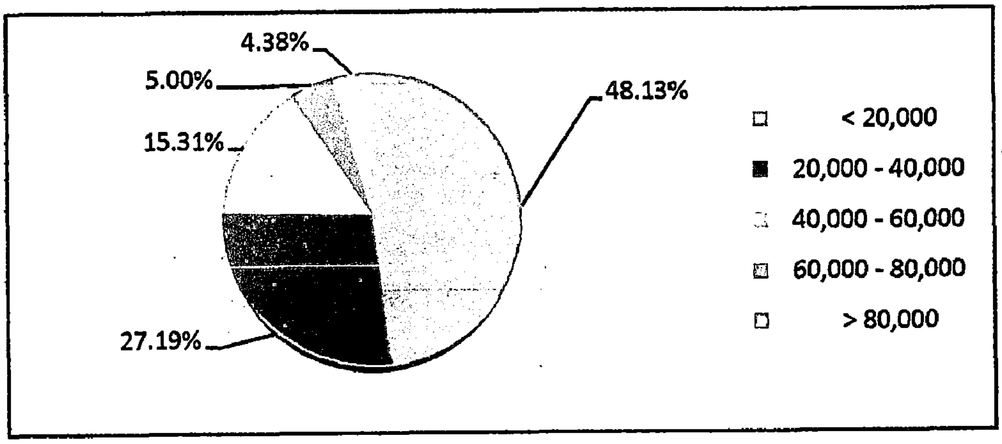


Fig. No. 4.1: Distribution of Households by Monthly Income

4.1.2. Population and Household Size

Population is one of the most important parameters, which decides the functions of the system. India is characterized by gigantic population, rapid population growth, low per capita availability of land, low per capita income, low per capita Gross Domestic Product, low per capita energy consumption, low per capita consumption of infrastructural services, etc. These above factors led to several socio-economic crises in the system. Since population is one of the major parameters in the system, the available number of population is considered as one of the important variables in the household survey, and classified into male and female categories, household size of the population with income groups, and presented in Table 4.2, Fig. 4.2 and in Fig. 4.3. This Table and these Figures reveal that there are 1535 population available in all 320 surveyed households. Of the total population, more than half (51.99 per cent) of them is male and the rest of them are female (48.01 per cent). It has been observed that the number of male and female population is decreasing along with increase in household income. It is observed that the percentage share of male and female population in different income categories of the households are almost identical, where in income group of Rs. 20,000-40,000 the per cent of male population is much higher i.e., 53.32 per cent for male, and rest of them (46.68 per cent) are female. Further, it has been observed that the average household size is 4.80 in the system. The maximum and minimum sizes of households are 5.04 and 4.44, which are confined in the monthly income group of Rs. 40,000-60,000 and Rs. 60,000-80,000 respectively. In income group-wise analysis, it has been observed that both male and female population confined in income group is decreasing along with increase in income groups, which reflect the households confined in each income group.

Table No. 4.2: Distribution of Population by Sex and Household Size

(Numbers/ Per cent)

Sl No.	Household Income (Rs. /month)	Male Population		Female Population		Total		Average Household Size
		Nos.	Per cent	Nos.	Per cent	Nos.	Per cent	
1	< 20,000	368	46.12 (51.69)	344	46.68 (48.31)	712	46.38 (100.00)	4.62
2	20,000 - 40,000	233	29.20 (53.32)	204	27.68 (46.68)	437	28.47 (100.00)	5.02
3	40,000 - 60,000	125	15.66 (50.61)	122	16.55 (49.39)	247	16.09 (100.00)	5.04
4	60,000 - 80,000	37	4.64 (52.11)	34	4.61 (47.89)	71	4.63 (100.00)	4.44
5	> 80,000	35	4.39 (51.47)	33	4.48 (48.53)	68	4.43 (100.00)	4.86
	Total	**798**	**100.00 (51.99)**	**737**	**100.00 (48.01)**	**1535**	**100.00 (100.00)**	**4.80**

Source: Primary Household Survey-2008

Note: Figures in Parenthesis Denote Row Percentage

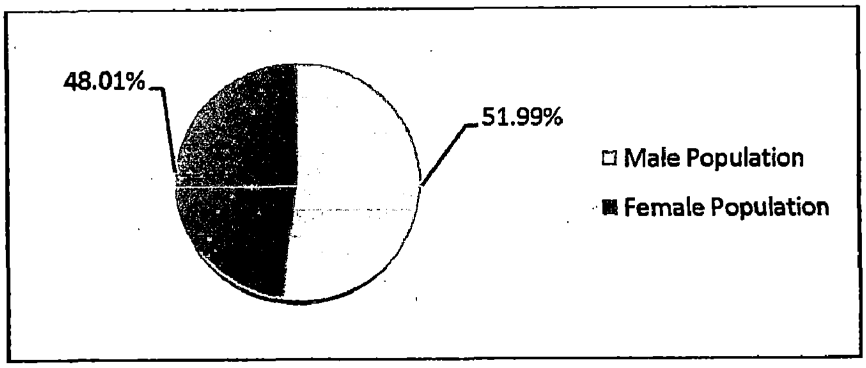


Fig. No. 4.2: Male and Female Population

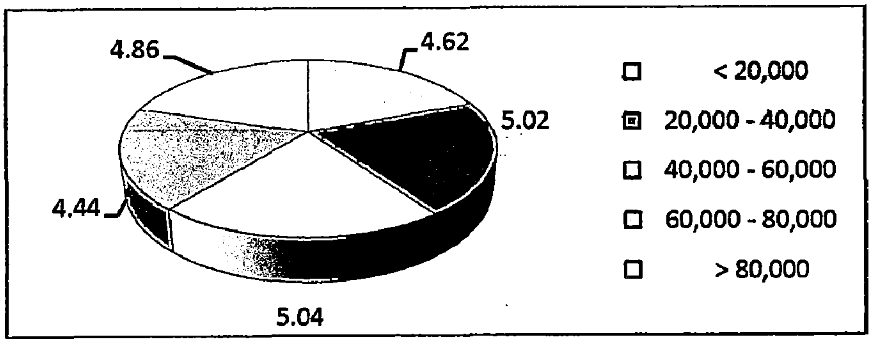


Fig. No. 4.3: Household Size in Different Household Income Group

4.1.3. Distribution of Population by Age Group:

The age group of population is playing a major role in the system, which decides the function of the system. The major activities of the population and their basic demand of different infrastructures in the system is depends on age-group of the population in the system. In general, less than 25 years age-group is engaged in education, in range of 25-60 age-group is considered as working group, and the above 60 years people mostly spend time in recreational and other household activities. Therefore, the basic need, demand, and aspiration of the different age group people vary. Having this knowledge in mind, the Investigator considered this as one of the parameters in the schedule, and conducted the investigation. The population by different age-group is grouped into seven groups, which include below 5, 5-18, 18-25, 25-40, 40-60 and above 60 years, and is clubbed with various income groups for analysis, and the results are presented in Table 4.3 and in Fig. 4.4. This Table and this Figure depict that above one-fourth (26.51 per cent) of the total population confined in the age-group of range 25-40, and followed by above one-fifth (21.17 per cent) of them is in the age-group of range 40-60, and about one-fifth (18.44 per cent) of them is confined to the age-group range 18-25. It is also observed that a meager (5.67 per cent) confined among the less than 5 years age group. A considerable amount of population (11.23 per cent) is found above the retired age as per Karnataka State Government ordinances. In income group analysis, it has been observed that in all age group, the available population is decreasing along with increase in income. It is further observed that the people belonging to the age group of 25-40 represents more in all income groups compare to rest of the age group categories. Further, it is also interesting to note that the persons belonging to the age group of 25-60 (25-40 and 40-60) has about half of the population, i.e., 47.68 per cent; which shows that working class population is much higher compared to the rest of the population in the city. As a consequence, steady economic growth has been observed in the city.

4.1.4. Marital Status:

Marital status is one of the most important social parameters, which also decides the functions of the system. In the Indian society, the married persons are much respected compared to the unmarried persons, but not the widows and widower. The widows and the widowers are not at all given respect in the social function, and there are lot of blind believes against them, and by and large an absolutely discrimination are perpetuated to them. Though the study area is confined in the urban system, and the sociology of urban system is almost different compared to the rural system, the study area is not an exceptional one in this regard, and the Investigator observed some kinds of discrimination in the system. Having the above in mind, the marital status of the people are studied and presented in Table 4.4. This table reveal that above half (55.90 per cent) of the total population is married and above two-fifth (40.59 per cent) of them are unmarried. Further, it has been observed that a very meager of 1.50 per cent and 2.02 per cent of them are widows and widowers respectively. It is further observed that the per cent of all groups, which include married persons, unmarried persons, widows and widowers are decreasing along with increase in income. The number of unmarried persons is very high in low income group category, i.e., below Rs. 20,000/-per month. The trend of married and unmarried population is more or less same in all income groups.

Table No. 4.3: Distribution of Population by Age Group

(Years/Numbers/ Per cent)

Sl No.	Household Income (Rs. /month)	Age in Years															
		< 5		5-18		18-25		25-40		40-60		60-65		> 65		Total	
		Nos.	Per cent	Nos.	Per cent	Nos.	Per cent	Nos.	Per cent	Nos.	Per cent	Nos.	Per cent	Nos.	Per cent	Nos.	Per cent
1	< 20,000	35	40.23 (4.92)	153	59.07 (21.49)	138	48.76 (19.38)	176	43.24 (24.72)	141	43.38 (19.80)	32	39.02 (4.49)	37	40.22 (5.20)	712	46.38 (100.00)
2	20,000 - 40,000	31	35.63 (7.09)	55	21.24 (12.59)	76	26.86 (17.39)	112	27.52 (25.63)	104	32.00 (23.80)	27	32.93 (6.18)	32	34.78 (7.32)	437	28.47 (100.00)
3	40,000 - 60,000	14	16.09 (5.67)	37	14.29 (14.98)	45	15.90 (18.22)	69	16.95 (27.94)	58	17.85 (23.48)	12	14.63 (4.86)	12	13.04 (4.86)	247	16.09 (100.00)
4	60,000 - 80,000	3	3.45 (4.23)	6	2.32 (8.45)	15	5.30 (21.13)	26	6.39 (36.62)	11	3.38 (15.49)	6	7.32 (8.45)	4	4.35 (5.63)	71	4.63 (100.00)
5	> 80,000	4	4.60 (5.88)	8	3.09 (11.76)	9	3.18 (13.24)	24	5.90 (35.29)	11	3.38 (16.18)	5	6.10 (7.35)	7	7.61 (10.29)	68	4.43 (100.00)
	Total	**87**	**100.00 (5.67)**	**259**	**100.00 (16.87)**	**283**	**100.00 (18.44)**	**407**	**100.00 (26.51)**	**325**	**100.00 (21.17)**	**82**	**100.00 (5.34)**	**92**	**100.00 (5.99)**	**1535**	**100.00 (100.00)**

Source: Primary Household Survey-2008

Note: Figures in Parenthesis Denote Row Percentage

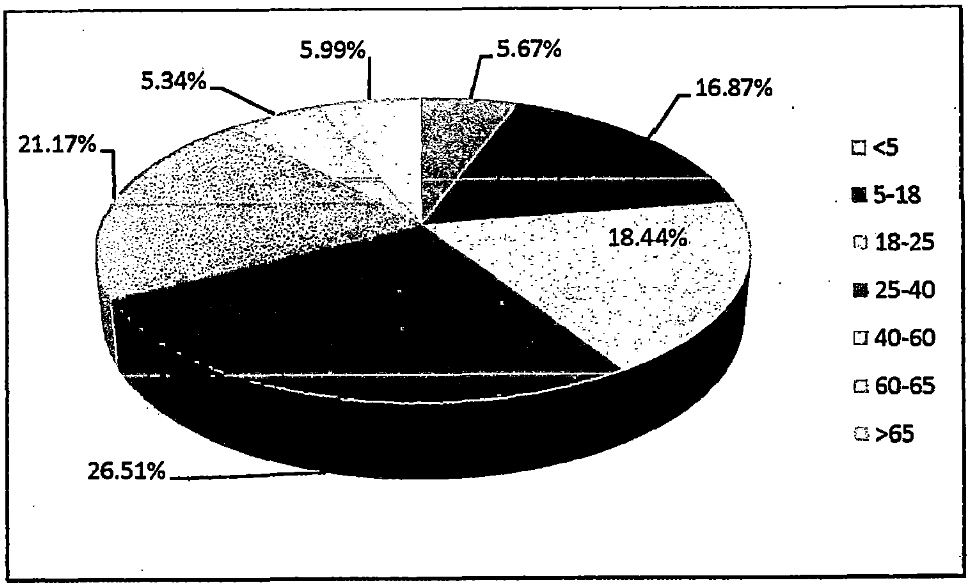


Fig. No. 4.4: Distribution of Population by Age Group

4.1.5. Education

Education is one of the most important parameters for the development of any system, since it is the indispensable requirement of human resources, and also decides the functions of the system. It is used as a tool to measure the socio-economic development of the nation. Education is one of the most dependent factors for the mobility of the people and to access the right job opportunities in the market. In the study area, education plays a major role for its development in all aspects. Having this knowledge in mind, it is tried to explore the academic qualification of the people in the system. To understand the status of educational qualifications in the system, population among the surveyed households is classified into people qualified up to Higher Secondary Class (HSC), Pre-University Course (PUC), Diploma, Under-Graduate (UG), Post-Graduate (PG), Technical, Medical and others, and is clubbed with various income groups for analysis, and the results are presented in Table 4.5 and in Fig. 4.5. This table and this figures reveal that of the total 1535 persons among the surveyed households, there are almost cent per cent (98.82 per cent) people are literate and a meager of 1.18 per cent persons are illiterate in the system.

Table No. 4.4: Distribution of Population by Marital Status

(Numbers/ Per cent)

Sl No.	Household Income (Rs. /month)	No. of Married		No. of Unmarried		No of Widows		No. of Widowers		Total	
		Nos.	Per cent	Nos.	Per cent	Nos.	Per cent	Nos.	Per cent	Nos.	Per cent
1	< 20,000	380	44.29 (53.37)	308	49.44 (43.26)	17	73.91 (2.39)	7	22.58 (0.98)	712	46.38 (100.00)
2	20,000 - 40,000	246	28.67 (56.29)	169	27.13 (38.67)	4	17.39 (0.92)	18	58.06 (4.12)	437	28.47 (100.00)
3	40,000 - 60,000	144	16.78 (58.30)	99	15.89 (40.08)	0	0.00 (0.00)	4	12.90 (1.62)	247	16.09 (100.00)
4	60,000 - 80,000	46	5.36 (64.79)	23	3.69 (32.39)	1	4.35 (1.41)	1	3.23 (1.41)	71	4.63 (100.00)
5	> 80,000	42	4.90 (61.76)	24	3.85 (35.29)	1	4.35 (1.47)	1	3.23 (1.47)	68	4.43 (100.00)
	Total	**858**	**100.00 (55.90)**	**623**	**100.00 (40.59)**	**23**	**100.00 (1.50)**	**31**	**100.00 (2.02)**	**1535**	**100.00 (100.00)**

Source: Primary Household Survey-2008

Note: Figures in Parenthesis Denote Row Percentage

Further, it is observed that about one-third (30.16 per cent) of the persons qualified PUC, and followed by people qualified in UG, up to HSC, Technical, PG, Diploma, Medical, and their the corresponding value are 22.93, 19.15, 6.71, 4.30, 4.17, 1.17, and 0.91 per cent respectively. In income group-wise analysis, it is observed that the population representing in higher education, which include UG, PG, Technical and others are increasing along with increase in income group up to the monthly income group of Rs. 20,000-40,000, and then observe the reverse trend, whereas all other education category except medical graduates, it is decreasing along with increase in income. In medical graduates, it is observed that it is increasing along with increase in income, but half (50.00 per cent) of them confined among the highest income group category, and above one-fourth (28.57 per cent) of them confined among the lowest income group category, and rest of them are scattered over all other income groups. Further, it has been also observed that the higher per cent of surveyed population is qualified PG, Technical and Medical in high income groups. This shows that households having good family income are having better education in the system, and it is significant that above one-tenth (11.92 per cent) of the surveyed population is qualified PG/Technical/Medical. The row percentage analysis also almost reflects the same trend of column percentage analysis. It is concluded from the above table that the people in the system are well aware the importance of education for the development of the system.

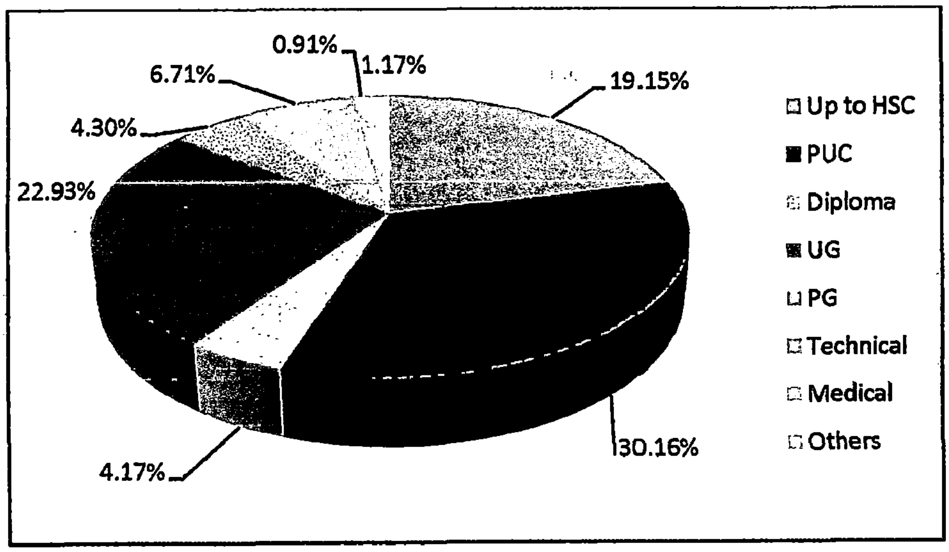


Fig. No. 4.5: Distribution of Population by Educational Qualification

Table No. 4.5: Distribution of Population by Educational Qualification

(Numbers/ Per cent)

Sl No.	Household Income (Rs. /month)	Educational Qualification											
		Up to HSC		PUC		Diploma		UG		PG		Technical	
		Nos.	Per cent	Nos.	Per cent	Nos.	Per cent	Nos.	Per cent	Nos.	Per cent	Nos.	Per cent
1	< 20,000	133	45.24 (18.67)	251	54.21 (35.25)	34	53.13 (4.78)	98	27.84 (13.76)	11	16.67 (1.54)	22	21.36 (3.09)
2	20,000 - 40,000	95	32.31 (21.74)	128	27.65 (29.29)	18	28.13 (4.12)	125	35.51 (28.60)	25	37.88 (5.72)	28	27.18 (6.41)
3	40,000 - 60,000	47	15.98 (19.03)	58	12.53 (23.48)	11	17.19 (4.45)	76	21.59 (30.77)	20	30.30 (8.10)	30	29.13 (12.15)
4	60,000 - 80,000	11	3.74 (15.49)	10	2.16 (14.08)	1	1.56 (1.41)	25	7.10 (35.21)	7	10.61 (9.86)	17	16.50 (23.94)
5	> 80,000	8	2.72 (11.76)	16	3.46 (23.53)	0	0.00 (0.00)	28	7.95 (41.18)	3	4.55 (4.41)	6	5.83 (8.82)
	Total	**294**	**100.00 (19.15)**	**463**	**100.00 (30.16)**	**64**	**100.00 (4.17)**	**352**	**100.00 (22.93)**	**66**	**100.00 (4.30)**	**103**	**100.00 (6.71)**

Source: Primary Household Survey-2008

Note: Figures in Parenthesis Denote Row Percentage

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Table No. 4.5: Distribution of Population by Educational Qualification

(Numbers/ Per cent)

Sl No.	Household Income (Rs. /month)	Educational Qualification					
		Medical		Others		Total	
		Nos.	Per cent	Nos.	Per cent	Nos.	Per cent
1	< 20,000	4	28.57 (0.56)	4	22.22 (0.56)	712	46.38 (100.00)
2	20,000 - 40,000	1	7.14 (0.23)	11	61.11 (2.52)	437	28.47 (100.00)
3	40,000 - 60,000	2	14.29 (0.81)	3	16.67 (1.21)	247	16.09 (100.00)
4	60,000 - 80,000	0	0.00 (0.00)	0	0.00 (0.00)	71	4.63 (100.00)
5	> 80,000	7	50.00 (10.29)	0	0.00 (0.00)	68	4.43 (100.00)
	Total	**14**	**100.00 (0.91)**	**18**	**100.00 (1.17)**	**1535**	**100.00 (100.00)**

Source: Primary Household Survey-2008

Note: Figures in Parenthesis Denote Row Percentage

4.1.6. Occupation

The occupation structure of the population is an important indicator to understand the status of development of the city and its region, and it is more or less influences the household's habit and their attitude, household income, standard of living, qualify of life, etc. The structure of occupation is influencing the overall development of the system. Keeping this in mind, an attempt is made to study the occupational structure of the system. To study the occupational structure of the households in the system, people involve in various occupation is grouped into three categories, namely primary occupation, secondary occupation, and tertiary occupation, and is clubbed with various income groups for analysis, and the results are presented in Table 4.6 and in Fig. 4.6. This table and this figure illustrate that just above two-fifth (43.45 per cent) of them are the working population, and the rest of them are dependent to them. Of the working population, above half (53.97 per cent) of them are confined in the tertiary occupation. Followed by, just above two-fifth (43.63 per cent) are confined under secondary sector, and the rest of them (2.40 per cent) represent the primary sector of the economy. This trend clearly shows that the study area is highly urbanized and industrialized as occupation in secondary and tertiary sectors are predominant.

4.1.6.1. Occupation in Primary Sector

It has been observed that only a few persons (2.40 per cent) engaged in primary occupation of the total 667 (43.45 per cent) persons employed among the surveyed household, and are confined among the lowest income group category, i.e., monthly income group of Rs. below 20,000/- only.

4.1.6.2. Occupation in Secondary Sector

It has been observed that just above two-fifth (43.63 per cent) of the population engaged in secondary sector of the employment. Of which, about three-fourth (78.70 per cent) are confined in the least two income groups, i.e., monthly income group of below Rs. 20,000/-, and Rs. 20,000-40,000/- and the rest of them are scattered over in almost all income groups. Further, it has been observed that the person engaged in secondary sectors of the economy is decreasing along with increase in income groups. The Table 4.6 reveals that more number of people confined in non-technical and lower order technical (Diploma), and majority of them are confined in the lowest two income group categories, which shows that education decides the occupational pattern and the income level of the households.

4.1.6.3. Occupation in Tertiary Sector

Considerable amount of working population (53.97 per cent) of the surveyed households is engaged in the Tertiary sector in the study area. The Table 4.6 and Fig. 4.7 reveal that the persons confined in tertiary occupation are decreasing along with increase in income. Further, it is also observed that about two-third (65.83 per cent) of the tertiary occupation are confined in the lowest two income group of categories, i.e., monthly income group of Rs. below 20,000/- and Rs. 20,000-40,000/- which positively reflect the persons qualification. This trend is also almost identical when people involve in tertiary occupation, which shows that persons qualify higher education, professionally qualified, etc., mostly involve in tertiary occupation.

4.1.7. Working Members of Households by Age Group

Analysis of different age group of working population in an urban system gives little insight about economic status of the particular urban system. The different age group demands different mode of transportation for their mobility to easy access for work place. The State Government, the Central Government, the Private firms, and the Public enterprises decide the retirement age of their employees. Distribution of working population by age group decides the requirement of modern, high-speed, efficient and affordable rapid transit system in the study area. Having this knowledge in mind, the Investigator considered this as one of the parameters in the schedule, and conducted the investigation. The working members of the households by age group is grouped into five groups, which include below 25 years, 25-40, 40-50, 50-60 and 60 years & above and is clubbed with various income groups for analysis, and the results are presented in Table 4.7 and in Fig. 4.7.

Table No. 4.6: Distribution of Working Population by Occupation

Sl. No.	Household Income (Rs./month)	Primary		Secondary		Tertiary		Total	
		Nos.	Per cent	Nos.	Per cent	Nos.	Per cent	Nos.	Per cent
1	< 20,000	16	100.00 (5.71)	120	41.24 (42.86)	144	40.00 (51.43)	280	41.98 (100.00)
2	20,000 - 40,000	0	0.00 (0.00)	109	37.46 (53.96)	93	25.83 (46.04)	202	30.28 (100.00)
3	40,000 - 60,000	0	0.00 (0.00)	44	15.12 (39.29)	68	18.89 (60.71)	112	16.79 (100.00)
4	60,000 - 80,000	0	0.00 (0.00)	11	3.78 (26.19)	31	8.61 (73.81)	42	6.30 (100.00)
5	> 80,000	0	0.00 (0.00)	7	2.41 (22.58)	24	6.67 (77.42)	31	4.65 (100.00)
	Total	**16**	**100.00 (2.40)**	**291**	**100.00 (43.63)**	**360**	**100.00 (53.97)**	**667**	**100.00 (100.00)**

Source: Primary Household Survey-2008
Note: Figures in Parenthesis Denote Row Percentage

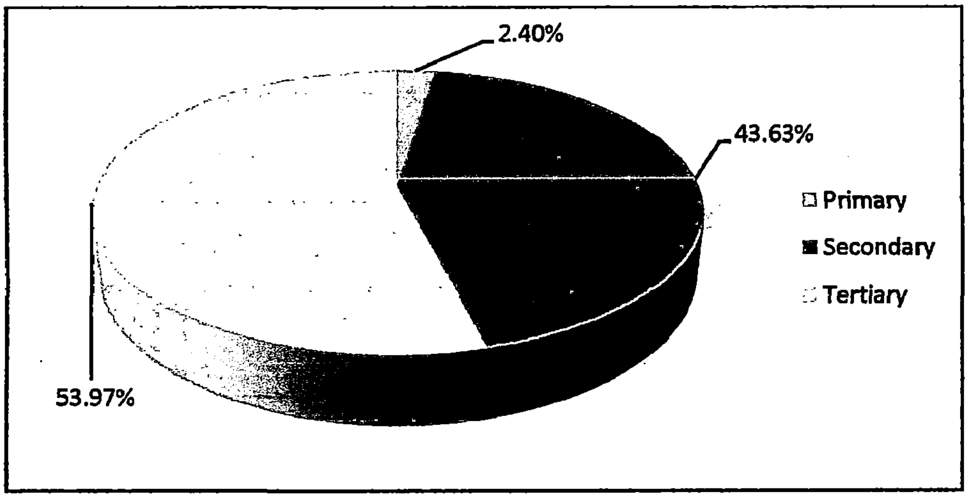

Fig. No. 4.6: Distribution of Working Population by Occupation

This Table and this Fig. reveal that above two-fifth (43.45 per cent) of the total surveyed population is working population. Of which, above two-fifth (43.03 per cent) of the households confined in the age group of 25-40 years. Followed by, about one-sixth (15.89 per cent), (15.14 per cent), about one-seventh (13.94 per cent) and about one-eighth (11.99 per cent) of the households confined in the age-group of below 25, 40-50, 50-60 and 60 years & above respectively in the study area. In income group analysis, the working age-group of members of household in below 25 years to 40-50 years are decreasing along with increase in income and the working age-group of 50-60 years are scattered over in almost all income groups. It can also be observed that the working age group of 60 & above are increasing along with increase in income up to the monthly household income group of Rs. 20,000-40,000 and then observe the reverse trend. It can be deduced from the table that the majority, i.e., above two-fifth (43.03 per cent) of the working population fall in the range 25-40 years, and it is evident from the analysis that the youths are dominant among the working population, and it shows majority of them are using two-wheeler and is representing about three-fourth (71.77 per cent) of the owned vehicular population (c.r.t. No. 4.33).

Table No. 4.7: Distribution of Working Members of Household by Age Group

(Years/Numbers/ Per cent)

SI No.	Household Income (Rs. /month)	Age in Years										Total	
		< 25		25-40		40-50		50-60		> 60			
		Nos.	Per cent	Nos.	Per cent	Nos.	Per cent	Nos.	Per cent	Nos.	Per cent	Nos.	Per cent
1	< 20,000	58	54.72 (20.71)	109	37.98 (38.93)	58	57.43 (20.71)	26	27.96 (9.29)	29	36.25 (10.36)	280	41.98 (100.00)
2	20,000 - 40,000	28	26.42 (13.79)	92	32.06 (45.32)	25	24.75 (12.32)	26	27.96 (12.81)	32	40.00 (15.76)	203	30.43 (100.00)
3	40,000 - 60,000	15	14.15 (13.51)	43	14.98 (38.74)	11	10.89 (9.91)	30	32.26 (27.03)	12	15.00 (10.81)	111	16.64 (100.00)
4	60,000 - 80,000	4	3.77 (9.52)	21	7.32 (50.00)	4	3.96 (9.52)	8	8.60 (19.05)	5	6.25 (11.90)	42	6.30 (100.00)
5	> 80,000	1	0.94 (3.23)	22	7.67 (70.97)	3	2.97 (9.68)	3	3.23 (9.68)	2	2.50 (6.45)	31	4.65 (100.00)
	Total	**106**	**100.00 (15.89)**	**287**	**100.00 (43.03)**	**101**	**100.00 (15.14)**	**93**	**100.00 (13.94)**	**80**	**100.00 (11.99)**	**667**	**100.00 (100.00)**

Source: Primary Household Survey-2008

Note: Figures in Parenthesis Denote Row Percentage

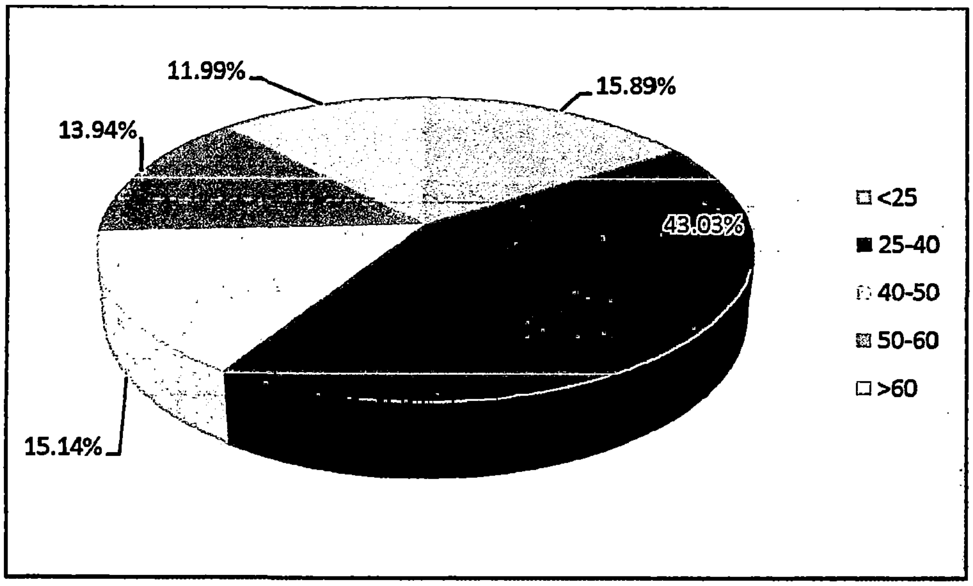

Fig. No. 4.7: Distribution of Working Members of Household by Age Group

4.1.8. Sources of Water Supply

The population explosion in the study area caused for the requirement of huge quantity of water for its survival. The metropolitan areas are facing acute shortage of water in general, and the study area in particular. The city administration is not providing the minimum quantity of water to its population; i.e., 135 Liters Per Capita Demand (LPCD) as per the World Health Organisation. The wealthy people manage their own source of water from bore well, open well, etc., but the poor people are totally deprived. Having this knowledge in mind, the Investigator considered this as one of the parameters in the schedule, and conducted the investigation. The sources of water supply are grouped into three groups, which include public supply system, own source and both (public supply system and own source) and is clubbed with various income groups for analysis, and the results are presented in Table 4.8 and in Fig. 4.8. This Table and this Fig. reveal that about four-fifth (79.06 per cent) of the surveyed households using public water supply system in the study area. Followed by, above one-fifth (20.93 per cent) and above one-seventh (15.31 per cent) of the surveyed households have their own source and both (public and own source of water supply) water supply system respectively in the study area. In income group analysis, the households confined within the public water supply system and own source of water supply system alone are decreasing along with increase in income. Further, the households confined in both (public and own source of water supply together) are increasing along with increase in income up to the monthly household income group of Rs. 20,000-40,000 and then observe the revere trend. It can be deduced from the table that the majority of surveyed households rely on public water supply system in the study area and the higher and the highest income group households have their own source along with public water supply system in the study area.

4.1.9. Distribution of Households by Sewerage Availability

Efficient and effectively managed sewerage systems in the urban areas led to good health in the urban system. The cities in developing countries in general and in the metropolitan areas in particular have inefficient and unplanned sewerage system. The unprecedented growth of population and migrated population into metropolitan areas demands huge sewerage infrastructure. Having this knowledge in mind, the Investigator considered this as one of the parameters in the schedule, and conducted the investigation. The available sewerage system at the grassroots level is grouped into four groups, which include septic tank, soak pit, sewer, and no facility and is clubbed with various income groups for analysis, and the results are presented in Table 4.9. This Table illustrate that above four-fifth (83.44 per cent) of the households had sewer line in the study area. Followed by, above one-fifteenth (6.88 per cent), and less than one-twentieth (4.38 per cent) of the households had soak pit and septic tank respectively; above one-twentieth (5.31 per cent) of the households confined in 'no facility' category in the study area. In income group analysis, the households confined with septic tank and 'no facility' categories are almost confined in the least income group, i.e., below Rs. 20,000/- month Further, it has been observed that the households confined with soak pit and sewer are decreasing along with increase in income. This table concludes that the majority (83.44 per cent) of the households had sewer line in the study area, and is the healthy symptom for development.

Table No. 4.8: Distribution of Households by Sources of Water Supply

(Numbers/Per cent)

Sl No.	Household Income (Rs. /month)	Public supply system		Own source		Both		Total	
		Nos.	Per cent	Nos.	Per cent	Nos.	Per cent	Nos.	Per cent
1	< 20,000	127	50.20 (82.47)	27	40.29 (17.53)	14	27.45 (9.09)	154	48.13 (100.00)
2	20,000 - 40,000	70	27.67 (80.45)	17	25.37 (19.55)	16	31.37 (18.39)	87	27.19 (100.00)
3	40,000 - 60,000	38	15.02 (77.55)	11	16.41 (22.44)	9	17.65 (18.36)	49	15.31 (100.00)
4	60,000 - 80,000	8	3.16 (50.00)	8	11.94 (50.00)	8	15.69 (50.00)	16	5.00 (100.00)
5	> 80,000	10	3.95 (71.42)	4	8.16 (28.58)	4	7.84 (28.28)	14	4.38 (100.00)
	Total	**253**	**100.00 (79.06)**	**67**	**100.00 (20.94)**	**51**	**100.00 (15.94)**	**320**	**100.00 (100.00)**

Source: Primary Household Survey-2008

Note: Figures in Parenthesis Denote Row Percentage

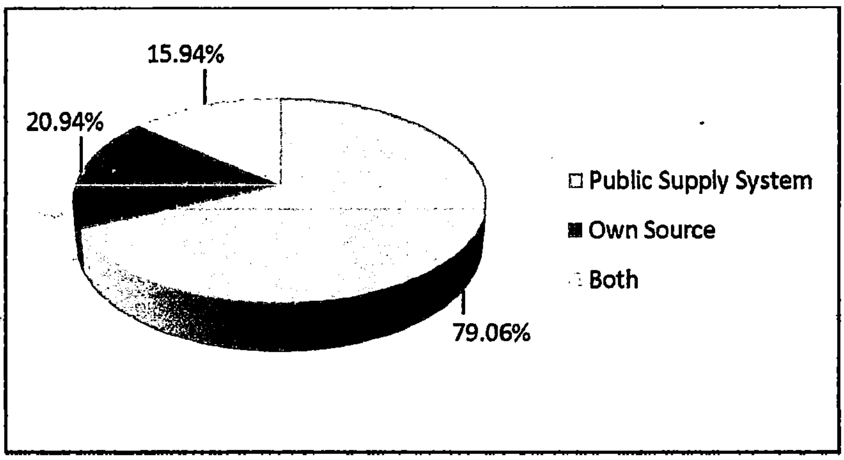

Fig. No. 4.8: Distribution of Households by Sources of Water Supply

4.1.10. Drainage System

The rapid growing population demands huge quantity of drainage infrastructure on one hand, and unpredictable natural hazards including heavy rainfall, rapid climatic change, on the other. As a consequence, blockage occurs often in the drainage, which led to soak, stagnation, hindrance in movement, spreading of diseases, etc., in the urban system. These problems are the continuing phenomena in most of the Indian cities. Having this knowledge in mind, the Investigator considered this as one of the parameters in the schedule, and conducted the investigation. The drainage system is grouped into three groups, which include open drainage, covered drainage and 'no proper drains' and is clubbed with various income groups for analysis, and the results are presented in Table 4.10. This Table reveal that about half (48.44 per cent) of the households have open drainage system in the study area. Followed by, another about half (44.69 per cent), and a meager (6.88 per cent) of the households confined in covered drainage system and 'no proper drains' categories respectively. In income group analysis, the households confined in the 'no proper drains' category belong to the lowest income group only, i.e., below Rs. 20,000/- per month. Followed by, the households confined in open drainage and covered drainage is decreasing along with increase in income. This table concludes that the majority, i.e., about half (48.44 per cent) of the households have open drainage system in the study area and the maximum per cent of higher and the highest income group households have covered drainage system in their locality.

Table No. 4.9: Distribution of Households by Sewerage Availability

(Numbers/ Per cent)

Sl No.	Household Income (Rs. /month)	Septic tank		Soak pit		Sewer		No facility		Total	
		Nos.	Per cent	Nos.	Per cent	Nos.	Per cent	Nos.	Per cent	Nos.	Per cent
1	< 20,000	12	85.71 (7.79)	11	50.00 (7.14)	115	43.07 (74.68)	16	94.12 (10.39)	154	48.13 (100.00)
2	20,000 - 40,000	2	14.29 (2.30)	7	31.82 (8.05)	77	28.84 (88.51)	1	5.88 (1.15)	87	27.19 (100.00)
3	40,000 - 60,000	0	0.00 (0.00)	3	13.64 (6.12)	46	17.23 (93.88)	0	0.00 (0.00)	49	15.31 (100.00)
4	60,000 - 80,000	0	0.00 (0.00)	0	0.00 (0.00)	16	5.99 (100.00)	0	0.00 (0.00)	16	5.00 (100.00)
5	> 80,000	0	0.00 (0.00)	1	4.55 (7.14)	13	4.87 (92.86)	0	0.00 (0.00)	14	4.38 (100.00)
	Total	**14**	**100.00 (4.38)**	**22**	**100.00 (6.88)**	**267**	**100.00 (83.44)**	**17**	**100.00 (5.31)**	**320**	**100.00 (100.00)**

Source: Primary Household Survey-2008

Note: Figures in Parenthesis Denote Row Percentage

Table No. 4.10: Distribution of Households by Drainage System

(Numbers/ Per cent)

Sl No.	Household Income (Rs. /month)	No Proper Drains		Covered		Open		Total	
		Nos.	Per cent	Nos.	Per cent	Nos.	Per cent	Nos.	Per cent
1	< 20,000	22	100.00 (14.29)	51	35.66 (33.12)	81	52.26 (52.60)	154	48.13 (100.00)
2	20,000 - 40,000	0	0.00 (0.00)	41	28.67 (47.13)	46	29.68 (52.87)	87	27.19 (100.00)
3	40,000 - 60,000	0	0.00 (0.00)	33	23.08 (67.35)	16	10.32 (32.65)	49	15.31 (100.00)
4	60,000 - 80,000	0	0.00 (0.00)	11	7.69 (68.75)	5	3.23 (31.25)	16	5.00 (100.00)
5	> 80,000	0	0.00 (0.00)	7	4.90 (50.00)	7	4.52 (50.00)	14	4.38 (100.00)
	Total	**22**	**100.00 (6.88)**	**143**	**100.00 (44.69)**	**155**	**100.00 (48.44)**	**320**	**100.00 (100.00)**

Source: Primary Household Survey-2008

Note: Figures in Parenthesis Denote Row Percentage

4.1.11. Distribution of Households by Waste Disposal

The rising income of the family commensurate with education, occupation, investment in market, etc., and thereby a change in lifestyle, the behavior, the diversified food consumption, etc., are occur, which results into generating huge quantity of waste at the household level. The properly planned disposal of waste at the household level depends on few factors, which include awareness about use, reuse, and recycling of wastes, the methods of segregation of wastes, etc. If the waste is segregated at the household level, then the segregated waste at the household level may be disposed off at the particular location for further recycling of the same in the urban system, thereby waste related problem shall be minimized. Having this knowledge in mind, the Investigator considered this as one of the parameters in the schedule, and conducted the investigation. The waste disposal practices at the grassroots level is grouped into four groups, which include using dustbin/PVC bag, storage container, burning, and throwing in the public, and is clubbed with various income groups for analysis, and the results are presented in Table 4.11. This Table illustrate that about nine-tenth (85.94 per cent) of the households keep dustbin/PVC bag to dispose their generated waste at the household level in the study area, and the rest of them, confined in throwing in the public, burning, and storing in the storage container, and their corresponding values are 6.56 per cent, 4.06 per cent and 3.44 per cent respectively in the study area. In income group analysis, the household confined in keeping the waste in the dustbin/PVC bags are decreasing along with increase in income. Followed by, the households confined in burning and throwing in the public categories are almost confined within the least income group category, i.e., below Rs. 20,000/- per month. It has also been observed that the households confined in storage container category scattered over in almost all income groups except one income group, i.e., below Rs. 20,000 per month. Further, it is interesting to note that the higher income households never throw the waste in the public places, and the rest throw waste either in the public or in other places. This table conclude that the people are aware the importance of waste management, and its consequences (including health problems) to the larger extent in the system.

Table No. 4.11: Distribution of Households by Waste Disposal

(Numbers/ Per cent)

Sl No.	Household Income (Rs. /month)	Storage container		Dustbin/PVC bag		Burning		Throwing in the public		Total	
		Nos.	Per cent	Nos.	Per cent	Nos.	Per cent	Nos.	Per cent	Nos.	Per cent
1	< 20,000	0	0.00 (0.00)	125	45.45 (81.17)	12	92.31 (7.79)	16	76.19 (10.39)	154	48.13 (100.00)
2	20,000 - 40,000	1	9.09 (1.15)	83	30.18 (95.40)	1	7.69 (1.15)	3	14.29 (3.45)	87	27.19 (100.00)
3	40,000 - 60,000	3	27.27 (6.12)	43	15.64 (87.76)	0	0.00 (0.00)	2	9.52 (4.08)	49	15.31 (100.00)
4	60,000 - 80,000	1	9.09 (6.25)	15	5.45 (93.75)	0	0.00 (0.00)	0	0.00 (0.00)	16	5.00 (100.00)
5	> 80,000	6	54.55 (42.86)	9	3.27 (64.29)	0	0.00 (0.00)	0	0.00 (0.00)	14	4.38 (100.00)
	Total	**11**	**100.00 (3.44)**	**275**	**100.00 (85.94)**	**13**	**100.00 (4.06)**	**21**	**100.00 (6.56)**	**320**	**100.00 (100.00)**

Source: Primary Household Survey-2008

Note: Figures in Parenthesis Denote Row Percentage

4.1.12. Opinion of Households on Water Quality

Water quality available in the area is one of the most important indicators of good health of the people in that area, and also a barometer of quality of life of the people in that area. The haphazard, unplanned and uncontrolled growth of industries especially illegal industries in the urban system is responsible for environmental degradation including surface and subsurface water contamination. At present, the major industries are generating huge quantity of both solid and liquid wastes and pumping these wastes into the rivers and natural water bodies which lead to deterioration of total water bodies in the system. In the study area, few pockets are affected with water related problems. Having this knowledge in mind, the Investigator considered this as one of the parameters in the schedule, and conducted the investigation. To get the opinion from the households about the available water quality, it is grouped into four groups, which include, very good, good, moderate and poor and is clubbed with various income groups for analysis, and the results are presented in Table 4.12 and in Fig. 4.9. This Table and this Fig. depict that above half (54.06 per cent) of the households get good quality of water in the study area. Followed by, above one-third (36.25 per cent), just above one-fourteenth (7.19 per cent), and a meager (2.50 per cent) of the households get moderate, poor and very good quality of water respectively, in the study area. In income group analysis, the households opinioned as very good, good, moderate, and poor qualify of water are decreasing along with increase in income. This table concludes that the households opinioned as poor water quality is more or less confined among the least income group category, i.e., below Rs. 20,000/- per month, which shows that the administrative authorities never bother the lowest income group category for infrastructure provision.

4.1.13. Opinion of Households on Air Quality

The unprecedented and uncontrolled growth of vehicular population specially proliferation of personalized vehicles on one hand, and unplanned cities with absence of plausible urban transport policy and strategies, inefficient public transportation system, and ineffective traffic management system on the other, are responsible for deterioration of air quality in the urban areas in general and in the metropolitan areas in particular.

Table No. 4.12: Opinion of Households on Water Quality

(Numbers/ Per cent)

Sl No.	Household Income (Rs. /month)	Very good		Good		Moderate		Poor		Total	
		Nos.	Per cent	Nos.	Per cent	Nos.	Per cent	Nos.	Per cent	Nos.	Per cent
1	< 20,000	4	50.00 (2.60)	93	53.76 (60.39)	40	34.48 (25.97)	17	73.91 (11.04)	154	48.13 (100.00)
2	20,000 - 40,000	2	25.00 (2.30)	52	30.06 (59.77)	31	26.72 (35.63)	2	8.70 (2.30)	87	27.19 (100.00)
3	40,000 - 60,000	1	12.50 (2.04)	16	9.25 (32.65)	30	25.86 (61.22)	2	8.70 (4.08)	49	15.31 (100.00)
4	60,000 - 80,000	0	0.00 (0.00)	4	2.31 (25.00)	10	8.62 (62.50)	2	8.70 (12.50)	16	5.00 (100.00)
5	> 80,000	1	12.50 (7.14)	8	4.62 (57.14)	5	4.31 (35.71)	0	0.00 (0.00)	14	4.38 (100.00)
	Total	**8**	**100.00 (2.50)**	**173**	**100.00 (54.06)**	**116**	**100.00 (36.25)**	**23**	**100.00 (7.19)**	**320**	**100.00 (100.00)**

Source: Primary Household Survey-2008

Note: Figures in Parenthesis Denote Row Percentage

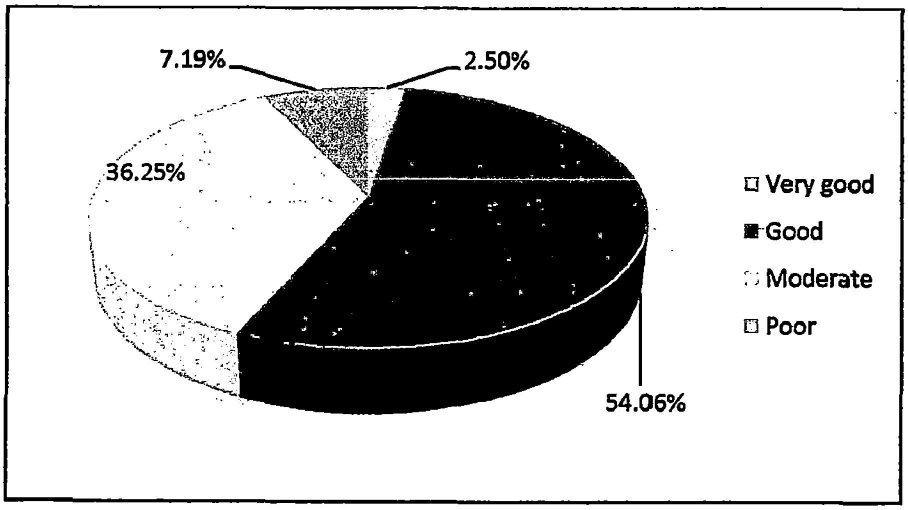

Fig. No. 4.9: Opinion of Households on Water Quality

The high volume of vehicular population, inadequate road space, absence of mass transportation system, inefficient and ineffective planning and management of transportation system, rapid growth of personalized vehicles, horizontal expansion of cities, etc., further aggravate the problems of environmental degradation in the study area. The polluted air is spreading diseases irrespective of age group of the people. Having this knowledge in mind, the Investigator considered this as one of the parameters in the schedule, and conducted the investigation. The opinion of the households about air quality is grouped into four groups, which include very good, good, moderate and poor, and is clubbed with various income groups for analysis, and the results are presented in Table 4.13 and in Fig. 4.10. This Table and this Fig. depict that above one-third (37.81 per cent) of the households opinioned that they have moderate quality of air in their locality. Further, about one-third (31.56 per cent), above one-fourth (28.75 per cent), and a meager (1.88 per cent) of the households opinioned as poor, good and very good quality of air in their locality respectively. In income group analysis, the households opinioned as very good, good, and moderate quality of air are decreasing along with increase in income. Further, it has been observed that the households opinioned as poor quality of air are almost confined within the least income group i.e., below Rs. 20,000/- per month. This table concludes that the majority of the households do not have high opinion about the air quality in the system.

Table No. 4.13: Opinion of Households on Air Quality

(Numbers/ Per cent)

Sl No.	Household Income (Rs. /month)	Very good		Good		Moderate		Poor		Total	
		Nos.	Per cent	Nos.	Per cent	Nos.	Per cent	Nos.	Per cent	Nos.	Per cent
1	< 20,000	3	50.00 (1.95)	30	32.61 (19.48)	49	40.50 (31.82)	72	71.29 (46.75)	154	48.13 (100.00)
2	20,000 - 40,000	0	0.00 (0.00)	35	38.04 (40.23)	34	28.10 (39.08)	18	17.82 (20.69)	87	27.19 (100.00)
3	40,000 - 60,000	2	33.33 (4.08)	19	20.65 (38.78)	25	20.66 (51.02)	3	2.97 (6.12)	49	15.31 (100.00)
4	60,000 - 80,000	0	0.00 (0.00)	3	3.26 (18.75)	6	4.96 (37.50)	7	6.93 (43.75)	16	5.00 (100.00)
5	> 80,000	1	16.67 (7.14)	5	5.43 (35.71)	7	5.79 (50.00)	1	0.99 (7.14)	14	4.38 (100.00)
	Total	**6**	**100.00 (1.88)**	**92**	**100.00 (28.75)**	**121**	**100.00 (37.81)**	**101**	**100.00 (31.56)**	**320**	**100.00 (100.00)**

Source: Primary Household Survey-2008

Note: Figures in Parenthesis Denote Row Percentage

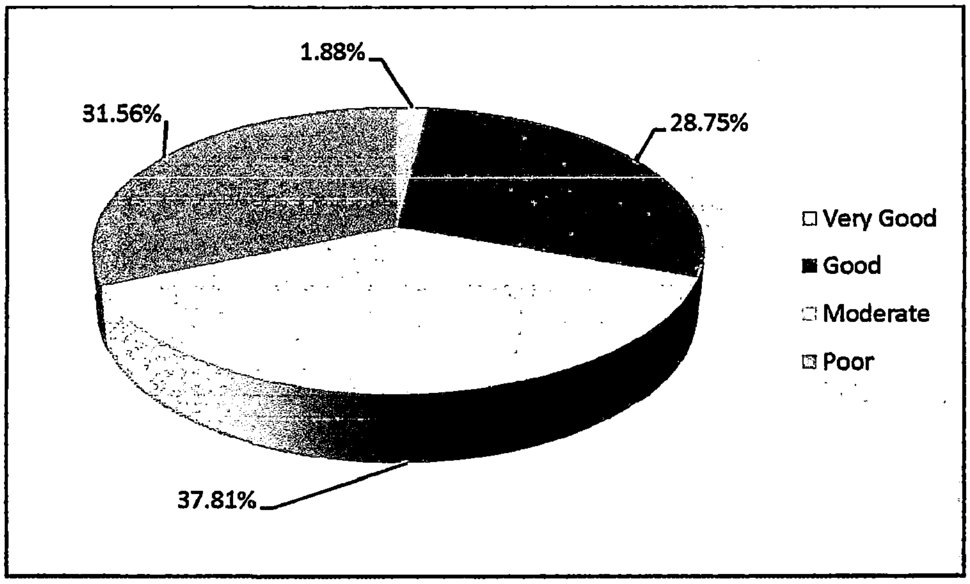

Fig. No. 4.10: Opinion of Households on Air Quality

4.1.14. Opinion of Households on Land Quality (Land Pollution)

Higher amount of construction activities; unauthorized, illegal, and haphazard growth of residences, harmful industries in the city, etc., are more or less responsible for deterioration of land quality in the system. The cities in developing countries are characterized by dense population, squatter settlements, slum population, street-dwellers, and persons engaged in informal sector activities, which include vegetable vendors, cobblers, etc., are also responsible for deterioration of land quality in their locality. Having this knowledge in mind, the Investigator considered this as one of the parameters in the schedule, and conducted the investigation. The opinion of the households about land quality (land pollution) is grouped into four groups, which include very good, good, moderate and poor and is clubbed with various income groups for analysis, and the results are presented in Table 4.14 and in Fig. 4.11. This Table and this Fig. illustrate that above half (55.00 per cent) of the households opinioned that they have good quality of land in the study area. Further, above one-fourth (28.44 per cent), about one-eighth (12.19 per cent) and a meager (4.38 per cent) of the households opinioned as moderate, poor and very good quality of land respectively. In income group analysis, the households opinioned as poor quality of land is almost confined within the lowest income group, i.e., household income group of Rs. 20,000/- per month. Further, it has been observed that the households opinioned as moderate quality of land are decreasing along with increase in income; the households opinioned as very good quality of land is scattered over in almost all income groups; the households confined with good quality of land is increasing along with increase in income up to the monthly household income group of Rs. 20,000-40,000, and then observe the reverse trend. This table concludes that the majority, i.e., above half (55.00 per cent) of the households opinioned that the study area has moderate quality of land.

4.1.15. Opinion of Households on Noise Pollution

The age-old, obsolete, and outdated vehicles; high volume of vehicles on road; inadequate and inefficient public transportation system; inefficient traffic management system; absence of mass transportation system; uncontrolled growth of personalized vehicles, heterogeneous traffic, overcrowded public transport buses in peak hours; traffic congestion, chaos, traffic jam, etc., lead to deterioration of environmental quality including air pollution, noise pollution, land pollution, etc., in the system. The noise level in almost all strategic areas include residential, commercial, and industrial areas exceed the prescribed standard limits. Having this knowledge in mind, the Investigator considered this as one of the parameters in the schedule, and conducted the investigation. The opinion of the households about noise pollution is grouped into four groups, which include very high, high, moderate and low and is clubbed with various income groups for analysis, and the results are presented in Table 4.15 and in Fig. 4.12. This Table and this Fig. illustrate that about half (46.56 per cent) of the households opinioned that they feel high noise pollution in the study area. Further, above two-fifth (40.31 per cent), one-tenth (10.00 per cent) and a very meager (3.13 per cent) of the households opinioned that they feel moderate, very high and low level of noise pollution respectively. In income group analysis, the households opinioned as low level of noise pollution is almost all confined within the least income group, i.e., below Rs. 20,000/- per month. Further, it has been observed that the households opinioned as very high, high and moderate quality of noise pollution are decreasing along with increase in income. This table concludes that about half (46.56 per cent) of the households opinioned that the study area has high noise pollution. Hence, the study area requires more attention pertain to noise pollution.

Table No. 4.14: Opinion of Households on Land Quality (Land Pollution)

(Numbers/ Per cent)

Sl No.	Household Income (Rs. /month)	Very good		Good		Moderate		Poor		Total	
		Nos.	Per cent	Nos.	Per cent	Nos.	Per cent	Nos.	Per cent	Nos.	Per cent
1	< 20,000	4	28.57 (2.60)	41	23.30 (26.62)	71	78.02 (46.10)	38	97.44 (24.68)	154	48.13 (100.00)
2	20,000 - 40,000	1	7.14 (1.15)	73	41.48 (83.91)	12	13.19 (13.79)	1	2.56 (1.15)	87	27.19 (100.00)
3	40,000 - 60,000	3	21.43 (6.12)	40	22.73 (81.63)	6	6.59 (12.24)	0	0.00 (0.00)	49	15.31 (100.00)
4	60,000 - 80,000	3	21.43 (18.75)	12	6.82 (75.00)	1	1.10 (6.25)	0	0.00 (0.00)	16	5.00 (100.00)
5	> 80,000	3	21.43 (21.43)	10	5.68 (71.43)	1	1.10 (7.14)	0	0.00 (0.00)	14	4.38 (100.00)
	Total	**14**	**100.00 (4.38)**	**176**	**100.00 (55.00)**	**91**	**100.00 (28.44)**	**39**	**100.00 (12.19)**	**320**	**100.00 (100.00)**

Source: Primary Household Survey-2008

Note: Figures in Parenthesis Denote Row Percentage

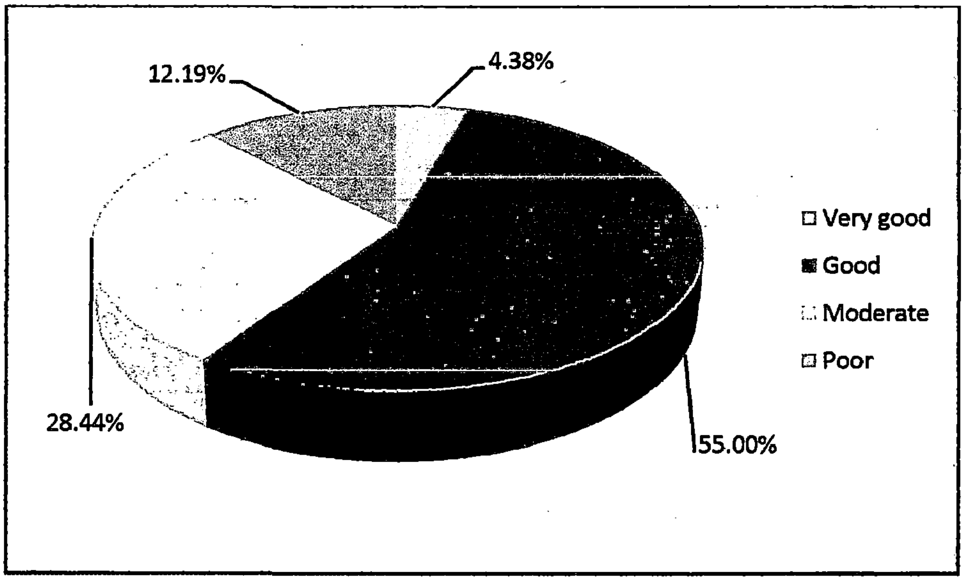

Fig. No. 4.11: Opinion of Households on Land Quality (Land Pollution)

4.1.16. Opinion of Households on Road Condition

Road transportation is dominated in Indian cities. The quality and quantity of road length plays a very significant role for the development of any system. The cities and towns of the developing countries are characterized by narrow lanes, pathetic road condition, poor maintenance, potholes, etc. The bad road condition lead to severe problems, which include road accidents, haphazard movement of heterogeneous traffic, increase in fuel consumption, lack of safety, increase in wear and tear of tires, unnecessary traffic congestion, breakdown of vehicles, traffic jams, etc. Having this knowledge in mind, the Investigator considered this as one of the parameters in the schedule, and conducted the investigation. The opinion of the households about road condition is grouped into five groups, which include good, moderate, poor, very poor and worse and is clubbed with various income groups for analysis, and the results are presented in Table 4.16 and in Fig. 4.13. This Table and this Fig. illustrate that above two-fifth (43.13 per cent) of the households had opinion that the road conditions in the study area is poor. Followed by, above one-fourth (27.50 per cent), above one-eighth (13.13 per cent), about one-tenth (9.06 per cent) and above one-fourteenth (7.19 per cent) of the households opinioned that the road condition is good, moderate, very poor and worse, respectively, in the study area.

Table No. 4.15: Opinion of Households on Noise Pollution

(Numbers/ Per cent)

Sl No.	Household Income (Rs. /month)	Very high		High		Moderate		Low		Total	
		Nos.	Per cent	Nos.	Per cent	Nos.	Per cent	Nos.	Per cent	Nos.	Per cent
1	< 20,000	13	40.63 (8.44)	76	51.01 (49.35)	57	44.19 (37.01)	8	80.00 (5.19)	154	48.13 (100.00)
2	20,000 - 40,000	12	37.50 (13.79)	41	27.52 (47.13)	33	25.58 (37.93)	1	10.00 (1.15)	87	27.19 (100.00)
3	40,000 - 60,000	5	15.63 (10.20)	21	14.09 (42.86)	22	17.05 (44.90)	1	10.00 (2.04)	49	15.31 (100.00)
4	60,000 - 80,000	2	6.25 (12.50)	5	3.36 (31.25)	9	6.98 (56.25)	0	0.00 (90.00)	16	5.00 (100.00)
5	> 80,000	0	0.00 (0.00)	6	4.03 (42.86)	8	6.20 (57.14)	0	0.00 (0.00)	14	4.38 (100.00)
	Total	**32**	**100.00 (10.00)**	**149**	**100.00 (46.56)**	**129**	**100.00 (40.31)**	**10**	**100.00 (3.13)**	**320**	**100.00 (100.00)**

Source: Primary Household Survey-2008

Note: Figures in Parenthesis Denote Row Percentage

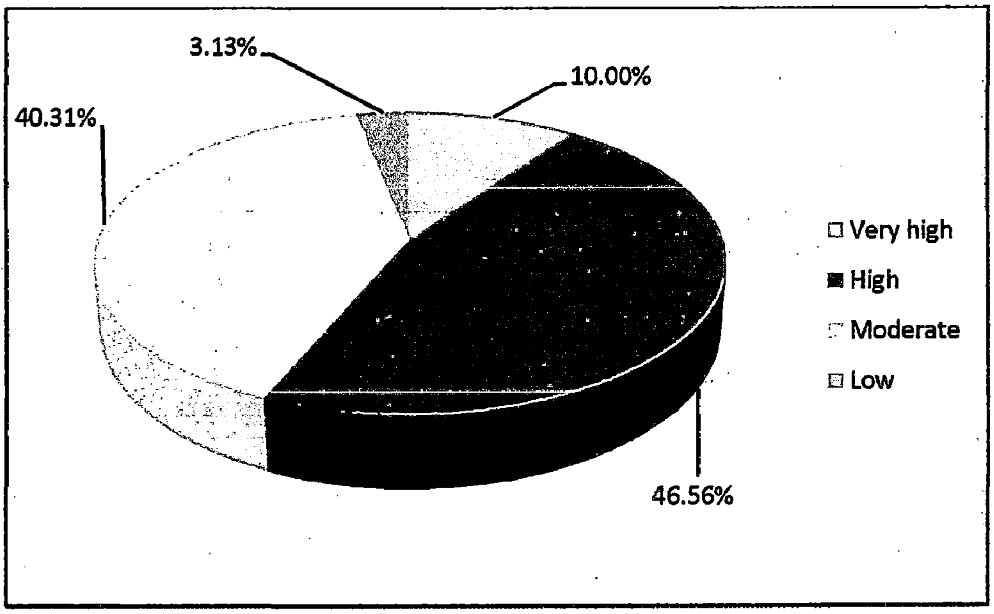

Fig. No. 4.12: Opinion of Households on Noise Pollution

In income group analysis, the households opinioned as very poor and worse road condition are almost confined within the least income group, i.e., below Rs. 20,000/- per month. Further, it has also been observed that the households opinioned as poor and moderate road condition are decreasing along with increase in income; it has also been observed that the households opinioned as good road condition are scattered over in almost all income groups. This table concludes that considerable amount of the households opinioned that either the road condition is moderate or poor or very poor or worst, therefore the road condition has to be improved in the system.

4.1.17. Opinion of Households on Road Maintenance

Road maintenance is one of the important aspects of road management. The concerned authorities who are working for the development of roads are responsible for road maintenance in the study area. The responsible authorities must involve continuously and constantly in road maintenance by considering the use, function, and importance of the road, such a way that it should not be a hindrance to road users. The Investigator strongly feels that this is one of the neglected areas to the concerned authorities. The properly maintained and managed road help to energy conservation, reduces the wear and tear of tires, increases the safety and speed of the vehicle, etc.

Table No. 4.16: Opinion of Households on Road Condition

(Numbers/ Per cent)

Sl No.	Household Income (Rs. /month)	Good		Moderate		Poor		Very poor		Worse		Total	
		Nos.	Per cent	Nos.	Per cent	Nos.	Per cent	Nos.	Per cent	Nos.	Per cent		
1	< 20,000	18	20.45 (11.69)	29	69.05 (18.83)	58	42.03 (37.66)	28	96.55 (18.18)	22	95.65 (14.29)	154	48.13 (100.00)
2	20,000 - 40,000	24	27.27 (27.59)	12	28.57 (13.79)	49	35.51 (56.32)	0	0.00 (0.00)	1	4.35 (1.15)	87	27.19 (100.00)
3	40,000 - 60,000	24	27.27 (48.98)	1	2.38 (2.04)	24	17.39 (48.98)	0	0.00 (0.00)	0	0.00 (0.00)	49	15.31 (100.00)
4	60,000 - 80,000	11	12.50 (68.75)	0	0.00 (0.00)	4	2.90 (25.00)	1	3.45 (6.25)	0	0.00 (0.00)	16	5.00 (100.00)
5	> 80,000	11	12.50 (78.57)	0	0.00 (0.00)	3	2.17 (21.43)	0	0.00 (0.00)	0	0.00 (0.00)	14	4.38 (100.00)
	Total	**88**	**100.00 (27.50)**	**42**	**100.00 (13.13)**	**138**	**100.00 (43.13)**	**29**	**100.00 (9.06)**	**23**	**100.00 (7.19)**	**320**	**100.00 (100.00)**

Source: Primary Household Survey-2008

Note: Figures in Parenthesis Denote Row Percentage

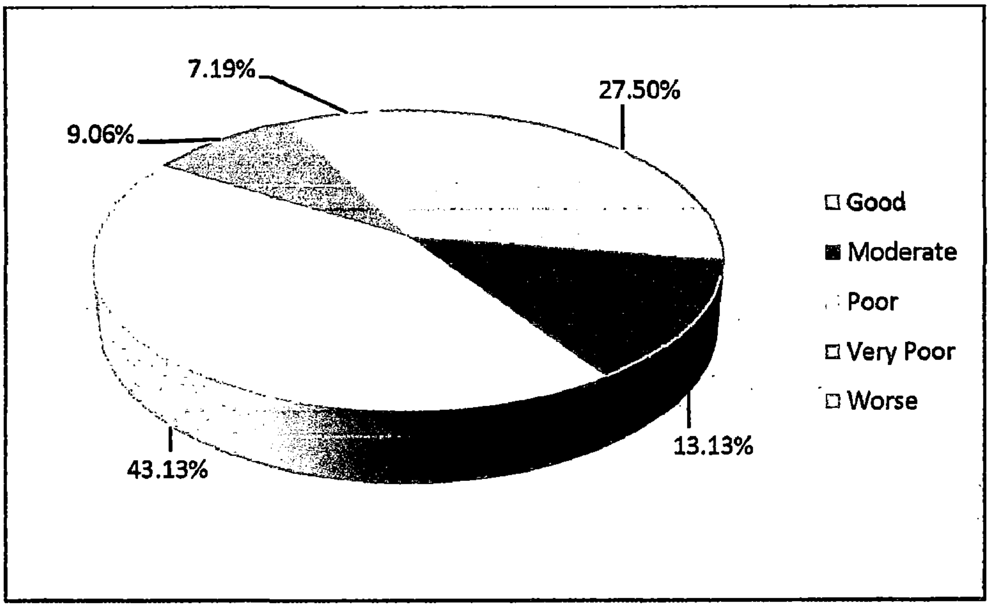

Fig. No. 4.13: Opinion of Households on Road Condition

Having this knowledge in mind, the Investigator considered this as one of the parameters in the schedule, and conducted the investigation. The opinion of the households about road maintenance is grouped into five groups, which include good, moderate, poor, very poor and worst, and is clubbed with various income groups for analysis, and the results are presented in Table 4.17 and in Fig. 4.14. This Table and this Fig. depict that above two-fifth (40.31 per cent) of the households opinioned that the road maintenance is poor in the study area. Followed by, above one-fifth (22.19 per cent), above one-seventh (15.31 per cent), above one-tenth (11.25 per cent and 10.94 per cent) of the households opinioned that the road maintenance are moderate, good, very poor and worst respectively in the study area. In income group analysis, the households opinioned as the worst road maintenance are decreasing along with increase in income group up to the monthly household income of Rs. 20,000-40,000, whereas the households opinioned as moderate maintenance of road are decreasing along with increase in income up to the monthly household income of Rs. 40,000-60,000; the households opinioned as in good road maintenance are scattered over in almost all income groups; the households opinioned as in very poor road maintenance are almost confined within the least income group, i.e., below Rs. 20,000/- per month; and the households opinioned as poor road maintenance are increasing along with increase in income up to the monthly household income group of Rs. 40,000-60,000 and then observe the reverse trend. This table concludes that the road maintenance is ineffective, and is very much essential since majority of them opinioned as poor maintenance of road in the system.

4.1.18. EXPENDITURE PATTERN OF HOUSEHOLD

The expenditure pattern of households is generally proportional to the number of earning members in the household. The expenditure pattern depends on several parameters, which include the life style, attitude, behaviour, food habits, cultural background, education level, literacy rate, inclination towards religious activities, routine schedules, weekend schedules, occasional trips, visiting to tourist places, etc. The expenditure pattern of households also varies further based on the following, which include family size, age-group of households, basic needs, aspirations, health problems, market behavior, etc. Having this knowledge in mind, the Investigator conducted a thorough investigation about the expenditure pattern of the households at the grassroots level through conducting primary household survey in the study area. The expenditure of households pertain to various activities, which include food, clothing, education, health, public transportation, loan repayment, energy consumption, recreation and entertainment, parking charges, telecommunication, water, house rent, etc. The collected data is very carefully analysed, and the results are grouped under different heads, and are presented below. They are:

Table No. 4.17: Opinion of Households on Road Maintenance

(Numbers/ Per cent)

Sl No.	Household Income (Rs. /month)	Good		Moderate		Poor		Very poor		Worst		Total	
		Nos.	Per cent	Nos.	Per cent	Nos.	Per cent	Nos.	Per cent	Nos.	Per cent	Nos.	Per cent
1	< 20,000	0	0.00 (0.00)	54	76.06 (35.06)	42	32.56 (27.27)	33	91.67 (21.43)	25	71.43 (16.23)	154	48.13 (100.00)
2	20,000 - 40,000	10	20.41 (11.49)	10	14.08 (11.49)	55	42.64 (63.22)	2	5.56 (2.30)	10	28.57 (11.49)	87	27.19 (100.00)
3	40,000 - 60,000	15	30.61 (30.61)	7	9.86 (14.29)	26	20.16 (53.06)	1	2.78 (2.04)	0	0.00 (0.00)	49	15.31 (100.00)
4	60,000 - 80,000	10	20.41 (62.50)	0	0.00 (0.00)	6	4.65 (37.50)	0	0.00 (0.00)	0	0.00 (0.00)	16	5.00 (100.00)
5	> 80,000	14	28.57 (100.00)	0	0.00 (0.00)	0	0.00 (0.00)	0	0.00 (0.00)	0	0.00 (0.00)	14	4.38 (100.00)
	Total	**49**	**100.00 (15.31)**	**71**	**100.00 (22.19)**	**129**	**100.00 (40.31)**	**36**	**100.00 (11.25)**	**35**	**100.00 (10.94)**	**320**	**100.00 (100.00)**

Source: Primary Household Survey-2008

Note: Figures in Parenthesis Denote Row Percentage

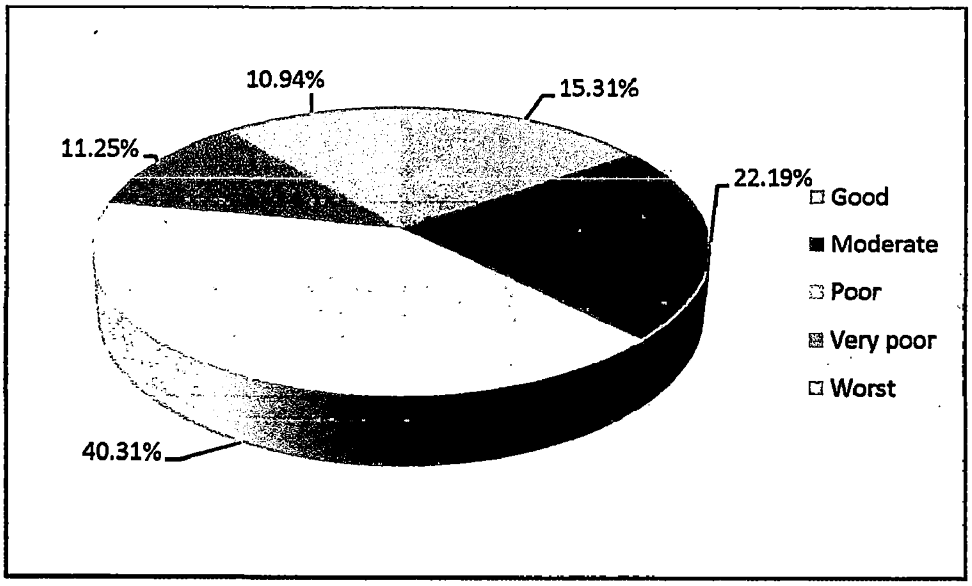

Fig. No. 4.14: Opinion of Households on Road Maintenance

4.1.18.1. Expenditure on Food

The very basic need of human being is food. Generally, the expenditure on food is more than any other expenditure of the households of economically weaker sections. Various parameters, which include the family size, household income, affordability, quality of life, education level, needs and aspirations of households, food habit, consumption patter of households, etc., decide expenditure on food. Having this knowledge in mind, the Investigator considered this as one of the parameters in the schedule, and conducted the investigation. The household expenditure on food is grouped into five groups, which include below Rs. 5000/-, Rs. 5000-7000, Rs. 7000-9000, Rs. 9000-11000 and Rs. 11000 & above per month and is clubbed with various income groups for analysis, and the results are presented in Table 4.18 and in Fig. 4.15. It has been observed from this Table and this Figure that about half (46.88 per cent) of the households spend in range of Rs. 5000-7000 per month towards expenditure on food. Followed by, above one-fifth (22.19 per cent) of them spend up to Rs. 5000/- per month towards the same; just one-fifth (20.00 per cent) of the households spend Rs. 7000-9000, and a very meager (5.31 per cent and 5.63 per cent) of the households spend Rs. 9000-11000 and Rs. 11000 & above per month respectively for the same purpose in the study area. It clearly shows that the maximum number of households, i.e., about half (46.88 per cent) of the surveyed households spend Rs. 5000-7000 per month on food and a very meager 5.63 per cent of the households spend more than Rs. 11000 per month on food in the study area. In income group-wise analysis, it has been observed that the households who spend Rs. below 5000/- and Rs. 5000-7000 per month for food is confined more in the lowest income group category, and their representation is decreasing along with increased in income, whereas the households who spend Rs. 7000-9000 per month for food is increasing along with increase in income up to the monthly income group of Rs. 40,000-60,000/- and then observed the reverse trend. Further, it has also been observed that the households who spend Rs. 9000-11,000 and Rs. 11,000 & more are scattered over in almost all income groups except the lowest household income group, i.e., below Rs. 20,000/- per month. It is inferred from the table that the higher and the highest income group personals would have been consuming good quality food products, and spend more money for the same though the household size is almost identical to other income groups. Therefore, much variation is observed in spending money towards food.

4.1.18.2. Expenditure on Clothes

Expenditure on clothes is another important parameter, which can be used to decide the functioning of any system. Generally, the higher income group people spend more amount for procuring luxurious items, whereas the lower income groups spend money for survival from their meager amount of income. The study area, where the investigation has been attempted is also not an exceptional one in this regard. Having this knowledge in mind, the Investigator has included expenditure pattern on clothes as one of the variables in the schedules for investigation. The expenditure pattern in clothes was grouped into five groups, which include less than Rs. 400/-, Rs. 400-800, Rs. 800-1200, Rs. 1200-1600 and more than Rs. 1600/- per month and is clubbed with various income groups for analysis, and the results are presented in Table 4.19 and in Fig. 4.16. This Table and this Figure illustrate that about one-third (32.81 per cent) of the households spend Rs. 400-800 per month for clothes.

Table No. 4.18: Distribution of Households Based on Expenditure on Food

(Rupees/ Month)

Sl No.	Household Income (Rs. /month)	Expenditure in Rupees per Month										Total	
		< 5000		5000-7000		7000-9000		9000-11000		> 11000			
		Nos.	Per cent	Nos.	Per cent	Nos.	Per cent	Nos.	Per cent	Nos.	Per cent	Nos.	Per cent
1	< 20,000	67	94.37 (43.51)	77	51.33 (50.00)	10	15.63 (6.49)	0	0.00 (0.00)	0	0.00 (0.00)	154	48.13 (100.00)
2	20,000 - 40,000	3	4.23 (3.45)	50	33.33 (57.47)	19	29.69 (21.84)	9	52.94 (10.34)	6	33.33 (6.90)	87	27.19 (100.00)
3	40,000 - 60,000	1	1.41 (2.04)	15	10.00 (30.61)	24	37.50 (48.98)	4	23.53 (8.16)	5	27.78 (10.20)	49	15.31 (100.00)
4	60,000 - 80,000	0	0.00 (0.00)	6	4.00 (37.50)	7	10.94 (43.75)	1	5.88 (6.25)	2	11.11 (12.50)	16	5.00 (100.00)
5	> 80,000	0	0.00 (0.00)	2	1.33 (14.29)	4	6.25 (28.57)	3	17.65 (21.43)	5	27.78 (35.71)	14	4.38 (100.00)
	Total	**71**	**100.00 (22.19)**	**150**	**100.00 (46.88)**	**64**	**100.00 (20.00)**	**17**	**100.00 (5.31)**	**18**	**100.00 (5.63)**	**320**	**100.00 (100.00)**

Source: Primary Household Survey-2008

Note: Figures in Parenthesis Denote Row Percentage

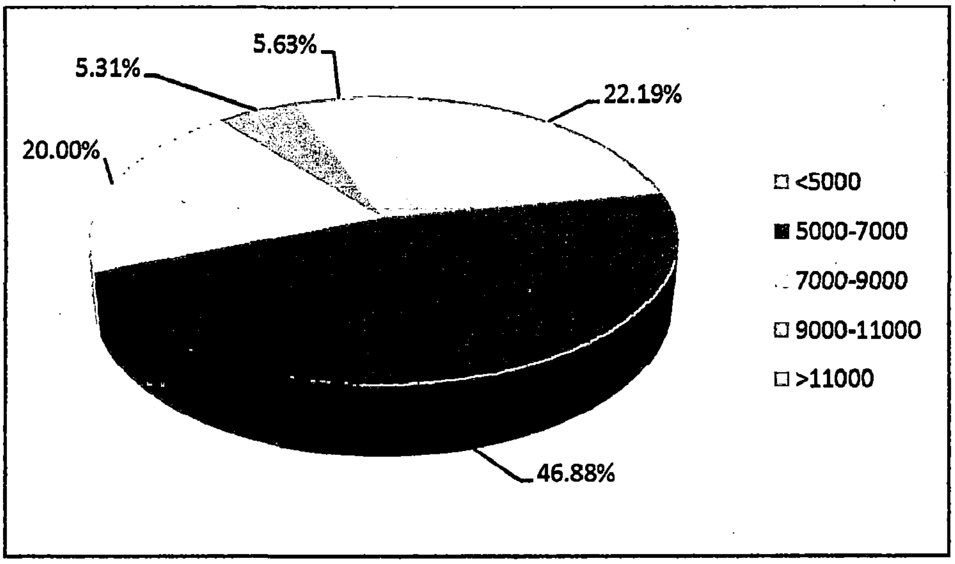

Fig. No. 4.15: Distribution of Households Based on Expenditure on Food

Followed by,, above one-fourth (26.56 per cent) of the households spend less than Rs. 400/- per month, above one-fifth (21.56 per cent) of the households spend Rs. 800-1200 per month, above one-tenth (10.94 per cent) of the households spend Rs. 1200-1600 per month and about one-tenth (8.13 per cent) spend above Rs. 1600 per month for this purpose. In income group analysis, it has been observed that the households spend below Rs. 400/- per month are almost confined within the lowest income group, i.e., below Rs. 20,000/- per month. Further, it has been observed that the households spend up to Rs. 400-800 per month for clothes are decreasing along with increase in income, whereas households confined in other groups who spend Rs. 800-1200, Rs. 1200-1600, and above Rs. 1600/- per month are increasing along with increase in income group up to the monthly household income group of Rs. 20,000-40,000 and then observe the reverse trend. It is painful to note that about nine-tenth (89.41 per cent) of the households confined within the expenditure group of less than Rs. 400/- per month and is confined to the lowest income group category, i.e., below Rs. 20,000/- per month and the rest of them are scattered over next two income group categories. The middle income group people also spend good amount of money for this purpose. It can be inferred from the Table that more number of households confined among the lowest and the next hierarchy of expenditure groups i.e., below Rs. 400/-, Rs. 400-800 per month in this regard, which reflects their monthly income, i.e., more number of people confined in the two lowest income groups.

4.1.18.3. Expenditure on Education

Expenditure on education is one of the most important parameters, which can also be considered for measuring the development of a State or the nation as a whole. In India, different States have been spending huge amount of money for education to improve the quality of human resource. The State like Kerala has been allocating more amount of money in its budget for human resource development, i.e., for education and health, and thereby the Kerala State achieved good quality of human resource, which can take up any kind of job not only in India but also in across the globe. It is evident from the World Bank report (2004) that the Kerala State stands the highest Human Resource Development Index (HRDI) compared to the most populous State (Uttar Pradesh) in India. Having this knowledge in mind, the Investigator added expenditure pertains to education as one of the variables in the schedule, which has been used for investigation to analyse the amount spend on education among the surveyed households. The surveyed households were grouped into five groups based on the expenditure on education, which include below Rs. 1000/-, Rs. 1000-2000, Rs. 2000-3000, Rs. 3000-4000, Rs. 4000-5000 and Rs. 5000 & above and they are clubbed with households of different income groups for analysis, and the results are presented in Table 4.20 and in Fig. 4.17. This Table and this Fig. illustrate that about two-fifth (38.99 per cent) of the households spend below Rs. 1000/- per month for education. Followed by, just above one-fourth (27.98 per cent) of the households spend Rs. 1000-2000 per month, above one-tenth (11.47 per cent) of the households spend Rs. 2000-3000 per month, about one-tenth (9.63 per cent) spend Rs. 3000-4000 per month, and the rest of them spend Rs. 4000-5000 and above Rs. 5000/- per month in this regard. It has been observed that above two-third (66.97 per cent) of the households confined together in the expenditure group of below Rs. 1000, Rs. 1000-2000 per month in this regard. In income group analysis, it has been observed that the households expenditure confined in less than Rs. 1000/-, Rs. 1000-2000, and Rs. 2000-3000 are decreasing along with increase in income, whereas the households confined in the expenditure groups of Rs. 3000-4000 to Rs. 5000 & above per month pertaining to education is scattered over in all income groups.

Table No. 4.19: Distribution of Households Based on Expenditure on Clothes

(Rupees/ Month)

Sl No.	Household Income (Rs. /month)	Expenditure in Rupees per Month										Total	
		< 400		400-800		800-1200		1200-1600		> 1600			
		Nos.	Per cent	Nos.	Per cent	Nos.	Per cent	Nos.	Per cent	Nos.	Per cent	Nos.	Per cent
1	< 20,000	76	89.41 (49.35)	56	53.33 (36.36)	17	24.64 (11.04)	3	8.57 (1.95)	2	7.69 (1.30)	154	48.13 (100.00)
2	20,000 - 40,000	7	8.24 (8.05)	36	34.29 (41.38)	24	34.78 (27.59)	10	28.57 (11.49)	10	38.46 (11.49)	87	27.19 (100.00)
3	40,000 - 60,000	2	2.35 (4.08)	9	8.57 (18.37)	18	26.09 (36.73)	11	31.43 (22.45)	9	34.62 (18.37)	49	15.31 (100.00)
4	60,000 - 80,000	0	0.00 (0.00)	3	2.86 (18.75)	5	7.25 (31.25)	7	20.00 (43.75)	1	3.85 (6.25)	16	5.00 (100.00)
5	> 80,000	0	0.00 (0.00)	1	0.95 (7.14)	5	7.25 (35.71)	4	11.43 (28.57)	4	15.38 (28.57)	14	4.38 (100.00)
	Total	**85**	**100.00 (26.56)**	**105**	**100.00 (32.81)**	**69**	**100.00 (21.56)**	**35**	**100.00 (10.94)**	**26**	**100.00 (8.13)**	**320**	**100.00 (100.00)**

Source: Primary Household Survey-2008

Note: Figures in Parenthesis Denote Row Percentage

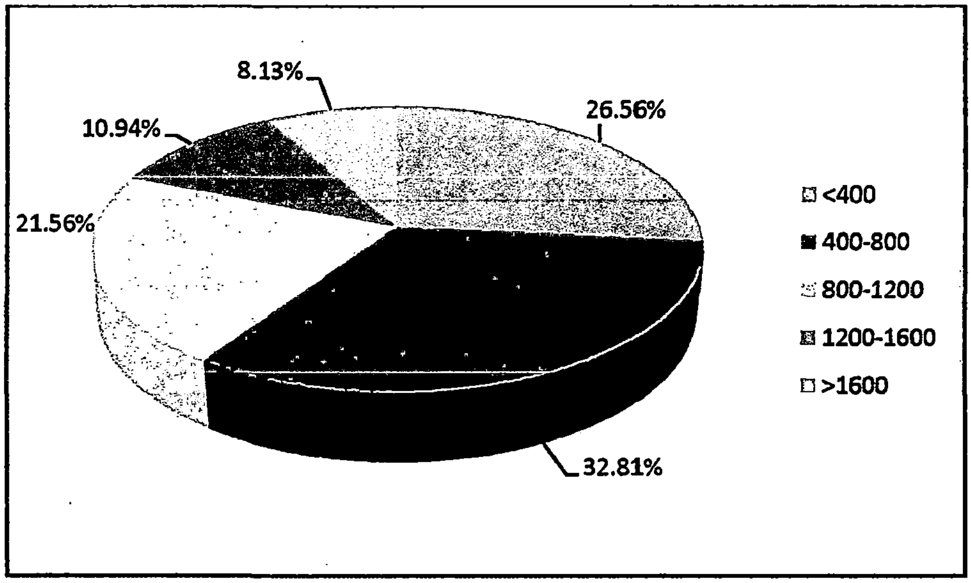

Fig. No. 4.16: Distribution of Households Based on Expenditure on Clothes

It can be deduced from this table that more number of households (66.97 per cent) spend up to Rs. 2000/- per month (household belong to the expenditure group of below Rs. 1000, and Rs. 1000-2000) pertaining to education, which also reflect their household income, i.e., more number of people confined the least income household group, i.e., below Rs. 20,000/- and Rs. 20,000-40,000. (C. Ref. Table 4.1).

4.1.18.4. Expenditure on Health

Health is also one of the most important parameters, which decides the functions of the system. Highly qualified and healthy human resource of the nation paves the way for steady development of the nation. As people say, health is wealth, as health is the most important wealth, and without health nothing can be prosper. As stated in expenditure on education, the State Govt. of Kerala in India spends more amount towards health of the State. One can observe from the budget of the Govt. of Kerala State that the State has been spending huge amount of money for Health and Education, which brought Human Development Index (HDI) up among the states in India. Having good health has multiple effects in development stream. Having this knowledge in mind, the Investigator added expenditure on health in the schedule and conducted the investigation.

Table No. 4.20: Distribution of Households Based on Expenditure on Education

(Rupees/ Month)

Sl No.	Household Income (Rs. /month)	Expenditure in Rupees per Month												Total	
		< 1000		1000-2000		2000-3000		3000-4000		4000-5000		> 5000			
		Nos.	Per cent	Nos.	Per cent	Nos.	Per cent	Nos.	Per cent	Nos.	Per cent	Nos.	Per cent	Nos.	Per cent
1	< 20,000	64	75.29 (56.64)	32	52.46 (28.32)	11	44.00 (9.73)	3	14.29 (2.65)	3	21.43 (2.65)	0	0.00 (0.00)	113	51.83 (100.00)
2	20,000 - 40,000	16	18.82 (27.59)	17	27.87 (29.31)	9	36.00 (15.52)	9	42.86 (15.52)	4	28.57 (6.90)	3	25.00 (5.17)	58	26.61 (100.00)
3	40,000 - 60,000	3	3.53 (10.00)	8	13.11 (26.67)	4	16.00 (13.33)	6	28.57 (20.00)	6	42.86 (20.00)	3	25.00 (10.00)	30	13.76 (100.00)
4	60,000 - 80,000	2	2.35 (22.22)	2	3.28 (22.22)	1	4.00 (11.11)	2	9.52 (22.22)	0	0.00 (0.00)	2	16.67 (22.22)	9	4.13 (100.00)
5	> 80,000	0	0.00 (0.00)	2	3.28 (25.00)	0	0.00 (0.00)	1	4.76 (12.50)	1	7.14 (12.50)	4	33.33 (50.00)	8	3.67 (100.00)
	Total	**85**	**100.00 (38.99)**	**61**	**100.00 (27.98)**	**25**	**100.00 (11.47)**	**21**	**100.00 (9.63)**	**14**	**100.00 (6.42)**	**12**	**100.00 (5.50)**	**218**	**100.00 (100.00)**

Source: Primary Household Survey-2008

Note: Figures in Parenthesis Denote Row Percentage

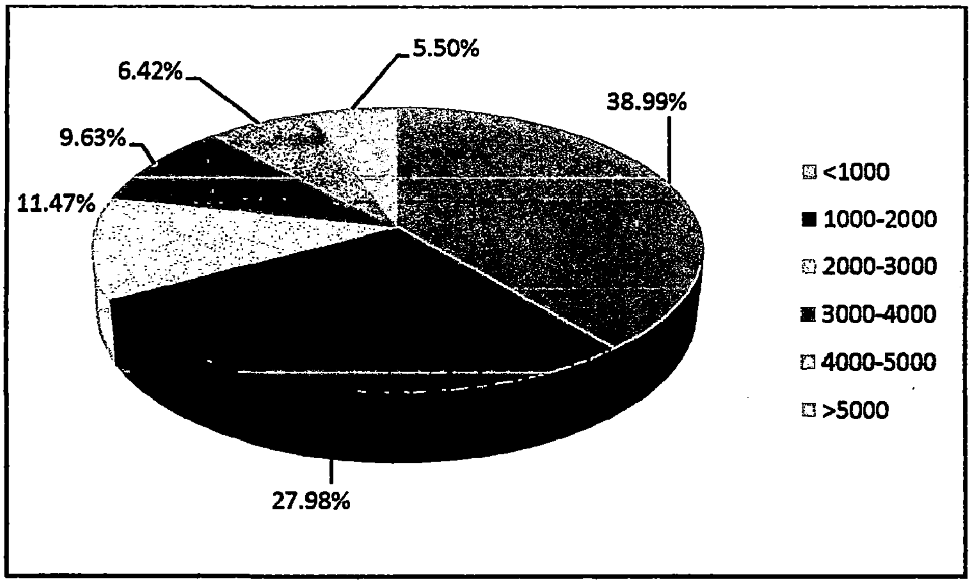

Fig. No. 4.17: Distribution of Households Based on Expenditure on Education

Expenditure on health is grouped into six groups, which include below Rs. 400, Rs. 400-800, Rs. 800-1200, Rs. 1200-1600, Rs. 1600-2000 and Rs. 2000 & above per month and is clubbed with household monthly income group for analysis, and the results of analysis are presented in Table 4.21 and in Fig. 4.18. This Table and this Fig. illustrate that about two-fifth (37.50 per cent) of the household spend Rs. 400-800 per month towards health. Followed by, above one-third (34.69 per cent) spend less than Rs. 400/- per month, just above one-sixth (15.63 per cent) of the households spend Rs. 800-1200 per month and rest of them are scattered into Rs. 1200-1600, Rs. 1600-2000, and Rs. 2000 & above expenditure groups. It is interesting to note that about three-fourth (72.19 per cent) of the households confined within the expenditure group of below Rs. 400/- and Rs. 400-800 and rest of them confined in other expenditures groups respectively. In income group analysis, it has been observed that the household confined in all expenditure group of below Rs. 400 to Rs. 800-1200 are decreasing along with increase in income groups, and the households confined in expenditure group of Rs. 1200-1600 to Rs. 2000/- & above per month are scattered over in almost all income groups and their representation is very meager. It is disinteresting to note that about half (48.13 per cent) of the households confined in the lowest income group category, i.e., below Rs. 20,000/- per month. Of which, above two-fifth (44.81 per cent) of the households confined the least expenditure category group towards health, i.e., below Rs. 400/- per month. Followed by, above one-third (37.01 per cent) of the households confined in the next hierarchy of expenditure group, i.e., Rs. 400-800 per month for the same purpose. It is further disinterest to note that above four-fifth (81.82 per cent) of the households of the least income group category together confined with in the expenditure group of less than Rs. 400/- per month and Rs. 400-800 per month. One can infer from this Table that the very less amount of money is spend towards health in the system.

4.1.18.5. Expenditure on Public Transportation

Using public transportation is one of the important parameters, which decides the function of Transportation System in any city. The study area is blessed with good transportation system and a considerable number of people use their private vehicles, which includes two-wheelers, three-wheelers, four-wheelers, bicycles, etc., for their day-to-day activities. It has been observed during the reconnaissance survey that good number of cars and two-wheelers are also used in the study area. In fact, as said in previous chapter, the study area is blessed with good number of industries, good number of educational institutions, research institutions, administrative institutions, transportation related institutions, etc. People those who are working in these institutions and other organizations using for their day-to-day activities either public transport or on their own transportation arrangement in the form of two-wheeler or three-wheeler. Besides this some industries, which include knowledge base industries, bio-technology industries, manufacturing industries, teaching institutions, schools, etc., send their own buses to collect their personals and students in the morning and dropped them in the evening. Having this knowledge in mind, the Investigator has included expenditure on public transportation in the schedule as one of the variables and conducted the investigation. The expenditure pattern of households are grouped into six groups which include below Rs. 300, Rs. 300-600, Rs. 600-900, Rs. 900-1200, Rs. 1200-1500 and Rs. 1500 & above and is clubbed with different income groups for analysis, and the results are presented in Table 4.22 and in Fig. 4.19. This Table and this Fig. reveal that about nine-tenth (86.25 per cent) of the households use public transportation system in the study area. Of which, about one-third (31.88 per cent) of the households spend Rs. 300-600 per month towards public transportation.

Table No. 4.21: Distribution of Households Based on Expenditure on Health

(Rupees/ Month)

Sl No.	Household Income (Rs. /month)	Expenditure in Rupees per Month												Total	
		< 400		400-800		800-1200		1200-1600		1600-2000		> 2000			
		Nos.	Per cent	Nos.	Per cent	Nos.	Per cent	Nos.	Per cent	Nos.	Per cent	Nos.	Per cent	Nos.	Per cent
1	< 20,000	69	62.16 (44.81)	57	47.50 (37.01)	19	38.00 (12.34)	1	7.69 (0.65)	6	42.86 (3.90)	2	16.67 (1.30)	154	48.13 (100.00)
2	20,000 - 40,000	21	18.92 (24.14)	39	32.50 (44.83)	18	36.00 (20.69)	4	30.77 (4.60)	2	14.29 (2.30)	3	25.00 (3.45)	87	27.19 (100.00)
3	40,000 - 60,000	13	11.71 (26.53)	15	12.50 (30.61)	9	18.00 (18.37)	4	30.77 (8.16)	3	21.43 (6.12)	5	41.67 (10.20)	49	15.31 (100.00)
4	60,000 - 80,000	5	4.50 (31.25)	6	5.00 (37.50)	0	0.00 (0.00)	3	23.08 (18.75)	1	7.14 (6.25)	1	8.33 (6.25)	16	5.00 (100.00)
5	> 80,000	3	2.70 (21.43)	3	2.50 (21.43)	4	8.00 (28.57)	1	7.69 (7.14)	2	14.29 (14.29)	1	8.33 (7.14)	14	4.38 (100.00)
	Total	**111**	**100.00 (34.69)**	**120**	**100.00 (37.50)**	**50**	**100.00 (15.63)**	**13**	**100.00 (4.06)**	**14**	**100.00 (4.38)**	**12**	**100.00 (3.75)**	**320**	**100.00 (100.00)**

Source: Primary Household Survey-2008

Note: Figures in Parenthesis Denote Row Percentage

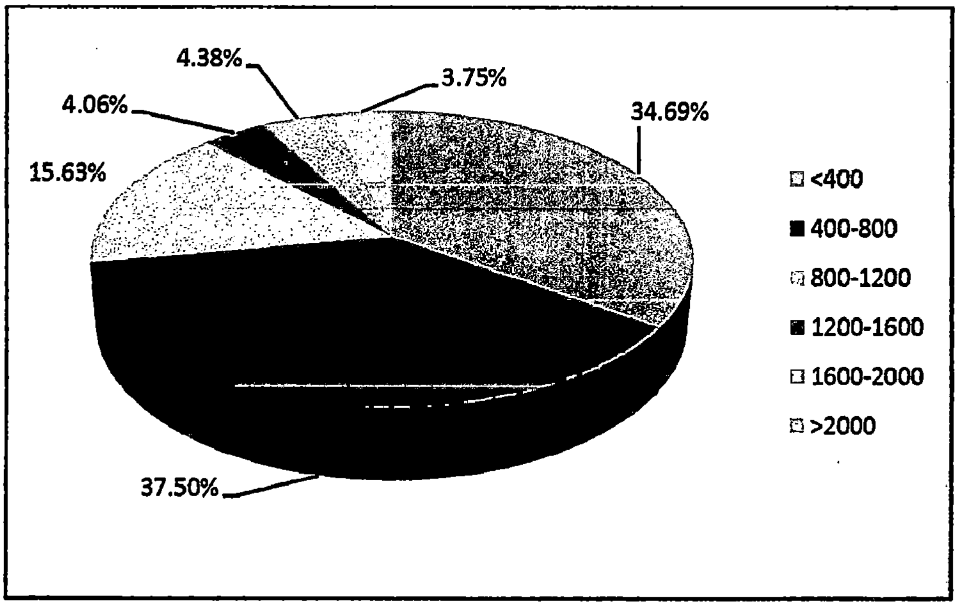

Fig. No. 4.18: Distribution of Households Based on Expenditure on Health

Followed by, about one-fourth (23.19 per cent) of the households spend less than Rs. 300, above one-fifth (22.10 per cent) of the households spend Rs. 900-1200, about one-ninth (12.68 per cent) of the households spend Rs. 600-900 and the rest of them spend Rs. 1200-1500, and Rs. 1500 & above respectively per month towards public transportation. It has been further observed that above half (55.07 per cent) of the households among the total households use public transportation, and spend up to Rs. 600/- per month for this purpose. In income group-wise analysis, it has been observed that the households confined in almost all expenditure group except the expenditure group of above Rs. 1500/- are decreasing along with increase in income groups, and in the expenditure group of above Rs. 1500 are increasing along with increase in income up to the monthly income group of Rs. 20,000-40,000, and then observe the reverse trend. It can be deduced from the table that the majority of households (about 90.00 per cent) use public transportation system for their day-to-day activities irrespective of income group categories.

Table No. 4.22: Distribution of Households Based on Expenditure on Public Transport Bangalore Metropolitan Transport Corporation Buses)

(Rupees/ Month)

Sl No.	Household Income (Rs. /month)	Expenditure in Rupees per Month												Total	
		< 300		300-600		600-900		900-1200		1200-1500		> 1500			
		Nos.	Per cent	Nos.	Per cent	Nos.	Per cent	Nos.	Per cent	Nos.	Per cent	Nos.	Per cent	Nos.	Per cent
1	< 20,000	31	48.44 (21.23)	44	50.00 (30.14)	25	71.43 (17.12)	36	59.02 (24.66)	6	42.86 (4.11)	4	28.57 (2.74)	146	52.90 (100.00)
2	20,000 - 40,000	24	37.50 (30.38)	24	27.27 (30.38)	6	17.14 (7.59)	12	19.67 (15.19)	5	35.71 (6.33)	8	57.14 (10.13)	79	28.62 (100.00)
3	40,000 - 60,000	5	7.81 (13.51)	17	19.32 (45.95)	3	8.57 (8.11)	8	13.11 (21.62)	3	21.43 (8.11)	1	7.14 (2.70)	37	13.41 (100.00)
4	60,000 - 80,000	1	1.56 (12.50)	2	2.27 (25.00)	1	2.86 (12.50)	3	4.92 (37.50)	0	0.00 (0.00)	1	7.14 (12.50)	8	2.90 (100.00)
5	> 80,000	3	4.69 (50.00)	1	1.14 (16.67)	0	0.00 (0.00)	2	3.28 (33.33)	0	0.00 (0.00)	0	0.00 (0.00)	6	2.17 (100.00)
	Total	**64**	**100.00 (23.19)**	**88**	**100.00 (31.88)**	**35**	**100.00 (12.68)**	**61**	**100.00 (22.10)**	**14**	**100.00 (5.07)**	**14**	**100.00 (5.07)**	**276**	**100.00 (100.00)**

Source: Primary Household Survey-2008

Note: Figures in Parenthesis Denote Row Percentage

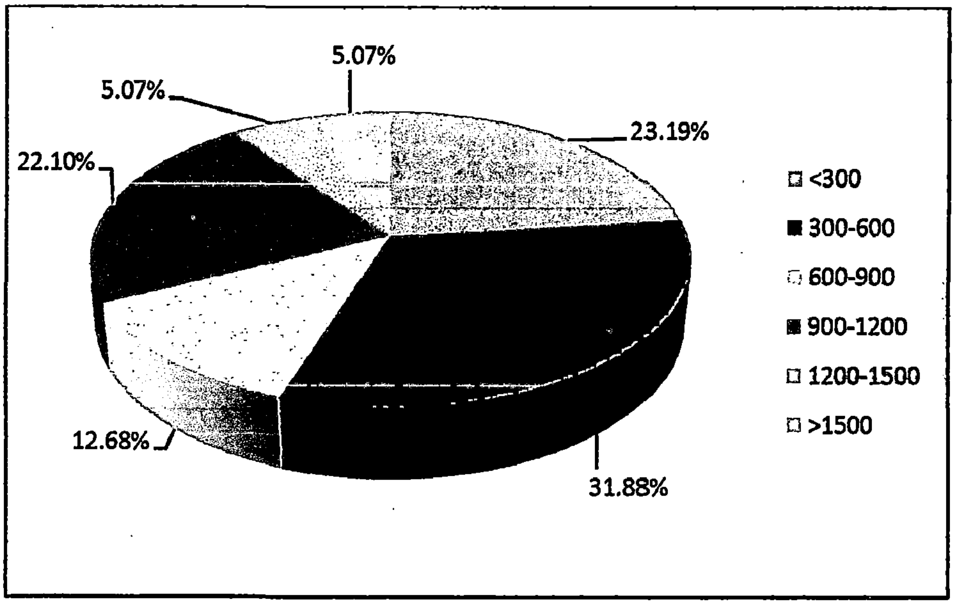

Fig. No. 4.19: Distribution of Households Based on Expenditure on Public Transport

4.1.18.6. Expenditure on House Rent

Shelter is one of the basic needs in human beings life. The wealth of the people, income of the people, income earnings opportunity of the people, etc., more or less decide the size of the house of the population. Since the study area is blessed with more number of knowledge-based industries, bio-technology industries, manufacturing industries, and other kinds of industries; research institutions, and educational institutions, large number of people migrated to the city, and this city's population increased considerably. Majority of the migrated population got accommodated themselves in the rented building to start with. The expenditure on rent may also be decided by the affordability of persons, their financial status, their life style, family size, etc. Having this knowledge in mind, the investigator has considered expenditure on house rent as one of the parameters in the schedule, and conducted the investigation in the study area. This house rent expenditure pattern is divided into six groups, which include expenditure below Rs. 2000, Rs. 2000-3000, Rs. 3000-4000, Rs. 4000-5000, Rs. 5000-6000 and Rs. 6000 & above per month and it is clubbed with various monthly household income groups for analysis, and the results are presented in Table 4.23 and in Fig. 4.20. This Table and this Fig. illustrate that there are about one-third (31.12 per cent) of the households are living in the rented houses and rest of them live on their own houses. It has been further observed that of the total rented households, about half (46.23 per cent) of them pay Rs. 2000/- per month as house rent, followed by, about one-fourth (24.53 per cent) spend Rs. 2000-3000 per month towards house rent and rest of them are scattered over in all other expenditure groups. It has further observed that about three-fourth (69.81 per cent) of the rented households confined in the lowest household income group, i.e., below Rs. 20,000 per month, of which about two-third (64.86 per cent) of the households spend below Rs. 2000/- per month towards house rent, which shows that more number of people confined in the lowest income group, and the lowest paid house rent group. In income group analysis, it is observed that most of the households are confined in the lowest income group category and few are confined in other categories. It can be deduced from the table that the lowest and the next hierarchy, i.e., household income group of below Rs. 20,000 and Rs. 20,000-40,000 per month mostly live in the rented buildings. It has also further observed that most of the households (87.23 per cent) of the total rented households are confined within the income groups of below Rs. 20,000/- and Rs. 20,000-40,000 per month, which shows that the financially weaker section are living in the rented houses.

4.1.18.7. Expenditure on Water

Water is one of the basic needs for human survival. Though the hierarchy of human needs food, clothing and shelter are kept as basic human needs, water form as a part of food in the system [3]. Having this knowledge in mind, the investigator considered expenditure on water as one of the variables in the schedule, and conducted the investigation in the study area. The expenditure on water is grouped under four groups, which include below Rs. 200, Rs. 200-400, Rs. 400-600 and Rs. 600 & above, and is clubbed with various household monthly income groups for analysis, and the results are presented in Table 4.24 and in Fig. 4.21. This Table and this Fig. depict that about half (48.44 per cent) of the surveyed households spend Rs. 200/- per month for water tariff. Followed by, above one-third (34.06 per cent) of the households spend Rs. 200-400, one-tenth (10.00 per cent) of the households spend Rs. 400-600, and the rest (7.50 per cent) of the households spend Rs. 600 & above per month towards water tariff. It is interesting to note that about half (48.13 per cent) of the surveyed households confined within the lowest income category, i.e., below Rs. 20,000/- per month.

Table No. 4.23: Distribution of Households Based on Expenditure on House Rent

(Rupees/ Month)

Sl No.	Household Income (Rs. /month)	Expenditure in Rupees per Month												Total	
		< 2000		2000-3000		3000-4000		4000-5000		5000-6000		> 6000			
		Nos.	Per cent	Nos.	Per cent	Nos.	Per cent	Nos.	Per cent	Nos.	Per cent	Nos.	Per cent	Nos.	Per cent
1	< 20,000	48	97.96 (64.86)	20	76.92 (27.03)	6	66.67 (8.11)	0	0.00 (0.00)	0	0.00 (0.00)	0	0.00 (0.00)	74	69.81 (100.00)
2	20,000 - 40,000	1	2.04 (5.26)	5	19.23 (26.32)	3	33.33 (15.79)	6	75.00 (31.58)	1	14.29 (5.26)	3	42.86 (15.79)	19	17.92 (100.00)
3	40,000 - 60,000	0	0.00 (0.00)	0	0.00 (0.00)	0	0.00 (0.00)	2	25.00 (25.00)	4	57.14 (50.00)	2	28.57 (25.00)	8	7.55 (100.00)
4	60,000 - 80,000	0	0.00 (0.00)	1	3.85 (33.33)	0	0.00 (0.00)	0	0.00 (0.00)	2	28.57 (66.67)	0	0.00 (0.00)	3	2.83 (100.00)
5	> 80,000	0	0.00 (0.00)	0	0.00 (0.00)	0	0.00 (0.00)	0	0.00 (0.00)	0	0.00 (0.00)	2	28.57 (100.00)	2	1.89 (100.00)
	Total	**49**	**100.00 (46.23)**	**26**	**100.00 (24.53)**	**9**	**100.00 (8.49)**	**8**	**100.00 (7.55)**	**7**	**100.00 (6.60)**	**7**	**100.00 (6.60)**	**106**	**100.00 (100.00)**

Source: Primary Household Survey-2008

Note: Figures in Parenthesis Denote Row Percentage

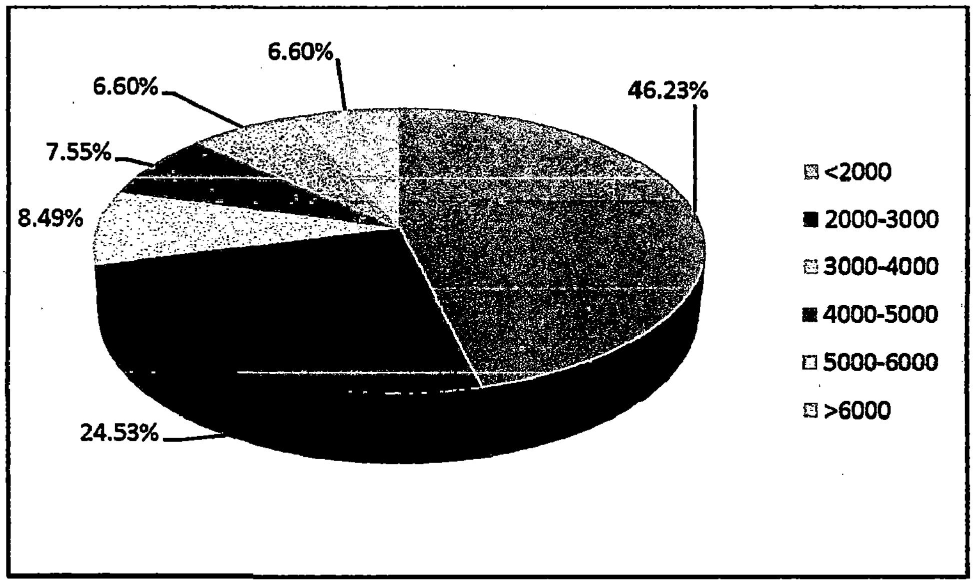

Fig. No. 4.20: Distribution of Households Based on Expenditure on House Rent

Of which, more than two-third (69.48 per cent) spend less than Rs. 200/- per month towards water tariff. Followed by, above two-fifth (21.43 per cent) spend Rs. 200-400 per month as water tariff from the same income group category. In income group analysis, it has been observed that the households confined below Rs. 200/- and Rs. 400-600 per month expenditure towards water are decreasing along with increase in income groups, whereas the household expenditures towards water Rs. 200-400 and above Rs. 600/- are increasing along with increase in income group of up to the monthly household income group of Rs. 20,000-40,000 and then observed the reverse trend. It is also further observed that above four-fifth (82.50 per cent) of the total surveyed households together spend less than Rs. 400/- per month, of which majority of them pay less than Rs. 200/- per month. It can be observed from the table that considerable amount of the households confined in the lowest income category, and their payment towards water is also very less.

Table No. 4.24: Distribution of Households Based on Expenditure on Water

(Rupees/ Month)

Sl No.	Household Income (Rs. /month)	Expenditure in Rupees per Month								Total	
		< 200		200-400		400-600		> 600			
		Nos.	Per cent	Nos.	Per cent	Nos.	Per cent	Nos.	Per cent	Nos.	Per cent
1	< 20,000	107	69.03 (69.48)	33	30.28 (21.43)	10	31.25 (6.49)	4	16.67 (2.60)	154	48.13 (100.00)
2	20,000 - 40,000	37	23.87 (42.53)	34	31.19 (39.08)	6	18.75 (6.90)	10	41.67 (11.49)	87	27.19 (100.00)
3	40,000 - 60,000	8	5.16 (16.33)	32	29.36 (65.31)	4	12.50 (8.16)	5	20.83 (10.20)	49	15.31 (100.00)
4	60,000 - 80,000	1	0.65 (6.25)	5	4.59 (31.25)	5	15.63 (31.25)	5	20.83 (31.25)	16	5.00 (100.00)
5	> 80,000	2	1.29 (14.29)	5	4.59 (35.71)	7	21.88 (50.00)	0	0.00 (0.00)	14	4.38 (100.00)
	Total	**155**	**100.00 (48.44)**	**109**	**100.00 (34.06)**	**32**	**100.00 (10.00)**	**24**	**100.00 (7.50)**	**320**	**100.00 (100.00)**

Source: Primary Household Survey-2008

Note: Figures in Parenthesis Denote Row Percentage

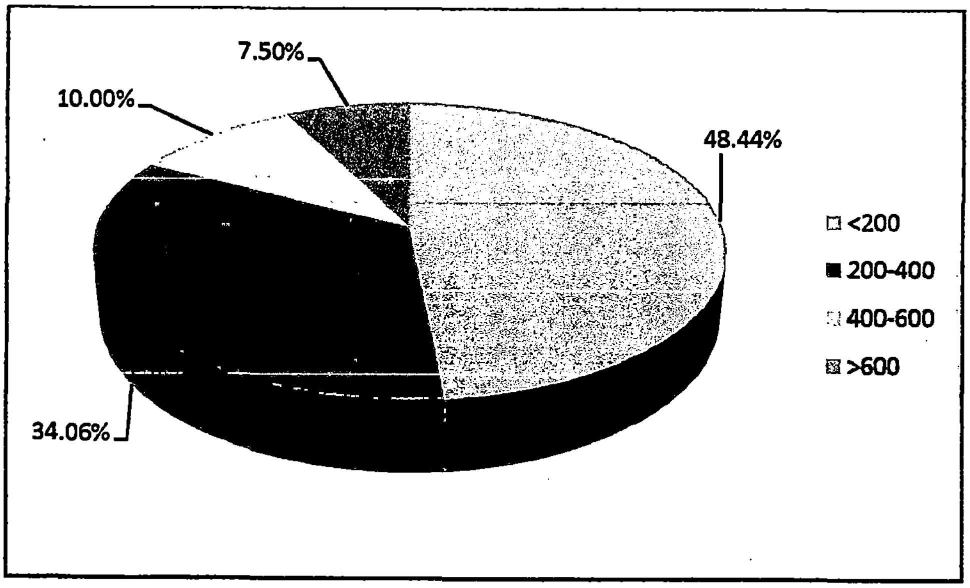

Fig. No. 4.21: Distribution of Households Based on Expenditure on Water

4.1.18.8. Expenditure on Energy

Energy is one of the most important parameters which can be used for quantifying the economic development of any nation. Various authors have done research in the field of energy and found there is a strong positive correlation between energy consumption and the national economy. Energy is the basic element for the development of any nation. At the micro level, expenditure on energy can be considered as one of the parameters, which can decide the economic status of the households. In fact, the higher income group households consume more quantity of electricity at the household level, and petrol/diesel for their commutation, whereas the lowest and lower income group households consume less quantity of electricity at the household level and the chances of petrol/diesel consumption is very less. Having this knowledge in mind, the Investigator considered this as one of the parameters in the schedule, and conducted the investigation. The household expenditure on energy is grouped into eight groups, which include below Rs. 1000, Rs. 1000-1500, Rs. 1500-2000, Rs. 2000-2500, Rs. 2500-3000, Rs. 3000-3500, Rs. 3500-4000, and Rs. 4000 & above and is clubbed with various income groups for analysis and the results are presented in Table 4.25 and Fig. 4.22. This Table and this Fig. illustrate that about one-fifth (18.13 per cent) of the households spend below Rs. 1000/- per month for energy consumption and are confined in the lowest income group category i.e., below Rs. 20,000/- per month. Followed by, above one-sixth (15.63 per cent), (15.00 per cent), (14.69 per cent) and (14.38 per cent) of the households spend Rs. 2500-3000, Rs. 2000-2500, above Rs. 4000/- and Rs. 3000-3500 per month respectively for this purpose; and about one-tenth (9.69 per cent and 8.13 per cent) of the households spend Rs. 1500-2000 and Rs. 3500-4000 per month respectively for the same purpose. In income group analysis, the households spend Rs. 2000-2500 per month towards energy consumption are decreasing along with increase in income up to the monthly household income group of Rs. 20,000-40,000. Further, it has been observed that the households spend from Rs. 2500 to more than Rs. 4000/- per month towards energy consumption is increasing along with increase in income up to the income group of Rs. 20,000-40,000 per month, and then observes the reverse trend. Further, it has been observed that the households spend up to Rs. 2000/- per month towards this purpose are more or less confined in the lowest income category i.e., Rs. 20,000/- per month. The household which spend above Rs. 2000/- per month towards energy consumption is scattered over in almost all income groups but the higher amount spending households are confined among the higher and the highest income groups. This table concludes that the higher income group households are spending more amount of money towards energy consumption.

4.1.18.9. Expenditure on Petrol

The transportation sector is purely relying on fossil fuel. Consumption of petrol at the household level can be considered as one of the important parameters to quantify the usage of vehicles and the standard of living in the study area. The unprecedented and uncontrolled growth of vehicular pollution and lack of urban transport policy leads to increase in consumption of petrol in the urban areas in general and in the metropolitan areas in particular. The expenditure pattern of petrol decides the mobility of the households, household activities, financial status, family status, cultural background, quality of life, aspirations of households, etc. Having this knowledge in mind, the Investigator considered this as one of the parameters in the schedule, and conducted the investigation.

Table No. 4.25: Distribution of Households Based on Expenditure on Energy

(Rupees/ Month)

Sl No.	Household Income (Rs. /month)	Expenditure in Rupees per Month													
		< 1000		1000-1500		1500-2000		2000-2500		2500-3000		3000-3500		3500-4000	
		Nos.	Per cent	Nos.	Per cent	Nos.	Per cent	Nos.	Per cent	Nos.	Per cent	Nos.	Per cent	Nos.	Per cent
1	< 20,000	58	100.00 (37.66)	14	100.00 (9.09)	28	90.32 (18.18)	26	54.17 (16.88)	16	32.00 (10.39)	8	17.39 (5.19)	2	7.69 (1.30)
2	20,000 - 40,000	0	0.00 (0.00)	0	0.00 (0.00)	2	6.45 (2.30)	20	41.67 (22.99)	17	34.00 (19.54)	24	52.17 (27.59)	10	38.46 (11.49)
3	40,000 - 60,000	0	0.00 (0.00)	0	0.00 (0.00)	1	3.23 (2.04)	2	4.17 (4.08)	14	28.00 (28.57)	10	21.74 (20.41)	8	30.77 (16.33)
4	60,000 - 80,000	0	0.00 (0.00)	0	0.00 (0.00)	0	0.00 (0.00)	0	0.00 (0.00)	2	4.00 (12.50)	3	6.52 (18.75)	5	19.23 (31.25)
5	> 80,000	0	0.00 (0.00)	0	0.00 (0.00)	0	0.00 (0.00)	0	0.00 (0.00)	1	2.00 (7.14)	1	2.17 (7.14)	1	3.85 (7.14)
	Total	**58**	**100.00 (18.13)**	**14**	**100.00 (4.38)**	**31**	**100.00 (9.69)**	**48**	**100.00 (15.00)**	**50**	**100.00 (15.63)**	**46**	**100.00 (14.38)**	**26**	**100.00 (8.13)**

Source: Primary Household Survey-2008

Note: Figures in Parenthesis Denote Row Percentage

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Table No. 4.25: Distribution of Households Based on Expenditure on Energy

(Rupees/ Month)

Sl No.	Household Income (Rs. /month)	Expenditure in Rupees per Month			
		> 4000		Total	
		Nos.	Per cent	Nos.	Per cent
1	< 20,000	2	4.26 (1.30)	154	43.69 (100.00)
2	20,000 - 40,000	14	29.79 (16.09)	87	29.35 (100.00)
3	40,000 - 60,000	14	29.79 (28.57)	49	16.72 (100.00)
4	60,000 - 80,000	6	12.77 (37.50)	16	5.46 (100.00)
5	> 80,000	11	23.40 (78.57)	14	4.78 (100.00)
	Total	**47**	**100.00 (14.69)**	**320**	**100.00 (100.00)**

Source: Primary Household Survey-2008

Note: Figures in Parenthesis Denote Row Percentage

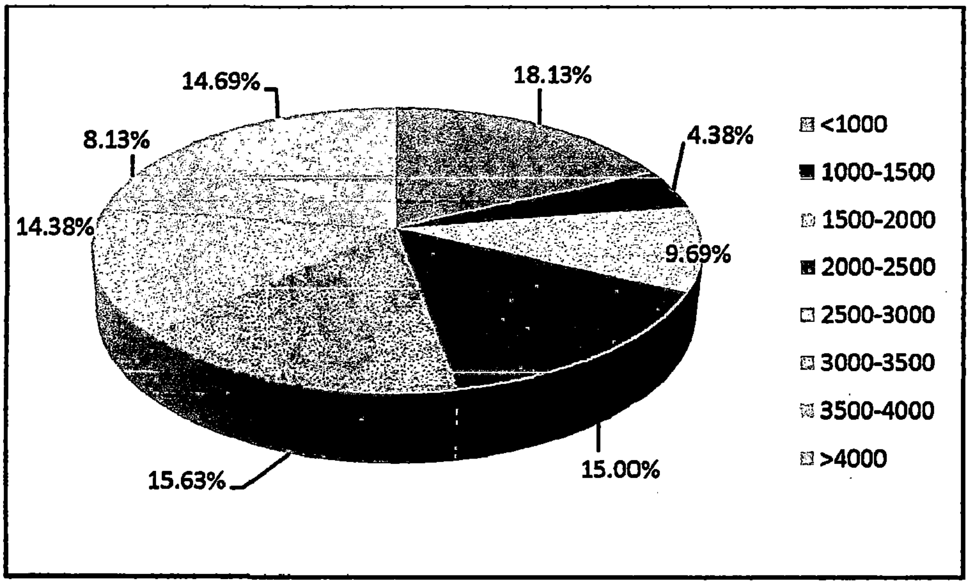

Fig. No. 4.22: Distribution of Households Based on Expenditure on Energy

The household expenditure on petrol is grouped into five groups, which includes monthly expenditure below Rs. 1000/-, Rs. 1000-2000, Rs. 2000-3000, Rs. 3000-4000 and Rs. 4000 & above, and is clubbed within various income groups for analysis, and the results are presented in Table 4.26 and in Fig. 4.23. This Table and this Fig. illustrate that about four-fifth (79.37 per cent) of the total surveyed household's spend money towards petrol consumption in the study area. Of which, about half (48.03 per cent) of the households spend Rs. 1000-2000 per month towards petrol consumption. Followed by, about one-third (30.31 per cent) and about one-tenth (9.84 per cent) of the households spend Rs. 2000-3000 and below Rs. 1000/- per month for the same purpose respectively; about one-fourteenth (7.09 per cent) of the households spend Rs. 3000-4000, and rest of them (4.72 per cent) spend Rs. 4000 & above per month respectively, for the same purpose. In income group analysis, the households spend Rs. 1000/- per month are confined in the least monthly household income group, i.e., below Rs. 20,000/- per month. Further, it has been observed that the households confined among the expenditure group Rs. 1000-2000 are decreasing along with the increase in income, the households confined the expenditure group Rs. 2000-3000 per month are increasing up to the monthly income group of Rs. 20,000-40,000 and then observe the reverse trend, and the households confined among the monthly expenditure group of Rs. 3000-4000, and Rs. 4000 & above are scattered over in almost all income groups. This table concludes that the lower income groups spend less amount of money for this purpose and the higher income groups spend more money for this purpose.

4.1.18.10. Expenditure on Total Parking Costs

Parking is one of the most important parameters in the urban areas. The rapid growth of population, uncontrolled growth of vehicular population and unplanned cities demands huge amount of parking facilities at their own premises, at working place, at shopping centres, market areas, on road parking, at recreation and entertainment centres, etc. Having this knowledge in mind, the Investigator considered this as one of the parameters in the schedule, and conducted the investigation. The expenditure on total parking costs includes two-wheeler and four-wheeler parking costs. The household expenditure on total parking costs is grouped into four groups, which include below Rs. 200/-, Rs. 200-400, Rs. 400-600 and Rs. 600 & above per month and is clubbed with various income groups for analysis, and the results are presented in Table 4.27 and in Fig. 4.24. This Table and this Fig. depict that about four-fifth (79.37 per cent) of the surveyed households have their own vehicles in the study area. Of these above one-third (34.65 per cent and 33.66 per cent) of the households spend Rs. 200-400 and below Rs. 200/- per month respectively towards parking costs. Followed by, about one-fourth (24.41 per cent) and about one-fourteenth (7.09 per cent) of the households spend Rs. 400-600 and above Rs. 600/- per month towards parking costs, respectively. In income group analysis, the households confined in the expenditure group of less than Rs. 200/- per month are decreasing along with increase in income. Further, it has been observed that the households confined in the expenditure group from Rs. 200/- to Rs. 600 & above are increasing along with increase in income up to the income group of Rs. 20,000-40,000 per month and then observe the reverse trend. It has also been observed that more than half (51.72 per cent) of them confined in the income group of Rs. 20,000-40,000 per month. This table concludes that the higher income group households spend more amount of money towards parking facility in the study area.

Table No. 4.26: Distribution of Households Based on Expenditure on Petrol

(Rupees/ Month)

Sl No.	Household Income (Rs. /month)	Expenditure in Rupees per Month										Total	
		< 1000		1000-2000		2000-3000		3000-4000		> 4000			
		Nos.	Per cent	Nos.	Per cent	Nos.	Per cent	Nos.	Per cent	Nos.	Per cent	Nos.	Per cent
1	< 20,000	25	100.00 (28.41)	51	41.80 (57.95)	11	14.29 (12.50)	1	5.56 (1.14)	0	0.00 (0.00)	88	34.65 (100.00)
2	20,000 - 40,000	0	0.00 (0.00)	49	40.16 (56.32)	30	38.96 (34.48)	5	27.78 (5.75)	3	25.00 (3.45)	87	34.25 (100.00)
3	40,000 - 60,000	0	0.00 (0.00)	19	15.57 (38.78)	20	25.97 (40.82)	5	27.78 (10.20)	5	41.67 (10.20)	49	19.29 (100.00)
4	60,000 - 80,000	0	0.00 (0.00)	2	1.64 (12.50)	12	15.58 (75.00)	1	5.56 (6.25)	1	8.33 (6.25)	16	6.30 (100.00)
5	> 80,000	0	0.00 (0.00)	1	0.82 (7.14)	4	5.19 (28.57)	6	33.33 (42.86)	3	25.00 (21.43)	14	5.51 (100.00)
	Total	**25**	**100.00 (9.84)**	**122**	**100.00 (48.03)**	**77**	**100.00 (30.31)**	**18**	**100.00 (7.09)**	**12**	**100.00 (4.72)**	**254**	**100.00 (100.00)**

Source: Primary Household Survey-2008

Note: Figures in Parenthesis Denote Row Percentage

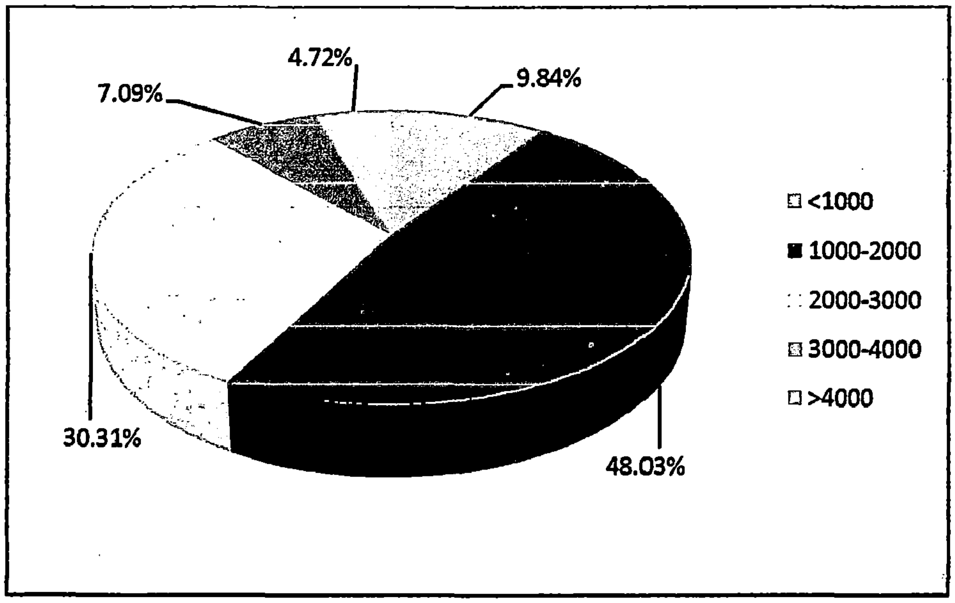

Fig. No. 4.23: Distribution of Households Based on Expenditure on Petrol

4.1.18.11. Expenditure on Loan Repayment

The Government liberalized policies and encouraged the people to meet their demands through loans on one hand, and the people are keen to avail loan facility for their family welfare, household expenditures, to buy vehicles, land and other related properties; for business, education, to become entrepreneur, etc., on the other. The expenditure on loan repayment is decided by various parameters including their family income, aspirations of the households, affordability, payback capacity, etc. Having this knowledge in mind, the Investigator considered this as one of the parameters in the schedule, and conducted the investigation. The household expenditure on loan repayment is grouped into seven groups which include below Rs. 1000/-, Rs. 1000-2000, Rs. 2000-3000, Rs. 3000-4000, Rs. 4000-5000, Rs. 5000-6000 and Rs. 6000 & above and is clubbed with various income groups for analysis, and the results are presented in Table 4.28 and in Fig. 4.25. This Table and this Fig. illustrate that about one-fourth (24.37 per cent) of the total surveyed households had loan facility in the study area. Of which, one-third (33.33 per cent) of the households spend Rs. 6000 & above towards loan repayment.

Table No. 4.27: Distribution of Households Based on Expenditure on Total Parking Costs

(Rupees/ Month)

Sl No.	Household Income (Rs. /month)	Expenditure in Rupees per Month								Total	
		< 200		200-400		400-600		>600			
		Nos.	Per cent	Nos.	Per cent	Nos.	Per cent	Nos.	Per cent	Nos.	Per cent
1	< 20,000	71	82.56 (80.68)	17	19.32 (19.32)	0	0.00 (0.00)	0	0.00 (0.00)	88	34.65 (100.00)
2	20,000 - 40,000	10	11.63 (11.49)	45	51.14 (51.72)	25	40.32 (28.74)	7	38.89 (8.05)	87	34.25 (100.00)
3	40,000 - 60,000	4	4.65 (8.16)	15	17.05 (30.61)	23	37.10 (46.94)	7	38.89 (14.29)	49	19.29 (100.00)
4	60,000 - 80,000	0	0.00 (0.00)	5	5.68 (31.25)	9	14.52 (56.25)	2	11.11 (12.50)	16	6.30 (100.00)
5	> 80,000	1	1.16 (7.14)	6	6.82 (42.86)	5	8.06 (35.71)	2	11.11 (14.29)	14	5.51 (100.00)
	Total	**86**	**100.00 (33.86)**	**88**	**100.00 (34.65)**	**62**	**100.00 (24.41)**	**18**	**100.00 (7.09)**	**254**	**100.00 (100.00)**

Source: Primary Household Survey-2008

Note: Figures in Parenthesis Denote Row Percentage

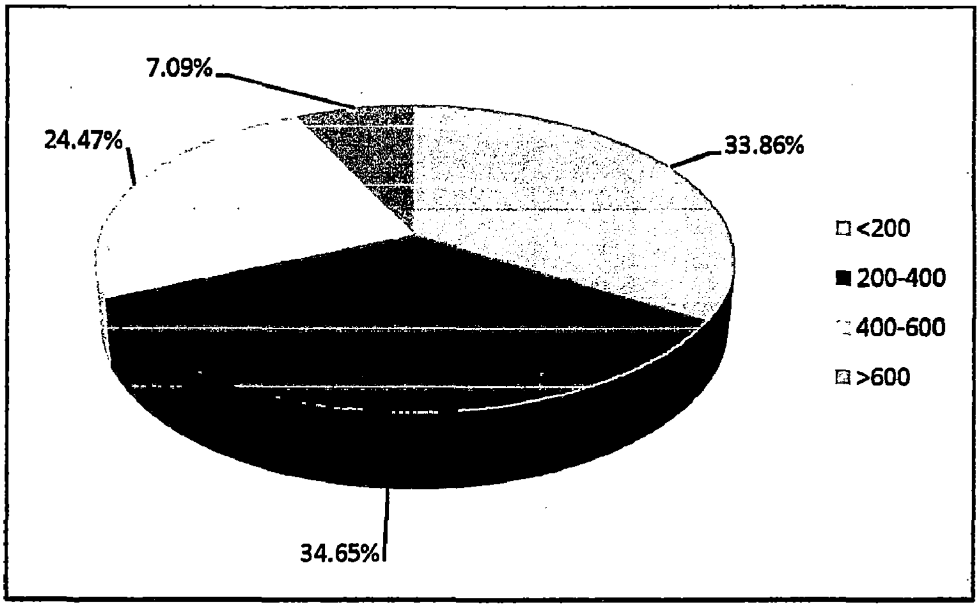

Fig. No. 4.24: Distribution of Households Based on Expenditure on Total Parking Costs

Followed by, just one-sixth (16.67 per cent) and about one-sixth (15.38 per cent) of the households spend below Rs. 1000/- and Rs. 1000-2000 per month towards loan repayment respectively; about one-eighth (11.54 per cent), above one-tenth (10.26 per cent), a meager (6.41 per cent and 6.41 per cent) of the households spend Rs. 5000-6000, Rs. 4000-5000, Rs. 2000-3000 and Rs. 3000-4000 per month respectively for the same purpose. In income group analysis, the households confined the expenditure group up to Rs. 4000-5000 are decreasing along with increase in income, and the households confined in the expenditure group of Rs. 5000-6000 and Rs. 6000 & above are increasing with increase in income up to the monthly household income group of Rs. 20,000-40,000, and then observe the reverse trend. It is also observed from the table that the household repaid below Rs. 1000/- per month and Rs. 1000-2000 per month are more or less confined among the income group of below Rs. 20,000/- per month, which shows that the least income group households avail lesser amount of loan. This table concludes that the higher income group households repay more money every month in the study area.

Table No. 4.28: Distribution of Households Based on Expenditure on Loan Repayment

(Rupees/ Month)

Sl No.	Household Income (Rs. /month)	Expenditure in Rupees per Month														Total	
		< 1000		1000-2000		2000-3000		3000-4000		4000-5000		5000-6000		> 6000			
		Nos.	Per cent	Nos.	Per cent	Nos.	Per cent	Nos.	Per cent	Nos.	Per cent	Nos.	Per cent	Nos.	Per cent	Nos.	Per cent
1	< 20,000	12	92.31 (35.29)	11	91.67 (32.35)	2	40.00 (5.88)	3	60.00 (8.82)	4	50.00 (11.76)	2	22.22 (5.88)	0	0.00 (0.00)	34	43.59 (100.00)
2	20,000 - 40,000	1	7.69 (4.17)	0	0.00 (0.00)	2	40.00 (8.33)	2	40.00 (8.33)	2	25.00 (8.33)	4	44.44 (16.67)	13	50.00 (54.17)	24	30.77 (100.00)
3	40,000 - 60,000	0	0.00 (0.00)	0	0.00 (0.00)	0	0.00 (0.00)	0	0.00 (0.00)	2	25.00 (18.18)	2	22.22 (18.18)	7	26.92 (63.64)	11	14.10 (100.00)
4	60,000 - 80,000	0	0.00 (0.00)	1	8.33 (20.00)	1	20.00 (20.00)	0	0.00 (0.00)	0	0.00 (0.00)	0	0.00 (0.00)	3	11.54 (60.00)	5	6.41 (100.00)
5	> 80,000	0	0.00 (0.00)	0	0.00 (0.00)	0	0.00 (0.00)	0	0.00 (0.00)	0	0.00 (0.00)	1	11.11 (25.00)	3	11.54 (75.00)	4	5.13 (100.00)
	Total	**13**	**100.00 (16.67)**	**12**	**100.00 (15.38)**	**5**	**100.00 (6.41)**	**5**	**100.00 (6.41)**	**8**	**100.00 (10.26)**	**9**	**100.00 (11.54)**	**26**	**100.00 (33.33)**	**78**	**100.00 (100.00)**

Source: Primary Household Survey-2008

Note: Figures in Parenthesis Denote Row Percentage

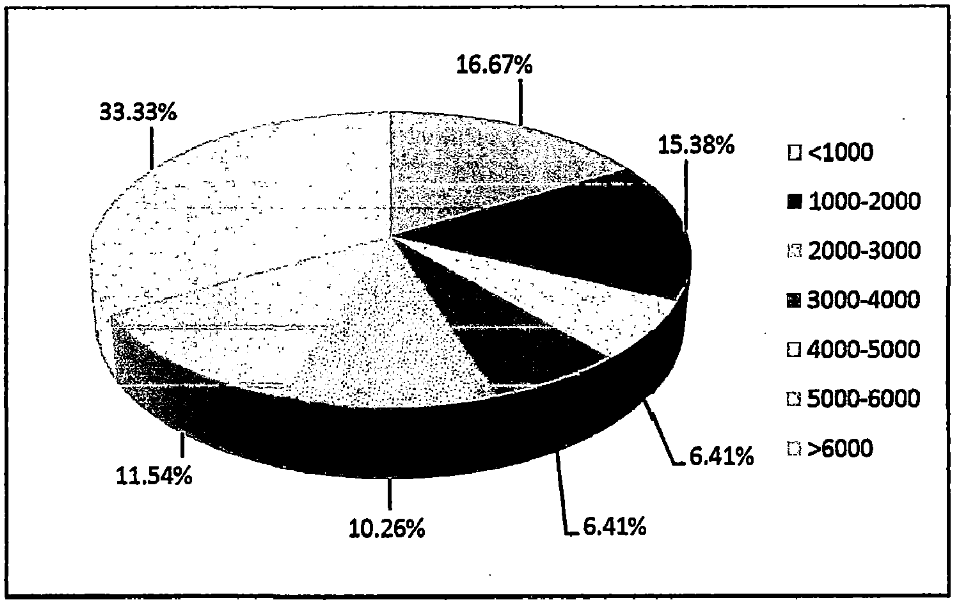

Fig. No. 4.25: Distribution of Households Based on Expenditure on Loan Repayment

4.1.18.12. Expenditure on Recreation and Entertainment

The economically well-off and affordable people spend more money towards leisure activities, which includes visiting parks, playgrounds, cinema theaters, drama theaters, attending cultural activities, visiting gardens, fountains, arts and exhibition, visiting tourist places, routine activities like gymnasium, yoga, meditation, pranayama, etc. The expenditure on recreation and entertainment decides the cultural background of the households, financial status, affordability, accessibility, family background, religious activities, educational background, awareness about health, needs and aspirations of the people, socialization, etc. Having this knowledge in mind, the Investigator considered the expenditure on recreation and entertainment as one the parameters in the schedule, and conducted the investigation. The household expenditure on recreation and entertainment is grouped into seven groups, which include household monthly expenditure group of below Rs. 400/-, Rs. 400-800, Rs. 800-1200, Rs. 1200-1600, Rs. 1600-2000, Rs. 2000-2400, and Rs. 2400 & above and is clubbed with various income groups for analysis, and the results are presented in Table 4.29 and in Fig. 4.26. This Table and this Fig. illustrate that about one-fourth (24.06 per cent) of the households spend Rs. 400-800 per month towards recreation and entertainment. Followed by, above one-sixth (15.94 per cent) , above one-seventh (14.38 per cent and 14.38 per cent) of the households spend Rs.

1200-1600, Rs. 800-1200 and Rs. 1600-2000 per month respectively towards recreation and entertainment; above one-tenth (11.56 per cent), and (10.31 per cent), and about one-tenth (9.38 per cent) of the households spend Rs. 2000-2400, Rs. 2400 & above, and less than Rs. 400/- per month respectively towards for this purpose. In income group analysis, the households confined in the expenditure group of below Rs. 400/- to Rs. 800-1200 per month are more or less confined the lowest household income group, i.e., below Rs. 20,000/- per month. Further, it has been observed that the households confined the expenditure group of Rs. 1200-1600 and Rs. 2000-2400 per month are increasing along with increase in income up to the monthly household income group of Rs. 20,000-40,000 and then observe the reverser trend. The expenditure groups from Rs. 2000 to above Rs. 2400 per month households are increasing along with increase in income group up to monthly household income group of Rs. 40,000-60,000 and then observed the reverse trend. This table concludes that the high income household personals spend more money towards recreation and entertainment in the study area.

4.1.18.13. Expenditure on Telecommunication

Telecommunication plays a major role in all levels including individual level, societal level, state level, national level and international level. In India telecommunication made a great revolution in recent years. It has penetrated to all sections of the society, irrespective of gender, religion, economically weaker section, people settled in squatters slums, streets, and the people are habituated to use telecommunication for their routine activities. The internet facility proved that it is an inevitable requirement to access important information in general and scientific & technological information in particular, at the global level. Having telephone, mobile and internet connection at the household level represents the economic status, awareness, education level, social connectivity, professional status, literacy level, etc. Various parameters, like family size, occupation pattern, socialization, specialization, professionalization, involved in academic activity, affordability, etc., decide the expenditure on telecommunication. Having this knowledge in mind, the Investigator considered this as one of the variables in the schedule, and conducted the investigation.

Table No. 4.29: Distribution of Households Based on Expenditure on Recreation and Entertainment

(Rupees/ Month)

Sl No.	Household Income (Rs. /month)	Expenditure in Rupees per Month														Total	
		< 400		400-800		800-1200		1200-1600		1600-2000		2000-2400		> 2400			
		Nos.	Per cent	Nos.	Per cent	Nos.	Per cent	Nos.	Per cent	Nos.	Per cent	Nos.	Per cent	Nos.	Per cent	Nos.	Per cent
1	< 20,000	30	100.00 (19.48)	72	93.51 (46.75)	39	84.78 (25.32)	7	13.73 (4.55)	4	8.70 (2.60)	2	5.41 (1.30)	0	0.00 (0.00)	154	48.13 (100.00)
2	20,000 - 40,000	0	0.00 (0.00)	5	6.49 (5.75)	7	15.22 (8.05)	30	58.82 (34.48)	24	52.17 (27.59)	12	32.43 (13.79)	9	27.27 (10.34)	87	27.19 (100.00)
3	40,000 - 60,000	0	0.00 (0.00)	0	0.00 (0.00)	0	0.00 (0.00)	9	17.65 (18.37)	15	32.61 (30.61)	14	37.84 (28.57)	11	33.33 (22.45)	49	15.31 (100.00)
4	60,000 - 80,000	0	0.00 (0.00)	0	0.00 (0.00)	0	0.00 (0.00)	5	9.80 (31.25)	3	6.52 (18.75)	3	8.11 (18.75)	5	15.15 (31.25)	16	5.00 (100.00)
5	> 80,000	0	0.00 (0.00)	0	0.00 (0.00)	0	0.00 (0.00)	0	0.00 (0.00)	0	0.00 (0.00)	6	16.22 (42.86)	8	24.24 (57.14)	14	4.38 (100.00)
	Total	**30**	**100.00 (9.38)**	**77**	**100.00 (24.06)**	**46**	**100.00 (14.38)**	**51**	**100.00 (15.94)**	**46**	**100.00 (14.38)**	**37**	**100.00 (11.56)**	**33**	**100.00 (10.31)**	**320**	**100.00 (100.00)**

Source: Primary Household Survey-2008

Note: Figures in Parenthesis Denote Row Percentage

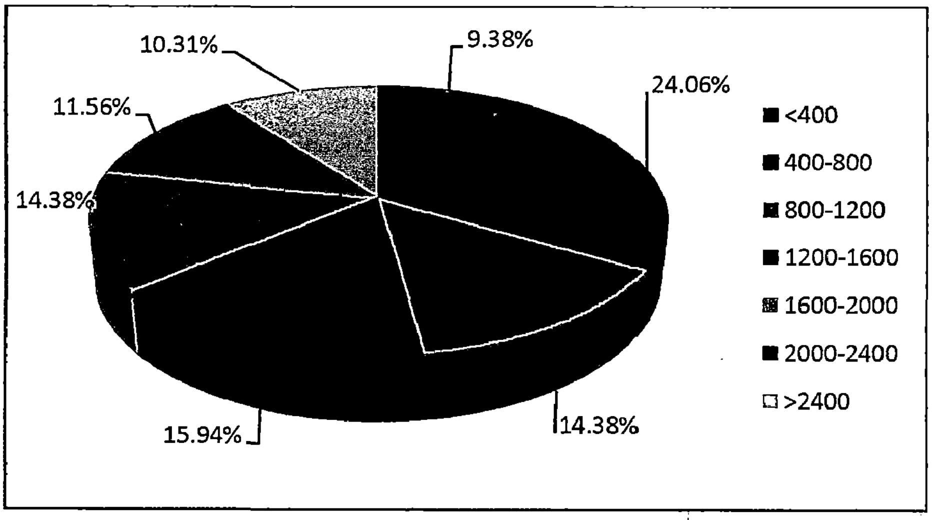

Fig. No. 4.26: Distribution of Households Based on Expenditure on Recreation and Entertainment

The household expenditure on telecommunication is grouped into eight groups, which include below Rs. 1000, Rs. 1000-1500, Rs. 1500-2000, Rs. 2000-2500, Rs. 2500-3000, Rs. 3000-3500, Rs. 3500-4000, and Rs. 4000 & above and is clubbed with various income groups for analysis, and the results are presented in Table 4.30 and in Fig. 4.27. This Table and this Fig. depict that above one-third (33.44 per cent) of the households spend below Rs. 1000/- per month towards telecommunication. Followed by, above one-eighth (12.58 per cent), above one-tenth (10.60 per cent), about one-tenth (9.93 per cent), (9.27 per cent and 9.27 per cent) of the households spend Rs. 2500-3000, Rs. 3500-4000, Rs. 2000-2500, Rs. 1500-2000, and Rs. 4000 & above per month respectively for this purpose; about one-eleventh (8.94 per cent) and a meager (5.96 per cent) of the households spend Rs. 1000-1500 and Rs. 3000-3500 per month respectively for this purpose. In income group analysis, the households confined in the expenditure group of up to Rs. 1500/- per month are decreasing along with increase in income, whereas the household spend from Rs. 2000/- to Rs. 3500/- per month towards telecommunication is increasing along with increase in income up to the income group of Rs. 20,000-40,000 per month and then observe the reverse trend. Further, it has been observed that the household confined in the expenditure group of Rs. 3000 to Rs. 4000/- & above are increasing along with increase in income up to the monthly household income group of Rs. 40,000-60,000 and then observe the reverse trend; the households spend up to Rs. 1500/- per month towards for this purpose confined in the lowest income categories i.e., Rs. 20,000/- and Rs. 20,000-40,000 per month; the household which spend more than Rs. 1500/- per month towards telecommunication is scattered over in almost all income groups but the higher amount spending households are confined among the higher and the highest income groups. This table concludes that the higher income group households are spending more amount of money towards telecommunication.

4.1.19. Household Savings

Household savings is one of the prime components, which lead capital formation in any country. Generally, household savings depends on several parameters include family size, occupation pattern, number of earning members, expenditure pattern, education level, awareness about savings and investment in different forms, etc. Savings in terms of investment in any form like land, property, and house, etc., represents the financial status, ability of savings, standard of living, quality of living etc. Having this knowledge in mind, the Investigator considered this as one of the parameters in the schedule, and conducted the investigation. The household savings is grouped into eleven groups, which include below Rs. 3000, Rs. 3000-6000, Rs. 6000-9000, Rs. 9000-12,000, Rs. 12,000-15,000, Rs. 15,000-18,000, Rs. 18,000-21000, Rs. 21,000-24,000, Rs. 24,000-27,000, Rs. 27,000-30,000 and Rs. 30,000 & above and is clubbed with various income groups for analysis, and the results are presented in Table 4.31 and in Fig. 4.28. This Table and this Fig. reveal that above nine-tenth (91.56 per cent) of the households save their earnings. It has been observed from this table and this fig. that above two-fifth (40.96 per cent) of the households save below Rs. 3000/- per month. Followed by, above one-eighth (12.63 per cent), about one-eighth (11.95 per cent), and above one-twelfth (8.87 per cent) of the households spend Rs. 3000-6000, Rs. 30,000 & above, Rs. 9000-12,000 per month savings respectively; and a very meager (6.83 per cent), (5.46 per cent), (4.78 per cent), (3.75 per cent), (2.39 per cent), (1.37 per cent), and (1.02 per cent) of the households save Rs. 6000-9000, Rs. 12,000-15,000, Rs. 24,000-27,000, Rs. 18,000-21,000, Rs. 21,000-24,000, Rs. 15,000-18,000 and Rs. 27,000-30,000 per month respectively in the study area.

Table No. 4.30: Distribution of Households Based on Expenditure on Telecommunication

(Rupees/ Month)

Sl No.	Household Income (Rs. /month)	Expenditure in Rupees per Month													
		< 1000		1000-1500		1500-2000		2000-2500		2500-3000		3000-3500		3500-4000	
		Nos.	Per cent	Nos.	Per cent	Nos.	Per cent	Nos.	Per cent	Nos.	Per cent	Nos.	Per cent	Nos.	Per cent
1	< 20,000	100	99.01 (73.53)	24	88.89 (17.65)	11	39.29 (8.09)	0	0.00 (0.00)	1	2.63 (0.74)	0	0.00 (0.00)	0	0.00 (0.00)
2	20,000 - 40,000	1	0.99 (1.14)	3	11.11 (3.45)	15	53.57 (17.24)	24	80.00 (27.59)	28	73.68 (32.18)	7	38.89 (8.05)	8	25.00 (9.19)
3	40,000 - 60,000	0	0.00 (0.00)	0	0.00 (0.00)	2	7.14 (4.08)	5	16.67 (10.20)	8	21.05 (16.33)	7	38.89 (14.29)	16	50.00 (32.65)
4	60,000 - 80,000	0	0.00 (0.00)	0	0.00 (0.00)	0	0.00 (0.00)	1	3.33 (6.25)	1	2.63 (6.25)	2	11.11 (12.50)	5	15.63 (31.25)
5	> 80,000	0	0.00 (0.00)	0	0.00 (0.00)	0	0.00 (0.00)	0	0.00 (0.00)	0	0.00 (0.00)	2	11.11 (14.29)	3	9.38 (21.43)
	Total	**101**	**100.00 (33.44)**	**27**	**100.00 (8.94)**	**28**	**100.00 (9.27)**	**30**	**100.00 (9.93)**	**38**	**100.00 (12.58)**	**18**	**100.00 (5.96)**	**32**	**100.00 (10.60)**

Source: Primary Household Survey-2008

Note: Figures in Parenthesis Denote Row Percentage

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Table No. 4.30: Distribution of Households Based on Expenditure on Telecommunication

(Rupees/ Month)

Sl No.	Household Income (Rs. /month)	Expenditure in Rupees per Month			
		> 4000		Total	
		Nos.	Per cent	Nos.	Per cent
1	< 20,000	0	0.00 (0.00)	136	45.03 (100.00)
2	20,000 - 40,000	1	3.57 (1.14)	87	28.81 (177.55)
3	40,000 - 60,000	11	39.29 (22.45)	49	16.23 (100.00)
4	60,000 - 80,000	7	25.00 (43.75)	16	5.30 (100.00)
5	> 80,000	9	32.14 (64.29)	14	4.64 (100.00)
	Total	**28**	**100.00 (9.27)**	**302**	**100.00 (100.00)**

Source: Primary Household Survey-2008

Note: Figures in Parenthesis Denote Row Percentage

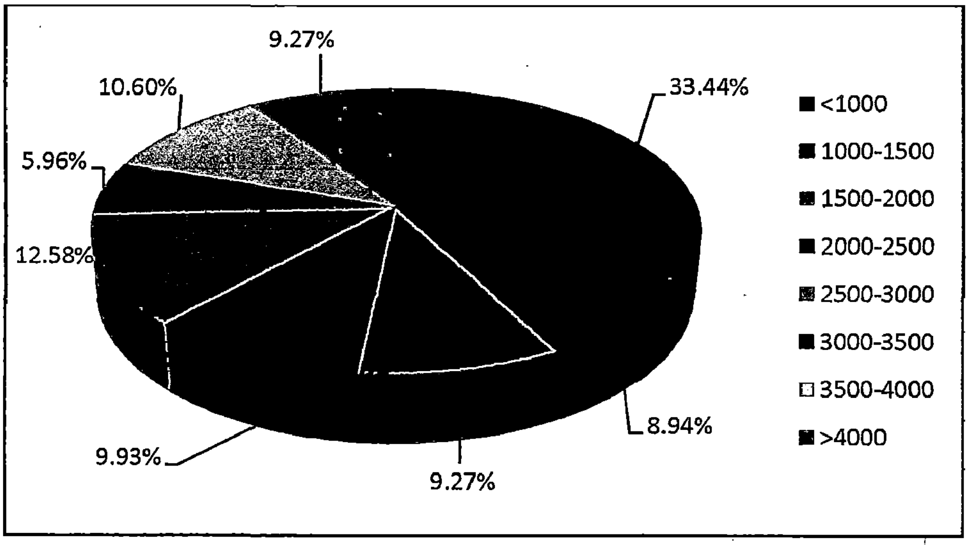

Fig. No. 4.27: Distribution of Households Based on Expenditure on Telecommunication

In income group analysis, the households confined in the savings group of up to Rs. 6000/- per month are decreasing along with increase in income up to the monthly household income group of Rs. 40,000-60,000 and thereafter no representation is observed. The households save Rs. 6000-12,000 are increasing along with increase in income up to the income group of Rs. 20,000-40,000 and then observe the reverse trend. Further, it has been observed that the households' savings from Rs. 12,000/- to Rs. 30,000/- per month are scattered over in almost all income groups but the higher amount savings are confined among the higher and the highest income groups. This table concludes that the households save irrespective of any income group they belong, which is the good symptom for the development of the nation.

4.2. VEHICLE OWNERSHIP-MOTORIZED AND NON-MOTORIZED VEHICLES

Rapid growth of urbanization, motorization, and industrialization lead to increase in economic activities and rise in household income in the urban system. This further lead to rapid increase in personalized vehicles and motorized vehicles in urban areas in general and metropolitan areas in particular. The shares of non-motorized vehicles are high in towns and below class I cities but the declining trend is observed in metropolitan and mega cities of the developing countries.

Table No. 4.31: Distribution of Households Based on Savings

(Rupees/ Month)

Sl No.	Household Income (Rs. /month)	Expenditure in Rupees per Month													
		< 3000		3000-6000		6000-9000		9000-12000		12000-15000		15000-18000		18000-21000	
		Nos.	Per cent	Nos.	Per cent	Nos.	Per cent	Nos.	Per cent	Nos.	Per cent	Nos.	Per cent	Nos.	Per cent
1	< 20,000	101	84.17 (78.91)	22	59.46 (17.19)	4	20.00 (3.13)	1	3.85 (0.78)	0	0.00 (0.00)	0	0.00 (0.00)	0	0.00 (0.00)
2	20,000 - 40,000	18	15.00 (20.93)	14	37.84 (16.28)	15	75.00 (17.44)	20	76.92 (23.26)	12	75.00 (13.95)	3	75.00 (3.49)	3	27.27 (3.49)
3	40,000 - 60,000	1	0.83 (2.04)	1	2.70 (2.04)	0	0.00 (0.00)	5	19.23 (10.20)	4	25.00 (8.16)	0	0.00 (0.00)	8	72.73 (16.33)
4	60,000 - 80,000	0	0.00 (0.00)	0	0.00 (0.00)	1	5.00 (6.25)	0	0.00 (0.00)	0	0.00 (0.00)	1	25.00 (6.25)	0	0.00 (0.00)
5	> 80,000	0	0.00 (0.00)	0	0.00 (0.00)	0	0.00 (0.00)	0	0.00 (0.00)	0	0.00 (0.00)	0	0.00 (0.00)	0	0.00 (0.00)
	Total	**120**	**100.00 (40.96)**	**37**	**100.00 (12.63)**	**20**	**100.00 (6.83)**	**26**	**100.00 (8.87)**	**16**	**100.00 (5.46)**	**4**	**100.00 (1.37)**	**11**	**100.00 (3.75)**

Source: Primary Household Survey-2008

Note: Figures in Parenthesis Denote Row Percentage

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Table No. 4.31: Distribution of Households Based on Savings

(Rupees/ Month)

Sl No.	Household Income (Rs. /month)	Expenditure in Rupees per Month									
		21000-24000		24000-27000		27000-30000		> 30000		Total	
		Nos.	Per cent	Nos.	Per cent	Nos.	Per cent	Nos.	Per cent	Nos.	Per cent
1	< 20,000	0	0.00 (0.00)	0	0.00 (0.00)	0	0.00 (0.00)	0	0.00 (0.00)	128	43.69 (100.00)
2	20,000 - 40,000	1	14.29 (1.16)	0	0.00 (0.00)	0	0.00 (0.00)	0	0.00 (0.00)	86	29.35 (100.00)
3	40,000 - 60,000	5	71.43 (10.20)	14	100.00 (28.57)	3	100.00 (6.12)	8	22.86 (16.33)	49	16.72 (100.00)
4	60,000 - 80,000	1	14.29 (6.25)	0	0.00 (0.00)	0	0.00 (0.00)	13	37.14 (81.25)	16	5.46 (100.00)
5	> 80,000	0	0.00 (0.00)	0	0.00 (0.00)	0	0.00 (0.00)	14	40.00 (100.00)	14	4.78 (100.00)
	Total	**7**	**100.00 (2.39)**	**14**	**100.00 (4.78)**	**3**	**100.00 (1.02)**	**35**	**100.00 (11.95)**	**293**	**100.00 (100.00)**

Source: Primary Household Survey-2008

Note: Figures in Parenthesis Denote Row Percentage

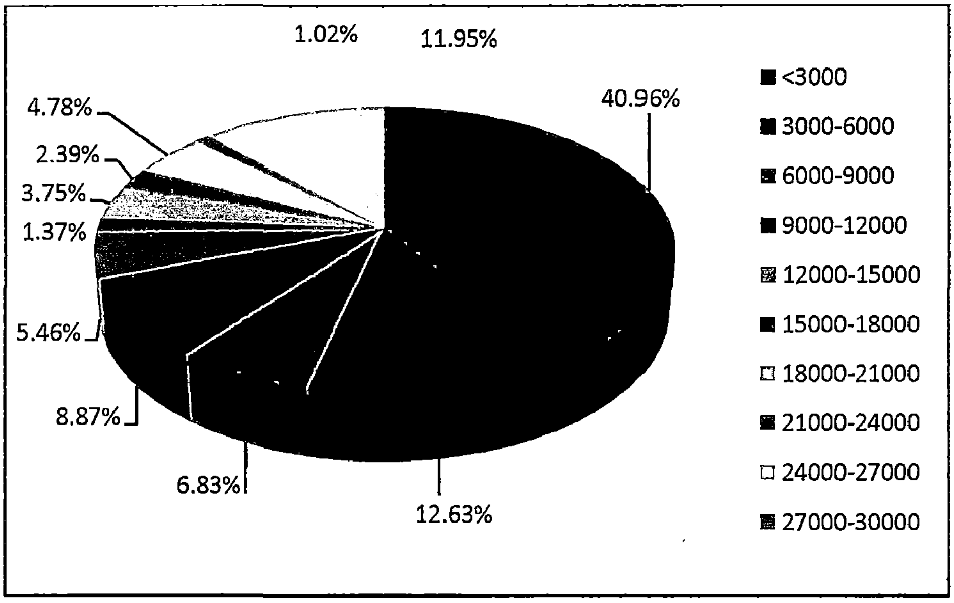

Fig. No. 4.28: Distribution of Households Based on Savings

Having this knowledge in mind, the Investigator conducted a household survey to assess the vehicle ownership rate, motorized and non-motorized vehicles at the grassroots level in the system, and the results are presented as below:

4.2.1. Vehicle Ownership

Rapid growth of urbanization, modernization and industrialization lead to increase in unprecedented growth and concentration of population in the urban areas in general, and in the metropolitan areas in particular. The available job opportunities in informal sectors, Government, private organizations, industries, service sectors, etc., are responsible for economic boom in the study area. As a consequence, manifold increase in household income, which lead to rapid increase in personalized vehicles in the study area. Having this knowledge in mind, the Investigator considered vehicle ownership as one of the parameters in the schedule, and conducted the investigation. The vehicle ownership of the households is grouped into three groups, which include household with two-wheelers, household with car and both (household with two-wheeler and car) and is clubbed with various income groups for analysis, and the results are presented in Table 4.32 and in Fig. 4.29. This Table and this Fig. depict that about three-fifth (59.06 per cent) of the households are having two-wheelers. Followed by, just above two-fifth (40.94 per cent) and about one-third (33.07 per cent) of the households have their own cars and both (two-wheelers and cars) respectively in the study area. In income group analysis, the households possessed two-wheeler vehicle ownership are decreasing along with increase in income, whereas the households possessed car ownership and both (two-wheelers and cars) are increasing along with increase in income up to the monthly household income group of Rs. 40,000-60,000 and then observe the reverse trend. This table concludes that the majority, i.e., three-fifth (59.06 per cent) of the households is having two-wheelers and it also reflects the availability of the lower and middle income group households in the study area, which generally possesses two-wheelers since their household income is less.

4.2.2. Distribution of Motorized Vehicles

In developing countries, rapid urbanization and raising income level are amplifying the demand for motorized mobility. Motorized vehicles are dominant in urban areas in the developed and in the developing countries. The rates of growth of motorized vehicles are very high in developed countries compare to the developing countries. Few advantages are observed in using motorized vehicles, which include saving time, covering long journey distance, convenience, comfort, accessibility, affordability, etc. The ratio of motorized vehicles to population is increasing in rapid pace. The increase in manifold household income, the non-availability of adequate public transport system, absence of mass transportation system, ineffective urban transport policies, etc., cause for rapid increase in personalized motorized vehicles in the urban area in general, and in the study area in particular. Having this knowledge in mind, the Investigator considered this as one of the parameters in the schedule, and conducted the investigation. The motorized vehicles available at the grassroots level is grouped into thee groups, which include two-wheeler, three-wheelers and car and is clubbed with various income groups for analysis, and the results are presented in Table 4.33 and in Fig. 4.30. This Table and this Fig. depict that the studied households have 496 motorized vehicles. Of which, about three-fourth (71.77 per cent) of the motorized vehicles are observed as two-wheelers.

Table No. 4.32: Distribution of Households with Vehicle Ownership

Sl. No.	Household Income (Rs. /month)	HHTWVO		HHCO		Both HHTWVO and HHCO		Total	
1	< 20,000	73	48.67 (82.95)	15	14.42 (17.05)	11	13.10 (12.50)	88	34.65 (100.00)
2	20,000 - 40,000	59	39.33 (67.82)	28	26.92 (32.18)	22	26.19 (25.29)	87	34.25 (100.00)
3	40,000 - 60,000	16	10.67 (32.65)	33	31.73 (67.35)	29	34.52 (59.18)	49	19.29 (100.00)
4	60,000 - 80,000	2	1.33 (12.50)	14	13.46 (87.50)	12	14.29 (75.00)	16	6.30 (100.00)
5	> 80,000	0	0.00 (0.00)	14	13.46 (100.00)	10	11.90 (71.43)	14	5.51 (100.00)
	Total	150	100.00 (59.06)	104	100.00 (40.94)	84	100.00 (33.07)	254	100.00 (100.00)

Source: Primary Household Survey-2008

Note: Figures in Parenthesis Denote Row Percentage

Note: HHTWVO-Households with Two-wheeler Vehicle Ownership

HHCO- Households with Car Ownership

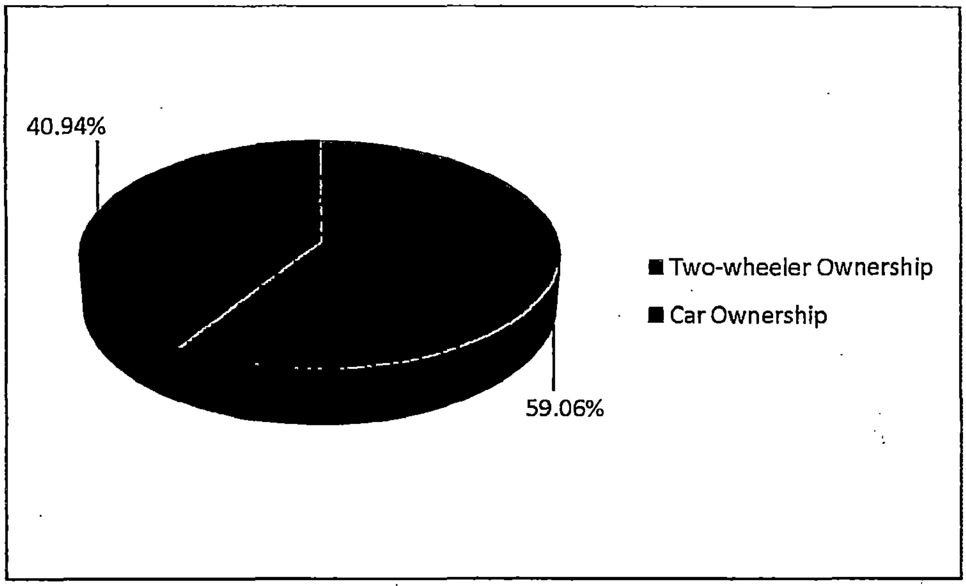

Fig. No. 4.29: Distribution of Households with Vehicle Ownership

Followed by, above one-fourth (27.62 per cent) of the motorized vehicles are observed as cars. It has been observed that only a meager (0.60 per cent) motorized three-wheelers (auto-rickshaws) available among the studied households. In income group analysis, the number of two-wheelers is increasing along with increase in income up to the monthly household income group of Rs. 20,000-40,000 and then observes the reverse trend. Further, it has also been observed that whatever three-wheelers available they are confined within the least income group of below Rs. 20,000/- per month, and the available number of cars are scattered in almost all income groups. This table concludes that the two-wheelers are dominant, i.e., about three-fourth (71.77 per cent) of the total vehicles available in the studied households, and more than two-third of them are confined within the lower income group categories, i.e., up to the income group of Rs. 20,000-40,000/- per month.

4.2.3. Bicycle Ownership

Bicycle riding is good for health, pollution-free, least cost effective, environment friendly, and user friendly mode of transportation, and unfortunately, in India, bicycle mode of transport is not at all considered in provision of transportation infrastructure.

Table No. 4.33: Distribution of Motorized Vehicles

(Numbers/ Per cent)

Sl No.	Household Income (Rs. /month)	No. of Two-wheelers		No. of Three-wheelers		No. of Cars		Total	
		Nos.	Per cent	Nos.	Per cent	Nos.	Per cent	Nos.	Per cent
1	< 20,000	106	29.78 (85.48)	3	100.00 (2.42)	15	10.95 (12.10)	124	24.60 (100.00)
2	20,000 - 40,000	135	37.92 (76.70)	0	0.00 (0.00)	41	29.93 (23.29)	176	35.89 (100.00)
3	40,000 - 60,000	70	19.66 (63.64)	0	0.00 (0.00)	40	29.20 (36.36)	110	22.18 (100.00)
4	60,000 - 80,000	22	6.18 (55.00)	0	0.00 (0.00)	18	13.14 (45.00)	40	8.06 (100.00)
5	> 80,000	23	6.46 (50.00)	0	0.00 (0.00)	23	16.79 (50.00)	46	9.27 (100.00)
	Total	**356**	**100.00 (71.77)**	**3**	**100.00 (0.61)**	**137**	**100.00 (27.62)**	**496**	**100.00 (100.00)**

Source: Primary Household Survey-2008

Note: Figures in Parenthesis Denote Row Percentage

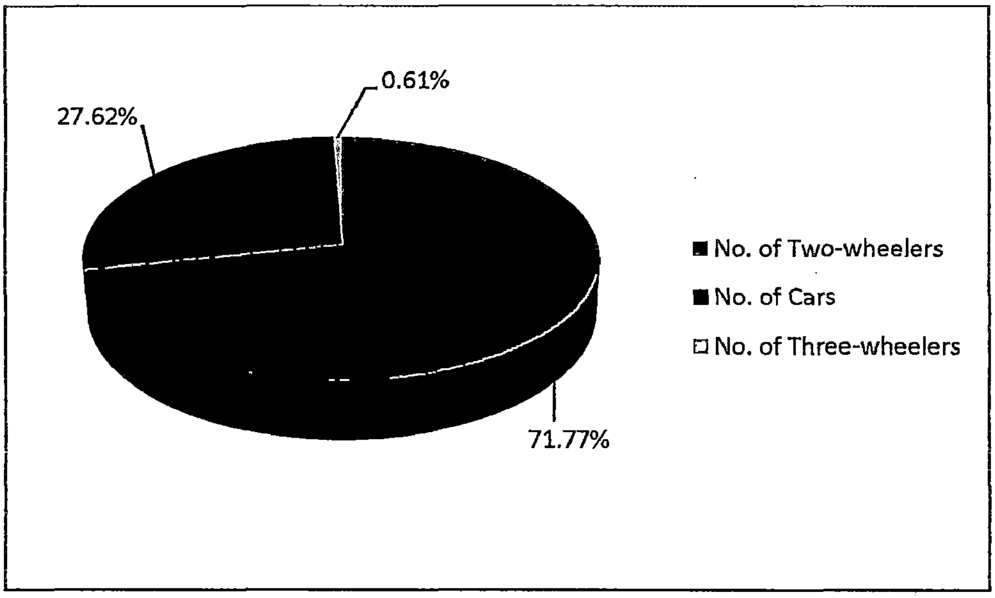

Fig. No. 4.30: Distribution of Motorized Vehicles

It has been observed that bicycle mode of transportation is not integrated along with other mode of transportation. It is essential to integrate bicycle mode and walking mode with the existing modes of transportation and to provide proper infrastructure facilities for greater mobility to the larger extent. The share of bicycle mode is little higher at the smaller cities and it is a very meager in metropolitan cities because of dominant motorized vehicles, especially personalized vehicles in the study area. Having this knowledge in mind, the Investigator considered this as one of the parameters in the schedule, and conducted the investigation. The bicycles available at the household level is grouped into two groups, which include household with one-cycle ownership and household with two-cycles ownership and is clubbed with various income groups for analysis, and the results are presented in Table 4.34 and in Fig. 4.31. This Table and this Fig. depict that about one-tenth (9.68 per cent) of the surveyed households have their own bicycles in the study area. Of which, above nine-tenth (93.55 per cent) of the households have one bicycles and a meager (about 6.45 per cent) of the households have two bicycles. In income group analysis, the household with one bicycle and two-bicycles are almost confined within the least income group, i.e., below Rs. 20,000/- per month. This table concludes that only the lowest income group category households (cent per cent) have bicycles in the study area and using for different purposes which include work, education, health, shopping, etc.

Table No. 4.34: Distribution of Households with Cycle Ownership

Sl. No.	Household Income (Rs. /month)	HH with one Cycle		HH with two Cycles		Total	
1	< 20,000	28	96.55 (93.33)	2	0.00 (6.67)	30	96.77 (100.00)
2	20,000 - 40,000	1	3.45 100.00	0	0.00 0.00	1 0	3.23 100.00
3	40,000 - 60,000	0	0.00 (0.00)	0	0.00 (0.00)	0	0.00 (0.00)
4	60,000 - 80,000	0	0.00 (0.00)	0	0.00 (0.00)	0	0.00 (0.00)
5	> 80,000	0	0.00 (0.00)	0	0.00 (0.00)	0	0.00 (0.00)
	Total	29	100.00 (100.00)	2	100.00 (100.00)	31	100.00 (100.00)

Source: Primary Household Survey-2008

Note: Figures in Parenthesis Denote Row Percentage

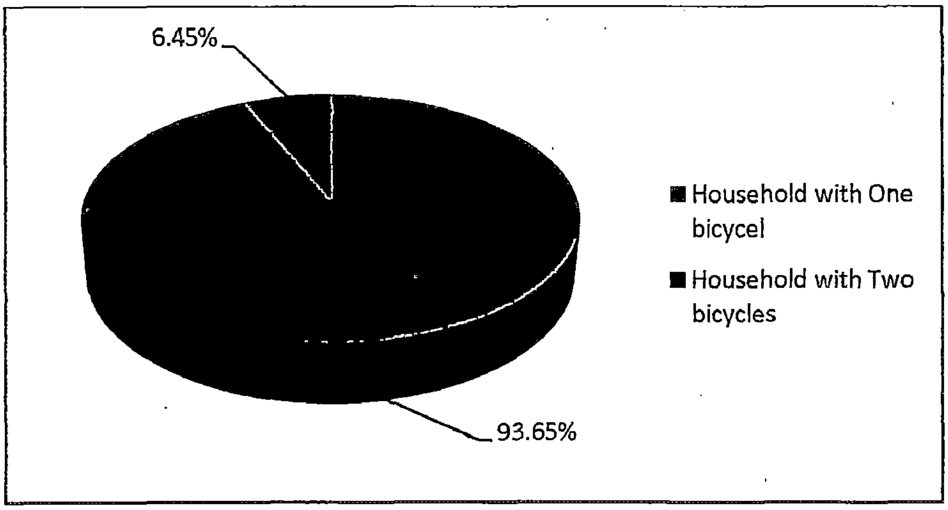

Fig. No. 4.31: Distribution of Households with Cycle Ownership

4.3. PARKING FACILITY

The unprecedented growth of cities in terms of population, vehicular population, population density and allied parameters demands huge parking areas in the urban system. The parking area demand is depends on few factors, which include household activities, economic activity of the urban system, vehicular population and their composition, occupation pattern, urban transport policies and strategies, growth of commercial activities, available infrastructural facilities and services, etc. Generally the parking areas is needed within living premises, at work place, at shopping, at recreation and entertainment, social-gathering, on-road parking, etc. Having this knowledge in mind, the Investigator conducted a household survey to assess the existing parking facility at work place, at shopping, and on-road parking at the grassroots level in the system. Pre-tested schedules were used for conducting the survey to assess the availability of parking areas in the system. The collected data are analysed thoroughly and the results are presented as below:

4.3.1. Parking Facility at Work Place, Shopping and Besides Roads

Parking is one of the major problems in the urban areas because of uncontrolled and unplanned growth of cities. Few factors are responsible for this parameter, which include the per cent of working population, location of work places and their residences, working hours, household activities, occupation pattern, needs and aspiration of the people, available recreation and entertainment facilities, dynamic behavior of the city, availability of big metro commercial complexes, malls, etc. Most of the working population in the urban areas uses their own personal vehicles for their mobility (to reach work place) because of absence of mass transport system and inefficient and inadequate public transportation available in the urban system. Having this knowledge in mind, the Investigator considered this as one of the parameters in the schedule, and conducted the investigation. The analysis of parking at work place is grouped into two groups, which include adequate and inadequate parking facilities at work place and is clubbed with various income groups for analysis, and the results are presented in Table 4.35 and in Fig. 4.32. This Table and this Fig. depict that half (50.00 per cent) of the households confined in adequate category, and rest of them (50.00 per cent) confined in inadequate category. In income group analysis, the households confined with adequate category are increasing along with increase in income up to the monthly household income group of Rs. 20,000-40,000 and then observe the reverse trend. Further, it has been observed that the households confined with inadequate category are decreasing along with increase in income. This table concludes that half (50.00 per cent) of the personalized vehicle owners did not get adequate parking facility in the study area.

Table No. 4.35: Distribution of Households with Parking Facility at Work Place

(Numbers/Per cent)

Sl No.	Household Income (Rs. /month)	Adequate		Inadequate		Total	
		Nos.	Per cent	Nos.	Per cent	Nos.	Per cent
1	< 20,000	23	18.11 (26.14)	65	51.18 (73.86)	88	34.65 (100.00)
2	20,000 - 40,000	48	37.80 (55.17)	39	30.71 (44.83)	87	34.25 (100.00)
3	40,000 - 60,000	29	22.83 (59.18)	20	15.75 (40.82)	49	19.29 (100.00)
4	60,000 - 80,000	13	10.24 (81.25)	3	2.36 (18.75)	16	6.30 (100.00)
5	> 80,000	14	11.02 (100.00)	0	0.00 (0.00)	14	5.51 (100.00)
	Total	**127**	**100.00 (50.00)**	**127**	**100.00 (50.00)**	**254**	**100.00 (100.00)**

Source: Primary Household Survey-2008

Note: Figures in Parenthesis Denote Row Percentage

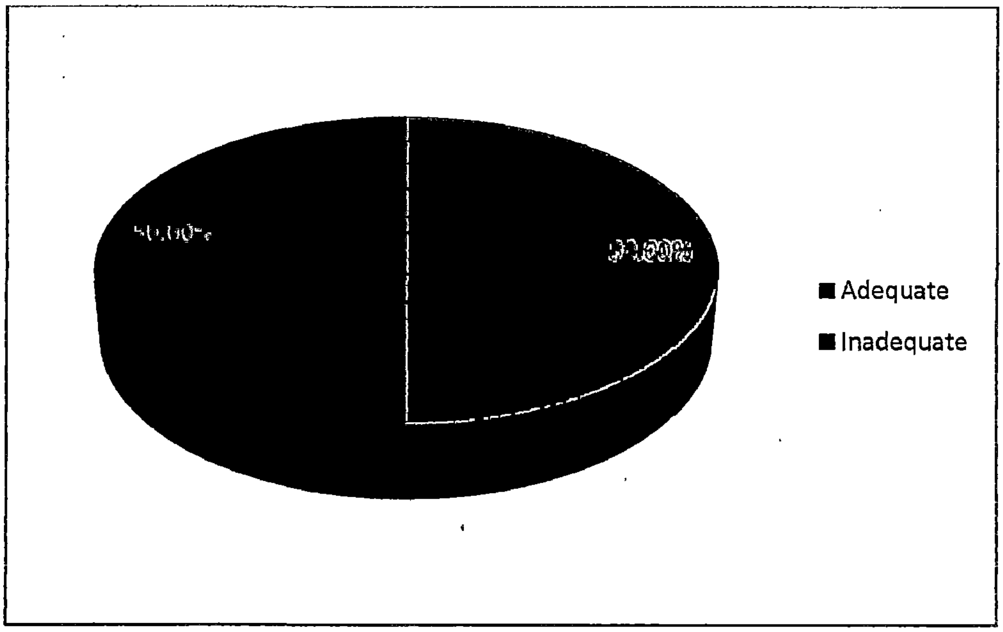

Fig. No. 4.32: Distribution of Households with Parking Facility at Work Place

4.3.2. Parking Facility at Shopping

The analysis of parking at shopping place is grouped into two groups, which include adequate and inadequate parking facilities in shopping areas and is clubbed with various income groups for analysis, and the results are presented in Table 4.36 and in Fig. 4.33. This Table and this Fig. depict that about four-fifth (77.95 per cent) of the households opinioned that inadequate parking at shopping areas and above one-fifth (22.05 per cent) of the households opinioned that adequate parking at shopping area. In income group analysis, the households confined in adequate category are decreasing along with increase in income, whereas the households confined with inadequate category are increasing along with increase in income up to the monthly household income group of Rs. 20,000-40,000 and then observe the reverse trend. This table clearly shows that the study area is facing acute shortage of parking facility in shopping area.

Table No. 4.36: Distribution of Households with Parking Facility at Shopping

(Numbers/ Per cent)

Sl No.	Household Income (Rs. /month)	Adequate		Inadequate		Total	
		Nos.	Per cent	Nos.	Per cent	Nos.	Per cent
1	< 20,000	31	55.36	57	28.79	88	34.65
			-35.23		-64.77		-100
2	20,000 - 40,000	21	37.5	66	33.33	87	34.25
			-24.14		-75.86		-100
3	40,000 - 60,000	3	5.36	46	23.23	49	19.29
			-6.12		-93.88		-100
4	60,000 - 80,000	1	1.79	15	7.58	16	6.3
			-6.25		-93.75		-100
5	> 80,000	0	0	14	7.07	14	5.51
			0		-100		-100
	Total	**56**	**100**	**198**	**100**	**254**	**100**
			-22.05		**-77.95**		**-100**

Source: Primary Household Survey-2008

Note: Figures in Parenthesis Denote Row Percentage

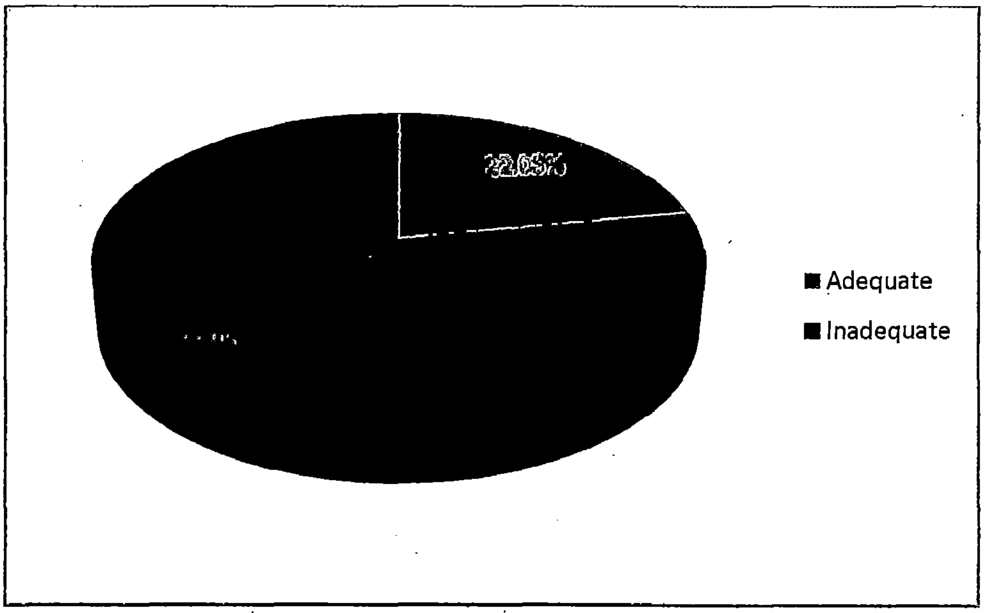

Fig. No. 4.33: Distribution of Households with Parking Facility at Shopping

4.3.3. Parking Facility at On Road Parking

The analysis of on road parking is grouped into two groups, which include adequate and inadequate parking facilities and is clubbed with various income groups for analysis, and the results are presented in Table 4.37 and in Fig. 4.34. This Table and this Fig. depict that about cent (97.64 per cent) of the households opinioned that on road parking is inadequate and a very meager (2.36 per cent) of the households opinioned that on road parking is adequate in the study area. In income group analysis, the households confined with adequate category are a very meager and scattered in first three income groups and the households with inadequate category are decreasing along with increase in income. This table concludes that the majority, i.e., about cent per cent (97.64 per cent) of the households irrespective of income group of households opinioned that there was grossly inadequate on road parking space to accommodate vehicles to perform their routine activities, weekend and occasional activities in the study area.

Table No. 4.37: Distribution of Households with Parking Facility at On Road Parking

(Numbers/ Per cent)

Sl. No.	Household Income (Rs. /month)	Adequate		Inadequate		Total	
		Nos.	Per cent	Nos.	Per cent	Nos.	Per cent
1	< 20,000	2	25.00 (2.27)	86	34.68 (97.73)	88	34.65 (100.00)
2	20,000 - 40,000	3	50.00 (3.45)	84	33.87 (96.55)	87	34.25 (100.00)
3	40,000 - 60,000	1	25.00 (2.04)	48	19.35 (97.96)	49	19.29 (100.00)
4	60,000 - 80,000	0	0.00 (0.00)	16	6.45 (100.00)	16	6.30 (100.00)
5	> 80,000	0	0.00 (0.00)	14	5.65 (100.00)	14	5.51 (100.00)
	Total	6	100.00 (2.36)	248	100.00 (97.64)	254	100.00 (100.00)

Source: Primary Household Survey-2008
Note: Figures in Parenthesis Denote Row Percentage

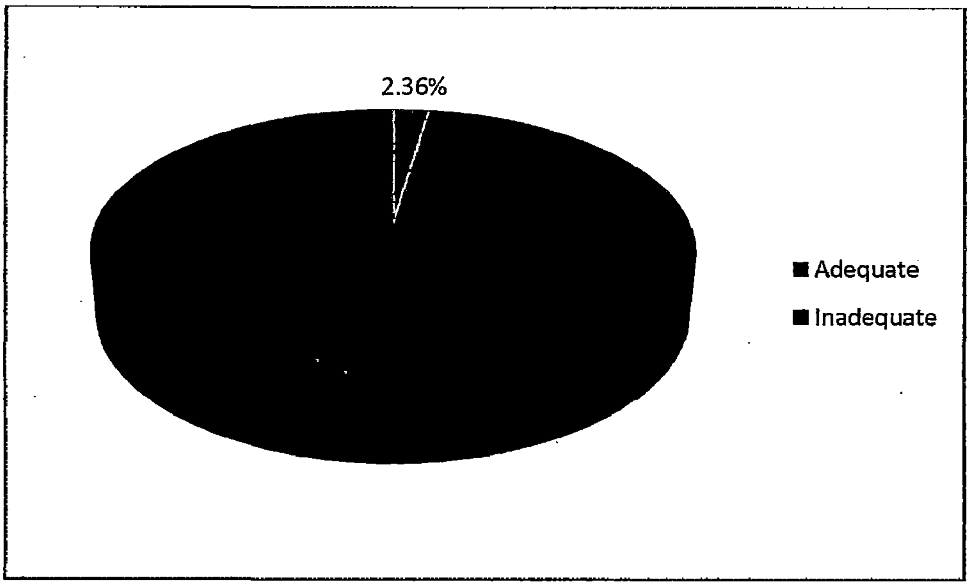

Fig. No. 4.34: Distribution of Households with Parking Facility at On Road Parking

4.4. TRAVEL CHARACTERISTICS OF THE HOUSEHOLD IN WEEKDAYS

The travel characteristics of the household in weekdays which include the purpose of the trips made by the members of the households, i.e., for work, education, shopping, and recreation purpose trips; the distribution of different trips by different mode of transports; the distribution of work, education, shopping and recreational purpose trips by different mode of transport; the distribution of households by total trips; the distribution of households by work and non-work purpose trips; the distribution of households by total trip length; the distribution of households by trip length for work and non-work purpose; the distribution of public transport trips by trip length; the distribution of households by travel time for work and non-work purpose; per capita trip rate by different mode of transport and purpose of trips; per capita trip rate in motorized and non-motorized trips; per capita trip rate in different mode of transport trips; per capita trip length in work and non-work purpose; per capita travel time in motorized and non-motorized trips; the distribution of trips by purpose in weekends; per capita trip rate in weekend trips, etc., studied carefully and analysed thoroughly, and the results are presented as below:

4.4.1. Distribution of Trips by Purpose

The distribution of trips performed by the members of the surveyed households for various purposes understands the function of the urban system. It gives knowledge about the amount of trips used for various purposes in the system. Analysis of trips for various purposes may also be useful for providing proper infrastructure to the urban residents through the Comprehensive Development Plan (CDP) of the city. Having this knowledge in mind, the Investigator considered this as one of the parameters in the schedule, and conducted the investigation. The distribution of trips by purpose is broadly grouped into four, which include work, education, shopping and recreation purpose trips and is clubbed with various income groups for analysis, and the results are presented in Table 4.38 and in Fig. 4.35. This Table and this Fig. depict that the total number of trips performed by the members of the total surveyed households are 2914. The per capita trip rate is 1.89. It has been observed from the Table and the Fig. that above two-fifth (43.10 per cent) of total trips made for work purpose. Followed by, above one-fourth (27.52 per cent), above one-sixth (17.71 per cent), and about one-eighth (11.67 per cent) of the total trips performed for education, shopping and recreational purpose respectively in the study area. In income group analysis, the trips made for work and education purpose are decreasing along with increase in income. Further, the trips performed for shopping and recreation purpose are increasing along with increase in income up to the monthly household income group of Rs. 20,000-40,000 and then observe the reverse trend. This table concludes that the majority of the trips are done for work purpose in the study area.

Table No. 4.38: Distribution of Trips by Purpose

(Numbers/ Day)

Sl. No.	Household Income (Rs. /month)	Trips per Day by Different Purpose									
		Work		Education		Shopping		Recreation		Total	
		Nos.	Per cent	Nos.	Per cent	Nos.	Per cent	Nos.	Per cent	Nos.	Per cent
1	< 20,000	534	42.52 (46.35)	402	50.12 (34.90)	168	32.56 (14.58)	48	14.12 (4.17)	1152	39.53 (100.00)
2	20,000 - 40,000	376	29.94 (42.82)	194	24.19 (22.10)	184	35.66 (20.96)	124	36.47 (14.12)	878	30.13 (100.00)
3	40,000 - 60,000	206	16.40 (38.15)	136	16.96 (25.19)	98	18.99 (18.15)	100	29.41 (18.52)	540	18.53 (100.00)
4	60,000 - 80,000	82	6.53 (44.57)	38	4.74 (20.65)	34	6.59 (18.48)	30	8.82 (16.30)	184	6.31 (100.00)
5	> 80,000	58	4.62 (36.25)	32	3.99 (20.00)	32	6.20 (20.00)	38	11.18 (23.75)	160	5.49 (100.00)
	Total	**1256**	**100.00 (43.10)**	**802**	**100.00 (27.52)**	**516**	**100.00 (17.71)**	**340**	**100.00 (11.67)**	**2914**	**100.00 (100.00)**

Source: Primary Household Survey-2008

Note: Figures in Parenthesis Denote Row Percentage

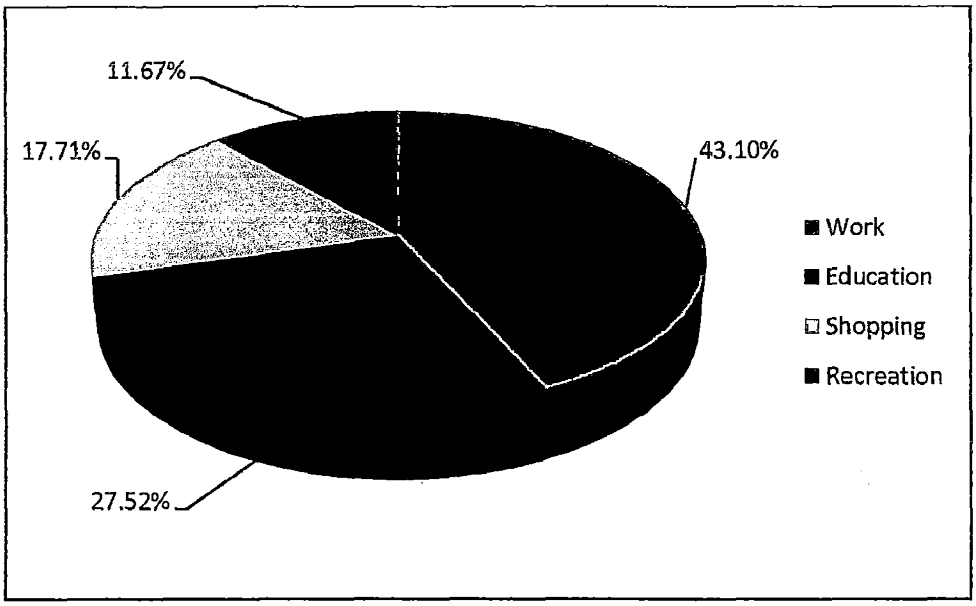

Fig. No. 4.35: Distribution of Trips by Purpose

4.4.2. Distribution of Trips by Different Mode of Transport

Distribution of trips by different mode of transport with the various income group households gives knowledge about the people's preference of their personalized vehicles and public mode of transport for their routine activities in the study area. This also gives the knowledge about the trend of using different mode of transport for household activities in future and also useful for designing urban transport policies in future. Having this knowledge in mind, the Investigator considered this as one of the parameters in the schedule, and conducted the investigation. The distribution of trips by different mode of transport is grouped into eight groups, which include walking, bicycle, two-wheeler, shared two-wheeler, three-wheeler, car, public transport (BMTC), and school buses/vans/private vehicles and is clubbed with various income groups for analysis, and the results are presented in Table 4.39 and in Fig. 4.36. This Table and this Fig. depict that the total number of trips performed by the members of the surveyed households are 2644, and the per capita trip rate is 1.72. It has been observed from the Table and the Fig. that above two-fifth (43.57 per cent) of the total trips performed by the two-wheelers in the study area. Followed by, about one-fourth (23.03 per cent), above one-sixth (16.72 per cent) of the total trips performed by the public transport and car mode of transport respectively; it has been observed that a very meager (7.79 per cent, 3.97 per cent, 3.63

per cent, and 1.29 per cent) of total trips performed by the private vehicles, auto rickshaws, bicycle and shared two-wheelers respectively in the study area. In income group analysis, the trips done by the public transport are decreasing along with increase in income. Further, it has been observed that the trips done by the bicycle are decreasing along with increase in income up to the monthly household income group of Rs. 40,000-60,000, and the majority is confined in the lowest income group households; the trips by two-wheeler are increasing along with increase in income up to the monthly household income group of Rs. 20,000-40,000 and then observe the reverse trend; Further, it has been observed that the trips done by shared-two-wheeler are increasing along with increase in income up to the monthly household income group of Rs. 40,000-60,000, whereas the trips done by the auto-rickshaw and car are scattered over in almost all income groups. This table concludes that the majority, i.e., above two-fifth (43.57 per cent) and about one-fourth (23.03 per cent) of the total trips performed by the two-wheeler and public transport respectively in the study area.

4.4.3. Distribution of Work Purpose Trips by Different Mode of Transport

Distribution of work purpose trips by different mode of transport used by different income group of households gives knowledge about the transportation function of the urban system. Having this knowledge in mind, the Investigator considered this as one of the parameters in the schedule, and conducted the investigation. The distribution of work purpose of trips by different mode of transport is grouped into non-motorized and motorized trips (eight). Further, the non-motorized trips, which include walking and bicycle trips; motorized trips, which include two-wheeler, three-wheeler, car, public transport (BMTC), KSRTC bus, and company van trips and is clubbed with various income groups for analysis, and the results are presented in Table 4.40 and in Fig. 4.37. This Table and this Fig. depict that above two-fifth (41.40 per cent) of the total work purpose trips performed by the wo-wheelers. Followed by, above one-fourth (27.38 per cent), above one-sixth (16.88 per cent), and a very meager (6.36 per cent) of the total work purpose trips were performed by the public transport (BMTC buses), car, and walking trips respectively.

Table No. 4.39 : Distribution Trips by Different Mode of Transport

(Numbers/ Per cent/ Day)

Sl No.	Household Income (Rs. /month)	Mode of Transport											
		Bicycle Trips		Two-wheeler Trips		Shared 2-wheeler Trips		Auto rickshaw Trips		Car Trips		Public Transport (BMTC) Trips	
		Nos.	Per cent	Nos.	Per cent	Nos.	Per cent	Nos.	Per cent	Nos.	Per cent	Nos.	Per cent
1	< 20,000	62	64.58 (6.60)	354	30.73 (37.66)	10	29.41 (1.06)	45	42.86 (4.79)	50	11.31 (5.32)	371	60.92 (39.47)
2	20,000 - 40,000	28	29.17 (3.34)	464	40.28 (55.37)	10	29.41 (1.19)	20	19.05 (2.39)	102	23.08 (12.17)	158	25.94 (18.85)
3	40,000 - 60,000	6	6.25 (1.12)	222	19.27 (41.57)	14	41.18 (2.62)	8	7.62 (1.50)	154	34.84 (28.84)	62	10.18 (11.61)
4	60,000 - 80,000	0	0.00 (0.00)	66	5.73 (37.08)	0	0.00 (0.00)	12	11.43 (6.74)	60	13.57 (33.71)	14	2.30 (7.87)
5	> 80,000	0	0.00 (0.00)	46	3.99 (29.87)	0	0.00 (0.00)	20	19.05 (12.99)	76	17.19 (49.35)	4	0.66 (2.60)
	Total	**96**	**100.00 (3.63)**	**1152**	**100.00 (43.57)**	**34**	**100.00 (1.29)**	**105**	**100.00 (3.97)**	**442**	**100.00 (16.72)**	**609**	**100.00 (23.03)**

Source: Primary Household Survey-2008

Note: Figures in Parenthesis Denote Row Percentage

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Table No. 4.39 : Distribution Trips by Different Mode of Transport

(Numbers/ Per cent/ Day)

Sl No.	Household Income (Rs. /month)	Mode of Transport			
		Private/School Van Trips		Total Trips	
		Nos.	Per cent	Nos.	Per cent
1	< 20,000	48	23.30 (5.11)	940	35.55 (100.00)
2	20,000 - 40,000	56	27.18 (6.68)	838	31.69 (100.00)
3	40,000 - 60,000	68	33.01 (12.73)	534	20.20 (100.00)
4	60,000 - 80,000	26	12.62 (14.61)	178	6.73 (100.00)
5	> 80,000	8	3.88 (5.19)	154	5.82 (100.00)
	Total	**206**	**100.00 (7.79)**	**2644**	**100.00 (100.00)**

Source: Primary Household Survey-2008

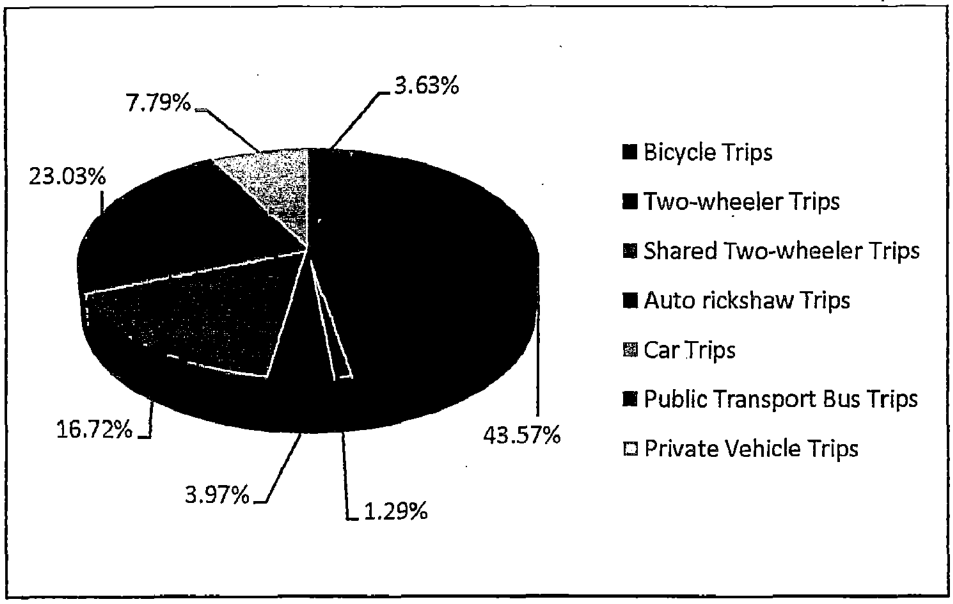

Fig. No. 4.36: Distribution Trips by Different Mode of Transport

Further, it has been observed that a very meager (4.14 per cent, 1.92 per cent, 1.44 per cent and 0.48 per cent) of total work purpose trips performed by the private vehicles, bicycle, three-wheeler (auto rickshaw) and the KSRTC buses respectively in the study area. In income group analysis, the work purpose trips done by the bicycle is almost confined within the least income group, i.e., below Rs. 20,000/-. Further, it has been observed that the work purpose trips done by the walking and public transport trips are decreasing along with increase in income; it has also been observed that the work purpose trips done by the two-wheeler, three-wheeler and company van are increasing along with increase in income up to the monthly household income group of Rs. 20,000-40,000 and then observe the reverse trend; the work purpose trips done by the KSRTC are confined to first two income groups, i.e., below Rs. 20,000 to 20,000-40,000 per month; the work purpose trips done by the car are scattered over in almost all income groups. This table concludes that the majority, i.e., above two-fifth (41.40 per cent) of work-purpose trips are performed by employing two-wheeler mode of transport in the study area.

Table No. 4.40: Distribution of Work Purpose Trips by Different Mode of Transport

(Numbers/ Day)

Sl No.	Household Income (Rs. /month)	Walking		Bicycle		Two-wheeler		Three-wheeler		Car		Public Transport (BMTC)		KSRTC Bus	
		Nos.	Per cent	Nos.	Per cent	Nos.	Per cent	Nos.	Per cent	Nos.	Per cent	Nos.	Per cent	Nos.	Per cent
1	< 20,000	56	70.00 (10.45)	22	91.67 (4.10)	186	35.77 (34.70)	6	33.33 (1.12)	22	10.38 (4.10)	228	66.28 (42.54)	2	33.33 (0.37)
2	20,000 - 40,000	18	22.50 (4.79)	2	8.33 (0.53)	198	38.08 (52.66)	8	44.44 (2.13)	52	24.53 (13.83)	78	22.67 (20.74)	4	66.67 (1.06)
3	40,000 - 60,000	4	5.00 (1.94)	0	0.00 (0.00)	92	17.69 (44.66)	0	0.00 (0.00)	70	33.02 (33.98)	26	7.56 (12.62)	0	0.00 (0.00)
4	60,000 - 80,000	2	2.50 (2.44)	0	0.00 (0.00)	28	5.38 (34.15)	2	11.11 (2.44)	32	15.09 (39.02)	12	3.49 (14.63)	0	0.00 (0.00)
5	> 80,000	0	0.00 (0.00)	0	0.00 (0.00)	16	3.08 (27.59)	2	11.11 (3.45)	36	16.98 (62.07)	0	0.00 (0.00)	0	0.00 (0.00)
	Total	**80**	**100.00 (6.36)**	**24**	**100.00 (1.92)**	**520**	**100.00 (41.40)**	**18**	**100.00 (1.44)**	**212**	**100.00 (16.88)**	**344**	**100.00 (27.38)**	**6**	**100.00 (0.48)**

Source: Primary Household Survey-2008

Note: Figures in Parenthesis Denote Row Percentage

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Table No. 4.40: Distribution of Work Purpose Trips by Different Mode of Transport

(Numbers/ Day)

Sl No.	Household Income (Rs. /month)	Company Van		Total	
		Nos.	Per cent	Nos.	Per cent
1	< 20,000	12	23.08 (2.24)	534	42.52 (100.00)
2	20,000 - 40,000	16	30.77 (4.26)	376	29.94 (100.00)
3	40,000 - 60,000	14	26.92 (6.80)	206	16.40 (100.00)
4	60,000 - 80,000	6	11.54 (7.32)	82	6.52 (100.00)
5	> 80,000	4	7.69 (6.90)	58	4.62 (100.00)
	Total	**52**	**100.00 (4.14)**	**1256**	**100.00 (100.00)**

Source: Primary Household Survey-2008
Note: Figures in Parenthesis Denote Row Percentage

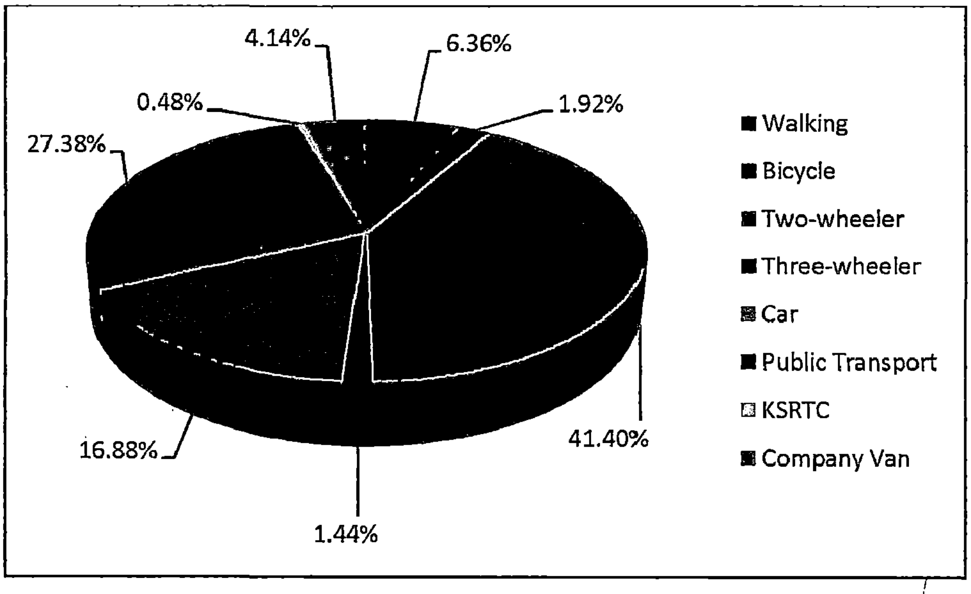

Fig. No. 4.37: Distribution of Work Purpose Trips by Different Mode of Transport

4.4.4. Distribution of Education Purpose Trips by Different Mode of Transport

The distribution of education purpose trips by different mode of transport and by different income group categories gives little knowledge about the function of the urban system in general, and the travel characteristics in particular. Educational institutions, which include Primary-Middle-High Schools, Science and Arts Colleges, Engineering Colleges, Medical Colleges, Teacher Training Institutes, Indian Institute of Science, Polytechnics, Nursing Institutes, Professional bodies, etc., are mushrooming in every nook and corner of the city. People use different mode of transportation for their purpose. Having this knowledge in mind, the Investigator considered this as one of the parameters in the schedule, and conducted the investigation. The distribution of trips for education purpose by different mode of transport is grouped into seven groups, which include walking, bicycle trips, two-wheeler, three-wheeler, car, public transport (BMTC), School bus/van trips and is clubbed with various income groups for analysis, and the results are presented in Table 4.41 and in Fig. 4.38. This Table and this Fig. depict that about three-tenth (29.67 per cent) of education purpose trips performed by the public transport. Further, about one-fourth (23.94 per cent), about one-fifth (18.70 per cent), and above one-seventh (14.72 per cent) of the total educational purpose trips were performed by walking, school bus/van and two-wheeler mode of transport respectively. It has also been observed that a very meager (7.48 per cent, 3.49 per cent and 2.00 per cent) of the total educational purpose trips were performed by the three-wheeler (auto rickshaw), bicycle, and car mode of transport respectively in the study area. In income group analysis, the educational trips by walking are decreasing along with increase in income, and are almost confined within the least income group i.e., below Rs. 20,000/- per month. Further, it has also been observed that the education trips done by the bicycle trips are more or less confined in the fist two income group categories, i.e., below Rs. 20,000-40,000. It has also been observed that the education purpose trips done by the two-wheeler trips are increasing along with increase in income up to the income group of Rs. 20,000-40,000 and then observe the reverse trend. Further, it has been observed that the work purpose by employing the public transport trips is decreasing along with increase in income. Trips made by the School bus/van are increasing along with increase in income up to the monthly household income group of Rs. 40,000-60,000 and then observe the reverse trend. Further, the trips made by the three-wheeler are decreasing along with increase in income up to the monthly household income group of Rs. 40,000-60,000 and then observe the reverse trend, whereas the trips made by the car are constant from monthly household income group of Rs. 20,000/- to Rs. 80,000/-, and sudden increase is recorded in the household income group of Rs. 80,000 & above. This table concludes that the public transport and walking mode play a significant role in educational purpose in the study area.

4.4.5. Distribution of Shopping Purpose Trips by Different Mode of Transport

The shopping centres from the neighbourhood shop to big malls spread over across the city. The big bazaars, metro centres, big commercial complexes are attracting the peoples and transportation plays a major role for satisfying the requirement of the people. The distribution of shopping purpose trips by different mode of transport and by different income group household's gives the understanding of the function of the urban system and priority of vehicles (different share of vehicles) used for the same. Having this knowledge in mind, the Investigator considered this as one of the parameters in the schedule, and conducted the investigation.

Table No. 4.41: Distribution of Education Purpose Trips by Different Mode of Transport

(Numbers/Day)

Sl No.	Household Income (Rs. /month)	Walking		Bicycle		Two-wheeler		Three-wheeler		Car		Public Transport (BMTC)		School bus/van		Total	
		Nos.	Per cent	Nos.	Per cent	Nos.	Per cent	Nos.	Per cent	Nos.	Per cent	Nos.	Per cent	Nos.	Per cent	Nos.	Per cent
1	< 20,000	172	89.58 (42.78)	12	42.86 (2.98)	32	27.12 (7.96)	18	30.00 (4.47)	2	12.50 (0.50)	130	54.62 (32.33)	36	24.00 (8.96)	402	50.62 (100.00)
2	20,000 - 40,000	16	8.33 (8.25)	14	50.00 (7.22)	42	35.59 (21.65)	12	20.00 (6.19)	2	12.50 (1.03)	72	30.25 (37.11)	36	24.00 (18.56)	194	24.07 (100.00)
3	40,000 - 60,000	4	2.08 (2.99)	2	7.14 (1.49)	34	28.81 (25.37)	6	10.00 (4.48)	2	12.50 (1.49)	32	13.45 (23.88)	54	36.00 (40.30)	134	16.63 (100.00)
4	60,000 - 80,000	0	0.00 (0.00)	0	0.00 (0.00)	4	3.39 (11.11)	8	13.33 (22.22)	2	12.50 (5.56)	2	0.84 (5.56)	20	13.33 (55.55)	36	4.71 (100.00)
5	> 80,000	0	0.00 (0.00)	0	0.00 (0.00)	6	5.08 (16.67)	16	26.67 (44.44)	8	50.00 (22.22)	2	0.84 (5.56)	4	2.67 (11.11)	36	3.97 (100.00)
	Total	**192**	**100.00 (23.94)**	**28**	**100.00 (3.49)**	**118**	**100.00 (14.72)**	60	**100.00 (7.48)**	16	**100.00 (2.00)**	**238**	**100.00 (29.67)**	**150**	**100.00 (18.70)**	**802**	**100.00 (100.00)**

Source: Primary Household Survey-2008

Note: Figures in Parenthesis Denote Row Percentage

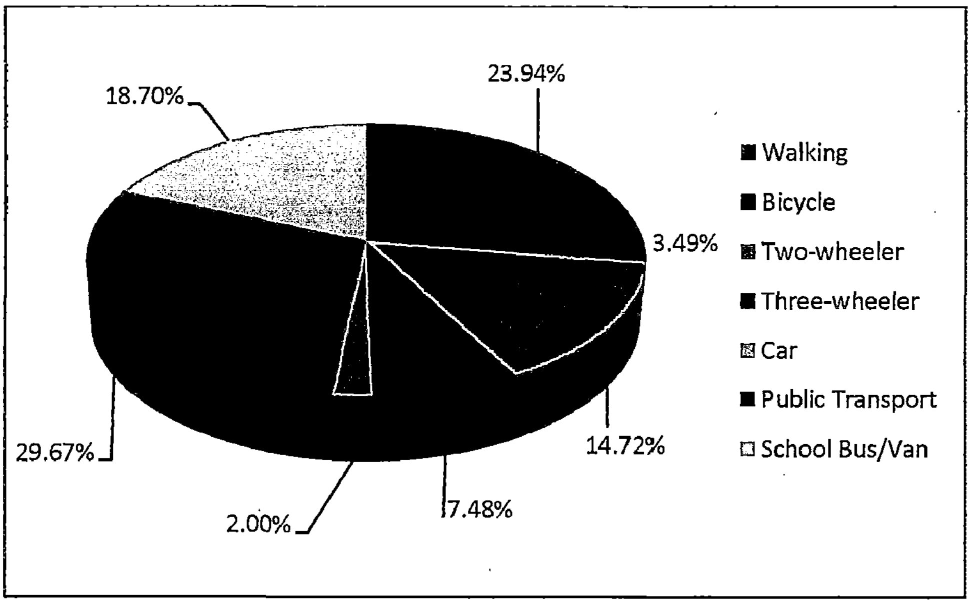

Fig. No. 4.38: Distribution of Education Purpose Trips by Different Mode of Transport

The distribution of trips for shopping purpose by different mode of transport is grouped into seven groups, which include walking, bicycle trips, two-wheeler, three-wheeler, car, public transport buses (BMTC), School bus/van trips and is clubbed with various income groups for analysis, and the results are presented in Table 4.42 and in Fig. 4.39. This Table and this Fig. depict that above three-fifth (60.85 per cent) of total shopping trips were performed by the two-wheelers. Further, above one-fourth (26.36 per cent) of the shopping trips were performed by car mode of trips; about a very meager (6.59 per cent, 3.88 per cent and 2.33 per cent) of total shopping purpose trips were done by bicycle, three-wheeler (auto rickshaw) and public transport mode respectively in the study area. In income group analysis, the shopping trips done by the bicycle are decreasing along with increase in income up to the monthly household income group of Rs. 40,000-60,000 and the majority of them is confined within the lowest income group households. Further, it has been observed that the shopping trips done by the three-wheeler is confined within the least income group i.e., below Rs. 20,000/- whereas the trips done by the public transport (BMTC) are confined within the fist two income group categories, i.e., below Rs. 20,000/- and Rs. 20,000-40,000; trips done by the two-wheeler are increasing along with increase in income up to the monthly household income group of Rs. 20,000-40,000 and then observe the reverse trend, and the trips done by car are increasing up to the monthly household income group of Rs. Rs. 40,000-60,000 and then observe the reverse trend. This table concludes that two-wheelers are used much for doing shopping activities in the study area.

4.4.6. Distribution of Recreation Purpose Trips by Different Mode of Transport

The recreation purpose trips considered in this study which include visiting to parks, playgrounds, gymnasium for playing, relaxing, jogging, visiting to temples/churches and mosques, etc. The study area has good infrastructure facilities for recreational purpose which attracts the people. The distribution of recreation purpose trips by different mode of transport gives little knowledge about the function of this urban system along with available modes of transportation and their importance for the same in the study area. Having this knowledge in mind, the Investigator considered this as one of the parameters in the schedule, and conducted the investigation. The distribution of recreation purpose trips by different mode of transport is grouped into six groups, which include walking, bicycle, two-wheeler, three-wheeler, car, and public transport (BMTC) and is clubbed with various income groups for analysis, and the results are presented in Table 4.43 and in Fig. 4.40. This Table and this Fig. depict that above three-fifth (62.35 per cent) of the recreational purpose trips were done by two-wheeler only. Followed by, above one-fourth (25.29) of the total recreational purpose trips were done by car mode of transport; and only a meager (5.29 per cent, 4.12 per cent and 2.94 per cent) of total recreational trips were done by three-wheeler, public transport and the bicycle mode respectively. In income group analysis, the recreational purpose trips done by the public transport are almost confined within the first two income group categories, i.e., below Rs. 20,000/- and Rs. 20,000-40,000. Further, it has been observed that the recreational purpose trips done by bicycle are confined within the first three income group categories; the trips done by three-wheeler are decreasing along with increase in income; trips done by two-wheeler are increasing along with increase in income up to the monthly household income group of Rs. 20,000-40,000 and then observe the reverse trend, whereas trips done by car are scattered over in almost all income groups. This table concludes that the recreation trips, i.e., above three-fifth (62.35 per cent) of the recreational trips were done by two-wheeler mode only.

Table No. 4.42: Distribution of Shopping Purpose Trips by Different Mode of Transport

Sl. No.	Household Income (Rs. /month)	Trips per Day by Different Purpose										Total	
		Bicycle		Two-wheeler		Three-wheeler		Car		Public Transport (BMTC)			
		Nos.	Per cent	Nos.	Per cent	Nos.	Per cent	Nos.	Per cent	Nos.	Per cent	Nos.	Per cent
1	< 20,000	22	64.71 (13.25)	106	33.76 (63.86)	14	70.00 (8.43)	18	13.24 (10.84)	6	50.00 (3.61)	166	32.18 (100.00)
2	20,000 - 40,000	10	29.41 (5.56)	128	40.76 (71.11)	0	0.00 (0.00)	36	26.47 (20.00)	6	50.00 (3.33)	180	34.88 (100.00)
3	40,000 - 60,000	2	5.88 (1.96)	54	17.20 (52.94)	0	0.00 (0.00)	46	33.82 (45.10)	0	0.00 (0.00)	102	19.76 (100.00)
4	60,000 - 80,000	0	0.00 (0.00)	14	4.46 (38.89)	6	30.00 (16.67)	16	11.76 (44.44)	0	0.00 (0.00)	36	6.98 (100.00)
5	> 80,000	0	0.00 (0.00)	12	3.82 (37.50)	0	0.00 (0.00)	20	14.71 (62.50)	0	0.00 (0.00)	32	6.20 (100.00)
	Total	**34**	**100.00 (6.59)**	**314**	**100.00 (60.85)**	**20**	**100.00 (3.88)**	**136**	**100.00 (26.36)**	**12**	**100.00 (2.33)**	**516**	**100.00 (100.00)**

Source: Primary Household Survey-2008

Note: Figures in Parenthesis Denote Row Percentage

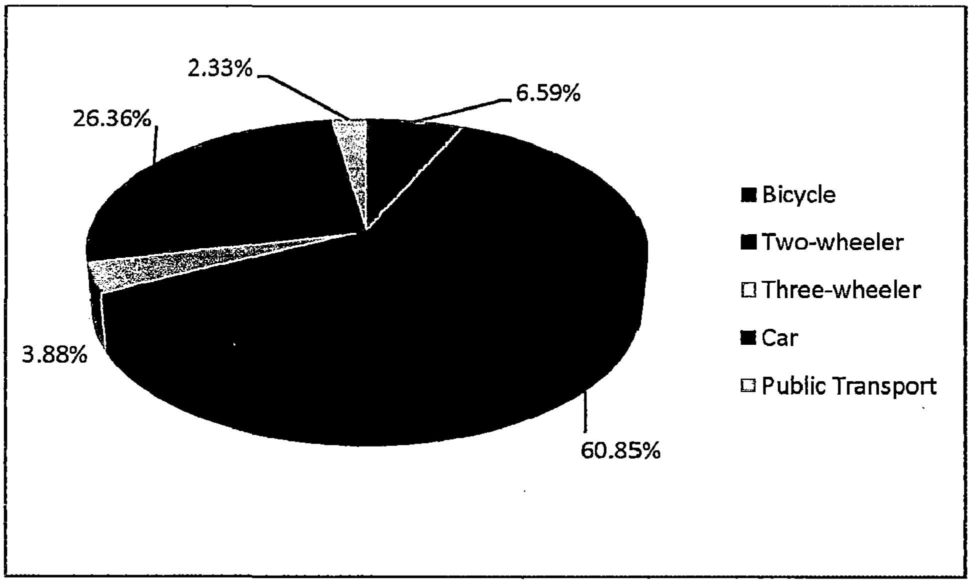

Fig. No. 4.39: Distribution of Shopping Purpose Trips by Different Mode of Transport

4.4.7. Distribution of Households by Total Trips

The range of trips performed by the households per day is one of the important parameters to assess the travel characteristics of the household. The minimum and maximum number of trips performed per household per day depends on few factors, which include their socio-economic condition, demographic features, household size, number of school going children, monthly household income, financial status, occupation pattern, number of working members in the household, dependents, educational background, literacy level, cultural background, etc. Having this knowledge in mind, the Investigator considered this as one of the parameters in the schedule, and conducted the investigation. The distribution of households by total trips is grouped into five groups, which include less than 8 trips, 8-12, 12-16, 16-20 and more than 20 trips per household per day and is clubbed with various income groups for analysis, and the results are presented in Table 4.44 and in Fig. 4.41. This Table and this Fig. depict that above half of (55.63 per cent) the total surveyed households performed 8-12 number of trips per household per day.

Table No. 4.43: Distribution of Recreational Purpose Trips by Different Mode of Transport

Sl. No.	Household Income (Rs. /month)	Trips per Day by Different Purpose										Total	
		Bicycle		Two-wheeler		Three-wheeler		Car		Public Transport (BMTC)			
		Nos.	Per cent	Nos.	Per cent	Nos.	Per cent	Nos.	Per cent	Nos.	Per cent	Nos.	Per cent
1	< 20,000	6	60.00 (9.09)	36	16.98 (54.55)	10	55.56 (15.15)	2	2.33 (3.03)	12	85.71 (18.18)	66	19.42 (100.00)
2	20,000 - 40,000	2	20.00 (1.61)	100	47.17 (80.65)	4	22.22 (3.23)	16	18.60 (12.90)	2	14.29 (1.61)	124	36.47 (100.00)
3	40,000 - 60,000	2	20.00 (2.22)	48	22.64 (53.33)	2	11.11 (2.22)	38	44.19 (42.22)	0	0.00 (0.00)	90	26.47 (100.00)
4	60,000 - 80,000	0	0.00 (0.00)	18	8.49 (64.29)	0	0.00 (0.00)	10	11.63 (35.71)	0	0.00 (0.00)	28	8.23 (100.00)
5	> 80,000	0	0.00 (0.00)	10	4.72 (31.25)	2	11.11 (6.25)	20	23.26 (62.50)	0	0.00 (0.00)	32	9.41 (100.00)
	Total	**10**	**100.00 (2.94)**	**212**	**100.00 (62.35)**	**18**	**100.00 (5.29)**	**86**	**100.00 (25.29)**	**14**	**100.00 (4.12)**	**340**	**100.00 (100.00)**

Source: Primary Household Survey-2008

Note: Figures in Parenthesis Denote Row Percentage

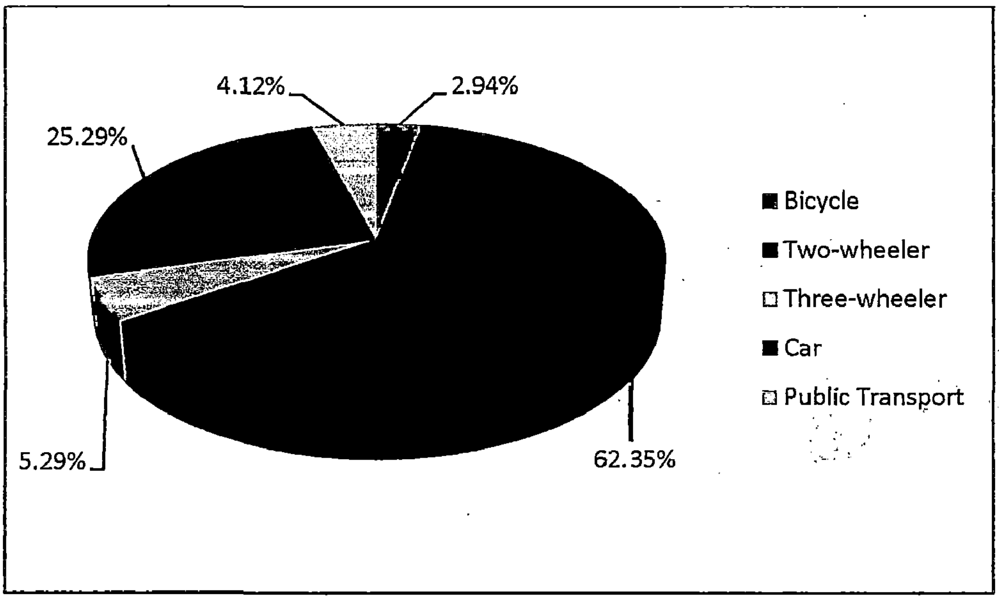

Fig. No. 4.40: Distribution of Recreational Purpose Trips by Different Mode of Transport

Followed by, about one-fourth (24.06 per cent), above one-tenth (10.31 per cent), above one-twentieth (5.63 per cent), and a very meager (4.38 per cent) of the surveyed households performed 12-16, less than 10, 16-20 and above 20 number of trips per household per day in the study area. In income group analysis, the household with less than 8 trips per household per day are almost confined within the least income group, i.e., below Rs. 20,000/- per month. Further, it has been observed that the households with 8-12, and 12-16 number of trips per household per day are decreasing along with increase in income; the households with 16-20 and more than 20 numbers of trips per household per day are increasing along with increase in income up to the monthly household income group of Rs. 20,000-40,000 and then observe the reverse trend. This table concludes that more than half (55.63 per cent) of the total households performed 8-12 number of trips per household per day in the study area.

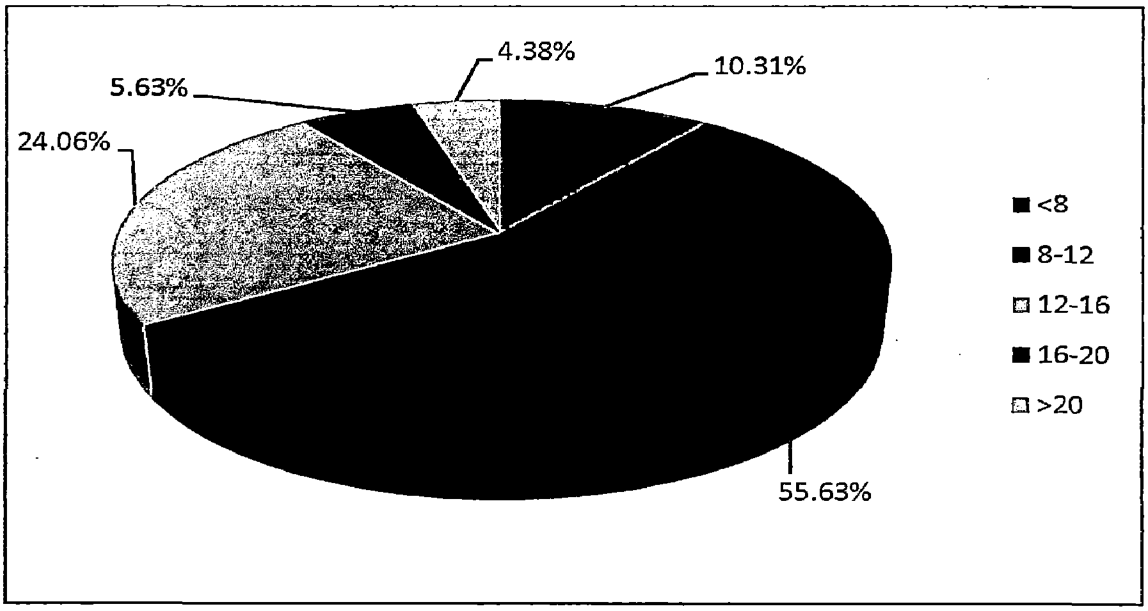

Fig. No. 4.41: Distribution of Households by Total Trips

Table No. 4.44: Distribution of Households by Total Trips

(Numbers/ Day)

Sl No.	Household Income (Rs. /month)	Total Number of Trips Per Household Per Day										Total	
		< 8		8-12		12-16		16-20		> 20			
		Nos.	Per cent	Nos.	Per cent	Nos.	Per cent	Nos.	Per cent	Nos.	Per cent	Nos.	Per cent
1	< 20,000	31	93.94 (20.13)	88	49.44 (57.14)	28	36.36 (18.18)	4	22.22 (2.60)	3	21.43 (1.95)	154	48.13 (100.00)
2	20,000 - 40,000	2	6.06 (2.30)	48	26.97 (55.17)	24	31.17 (27.59)	9	50.00 (10.34)	4	28.57 (4.60)	87	27.19 (100.00)
3	40,000 - 60,000	0	0.00 (0.00)	30	16,85 (61.22)	12	15.58 (24.49)	4	22.22 (8.16)	3	21.43 (6.12)	49	15.31 (100.00)
4	60,000 - 80,000	0	0.00 (0.00)	8	4.49 (50.00)	5	6.49 (31.25)	1	5.56 (6.25)	2	14.29 (12.50)	16	5.00 (100.00)
5	> 80,000	0	0.00 (0.00)	4	2.25 (28.57)	8	10.39 (57.14)	0	0.00 (0.00)	2	14.29 (14.29)	14	4.38 (100.00)
	Total	**33**	**100.00 (10.31)**	**178**	**100.00 (55.63)**	**77**	**100.00 (24.06)**	**18**	**100.00 (5.63)**	**14**	**100.00 (4.38)**	**320**	**100.00 (100.00)**

Source: Primary Household Survey-2008

Note: Figures in Parenthesis Denote Row Percentage

4.4.7.1. Distribution of Households by Work Purpose Trips

Work purpose trips are dominant in the urban areas, in general. The distribution of surveyed households by different range of work purpose trips gives the understanding the function of the urban system, and the travel characteristics of the different income group of households. The minimum and maximum number of work purpose trips per household per day depends on few factors, which include the number of working members in the family, capacity of earning, easy access to work place, available efficient public transportation system, car pooling, vehicle ownership, education level, affordability, importance and use of telecommunication system, etc. Having this knowledge in mind, the Investigator considered this as one of the parameters in the schedule, and conducted the investigation. The distribution of households by work purpose trips is grouped into five groups, which include less than 2 trips, 2-4, 4-6, 6-8, and more than 8 trips per household per day, and is clubbed with various income groups for analysis, and the results are presented in Table 4.45 and in Fig. 4.42. This Table and this Fig. depict that about half (44.69 per cent) of the surveyed households performed 2-4 number of trips per household per day for work purpose in the study area. Followed by, about two-fifth (36.56 per cent), one-tenth (10.00 per cent), one-twentieth (5.00 per cent) and a very meager (3.75 per cent) of the total surveyed households performed less than 2, 4-6, 6-8 and above 8 number of trips per household per day in the study area. In income group analysis, the households performed less than 2, and 2-4 numbers of trips per household per day are decreasing along with increase in income, whereas the households performed 4-6 number of trips per household per day are scattered over in almost all income groups. Further, it has been observed that the households by work purpose for above 8 trips are increasing along with increase in income up to the monthly household income group of Rs. 20,000-40,000 and then observe the reverse trend, whereas the households with work purpose of 6-8 trips are mostly confined within the first two income group categories, i.e., below Rs. 20,000 to Rs. 20,000-40,000 per month. This table concludes that the about half (44.69 per cent) of households performed 2-4 numbers of trips per household per day for work purpose in the study area, which indicates few members of the family are working in the study area.

Table No. 4.45: Distribution of Households by Work Purpose Trips

(Numbers/ Day)

Sl No.	Household Income (Rs. /month)	Number of Trips Per Household Per Day										Total	
		< 2		2-4		4-6		6-8		> 8			
		Nos.	Per cent	Nos.	Per cent	Nos.	Per cent	Nos.	Per cent	Nos.	Per cent	Nos.	Per cent
1	< 20,000	73	62.39 (47.40)	59	41.26 (38.31)	14	43.75 (9.09)	6	37.50 (3.90)	2	16.67 (1.30)	154	48.13 (100.00)
2	20,000 - 40,000	26	22.22 (29.89)	41	28.67 (47.13)	8	25.00 (9.20)	6	37.50 (6.90)	6	50.00 (6.90)	87	27.19 (100.00)
3	40,000 - 60,000	12	10.26 (24.49)	26	18.18 (53.06)	9	28.13 (18.37)	0	0.00 (0.00)	2	16.67 (4.08)	49	15.31 (100.00)
4	60,000 - 80,000	3	2.56 (18.75)	8	5.59 (50.00)	0	0.00 (0.00)	4	25.00 (25.00)	1	8.33 (6.25)	16	5.00 (100.00)
5	> 80,000	3	2.56 (21.43)	9	6.29 (64.29)	1	3.13 (7.14)	0	0.00 (0.00)	1	8.33 (7.14)	14	4.38 (100.00)
	Total	**117**	**100.00 (36.56)**	**143**	**100.00 (44.69)**	**32**	**100.00 (10.00)**	**16**	**100.00 (5.00)**	**12**	**100.00 (3.75)**	**320**	**100.00 (100.00)**

Source: Primary Household Survey-2008

Note: Figures in Parenthesis Denote Row Percentage

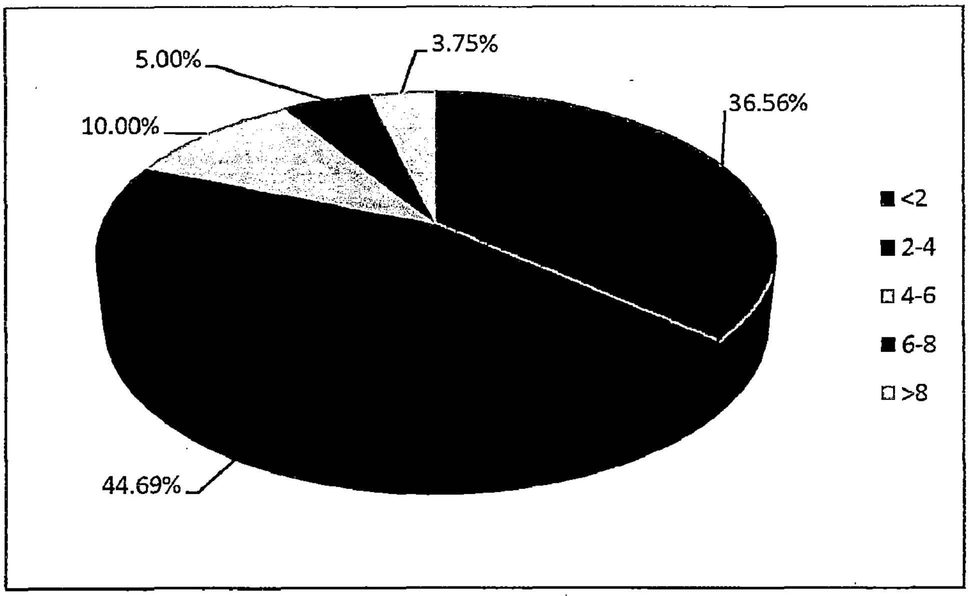

Fig. No. 4.42: Distribution of Households by Work Purpose Trips

4.4.7.2. Distribution of Households by Non-Work Purpose Trips

The non-work purpose trips play a significant role in the urban areas. In general, off-peak hour traffic of any city carries majority of non-working population for non-work purposes, which include shopping, recreation, entertainment, health, social-gathering, etc. The distribution of households by non-work purpose trips by different income group households gives little knowledge about the function of the urban system. Having this knowledge in mind, the Investigator considered this as one of the parameters in the schedule, and conducted the investigation. The distribution of households by non-work purpose trips is grouped into six groups, which include less than 4 trips, 4-6, 6-8, 8-10, 10-12 and more than 12 trips per household per day and is clubbed with various income groups for analysis, and the results are presented in Table 4.46 and in Fig. 4.43. This Table and this Fig. illustrate that above one-third (33.75 per cent) of the households performed 6-8 number of non-work purpose trips per household per day in the study area. Followed by, above one-fifth (21.56 per cent, 20.63 per cent), and about one-tenth (9.38 per cent) of the households performed 4-6, 8-10, and 10-12 number of trips per household per day respectively. Further, it has also been observed that about one-thirteen (7.50 per cent) and above one-fourteenth (7.19 per cent) of the total surveyed households are performed more than 12 and less than 4 number of trips per household per day for non-work purpose respectively in the study area. In income group analysis, the households confined less than 4 number of non-work purpose trips per day are almost confined within the least income group, i.e., below Rs. 20,000/-; the households confined within 4-6, 6-8 and 8-10 number of trips per household per day is decreasing along with increase in income; the households confined within 10-12, and above 12 number of trips per household per day are increasing along with increase in income up to the monthly household income group of Rs. 20,000-40,000 and then observe the reverse trend. It seem to be that the nonworking population engaged in business activities, and are earning good amount of income. It is further stated that more than half of the persons (53.97 per cent) are confined in the tertiary segment of the occupation (c.r.t. 4.6) of the total working population. Therefore, the higher income group people perform more trips pertain to non-working activities.

4.4.8. Distribution of Households by Total Trip Length

In this Investigation, the total trip length performed by the household per day is considered as equal to total motorized and total non-motorized trip length. The total trip length performed by the households is one of the important parameters in urban travel characteristics of the household. The different range of total trip length performed by the households depends on few factors, which include the household size, occupation pattern, dependents, the financial status, the location of work places, the availability of facilities and services from the residences, the vehicle ownership, the horizontal expansion of the city; available efficient, affordable, reliable, environmentally friendly, high-speed, safe mass transportation system; awareness about science and technology, information system, telecommunication, etc., in the study area. The distribution of households by total trip length per household per day by different income group category of households gives little knowledge about the function of the urban system and the travel characteristics of the household. Having this knowledge in mind, the Investigator considered this as one of the variables in the schedule, and conducted the investigation. The distribution of households by total trip length per household per day is grouped into six groups, which include less than 50, 50-75, 75-100, 100-125, 125-150 and more than 150 km per household per day and is clubbed with various income groups for analysis, and the results are presented in Table 4.47 and in Fig. 4.44.

Table No. 4.46: Distribution of Households by Non-Work Purpose Trips

(Numbers/ Day)

Sl No.	Household Income (Rs. /month)	Number of Trips Per Household Per Day												Total	
		< 4		4-6		6-8		8-10		10-12		> 12			
		Nos.	Per cent	Nos.	Per cent	Nos.	Per cent	Nos.	Per cent	Nos.	Per cent	Nos.	Per cent	Nos.	Per cent
1	< 20,000	19	82.61 (12.34)	38	55.07 (24.68)	52	48.15 (33.77)	33	50.00 (21.43)	6	20.00 (3.90)	6	25.00 (3.90)	154	48.13 (100.00)
2	20,000 - 40,000	4	17.39 (4.60)	17	24.64 (19.54)	29	26.85 (33.33)	17	25.76 (19.54)	12	40.00 (13.79)	8	33.33 (9.20)	87	27.19 (100.00)
3	40,000 - 60,000	0	0.00 (0.00)	9	13.04 (18.37)	17	15.74 (34.69)	12	18.18 (24.49)	6	20.00 (12.24)	5	20.83 (10.20)	49	15.31 (100.00)
4	60,000 - 80,000	0	0.00 (0.00)	4	5.80 (25.00)	6	5.56 (37.50)	2	3.03 (12.50)	1	3.33 (6.25)	3	12.50 (18.75)	16	5.00 (100.00)
5	> 80,000	0	0.00 (0.00)	1	1.45 (7.14)	4	3.70 (28.57)	2	3.03 (14.29)	5	16.67 (35.71)	2	8.33 (14.29)	14	4.38 (100.00)
	Total	**23**	**100.00 (7.19)**	**69**	**100.00 (21.56)**	**108**	**100.00 (33.75)**	**66**	**100.00 (20.63)**	**30**	**100.00 (9.38)**	**24**	**100.00 (7.50)**	**320**	**100.00 (100.00)**

Source: Primary Household Survey-2008

Note: Figures in Parenthesis Denote Row Percentage

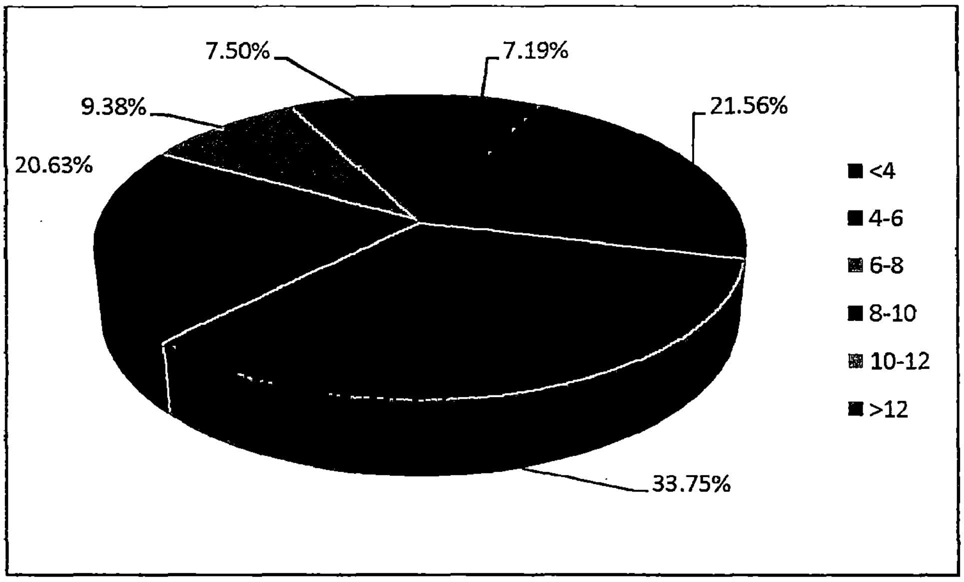

Fig. No. 4.43: Distribution of Households by Non-Work Purpose Trips

This Table and this Fig. illustrate that about one-third (30.63 per cent) of the households performed 50-75 km trip length per household per day. Followed by, just above one-fourth (25.94 per cent), about one-fourth (24.38 per cent), and about one-tenth (9.38 per cent) of the households performed 75-100, less than 50, and 100-125 km trip length per household per day respectively in the study area; a very meager (5.31 per cent and 4.38 per cent) of the households performed more than 150 km and 125-150 km per household per day respectively in the study area. In income group analysis, the households performed less than 50 km per household per day are confined within the least monthly household income group, i.e., below Rs. 20,000/-. Further, it has been observed that the households performed 50-75 km trip lengths per household per day are decreasing along with increase in income; the households performed 75-100 and more than 150 km trip length per household per day are increasing along with increase in income up to the monthly household income group of Rs. 20,000-40,000 and then observe the reverse trend, whereas the household confined within 100-125 and 125-150 km are increasing along with increase in income up to the monthly household income group of Rs. 40,000-60,000, and then observe the reverse trend. This clearly shows that the study area badly need of efficient and high-capacity mass transit system for their mobility. This table concludes that the majority, i.e., about one-third (30.63 per cent) of households performed 50-75 km trip length per household per day in the study area.

Table No. 4.47: Distribution of Households by Total Trip Length

(Kilometers/ Day)

Sl No.	Household Income (Rs. /month)	Total Trip Length in Kilometers Per Household Per Day												Total	
		< 50		50-75		75-100		100-125		125-150		> 150			
		Nos.	Per cent	Nos.	Per cent	Nos.	Per cent	Nos.	Per cent	Nos.	Per cent	Nos.	Per cent	Nos.	Per cent
1	< 20,000	71	91.03 (46.10)	48	48.98 (31.17)	25	30.12 (16.23)	6	20.00 (3.90)	2	14.29 (1.30)	2	11.76 (1.30)	154	48.13 (100.00)
2	20,000 - 40,000	7	8.97 (8.05)	29	29.59 (33.33)	31	37.35 (35.63)	8	26.67 (9.20)	4	28.57 (4.60)	8	47.06 (9.20)	87	27.19 (100.00)
3	40,000 - 60,000	0	0.00 (0.00)	16	16.33 (32.65)	14	16.87 (28.57)	10	33.33 (20.41)	5	35.71 (10.20)	4	23.53 (8.16)	49	15.31 (100.00)
4	60,000 - 80,000	0	0.00 (0.00)	3	3.06 (18.75)	5	6.02 (31.25)	4	13.33 (25.00)	2	14.29 (12.50)	2	11.76 (12.50)	16	5.00 (100.00)
5	> 80,000	0	0.00 (0.00)	2	2.04 (14.29)	8	9.64 (57.14)	2	6.67 (14.29)	1	7.14 (7.14)	1	5.88 (7.14)	14	4.38 (100.00)
	Total	**78**	**100.00 (24.38)**	**98**	**100.00 (30.63)**	**83**	**100.00 (25.94)**	**30**	**100.00 (9.38)**	**14**	**100.00 (4.38)**	**17**	**100.00 (5.31)**	**320**	**100.00 (100.00)**

Source: Primary Household Survey-2008

Note: Figures in Parenthesis Denote Row Percentage

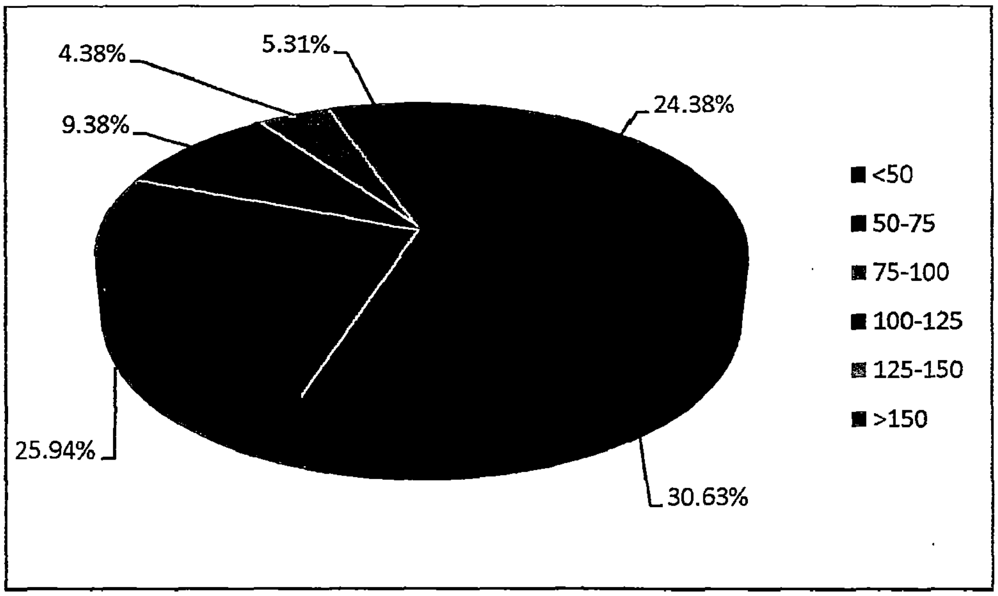

Fig. No. 4.44: Distribution of Households by Total Trip Length

4.4.8.1. Distribution of Households by Trip Length for Work Purpose

The unplanned and uncontrolled growth of cities, the separation of residences and workplaces, absence of efficient transport policies and strategies, scope for horizontal expansion of cities in Comprehensive Development Plan (CDP) exercises, the rapid growth of urbanization, industrialization are mainly responsible for increase in trip length for work purpose in the urban system. The separation of working areas from the residential areas lead to increase in trip length, high fuel consumption, travel time, travel cost, risk, tension, anxiety, etc. The integrated land use and transportation plan along with strict planning measures mitigate the problems to the larger extent. The distribution of households by different range of trip length per household per day helps for understanding the function of the urban system. Having this knowledge in mind, the Investigator considered this as one of the parameters in the schedule, and conducted the investigation. The distribution of households by trip length for work purpose per household per day is grouped into six groups, which include less than 20, 20-40, 40-60, 60-80, 80-100 and more than 100 km per household per day and is clubbed with various income groups for analysis, and the results are presented in Table 4.48 and in Fig. 4.45. This Table and this Fig. illustrate that about one-third (30.31 per cent) of the households performed 40-60 km trip length per household per day for work purpose in the study area.

Followed by, above one-fourth (26.56 per cent), about one-fourth (24.38 per cent) and above one-tenth (10.31 per cent) of the households performed 20-40, less than 20, and 60-80 km trip length per household per day for work purpose; it has also been observed that a very meager (5.00 per cent and 3.44 per cent) of the households performed above 100 km and 80-100 km trip length per household per day in the study area. In income group analysis, the households performed less than 20, 20-40, 40-60 and 60-80 km trip length per household per day are decreasing along with increase in income; the households performed 80-100 and above 100 km trip length per household per day are scattered over in almost all income groups. This table concludes that the majority, i.e., about one-third (30.31 per cent) of the households performed 40-60 km trip length per household per day for work purpose in the study area, which is not a smaller distance.

4.4.8.2. Distribution of Households by Trip Length in Non-Work Purpose

The working and dependent population are spending their leisure time for non-work purpose too. The distribution of households by different range of trip length per household per day in non-work purpose also gives little knowledge about the function of the urban system. Having this knowledge in mind, the Investigator considered this as one of the parameters in the schedule, and conducted the investigation. The distribution of households by trip length in non-work purpose per household per day is grouped into four groups, which include less than 20, 20-40, 40-60, and more than 60 km per household per day and is clubbed with various income groups for analysis, and the results are presented in Table 4.49 and in Fig. 4.46. This Table and this Fig. illustrate that above two-fifth (43.44 per cent) of the households performed 20-40 km trip length per household per day for non-work purpose. Followed by, about one-third (31.25 per cent), above one-sixth (17.19 per cent), and about one-twelfth (8.13 per cent) of the households performed less than 20, 40-60 and above 60 km trip length per household per day for non-work purpose respectively in the study area. In income group analysis, the households performed less than 20 and 20-40 km trip length per household per day are decreasing along with increase in income.

Table No. 4.48: Distribution of Households by Trip Length for Work Purpose

(Kilometers/ Day)

Sl No.	Household Income (Rs. /month)	Trip Length in Kilometers Per Household Per Day												Total	
		< 20		20-40		40-60		60-80		80-100		> 100			
		Nos.	Per cent	Nos.	Per cent	Nos.	Per cent	Nos.	Per cent	Nos.	Per cent	Nos.	Per cent	Nos.	Per cent
1	< 20,000	58	74.36 (37.66)	49	57.65 (31.82)	33	34.02 (21.43)	11	33.33 (7.14)	2	18.18 (1.30)	1	6.25 (0.65)	154	48.13 (100.00)
2	20,000 - 40,000	13	16.67 (14.94)	21	24.71 (24.14)	28	28.87 (32.18)	10	30.30 (11.49)	6	54.55 (6.90)	9	56.25 (10.34)	87	27.19 (100.00)
3	40,000 - 60,000	5	6.41 (10.20)	9	10.59 (18.37)	22	22.68 (44.90)	9	27.27 (18.37)	1	9.09 (2.04)	3	18.75 (6.12)	49	15.31 (100.00)
4	60,000 - 80,000	0	0.00 (0.00)	4	4.71 (25.00)	7	7.22 (43.75)	2	6.06 (12.50)	2	18.18 (12.50)	1	6.25 (6.25)	16	5.00 (100.00)
5	> 80,000	2	2.56 (14.29)	2	2.35 (14.29)	7	7.22 (50.00)	1	3.03 (7.14)	0	0.00 (0.00)	2	12.50 (14.29)	14	4.38 (100.00)
	Total	**78**	**100.00 (24.38)**	**85**	**100.00 (26.56)**	**97**	**100.00 (30.31)**	**33**	**100.00 (10.31)**	**11**	**100.00 (3.44)**	**16**	**100.00 (5.00)**	**320**	**100.00 (100.00)**

Source: Primary Household Survey-2008

Note: Figures in Parenthesis Denote Row Percentage

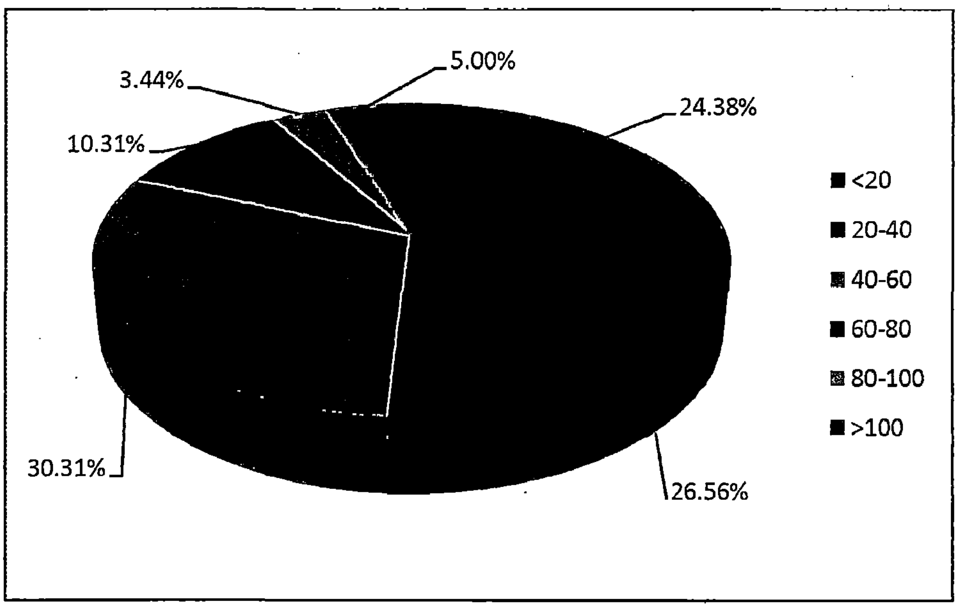

Fig. No. 4.45: Distribution of Households by Trip Length for Work Purpose

Further, it has been observed that the households performed 40-60 km trip length per household per day are increasing along with increase in income up to the monthly household income group of Rs. 20,000-40,000 and then observe the reverse trend, and above 60 km trip length per household per day are scattered over in almost all income groups. This table concludes that the majority, i.e., above two-fifth (43.44 per cent) of the households performed 20-40 km trip length per household per day in the study area for non-work purposes.

4.4.8.3. Distribution of Public Transport Trips by Trip Length (BMTC Buses)

The distribution of public transport trips by different range of trip length performed by household per day gives knowledge about the pattern of use and importance of public transportation in the urban system. Having this knowledge in mind, the Investigator considered this as one of the parameters in the schedule, and conducted the investigation. The distribution of public transport trips by different range of trip length performed by different income groups is grouped into six groups, which include the trip length performed by public transport per day are less than 3, 3-6, 6-9, 9-12, 12-15 and more than 15 km and is clubbed with various income groups for analysis, and the results are presented in Table 4.50 and in Fig. 4.47.

Table No. 4.49: Distribution of Households by Trip Length in Non-Work Purpose

(Kilometres/Day)

Sl No.	Household Income (Rs. /month)	Trip Length in Kilometres Per Household Per Day								Total	
		< 20		20-40		40-60		> 60			
		Nos.	Per cent	Nos.	Per cent	Nos.	Per cent	Nos.	Per cent	Nos.	Per cent
1	< 20,000	74	74.00 (48.05)	62	44.60 (40.26)	14	25.45 (9.09)	4	15.38 (2.60)	154	48.13 (100.00)
2	20,000 - 40,000	19	19.00 (21.84)	46	33.09 (52.87)	19	34.55 (21.84)	3	11.54 (3.45)	87	27.19 (100.00)
3	40,000 - 60,000	4	4.00 (8.16)	19	13.67 (38.78)	12	21.82 (24.49)	14	53.85 (28.57)	49	15.31 (100.00)
4	60,000 - 80,000	2	2.00 (12.50)	6	4.32 (37.50)	6	10.91 (37.50)	2	7.69 (12.50)	16	5.00 (100.00)
5	> 80,000	1	1.00 (7.14)	6	4.32 (42.86)	4	7.27 (28.57)	3	11.54 (21.43)	14	4.38 (100.00)
	Total	**100**	**100.00 (31.25)**	**139**	**100.00 (43.44)**	**55**	**100.00 (17.19)**	**26**	**100.00 (8.13)**	**320**	**100.00 (100.00)**

Source: Primary Household Survey-2008

Note: Figures in Parenthesis Denote Row Percentage

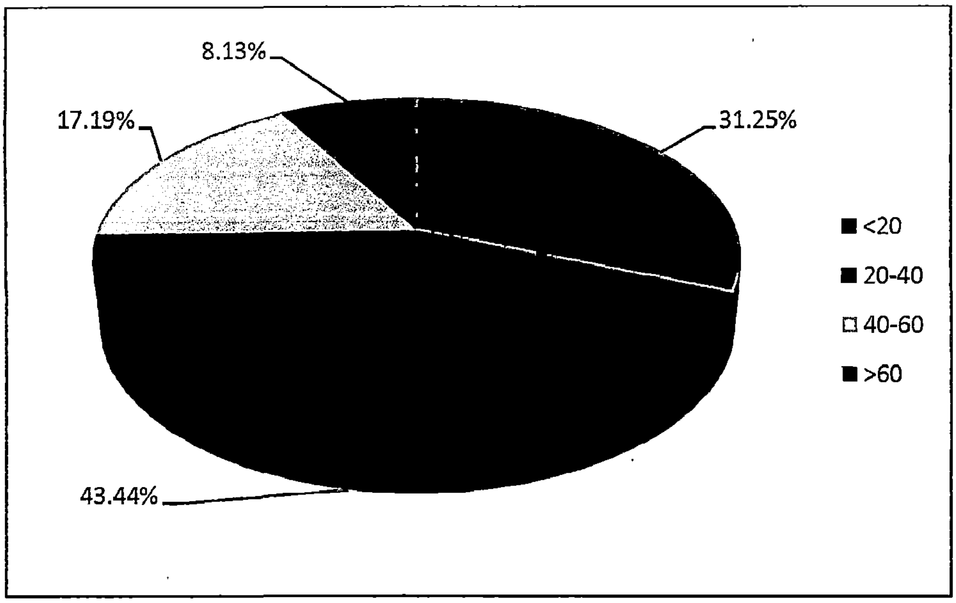

Fig. No. 4.46: Distribution of Households by Trip Length in Non-Work Purpose

This Table and this Fig. depict that the total number of public transport trips performed by the members of the households are 609. Of which, about three-tenth (29.06 per cent) of public transport trips performed 3-6 km trip length per day. Followed by, above one-fourth (27.91 per cent), about one-fourth (22.99 per cent), and about one-twelfth (8.21 per cent) of the public transport trips performed 6-9, 9-12, and 12-15 km trip length respectively in the study area; a meager (6.24 per cent and 5.58 per cent) of the public transport trips performed less than 3 km, and above 34 km trip length per day. In income group analysis, the public transport trips confined within the trip length of less than 3 km, and 12-15 km trip length are decreasing along with increase in income up to the monthly household income group of Rs. 40,000-60,000. Further, trips confined the trip length of 3-6, 6-9, 9-12 and more than 15 km are decreasing along with increase in income. This table concludes that the majority, i.e., about three-tenth (29.06 per cent) of public transport trips performed the trip length of 3-6 km in the study area.

4.4.9. Distribution of Households by Travel Time for Work Purpose

The distribution of households by travel time for work purpose per household per day gives little knowledge in the function of the urban system. Having this knowledge in mind, the Investigator considered this as one of the parameters in the schedule, and conducted the investigation.

Table No. 4.50: Distribution of Public Transport Trips (BMTC bus trips) by Trip Length

(Kilometres/Day)

Sl No.	Household Income (Rs. /month)	Trip Length in Kilometres Per Day												Total	
		< 3		3-6		6-9		9-12		12-15		> 15			
		Nos.	Per cent	Nos.	Per cent	Nos.	Per cent	Nos.	Per cent	Nos.	Per cent	Nos.	Per cent	Nos.	Per cent
1	< 20,000	22	57.89 (5.96)	109	61.58 (29.54)	114	67.06 (30.89)	82	58.57 (22.22)	28	56.00 (7.59)	14	41.18 (3.79)	369	60.59 (100.00)
2	20,000 - 40,000	12	31.58 (7.59)	44	24.86 (27.85)	32	18.82 (20.25)	38	27.14 (24.05)	20	40.00 (12.66)	12	35.29 (7.59)	158	25.94 (100.00)
3	40,000 - 60,000	4	10.53 (6.25)	20	11.30 (31.25)	16	9.41 (25.00)	16	11.43 (25.00)	2	4.00 (3.13)	6	17.65 (9.38)	64	10.51 (100.00)
4	60,000 - 80,000	0	0.00 (0.00)	2	1.13 (14.29)	8	4.71 (57.14)	2	1.43 (14.29)	0	0.00 (0.00)	2	5.88 (14.29)	14	2.30 (100.00)
5	> 80,000	0	0.00 (0.00)	2	1.13 (50.00)	0	0.00 (0.00)	2	1.43 (50.00)	0	0.00 (0.00)	0	0.00 (0.00)	4	0.66 (100.00)
	Total	**38**	**100.00 (6.24)**	**177**	**100.00 (29.06)**	**170**	**100.00 (27.91)**	**140**	**100.00 (22.99)**	**50**	**100.00 (8.21)**	**34**	**100.00 (5.58)**	**609**	**100.00 (100.00)**

Source: Primary Household Survey-2008

Note: Figures in Parenthesis Denote Row Percentage

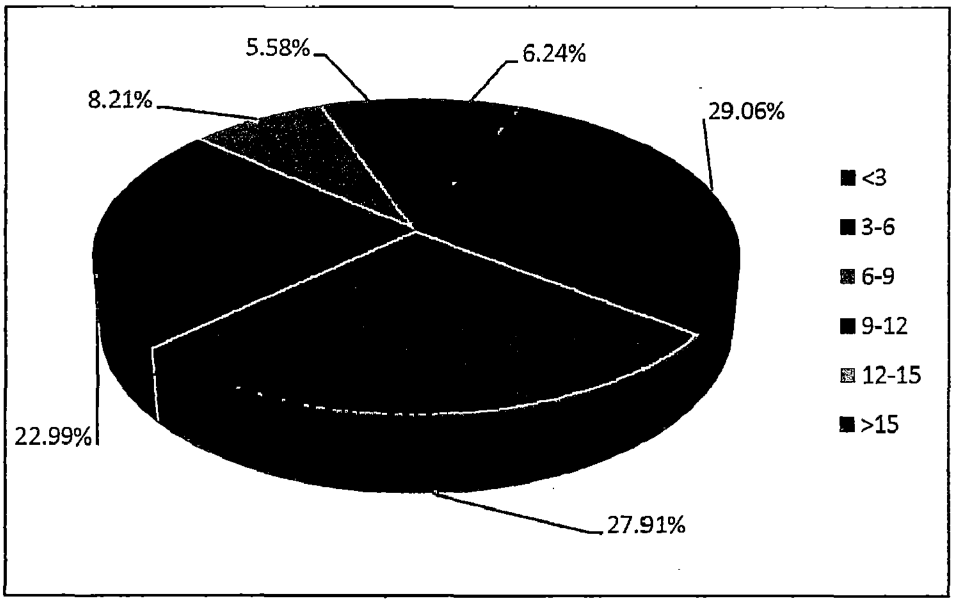

Fig. No. 4.47: Distribution of Public Transport Trips (BMTC bus trips) by Trip Length

Distribution of households by travel time for work purpose is grouped into six groups, which include less than 1, 1-2, 2-3, 3-4, 4-5 and above 5 hr travel time and is clubbed with various income groups for analysis, and the results are presented in Table 4.51 and in Fig. 4.48. This Table and this Fig. illustrate that above one-fourth (27.19 per cent) and (25.94 per cent) of the total surveyed households spend 1-2 hr and 2-3 hr respectively for work purpose in the study area. Followed by, about one-fourth (22.81 per cent), about one-tenth (9.06 per cent), about one-thirteenth (7.50 per cent) and (7.50 per cent) of the households spend 3-4, 4-5, above 5 and less than one hour respectively in the study area for the same purpose. In income group analysis, the households spend less than 1, 1-2, 2-3, and 3-4 hr are decreasing along with increase in income. Further, it has been observed that the households spend 4-5 and more than 5 hr are increasing along with increase in income up to the monthly household income of Rs. 20,000-40,000 and then observe the reverse trend. This table concludes that the majority, i.e., above one-fourth (27.19 per cent and 25.94 per cent) of the surveyed households spend 1-2 and 2-3 hr respectively for work purpose in the study area.

Table No. 4.51: Distribution of Households by Travel Time for Work Purpose

(Hours/ Day)

Sl No.	Household Income (Rs. /month)	Travel Time in Hours Per Household Per Day												Total	
		< 1		1-2		2-3		3-4		4-5		> 5			
		Nos.	Per cent	Nos.	Per cent	Nos.	Per cent	Nos.	Per cent	Nos.	Per cent	Nos.	Per cent	Nos.	Per cent
1	< 20,000	19	79.17 (12.34)	56	64.37 (36.36)	39	46.99 (25.32)	30	41.10 (19.48)	7	24.14 (4.55)	3	12.50 (1.95)	154	48.13 (100.00)
2	20,000 - 40,000	3	12.50 (3.45)	18	20.69 (20.69)	28	33.73 (32.18)	17	23.29 (19.54)	10	34.48 (11.49)	11	45.83 (12.64)	87	27.19 (100.00)
3	40,000 - 60,000	1	4.17 (2.04)	10	11.49 (20.41)	10	12.05 (20.41)	16	21.92 (32.65)	7	24.14 (14.29)	5	20.83 (10.20)	49	15.31 (100.00)
4	60,000 - 80,000	0	0.00 (0.00)	2	2.30 (12.50)	3	3.61 (18.75)	3	4.11 (18.75)	5	17.24 (31.25)	3	12.50 (18.75)	16	5.00 (100.00)
5	> 80,000	1	4.17 (7.14)	1	1.15 (7.14)	3	3.61 (21.43)	7	9.59 (50.00)	0	0.00 (0.00)	2	8.33 (14.29)	14	4.38 (100.00)
	Total	**24**	**100.00 (7.50)**	**87**	**100.00 (27.19)**	**83**	**100.00 (25.94)**	**73**	**100.00 (22.81)**	**29**	**100.00 (9.06)**	**24**	**100.00 (7.50)**	**320**	**100.00 (100.00)**

Source: Primary Household Survey-2008

Note: Figures in Parenthesis Denote Row Percentage

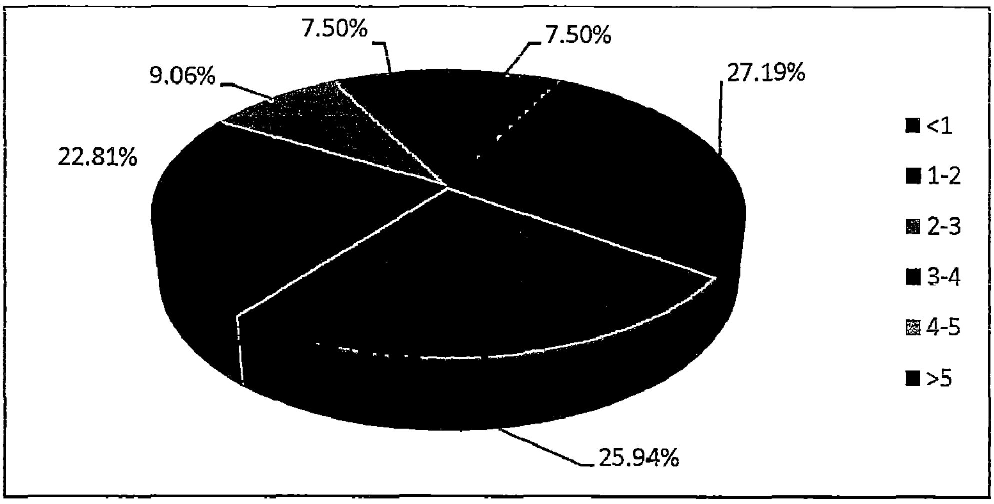

Fig. No. 4.48: Distribution of Households by Travel Time for Work Purpose

4.4.10. Distribution of Households by Travel Time in Non-Work Purpose Trips

Travel time in non-work purpose is one of the important parameters of travel characteristics of the household. Various parameters like number of earning and non-earning members, age-group, financial status, standard of living, cultural background, needs and aspirations of the households, etc., decide the travel time for non-work purpose trips in the urban areas. The distribution of households by travel time for non-work purpose gives the importance of non-work purpose trips and also functions of the urban system. Having this knowledge in mind, the Investigator considered this as one of the parameters in the schedule, and conducted the investigation. The distribution of households by travel time in non-work purpose trips is grouped into five groups, which include less than 2, 2-3, 3-4, 4-5 and above 5 hr travel time and is clubbed with various income groups for analysis, and the results are presented in Table 4.52 and in Fig. 4.49. This Table and this Fig. depict that above one-third (35.63 per cent) of the surveyed households spend 2-3 hr for non-work purpose in the study area. Followed by, just above one-fifth (20.94 per cent), one-fifth (20.00 per cent), above one-eighth (12.81 per cent) and above one-tenth (10.63 per cent) of the households spend 3-4, less than 2, 4-5 and above 5 hr for non-work purpose trips respectively in the study area. In income group analysis, it has been observed that the households spend less than 2, 2-3, and 3-4 hr travel time for non-work purpose are decreasing along with increase in income.

Table No. 4.52: Distribution of Households by Travel Time for Non-Work Purpose

(Hours/ Day)

Sl No.	Household Income (Rs. /month)	Travel Time in Hours Per Household Per Day										Total	
		< 2		2-3		3-4		4-5		> 5			
		Nos.	Per cent	Nos.	Per cent	Nos.	Per cent	Nos.	Per cent	Nos.	Per cent	Nos.	Per cent
1	< 20,000	44	68.75 (28.57)	54	47.37 (35.06)	36	53.73 (23.38)	12	29.27 (7.79)	8	23.53 (5.19)	154	48.13 (100.00)
2	20,000 - 40,000	13	20.31 (14.94)	31	27.19 (35.63)	20	29.85 (22.99)	17	41.46 (19.54)	6	17.65 (6.90)	87	27.19 (100.00)
3	40,000 - 60,000	4	6.25 (8.16)	18	15.79 (36.73)	6	8.96 (12.24)	8	19.51 (16.33)	13	38.24 (26.53)	49	15.31 (100.00)
4	60,000 - 80,000	2	3.13 (12.50)	7	6.14 (43.75)	1	1.49 (6.25)	2	4.88 (12.50)	4	11.76 (25.00)	16	5.00 (100.00)
5	> 80,000	1	1.56 (7.14)	4	3.51 (28.57)	4	5.97 (28.57)	2	4.88 (14.29)	3	8.82 (21.43)	14	4.38 (100.00)
	Total	**64**	**100.00 (20.00)**	**114**	**100.00 (35.63)**	**67**	**100.00 (20.94)**	**41**	**100.00 (12.81)**	**34**	**100.00 (10.63)**	**320**	**100.00 (100.00)**

Source: Primary Household Survey-2008

Note: Figures in Parenthesis Denote Row Percentage

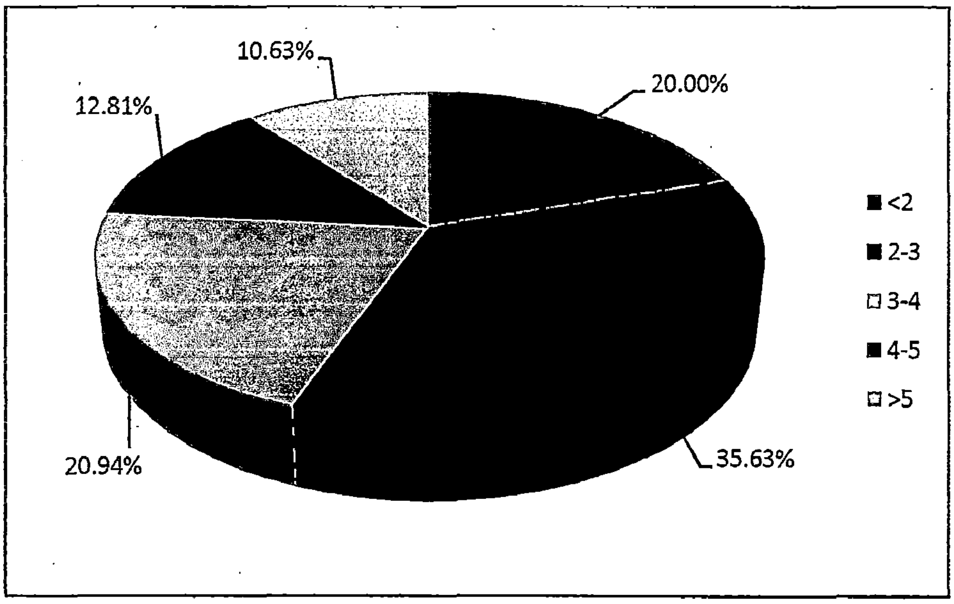

Fig. No. 4.49: Distribution of Households by Travel Time for Non-Work Purpose

Further, it has been observed that the households spend 4-5 hr for non-work purpose are increasing along with increase in income up to the monthly household income group of Rs. 20,000-40,000 and then observe the reverse trend, whereas the households spend more than 5 hr are scattered over in almost all income groups. This table concludes that above one-third (35.63 per cent) of the households spend 2-3 hr for non-work purpose in the study area.

4.4.11. Per Capita Trip Rate by Different Mode of Transport and Purpose of Trips

The per capita trip rate of different mode of transport in different purpose of trips is important output of the travel characteristics of the household. This gives little knowledge about the function of the urban system. The per capita trip rates are useful to forecast the travel demand for future by different mode and different purpose of trips. Having this knowledge in mind, the Investigator analysed the trip rate from the previous Tables and the results are presented in Table 4.53 and in Fig. 4.50. This Table and this Fig. depict that the per capita trip rate for work, education, shopping and recreation purposes are 0.82, 0.53, 0.52 and 0.77 respectively. The per capita trip rate for different purpose of trips are scattered over different mode of transport system available in the study area. This table concludes that the per capita trip rates for work purpose done by the two-wheeler are 0.34, and it is the highest among the other purpose and other mode of transport in the study area.

Table No. 4.53: Per Capita Trip Rate by Different Mode of Transport and Purpose of Trips

Sl. No.	Mode of Transport	Work PCTR	Education PCTR	Shopping PCTR	Recreation PCTR
1	Walking	0.05	0.13	0.19	0.55
2	Bicycle	0.02	0.02	0.02	0.01
3	Two-wheeler	0.34	0.08	0.20	0.14
4	Three-wheeler	0.01	0.04	0.01	0.01
5	Car	0.14	0.01	0.09	0.06
6	Public Transport buses (BMTC)	0.22	0.16	0.01	0.01
7	KSRTC	0.00	0.00	0.00	0.00
8	Private Transport	0.03	0.10	0.00	0.00
9	**Total**	**0.82**	**0.53**	**0.52**	**0.77**

Source: Primary Household Survey-2008

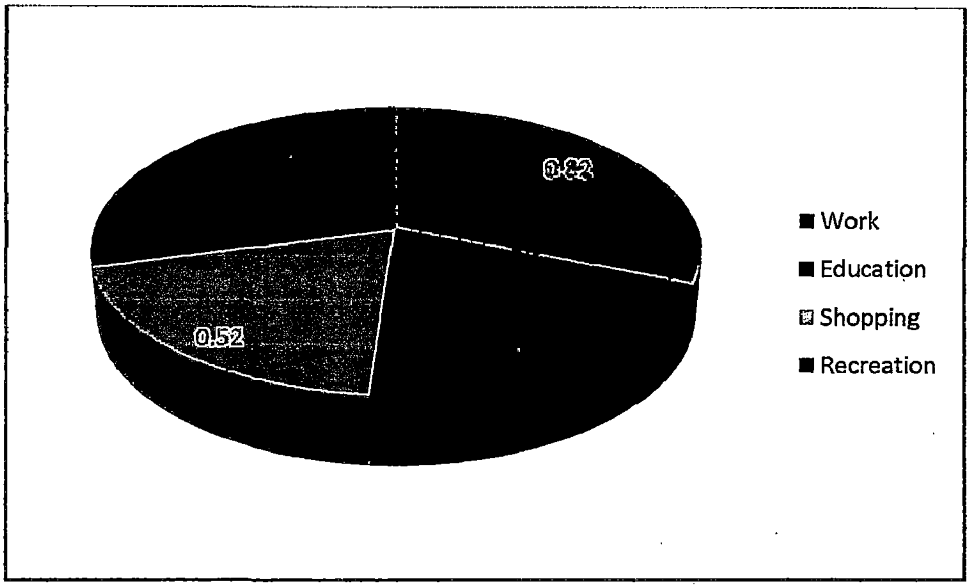

Fig. No. 4.50: Per capita Trip Rate in Different Purposes

Table No. 4.54: Distribution of Trip Rate in Motorized and Non-Motorized Trips

Sl No.	Household Income (Rs. /month)	Total Population	Motorized trips	PCTR	Non-motorized trips	PCTR	Total Trips	PCTR
1	< 20,000	712	880	1.24	870	1.22	1750	2.46
2	20,000 - 40,000	437	812	1.86	346	0.79	1158	2.65
3	40,000 - 60,000	247	528	2.14	166	0.67	694	2.81
4	60,000 - 80,000	71	178	2.51	52	0.73	230	3.24
5	> 80,000	68	154	2.26	54	0.79	208	3.06
	Total	**1535**	**2552**	**1.66**	**1488**	**0.97**	**4040**	**2.63**

Source: Primary Household Survey-2008

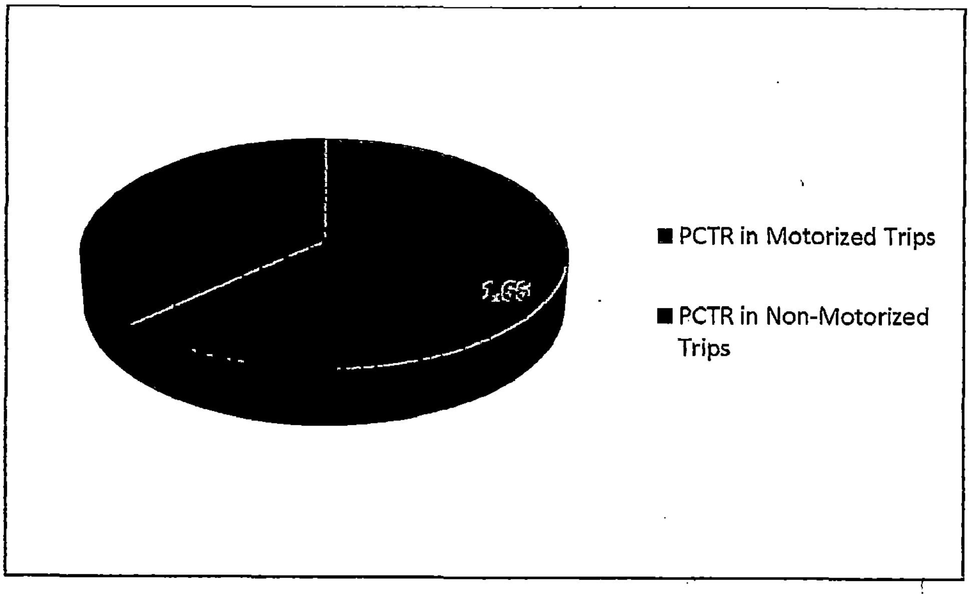

Fig. No. 4.51: Per Capita Trip Rate in Motorized and Non-Motorized Trips

4.4.12. Distribution of Trip Rate in Motorized and Non-Motorized Trips

The per capita trip rate in motorized and non-motorized trips by different income group households is output of travel characteristics of the surveyed households. This gives little knowledge about the function of the urban system and is also useful to forecast the future travel demand, and to workout the desirable modal split for the growing cities. Having this knowledge in mind, the Investigator analysed the same in this investigation, and presented in Table 4.54 and in Fig. 4.51. This Table and this Fig. depict that the per capita trip rate in motorized and non-motorized trips are 1.66 and 0.97 respectively. The per capita trip rates of the total trips are 2.63 in the study area. This table concludes that the per capita trip rate of motorized trips are higher, i.e., 1.66, than non-motorized trip rate.

4.4.13. Per Capita Trip Rate in Different Mode of Transport Trips

The per capita trip rate in different mode of transport trips with walking and without walking is analysed and the results are presented in Table 4.55. This Table depicts that the per capita trip rate with and without walking trips are 2.63 and 1.72 respectively. The per capita trip rate with and without walking trips are scattered over in almost all mode of transport in the study area. This table concludes that the per capita trip rate in walking mode is 0.91 and in without walking mode, two-wheeler mode is 0.75 which is higher among the other mode of transport in the study area.

Table No. 4.55: Per Capita Trip Rate in Different Mode of Transport Trips

Sl. No.	Mode of Transport	With Walking	Without Walking
		PCTR	PCTR
1	Walking	0.91	0.00
2	Bicycle	0.06	0.06
3	Two-wheeler	0.75	0.75
4	Shared Two-wheeler	0.02	0.02
5	Three-wheeler	0.07	0.07
6	Car	0.29	0.29
7	Public Transport	0.40	0.40
8	Private Transport	0.13	0.13
9	***Total***	**2.63**	**1.72**

Source: Primary Household Survey-2008

4.4.14. Distribution of Per Capita Trip Length Rate in Work and Non-Work Purpose

The per capita trip length rate in work and non-work purpose by different income group categories are analysed and the results are presented in Table 4.56 and Fig. 4.52. This Table and this Fig. depict that the per capita trip length rate in work, non-work purpose and total (work and non-work purpose) are 9.22 km, 6.14 km and 15.36 km respectively in the study area. This table concludes that the per capita trip rate in motorized trip length of work purpose are 9.09 km and 43.61 km, are higher than the non-work purpose trips.

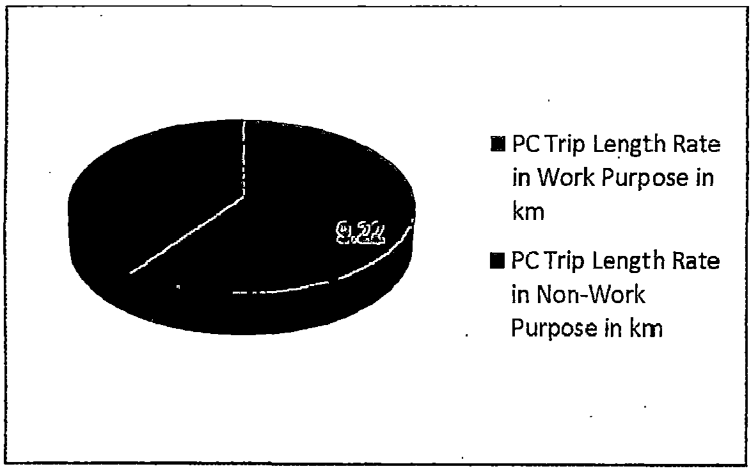

Fig. No. 4.52: Per Capita Trip Length in Work and Non-Work Purpose

Table No. 4.56: Per Capita Trip Length in Work and Non-Work Purpose

Sl No.	Household Income (Rs. /month)	Total Population	TLWP in km	PCTLW	TLNWP in km	PCTLNW	TTL in km	PCTTL
1	< 20,000	712	5073	7.13	3116	4.37	8189	11.50
2	20,000 - 40,000	437	4730	10.82	2858	6.54	7588	17.36
3	40,000 - 60,000	247	2588	10.48	2156	8.73	4744	19.21
4	60,000 - 80,000	71	960	13.52	692	9.75	1652	23.27
5	> 80,000	68	800	11.76	606	8.92	1406	20.68
	Total	**1535**	**14151**	**9.22**	**9428**	**6.14**	**23579**	**15.36**

Source: Primary Household Survey-2008

Table No. 4.57: Per Capita Travel Time in Motorized and Non-Motorized Trips

Sl No.	Household Income (Rs. /month)	Total Population	Total Travel Time Per Person and Per Household Per Day in Hr					
			In Motorized Trips		In Non-Motorized Trips		Total Time	
			TT	PCTT	TSNMT	PCTSNM	TTMNMT	PCTT
1	< 20,000	712	492	0.69	301	0.42	793	1.11
2	20,000 - 40,000	437	459	1.05	120	0.27	579	1.32
3	40,000 - 60,000	247	292	1.18	56	0.23	348	1.41
4	60,000 - 80,000	71	110	1.55	18	0.25	128	1.80
5	> 80,000	68	86	1.26	19	0.28	105	1.54
	Total	**1535**	**1439**	**0.94**	**514**	**0.33**	**1953**	**1.27**

Source: Primary Household Survey-2008

Note: TT: Travel Time in hr

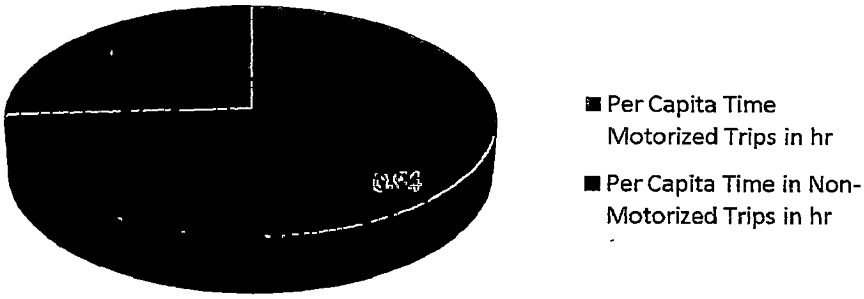

Fig. No. 4.53: Per Capita Travel Time in Motorized and Non-Motorized Trips

4.4.15. Distribution of Travel Time Rate in Motorized and Non-Motorized Trips

Per capita travel time trip rate in motorized and non-motorized trips by different income group categories are analysed and the results are presented in Table 4.57 and in Fig. 4.53. This Table and this Fig. depict that the per capita travel time rate in motorized, non-motorized and total (motorized and non-motorized trips) are 0.94 hr, 0.33 hr and 1.27 hr respectively. This table concludes that the per capita travel time rates are 0.94 hr, which is higher than the non-motorized trips.

4.5. TRAVEL CHARACTERISTICS OF THE HOUSEHOLD IN WEEKEND DAYS

Most of the organizations, public and private enterprises are functioning only five days in a week. In general, the affluent families, bachelors, couples working in multi-national companies, working employees, and dependents, migrants from different parts of State in India make a trip in weekend for various purposes in weekend days. The travel characteristics of the household in weekend days are also very significant in urban areas in general and metropolitan areas in particular. The weekend days trips depends on few parameters, which include regular household activities, needs and aspirations of the family, cultural and religious background, vehicle ownership, family size, occupation pattern, educational background, health awareness, social obligations, social-gathering, availability of facilities and services, to fulfill their next week demand of household articles, groceries, etc. Having this knowledge in mind, the Investigator considered weekend travel characteristics in this investigation, and the results are presented as below:

4.5.1. Distribution of Trips by Purpose (Weekend)

The rapid change in socio-economic condition of the people, changes in life style, standard of living, quality of life, financial status, vehicle ownership, available facilities and services, etc., lead to make good number of trips at the weekend. The distribution of trips for different purpose at the weekend also gives little knowledge about the function of the urban system. Having this knowledge in mind, the Investigator considered this as one of the parameters in the schedule, and conducted the investigation. The distribution of trips by purpose is grouped into four groups, which include shopping, recreation, entertainment and social gathering purpose trips and is clubbed with various income groups for analysis, and the results are presented in Table 4.58 and in Fig. 4.54. This Table and this Fig. depict that about two-fifth (37.00 per cent) of the total trips were done for shopping purposes at the weekend. Followed by, about one-fourth (23.53 per cent), (23.07 per cent), and about one-sixth (16.41 per cent) of the total trips are done for social-gathering, recreation and entertainment purposes at the weekend in the study area. In income group analysis, the weekend trips for shopping, recreation and social-gathering purpose are decreasing along with increase in income. Further, it has also been observed that the weekend trips for entertainment purpose are increasing along with increase in income up to the monthly household income group of Rs. 20,000-40,000 and then observe the reverse trend. This table concludes that the majority of weekend trips, i.e., about two-fifth (37.00 per cent) are done for shopping purposes in the study area, which shows that the people are spending their weekend time for either shopping or recreation purpose in the study area.

Table No. 4.58: Distribution of Trips by Purpose [Weekend]

(Numbers/ Per cent)

Sl No.	Household Income (Rs. /month)	Shopping Trips		Recreation Trips		Entertainment Trips		Social gathering Trips		Total Trips	
		Nos.	Per cent	Nos.	Per cent	Nos.	Per cent	Nos.	Per cent	Nos.	Per cent
1	< 20,000	206	43.10 (40.08)	136	45.64 (26.46)	64	30.19 (12.45)	106	34.87 (20.62)	514	39.78 (100.00)
2	20,000 - 40,000	128	26.78 (33.86)	78	26.17 (20.63)	86	40.57 (22.75)	86	28.29 (22.75)	378	29.26 (100.00)
3	40,000 - 60,000	88	18.41 (36.97)	52	17.45 (21.85)	34	16.04 (14.29)	62	20.39 (26.05)	238	18.42 (100.00)
4	60,000 - 80,000	30	6.28 (32.61)	20	6.71 (21.74)	14	6.60 (15.22)	28	9.21 (30.43)	92	7.12 (100.00)
5	> 80,000	26	5.44 (37.14)	12	4.03 (17.14)	14	6.60 (20.00)	22	7.24 (31.43)	70	5.42 (100.00)
	Total	**478**	**100.00 (37.00)**	**298**	**100.00 (23.07)**	**212**	**100.00 (16.41)**	**304**	**100.00 (23.53)**	**1292**	**100.00 (100.00)**

Source: Primary Household Survey-2008

Note: Figures in Parenthesis Denote Row Percentage

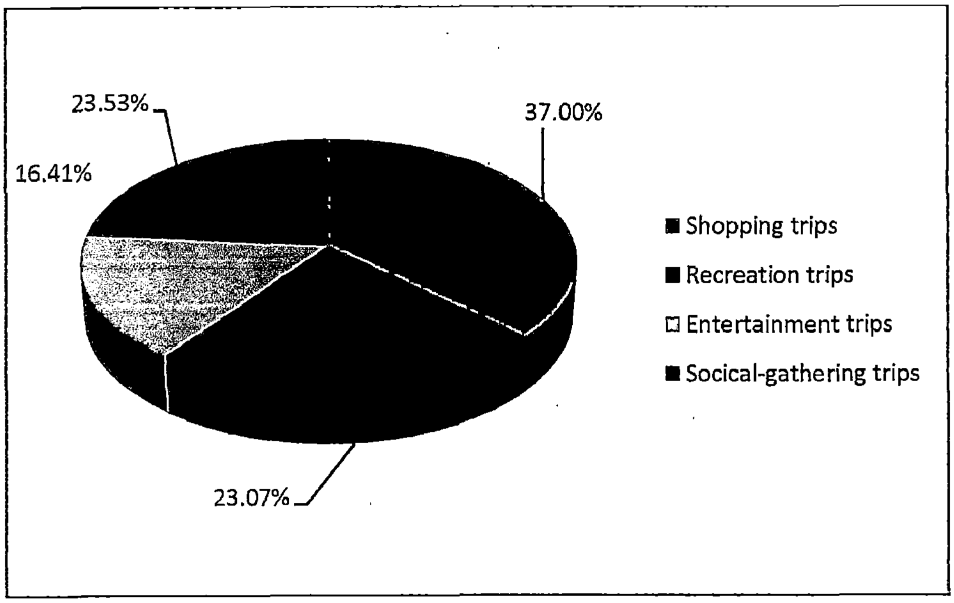

Fig. No. 4.54: Distribution of Trips by Purpose [Weekend]

4.5.2. Distribution of Trip Rate by Purpose in Weekend Trips

The per capita trip rate at weekend trips is the outcome of the household survey analysis. This is very useful to understand the travel characteristics at weekend and also to forecast the travel pattern of households at weekend in future. Having this knowledge in mind, the Investigator analysed the trip rate at the weekend from the previous Table and the results are presented in Table 4.59 and Fig. 4.55. This Table and this Fig. depict that the per capita trip rate of shopping, recreation, entertainment, social-gathering purpose trips and total trips at weekend are 0.31, 0.19, 0.14, 0.20 and 0.84 respectively. This table concludes that the per capita trip rate at weekend is higher (0.31) in shopping purpose among the other purpose trips in the study area.

Table No. 4.59: Distribution of Trip Rate by Purpose in Weekend Trips

Sl No.	Household Income (Rs. /month)	Total Population	PCTRS	PCTRR	PCTRE	PCTRSG	PCTR
1	< 20,000	712	0.29	0.19	0.15	0.15	0.72
2	20,000 - 40,000	437	0.29	0.18	0.20	0.20	0.86
3	40,000 - 60,000	247	0.36	0.21	0.25	0.25	0.96
4	60,000 - 80,000	71	0.42	0.28	0.39	0.39	1.30
5	> 80,000	68	0.38	0.18	0.26	0.26	1.03
	Total	**1535**	**0.31**	**0.19**	**0.20**	**0.20**	**0.84**

Source: Primary Household Survey-2008

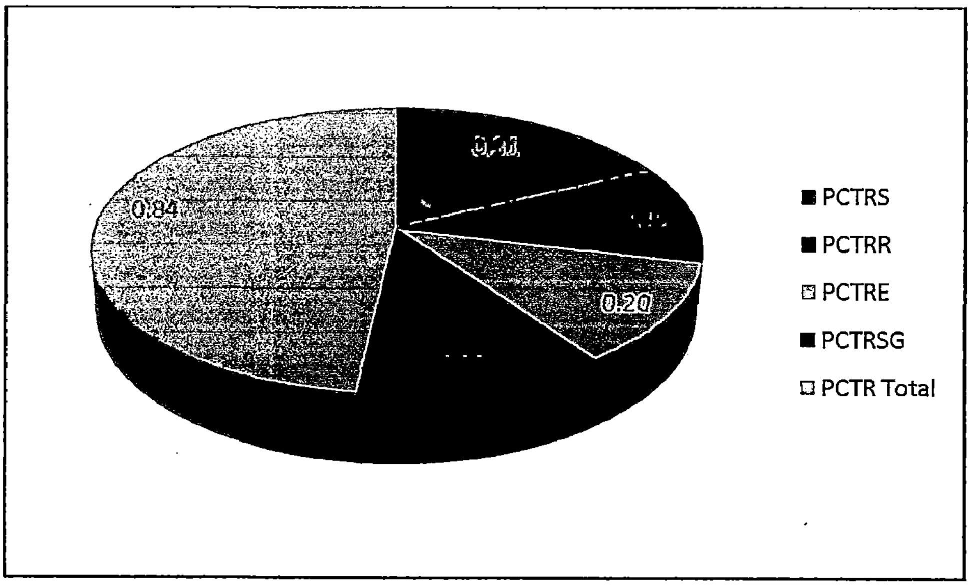

Fig. No. 4.55: Per Capita Trip Rate by Purpose in Weekend Days

4.6. CONCLUSION

In this present chapter, a detailed analysis was done pertaining to socio-economic condition, analysis of infrastructure facilities and household travel characteristics in weekdays and weekend days in the study area. Analysis of the data provided an insight about the system, its functions, and also paved the way for identifying the most important control parameters, which decide the functions of the system. To understand the functions of the system, System Dynamics technique was employed. Further, System Dynamic models were developed based on the System Dynamic technique, and employed in this present investigation, and is presented in the subsequent chapter-5.

CHAPTER-5

APPLICATION OF THEORY, AND MODELS

5.0 INTRODUCTION

In this present investigation, the Investigator has done thorough investigation at the grassroots level to understand the functions of the system. Larger numbers of parameters which influence highly in deciding the functions of the system are termed as control parameters. In this chapter, the control parameters that decide the functions of the system (study area) are identified by employing field studies; employing statistical techniques like correlation, and regression; discussion with experts and employing the secondary sources of data. Multiple regression models have been developed based on the available data. Further, Systems Dynamic Technique is employed, and appropriate System Dynamics models are developed and validated for accuracy. Plausible scenarios are thereafter developed and tested in the validated System Dynamics model under various alternative conditions to understand the functions of the system. The Investigator observes that the Public Transportation System is an integral part of the system, and therefore, an attempt has been made to develop an integrated model consisting of various subsystems to evolve feasible policies for integrated development of the study area (system).

5.1. CORRELATION COEFFICIENTS METHOD

Correlation analysis helps in analyzing the co-variation of two or more variables. It refers to the techniques used in measuring the association between the variables. The measure of correlation is known as correlation coefficient, and it summarizes the direction and degree of association. Having this knowledge in mind, the Investigator has therefore, attempted to use Correlation Coefficient method to analyse the parameters of various subsystems that highly influence the system. The household data collected in this investigation are utilized for the said purpose and correlation coefficients between the dependent variable and the independent variables have been established. Monthly

Table No. 5.1: Association between Monthly Income and other Variables

Sl. No.	Variables	Correlation Coefficient (r^2)	Interpretation
3	Expenditure on Energy	0.400	
4	Expenditure towards Loan Repayment	0.400	
5	Recreation Purpose Trips	0.390	
6	Educational Qualification: UG	0.380	
7	Expenditure on Water	0.360	
8	Expenditure on House rent	0.350	
9	Trip Length in Work Purpose	0.345	
10	Total Trips	0.336	
11	Travel Time in Non-work Purpose	0.335	
12	Educational Qualification: Technical	0.330	
13	Expenditure on Education	0.330	
14	Travel Time in Work Purpose	0.327	
15	Tertiary Occupation	0.326	
16	Expenditure on Health	0.310	
Size of Correlation		Below 0.30	
1	Non-work purpose trips	0.291	
2	Two-wheeler trips	0.256	
3	Private Vehicle trips	0.254	
4	Shopping Purpose Trip in Weekend day	0.246	
5	Social gathering trip in Weekend day	0.223	
6	Work purpose trips	0.211	
7	Educational Qualification: Medical	0.200	
8	Educational Qualification	0.190	
9	Entertainment purpose trips in weekend day	0.170	
10	Three-wheeler trips (Auto rickshaw trips)	0.169	
11	Employment	0.138	
12	Shopping purpose trips	0.130	
13	Male Population	0.100	
14	Recreation purpose trips in weekend day	0.056	
15	Shared two-wheeler trips	0.031	
16	Educational Qualification: Others	0.030	
17	Education purpose trips	0.022	
Size of Correlation		Negative	
1	Primary occupation	-0.159	
2	Secondary occupation	-0.107	
3	Educational Qualification: up to HSC	-0.200	
4	Educational Qualification: PUC	-0.140	
5	Educational Qualification: Diploma	-0.060	
6	Expenditure on Public Transportation	-0.170	
7	Non-motorized trips	-0.287	
8	Non-motorized trip length	-0.229	
9	Non-motorized travel time	-0.275	
10	Walking trips	-0.251	
11	Bicycle trips	-0.147	
12	Public transport trips	-0.226	

5.2. CONTROL PARAMETERS

Attempt has been made to study the correlation between other variables having an influence on Transportation system. The various control parameters of different subsystems of the system are decided based on the correlation coefficient method and are presented in the following sections of this chapter.

5.2.1. Correlation Coefficient of Economic Parameters

The parameters such as, occupation and employment of the households are considered for analyzing the economic conditions of the system. The occupations of the households in the system are broadly classified into involvement in primary sector, secondary sector and the tertiary sector. Correlation has been attempted based on the household data collected at the grassroots level. In this, monthly household income has been taken as dependent variable and various occupations, employment, etc., have been considered as independent variables. The correlation coefficient of these occupations and employment with the monthly household income are presented in Table 5.2. This table reveals that there is a positive correlation between monthly income with the tertiary sector occupation and employment, and the negative correlation with the primary and secondary sector occupation in the study area. In income group analysis, the first two income groups category having positive correlation with tertiary sector; the households belong to income group of Rs. 40,000-60,000 having positive correlation with secondary sector. This table concludes that there is a positive and little higher correlation with monthly income with tertiary sector of the economy and employment among the other income group households.

5.2.2. Correlation coefficient of Demographic Parameters

The parameters such as male-female gender, population, educational qualifications, basic expenditures, non-basic expenditures, motorized trips, non-motorized trips, trip length, travel time, walking trips, bicycle trips, two-wheeler trips, shared two-wheeler trips, auto rickshaw trips, car trips, public transport trips, private vehicle trips, different purpose of trips in weekdays, which include work purpose trips, education purpose trips, shopping purpose trips, recreation purpose trips and non-work purpose trips, trip length in work, trip length in non-work purpose, total trip length, travel time in work purpose, travel time in non-work purpose, total travel time, different purpose of trips in weekends including shopping purpose, recreation purpose, entertainment purpose and social gathering, etc., are considered as independent variables and monthly household income has been considered as dependent variable and the summary of the correlation coefficient with the monthly household income is presented in Table 5.2.

Correlation coefficient between monthly household income and male, female and total population are 0.09, 0.100 and 0.100. This shows that correlation coefficients of female gender are higher than male gender. In income group analysis, correlation coefficient of male gender are higher than female gender in the household income group of below Rs. 20,000 and Rs. 40,000-60,000 except in Rs. 20,000-40,000 whereas the correlation coefficient of total population is higher in the lowest income group, i.e., below Rs. 20,000/- per month among the income groups.

Correlation coefficient between monthly household income and educational qualification, which include <HSC, PUC, Diploma, UG, PG, Technical, Medical and Others are -0.200, -0.140, -0.060, 0.380, 0.190, 0.330, 0.200, and 0.030 respectively. It has been observed that the correlation coefficients of UG and Technical are higher among the educational qualification. In income group analysis, the correlation coefficients of <HSC, PUC, PG and Medical are higher in monthly household income group of Rs. 40,000-60,000 among the income groups, whereas the correlation coefficients of Diploma, and others are higher in monthly household income group of Rs. 20,000-40,000 among the income groups; the correlation coefficients of UG and Technical are higher in monthly household income group of below Rs. 20,000 among the income groups. This analysis gives knowledge about monthly household income and educational status, and reveals that higher income group personals pursue higher and professional education in the system.

5.2.3. Correlation Coefficient of Expenditure Parameters

The expenditure parameters are broadly classified into two categories, which include basic and non-basic expenditures. The basic expenditure parameters, which include food, clothing, education, energy, health and water; the non-basic expenditure parameters, which include public transportation, house rent, cost of petrol, total parking costs, loan repayment, recreation, and entertainment and telecommunication are considered for analyzing the expenditure pattern of the system. Correlation has been attempted based on the household data collected. In this, monthly household income has been taken as dependent variable and parameters coming under basic expenditure and non-basic expenditure have been considered as independent variables. The correlation coefficients of these basic and non-basic parameters with household monthly income are presented in Table 5.2. It has been observed from the Table 5.2 that the correlation coefficient (r^2) of basic expenditure on food, clothes, education, energy, health and water are 0.670, 0.610, 0.330, 0.400, 0.310, and 0.360 respectively. This indicates that expenditure on food is having the highest correlation coefficient with monthly household income, whereas, expenditure on health is having the lowest correlation coefficient with monthly household income among the basic expenditure parameters. It has also been observed from the Table 5.2 that the lowest income group households, i.e., below Rs. 20,000/- per month have highest correlation in all basic expenditures, which includes food, clothes, education, health, and water except expenditure on energy among the income group households in the study area. The higher income group household, i.e., Rs. 40,000-60,000 is having the highest correlation in expenditure towards energy with monthly income among the income group of households. It is observed from the Table 5.2 that the correlation coefficient (r^2) for non-basic expenditure parameters include public transportation, house rent, petrol, total parking costs, loan repayment, recreation and entertainment, and telecommunication are -0.17, 0.35, 0.66, 0.65, 0.40, 0.77, and 0.86 respectively. It is found that the expenditure parameters like telecommunication, recreation and entertainment is having high positive correlation coefficient with monthly household income, whereas expenditure parameters like petrol and total parking costs are having moderate positive correlation coefficient with monthly income among the non-basic expenditure parameters. Further, it is interesting to note that there is a negative correlation coefficient between monthly income and expenditure on public transportation. This table concludes that the lowest income group households having higher correlation coefficient between monthly income and non-basic expenditure among the income group households except in expenditure on energy. The monthly household income group, i.e., Rs. 40,000-60,000 is having higher correlation coefficient on expenditure pertain to energy with monthly income among the income group households.

5.2.4. Correlation Coefficient for Travel Characteristics

5.2.4.1. Correlation Coefficient of Motorized, Non- Motorized Trips-Trip Length-Travel Time

The travel characteristics of the household are broadly classified under three heads, which include number of trips, covered trip length and travel time. This is further classified into motorized and non-motorized trips; motorized and non-motorized trip length; time spent in motorized and non-motorized trips; the different mode of travel used, which include walking, bicycle, two-wheeler, shared two-wheeler, three-wheeler (auto rickshaw), four-wheeler (car), public transport, and private vehicle trips; different purpose trips in weekday which include work, education, shopping, recreation and non-work purpose trips; trip length in work and non-work purpose; travel time in work and non-work purpose; are considered for correlation analysis. Correlation has been attempted based on the household data collected. In this, monthly income has been considered as dependent variable and all other travel characteristics of the household are considered as independent variables.

It is observed from the Table No. 5.2 that the correlation coefficient (r^2) of motorized trips, non-motorized trips, total trips, motorized trip length, non-motorized trip length, total trip length, travel time in motorized vehicles, time spent in non-motorized vehicles, and total travel time are 0.529, -0.287, 0.336, 0.530, -0.229, 0.500, 0.551, -0.275, and 0.462 respectively. It is found that the motorized trips, motorized trip length and total travel time are having higher correlation with monthly household income among these variables whereas, non-motorized trips, non-motorized trip length, time spent for non-motorized trips are having negative correlation with monthly income. It has also been observed from the Table that the lowest income group households have higher correlation coefficient in motorized trips, total trips, motorized trip length, total trip length, travel time in motorized vehicles and total travel time with the monthly income among income group households.

5.2.4.2. Correlation Coefficient of Motorized, Non- Motorized Trips

It has been observed from the Table No. 5.2 that the correlation coefficient (r^2) of walking trips, bicycle trips, two-wheeler trips, shared two-wheeler trips, three-wheeler trips, car trips, public transport trips, and private vehicle trips are -0.251, -0.147, 0.256, 0.031, 0.169, 0.614, -0.226, and 0.254 respectively. It reveals that the correlation coefficient of car trips has the highest correlation with monthly income. The walking trips, bicycle trips, and public transport trips are having the negative correlation with monthly income, since expenditure for these purposes is negligible.

5.2.4.3. Correlation Coefficient of Trips by Purpose

It is observed from the Table No. 5.2 that the correlation coefficient (r^2) of work, education, shopping, recreation and non-work purpose are 0.211, 0.022, 0.130, 0.390, and 0.291 respectively. The correlation coefficient of recreation trips is having the highest correlation with monthly income, whereas the shopping purpose trips are having the least correlation coefficient with monthly income among the weekday purpose of trips. This table concludes that the lowest income group households, i.e., below Rs. 20,000/- per month are having higher correlation coefficient between different purpose of trips in weekdays among the income group of households.

5.2.4.4. Correlation Coefficient of Trip Length, Travel Time for Work Purpose

It is observed from the Table No.5.2 that the correlation coefficient (r^2) of trip length in work purpose, trip length in non-work purpose, total trip length, travel time for work, time spent for non-work and total travel time, are 0.345, 0.435, 0.503, 0.327, 0.335, and 0.463 respectively. It is found that the total trip length in work purpose, and total travel time are having the highest correlation with monthly income among other variables. It has also been observed from the table that the lowest income group households are having the highest correlation coefficient in trip length in work purpose, total trip length in work purpose, travel time in work purpose and total travel time among the income group of households and the income group households, i.e., Rs. 40,000-60,000 are having the highest correlation coefficient in non-work trip length and travel time in non-work purpose with monthly income among income group households.

5.2.5. Weekend Trips by Purpose

It has been observed from the Table 5.2 that the correlation coefficient (r^2) of weekend purpose trips which include shopping, recreation, entertainment and social gathering trips are 0.246, 0.056, 0.170, and 0.223 respectively. The correlation coefficients of shopping and social-gathering purpose trips are having the highest correlation with the monthly income in weekend days, whereas the recreation and entertainment purpose trips show moderate correlation coefficient with monthly income in weekend days. This table concludes that the highest income group households, i.e., Rs. 40,000-60,000 are having the highest correlation coefficient in shopping and recreation purpose trips with monthly income among the income group households.

Table No. 5.2: Correlation Coefficient between Monthly Household Income and Various Variables of Primary Household Survey

Sl. No.	Variables	Household Income Rs./month			Total
		< 20,000	20,000- 40,000	40,000- 60,000	
Correlation Coefficient between Monthly Household Income and Employment in Different Sectors of the Economy in the System					
1.1	Primary Sector	-0.543	-0.331	0.000	-0.159
1.2	Secondary Sector	0.059	0.105	0.294	-0.107
1.3	Tertiary Sector	0.472	0.309	0.066	0.326
1.4	Employment	0.359	0.287	0.257	0.138
Correlation between Monthly Household Income and Population in the System					
2.1	Male Population	0.342	0.282	0.342	0.090
2.2	Female Population	0.318	0.286	0.268	0.100
2.3	Total Population	0.393	0.315	0.316	0.100
Correlation between Monthly Household Income and Educational Qualification in the System					
3.1	< HSC	0.045	0.204	0.257	-0.200
3.2	PUC	0.143	-0.085	0.172	-0.140
3.3	Diploma	0.157	0.237	0.110	-0.060
3.4	UG	0.382	0.279	0.228	0.380
3.5	PG	0.193	0.089	0.216	0.190
3.6	Technical	0.188	0.088	0.047	0.330
3.7	Medical	0.014	-0.126	0.129	0.200
3.8	Others	0.145	0.236	0.064	0.030
Correlation Coefficient between Monthly Household Income and Basic Expenditure Parameters in the System					
4.1	Food	0.775	0.423	0.413	0.670
4.2	Clothes	0.495	0.464	0.345	0.610
4.3	Education	0.302	0.059	0.048	0.330
4.4	Energy	0.316	0.297	0.337	0.400

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Table No. 5.2: Correlation Coefficient between Monthly Household Income and Various Variables of Primary Household Survey

Sl. No.	Variables	Household Income Rs./month			Total
		< 20,000	20,000- 40,000	40,000- 60,000	
4.5	Health	0.264	0.148	0.218	0.310
4.6	Water	0.291	-0.069	0.083	0.360
Correlation between Monthly Household Income and Non-Basic Expenditure Parameters in the System					
5.1	Public Transport Cost (BMTC)	0.135	-0.119	0.190	-0.170
5.2	House rent	0.229	0.054	0.195	0.350
5.3	Cost of Petrol	0.465	0.332	0.444	0.660
5.4	Total Parking Costs	0.473	0.391	0.011	0.650
5.5	Loan Repayment	0.223	0.065	0.181	0.400
5.6	Recreation and Entertainment	0.700	0.389	0.249	0.770
5.7	Telecommunication	0.608	0.616	0.254	0.860
Correlation between Monthly Household Income and Motorized, Non-Motorized Trip-Trip Length-Travel Time					
6.1	Motorized Trips	0.594	0.447	0.340	0.529
6.2	Non-Motorized Trips	-0.104	-0.057	0.100	-0.287
6.3	Total Trips	0.445	0.357	0.310	0.336
6.4	Motorized Trip Length	0.541	0.172	0.490	0.530
6.5	Non-Motorized Trip Length	-0.103	-0.139	0.150	-0.229
6.6	Total Trip Length	0.549	0.150	0.480	0.500
6.7	Travel Time in Motorized Trips	0.574	0.252	0.360	0.551
6.8	Time Spent in Non-Motorized Trips	-0.083	-0.008	0.060	-0.275
6.9	Total Travel Time	0.540	0.234	0.380	0.462
Correlation between Monthly Household Income and Motorized, Non-Motorized Trips					
7.1	Walking Trips	-0.061	0.034	0.050	-0.251
7.2	Bicycle Trips	-0.123	-0.157	0.170	-0.147
7.3	Two-wheeler Trips	0.307	0.286	0.050	0.256
7.4	Shared Two-wheeler Trips	-0.067	-0.108	0.170	0.031
7.5	Auto rickshaw Trips	0.025	0.034	0.220	0.169
7.6	Car Trips	0.307	0.277	0.150	0.614
7.7	Public Transport Trips	0.188	-0.028	0.160	-0.226
7.8	Private/School Van Trips	0.185	0.178	0.200	0.254
Correlation between Monthly Household Income and Purpose of Trips					
8.1	Work Purpose Trips	0.275	0.255	0.210	0.211
8.2	Education Purpose Trips	0.078	0.126	0.390	0.022
8.3	Shopping Purpose Trips	0.161	-0.088	-0.180	0.130
8.4	Recreation Purpose Trips	0.344	0.333	0.180	0.390
8.5	Non-Work Purpose Trips	0.326	0.255	0.310	0.291
Correlation between Monthly Household Income and Trip Length, Travel Time for Work Purpose					
9.1	Trip Length in Work Purpose	0.460	0.114	0.290	0.345
9.2	Trip Length in Non-Work Purpose	0..335	0.097	0.440	0.435
9.3	Total Trip Length	0.549	0.147	0.482	0.503

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Table No. 5.2: Correlation Coefficient between Monthly Household Income and Various Variables of Primary Household Survey

Sl. No.	Variables	Household Income Rs./month			Total
		< 20,000	20,000- 40,000	40,000- 60,000	
9.4	Travel Time in Work Purpose	0.437	0.153	0.130	0.327
9.5	Travel Time in Non-Work Purpose	0.312	0.146	0.440	0.335
9.6	Total Travel Time	0.547	0.225	0.390	0.463
Correlation between Monthly Household Income and Weekend Trips by Purpose					
10.1	Shopping Purpose Trips	0.314	0.321	0.333	0.246
10.2	Recreation Purpose Trips	0.100	-0.191	0.169	0.056
10.3	Entertainment Purpose Trips	0.049	0.142	0.067	0.170
10.4	Social gathering Purpose Trips	0.150	-0.133	-0.162	0.223

Note: The Household Income Group between Rs. 60,000-80,000 and above Rs. 80,000 having numbers less than 30, i.e., 16 and 14 Respectively. Hence correlation is not attempted for these groups. However, for calculating total, all households have been considered together [137].

5.3. REGRESSION ANALYSIS

5.3.1. MULTIPLE REGRESSION MODEL

Regression analysis is a statistical technique, which is done to understand the functional relationship among variables and thereby provide a mechanism for forecasting. It, thus, helps to estimate the unknown values of one variable from known values of another variable. The variable, which is used to predict the variable of interest is termed as the independent variable, and the variable which is predicted in known as dependent variable. It is presented by a regression line or regression equation. Based on the above parameters, Multiple Regression Model has been attempted in this investigation to find out the casual relationship between various parameters by using SPSS (Statistical Package for Social Scientists) (Table 5.3) software. Two regression equations have been evolved-one to establish a relationship between monthly income, and basic and non-basic expenditure parameters in the study area; and good numbers of regression equations have been evolved to establish a relationship between travel characteristics of the household with different mode of transport available in the study area.

5.3.2. Multiple Regression Equation for Income

For evaluation, the monthly income has been considered as the dependent variable (y) and basic expenditures, non-basic expenditures, and motorized trips are considered as independent variables (x_1, x_2, x_3,....x_n). Fifteen different models have been attempted by taking 6, 7, 11, 7, 7, 7, 8, 7, 5, 6, 19, 18, 16, 15 and 19 predictor variables respectively and presented in the following section.

Table No. 5.3: Multiple Regression Coefficients in Different Models Based on Primary Household Survey

Sl. No.	Regression Models	r	r2	Adjusted r2
1	Multiple Regression Model for Basic Expenditure Parameters	1.000	0.999	0.999
2	Multiple Regression Model for Non-Basic Expenditures	1.000	1.000	1.000
3	Multiple Regression Model for Motorized and Non-motorized trips-trip length- travel time	1.000	0.999	0.999
4	Multiple Regression Model for Walking Trips	1.000	1.000	1.000
5	Multiple Regression Model for Bicycle Trips	0.999	0.997	0.997
6	Multiple Regression Model for Public Transport Trips	0.999	0.999	0.999
7	Multiple Regression Model for Car Trips	1.000	0.999	0.999
8	Multiple Regression Model for Two-wheeler Trips	1.000	1.000	1.000
9	Multiple Regression Model for Three Wheeler Trips	0.997	0.995	0.995
10	Multiple Regression Model for Private Vehicle Trips	0.998	0.996	0.996
11	Multiple Regression Model for Work Purpose Trips	1.000	1.000	1.000
12	Multiple Regression Model for Education Purpose Trips	1.000	1.000	1.000
13	Multiple Regression Model for Shopping Purpose Trips	1.000	1.000	1.000
14	Multiple Regression Model for Recreational Purpose	1.000	1.000	1.000
15	Multiple Regression Model for Weekend Trips	1.000	1.000	1.000

r^2 = Multiple coefficient of determination

r = $\sqrt{r2}$ Multiple correlation coefficient

In this present investigation, multiple regressions is attempted to find out the tangible relationships of dependent variable, i.e., monthly household income with independent variables, such as, economic parameters, demographic parameters, expenditure parameters, travel characteristics of the households, etc., based on the above control parameters. Multiple regression models are attempted separately for the parameters, and it is observed that those expenditure parameters, and travel characteristics of the household parameters show the tangible relationships in the system.

5.3.3. Model No. 1: Multiple Regression Model for Basic Expenditure Parameters

Multiple Regressions is attempted on basic expenditure parameters by considering monthly household income as the dependent variable (y) and basic expenditure parameters, such as, food, clothes, education, energy, health, and water are considered as independent variables. This model clearly indicates that the expenditure on food, clothes, and energy are highly significant among the independent variables. The results (Coefficients) of this model are presented in Table 5.4. The multiple regression equation is employed, and is considered as below:

$y = f(x_1, x_2, x_3, \ldots x_n)$

The Multiple Regressions obtained by employing the above function is

$y = 1.738x_1 + 6.525x_2 + 0.045x_3 + 5.259x_4 - 0.929x_5 + 7.306x_6 + 878.340$

$r^2 = 0.999$

Whereas, y = Monthly Household Income in Rupees

x_1 = Expenditure on Food in Rs.

x_2 = Expenditure on Clothes in Rs.

x_3 = Expenditure on Education in Rs.

x_4 = Expenditure on Energy in Rs.

X_5 = Expenditure on Health in Rs.

X_6 = Expenditure on Water in Rs.

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	1.000	0.999	0.999	1.5681225E4

Predictors: (Constant), Expenditure on Food in Rs., Expenditure on Clothes in Rs., Expenditure on Education in Rs., Expenditure on Energy in Rs., Expenditure on Health in Rs., Expenditure on Water in Rs.

Table No. 5.4: Coefficients of Model No. 1

Model		Unstandardized Coefficients		Standardized Coefficients		
		B	Std. Error	Beta	t	Sig.
1	(Constant)	-4.393	879.340		0.005	0.996
	Expenditure on Food in Rs.	1.738	0.383	0.353	4.536	0.000
	Expenditure on Clothes in Rs.	6.525	2.411	0.168	2.706	0.007
	Expenditure on Education in Rs.	0.045	0.486	0.002	0.093	0.926
	Expenditure on Energy in Rs.	5.259	0.839	0.430	6.265	0.000
	Expenditure on Health in Rs.	-0.929	1.435	-0.021	-0.647	0.518
	Expenditure on Water in Rs.	7.306	3.884	0.068	1.881	0.061

Dependent Variable: Monthly Income in Rs.

Regression equation in standard score form is thus,

$y = 0.353x_1 + 0.168x_2 + 0.002x_3 + 0.430x_4 - 0.021x_5 + 0.068x_6$

Whereas, y = Monthly Household Income in Rupees

x_1 = Expenditure on Food in Rs.

x_2 = Expenditure on Clothes in Rs.

x_3 = Expenditure on Education in Rs.

x_4 = Expenditure on Energy in Rs.

X_5 = Expenditure on Health in Rs.

X_6 = Expenditure on Water in Rs.

5.3.4. Model 2: Multiple Regression Model for Non-Basic Expenditure Parameters

Multiple Regressions is attempted on Non-basic expenditure parameters by considering monthly household income as the dependent variable (y) and non-basic expenditure parameters, such as, public transportation, house rent, petrol, total parking costs, loan repayment and recreation and entertainment are considered as independent variables. This model clearly indicates that the expenditure on loan repayment, recreation and entertainment and telecommunication parameters are highly significant among the independent variables. The results (Coefficients) of this model are presented in Table 5.5. The multiple regression equation is employed, and is considered as below:

$y = f(x_1, x_2, x_3, \ldots x_n)$

The Multiple Regressions obtained by employing the above function is

$y = -0.519x_1 + 0.558x_2 + 1.188x_3 - 3.485x_4 + 0.759x_5 + 6.739x_6 + 10.241x_7 + 621.296$

$r^2 = 1.000$

Whereas, y = Monthly Household Income in Rupees

x_1 = Expenditure on Public Transportation in Rs.

x_2 = Expenditure on House rent in Rs.

x_3 = Expenditure on Petrol in Rs.

x_4 = Expenditure on Total Parking Costs in Rs.

X_5 = Expenditure on Loan Repayment in Rs.

X_6 = Expenditure on Recreation and Entertainment in Rs.

X_7 = Expenditure on Telecommunication in Rs.

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	1.000	1.000	1.000	1.1079549E4

Predictors: (Constant), Expenditure on Public Transportation in Rs.,
Expenditure on House rent in Rs., Expenditure on Petrol in Rs.,
Expenditure on Total Parking costs in Rs., Expenditure on Loan Repayment in Rs.,
Expenditure on Recreation and Entertainment in Rs.,
Expenditure on Telecommunication in Rs.

Table No. 5.5: Coefficients of Model No. 2

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	6.958	621.296		0.011	0.991
	Expenditure on Public Transportation in Rs.	-0.519	1.014	-0.010	-0.511	0.610
	Expenditure on House rent in Rs.	0.558	0.364	0.016	1.534	0.126
	Expenditure towards Petrol in Rs.	1.188	0.678	0.063	1.751	0.081
	Expenditure towards Total Parking costs in Rs.	-3.485	4.229	-0.030	-0.824	0.410
	Expenditure towards Loan repayment in Rs.	0.759	0.171	0.036	4.442	0.000
	Expenditure on Recreation and Entertainment in Rs.	6.739	1.228	0.292	5.486	0.000
	Expenditure on Telecommunication	10.241	0.823	0.633	12.443	0.000

Dependent Variable: Monthly Income in Rs.

Regression equation in standard score form is thus,

$y = - 0.010x_1 + 0.016x_2 + 0.063x_3 - 0.030x_4 + 0.036x_5 + 0.292x_6 + 0.633x_7$

Whereas, y = Monthly Household Income in Rupees

x_1 = Expenditure on Public Transportation in Rs.

x_2 = Expenditure on House rent in Rs.

x_3 = Expenditure on Petrol in Rs.

x_4 = Expenditure on Total Parking Costs in Rs.

X_5 = Expenditure on Loan Repayment in Rs.

X_6 = Expenditure on Recreation and Entertainment in Rs.

X_7 = Expenditure on Telecommunication in Rs.

5.3.5. Model 3: Multiple Regression Model for Motorized and Non-Motorized Trips-Trip Length-Travel Time

Multiple Regressions is attempted on Motorized and Non-motorized trips, trip length and travel time of travel characteristics of the surveyed household by considering monthly household income as the dependent variable (y) and vehicle ownership, family size, motorized trips, non-motorized trips, total motorized and non-motorized trips, motorized trip length, non-motorized trip length, total motorized and non-motorized trip length, travel time in motorized trips, time spent in non-motorized trip and total time spent for motorized and non-motorized trips are considered as independent variables. This model indicates that the vehicle ownership, family size, number of motorized trips and total time spent in motorized and non-motorized trips are highly significant among the independent variables. The results (Coefficients) of this model are presented in Table 5.6. The multiple regression equation employed in this analysis is presented as below:

$y = f(x_1, x_2, x_3, \ldots.. x_n)$

The Multiple Regressions obtained by employing the above function is

$$y = 7957.533x_1 - 3328.658x_2 + 3305.129x_3 + 584.700x_4 + 130.768x_5 - 3.733x_6 + 33.908\,x_7 + 1000.322$$

$r^2 = 0.999$

Whereas, y = Monthly Household Income in Rupees

x_1 = Vehicle ownership

x_2 = Family size

x_3 = Number of Motorized Trips

x_4 = Number of Non-motorized Trips

X_5 = Non-motorized trip length in km

X_6 = Time spent in Non-motorized trips in min

X_7 = Total Time spent in Motorized and Non-motorized trips in min

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	1.000	0.999	0.999	1.7838500E4

Predictors: (Constant), Vehicle Ownership, Family size, Number of Motorized trips, Number of Non-motorized trips, Total Motorized and Non-motorized trips, Motorized Trip Length in km, Non-motorized Trip Length in km, Total Motorized and Non-motorized Trip Length in km, Travel time in Motorized Trips in min, Time spent in non-motorized trips/vehicles in min, Total time spent for motorized and non-motorized trips in min

Table No. 5.6: Coefficients of Model No. 3

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	-15.181	1000.322		-0.015	0.988
	Vehicle Ownership	7957.533	2701.719	0.192	2.945	0.003
	Family size	-3328.658	678.541	-0.487	-4.906	0.000
	Number of Motorized trips	3305.129	622.922	0.803	-5.306	0.000
	Number of Non-motorized trips	584.700	1124.398	0.083	0.520	0.603
	Non-motorized Trip Length in km	130.768	350.983	0.040	0.373	0.710
	Time spent in Non-motorized Trips in min	-3.733	54.800	-0.011	-0.068	0.946
	Total time spent for Motorized and Non-motorized Trips in min	33.908	13.329	0.378	2.544	0.011

Dependent Variable: Monthly Income in Rs.

Excluded Variables

Model	Beta In	t	Sig.	Partial correlation	Collinearity statistics: Tolerance
1 Total Motorized and Non-motorized Trips	-18.826	-0.257	0.797	-0.015	5.455 E-10
Motorized Trip Length in km					
Total Motorized and Non-motorized Trip	0.150	1.064	0.288	0.060	0.000
Length in km	0.173	1.064	0.288	0.060	0.000
Travel time in Motorized Trips in min	2.040E2	0.257	0.797	0.015	4.645 E-12

5.3.6. Model 4: Multiple Regression Model for Walking Trips

Multiple Regressions is attempted on walking trips of travel characteristics of the surveyed households by considering number of walking trips per household per day as the dependent variable (y) and monthly income, family size, total walking trip length, and walking trip length in work, education, shopping and recreation purpose are considered as independent variables. This model indicates that except monthly income all considered variables in this model are highly significant among the independent variables. The results (Coefficients) of this model are presented in Table 5.7. The multiple regression equation employed in this analysis is presented as below:

$y = f(x_1, x_2, x_3, \ldots\ldots x_n)$

The Multiple Regressions obtained by employing the above function is

$y = 1.28E\text{-}7x_1 + 0.060x_2 + 0.276x_3 + 0.179x_4 + 0.074x_5 + 0.326x_6 + 0.159\,x_7 + 0.061$

$r^2 = 1.000$

Whereas, y = Number of Walking Trips per Household per day

x_1 = Monthly Household Income in Rupees

x_2 = Family size

x_3 = Total walking trip length in km

x_4 = Walking Trip Length in Work purpose in km

X_5 = Walking Trip Length in Education purpose in km

X_6 = Walking Trip Length in Shopping purpose in km

X_7 = Walking Trip Length in Recreational purpose in km

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	1.000	1.000	1.000	1.0885450

Predictors: (Constant), Monthly income in Rs., Family size, Total walking trip length in km, Trip Length by walking in km, walking trip length in work purpose in km, Walking trip length in education purpose in km, Walking trip length in shopping purpose in km, Walking trip length in recreational purpose in km

Table No. 5.7: Coefficients of Model No. 4

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	0.000	0.061		0.007	0.994
	Monthly income in Rs.	1.28E-7	0.000	0.001	0.053	0.958
	Family size	0.060	0.024	0.066	2.550	0.011
	Total walking trip length in km	0.276	0.019	0.570	14.177	0.000
	Walking trip length in work purpose in km	0.179	0.037	0.026	4.876	0.000
	Walking trip length in education purpose in km	0.074	0.016	0.025	4.713	0.000
	Walking trip length in shopping purpose in km	0.326	0.042	0.101	7.845	0.000
	Walking trip length in recreational purpose in km	0.159	0.021	0.212	7.470	0.000

Dependent Variable: Number of walking trips per household per day

5.3.7. Model 5: Multiple Regression Model for Bicycle Trips

Multiple Regressions is attempted on bicycle trips of travel characteristics of the surveyed households by considering number of bicycle trips per household per day as the dependent variable (y) and monthly income, family size, total bicycle trip length, bicycle trip length in work, education, shopping and recreation purpose are considered as independent variables. This model reveals that the total bicycle trip lengths, bicycle trip length in work, shopping and recreation variables are highly significant among the independent variables. The results (Coefficients) of this model are presented in Table 5.8. The multiple regression equation employed in this analysis is presented as below:

$y = f(x_1, x_2, x_3, \ldots .x_n)$

The Multiple Regressions obtained by employing the above function is

$y = -1.803E\text{-}7x_1 + 0.004x_2 + 0.305x_3 - 0.114x_4 - 0.040x_5 + 0.074x_6 - 0.033x_7 + 0.017$

$r^2 = 0.997$

Whereas, y = Number of Bicycle Trips per Household per day

x_1 = Monthly Household Income in Rupees

x_2 = Family size

x_3 = Total Bicycle Trip Length in km

x_4 = Bicycle Trip Length in Work purpose in km

X_5 = Bicycle Trip Length in Education purpose in km

X_6 = Bicycle Trip Length in Shopping purpose in km

X_7 = Bicycle Trip Length in Recreation purpose in km

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	0.999	0.997	0.997	0.2964835

Predictors: (Constant), Monthly income in Rs., Family size, Total bicycle trip length in km, Bicycle trip length in work purpose in km, Bicycle trip length in education purpose in km, Bicycle trip length in shopping purpose in km, Bicycle trip length in recreation purpose in km

Table No. 5.8: Coefficients of Model No. 5

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	0.017	0.017		-0.022	0.983
	Monthly income in Rs.	-1.803E-7	0.000	-0.019	-0.305	0.761
	Family size	0.004	0.004	0.070	1.047	0.296
	Total bicycle trip length in km	0.305	0.021	1.089	14.278	0.000
	Bicycle trip length in work purpose in km	-0.114	0.021	-0.154	-5.404	0.000
	Bicycle trip length in education purpose in km	-0.040	0.023	-0.042	-1.737	0.083
	Bicycle trip length in shopping purpose in km	0.074	0.028	0.067	2.617	0.009
	Bicycle trip length in recreational purpose in km	-0.033	0.014	-0.018	-2.259	0.025

Dependent Variable: Number of Bicycle trips per Household per day

5.3.8. Model 6: Multiple Regression Model for Public Transport Trips

Multiple Regressions is attempted on Public Transport Trips of travel characteristics of the surveyed households by considering number of public transport trips per household per day as the dependent variable (y) and monthly income, family size, total trip length by public transport, trip length by public transport in work, education, shopping and recreation purposes are considered as independent variables. This model reveals that the monthly incomes, family size, trip length by public transport in work and education purpose parameters are highly significant among the independent variables. The results (Coefficients) of this model are presented in Table 5.9. The multiple regression equation employed in this analysis is presented as below:

$y = f(x_1, x_2, x_3, \ldots x_n)$

The Multiple Regressions obtained by employing the above function is

$y = -7.306E\text{-}6x_1 + 0.167x_2 + 0.082x_3 + 0.082x_4 + 0.109x_5 - 0.013x_6 + 0.068$

$r^2 = 0.999$

Whereas, y = Number of Public Transport Trips per Household per day

x_1 = Monthly Household Income in Rupees

x_2 = Family size

x_3 = Trip Length by Public Transport in Work purpose in km

x_4 = Trip Length by Public Transport in Education purpose in km

X_5 = Trip Length by Public Transport in Shopping purpose in km

X_6 = Trip Length by Public Transport in Recreation purpose in km

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	0.999	0.999	0.999	1.2191397

Predictors: (Constant), Monthly income in Rs., Family size, Trip length by public transport in km, Trip length by public transport in work purpose in km, Trip length by public transport in education purpose in km, Trip length by public transport in shopping purpose in km, Trip length by public transport in recreation purpose in km

Table No. 5.9: Coefficients of Model No. 6

Model		Unstandardized Coefficients		Standardized Coefficients		
		B	Std. Error	Beta	t	Sig.
1	(Constant)	0.000	0.068		-0.007	0.994
	Monthly income in Rs.	-7.360E-6	0.000	-0.127	-3.041	0.003
	Family size	0.167	0.020	0.420	8.260	0.000
	Trip length by public transport in work purpose in km	0.082	0.004	0.456	19.840	0.000
	Trip length by public transport in education purpose in km	0.082	0.006	0.246	14.837	0.000
	Trip length by public transport in shopping purpose in km	0.109	0.061	0.009	1.802	0.072
	Trip length by public transport in recreation purpose in km	-0.013	0.031	-0.002	-0.416	0.678

Dependent Variable: Number of Public Transport Trips per Household per day

Excluded Variables

Model	Beta In	t	Sig.	Partial correlation	Collinearity statistics: Tolerance
1 Total Trip Length in Public Transport in km	-10.015	-0.172	0.863	-0.010	1.194E-9

5.3.9. Model 7: Multiple Regression Model for Four-wheeler trips (Car trips)

Multiple Regressions is attempted on Four-wheeler trips of travel characteristics of the surveyed households by considering number of four-wheeler (car) trips per household per day as the dependent variable (y) and monthly income, family size, vehicle ownership, total trip length by car, trip length by car in work, education, shopping and recreation purposes are considered as independent variables. This model reveals that the family size, trip lengths by car in work, education, shopping and recreational purpose parameters are highly significant among the independent variables. The results (Coefficients) of this model are presented in Table 5.10. The multiple regression equation employed in this analysis is presented as below:

$y = f(x_1, x_2, x_3, \ldots x_n)$

The Multiple Regressions obtained by employing the above function is

$y = -3.435E\text{-}6x_1 + 0.019x_2 + 0.042x_3 + 0.008x_4 + 0.048x_5 + 0.138x_6 + 0.255x_7 + 0.121\,x_8 + 0.036$

$r^2 = 0.999$

Whereas, y = Number of Four-wheeler (Car) Trips per Household per day

x_1 = Monthly Household Income in Rupees

x_2 = Vehicle Ownership; x_3 = Family size

x_4 = Total Trip Length by Car in km

x_5 = Trip Length by Car in Work purpose in km

x_6 = Trip Length by Car in Education purpose in km

X_7 = Trip Length by Car in Shopping purpose in km

X_8 = Trip Length by Car in Recreation purpose in km

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	1.000	0.999	0.999	0.6468245

Predictors: (Constant), Monthly income in Rs., Family size, Vehicle ownership, Total trip length by car in km, Trip length by car in work purpose in km, Trip length by car in education purpose in km, Trip length by car in shopping purpose in km, Trip length by car in recreation purpose in km

Table No. 5.10: Coefficients of Model No. 7

Model		Unstandardized Coefficients		Standardized Coefficients		
		B	Std. Error	Beta	t	Sig.
1	(Constant)	0.001	0.036		0.025	0.980
	Monthly income in Rs.	-3.435E-6	0.000	-0.081	-1.555	0.121
	Vehicle ownership	0.019	0.083	0.011	0.230	0.819
	Family size	0.042	0.011	0.146	3.708	0.000
	Total trip length by car in km	0.008	0.012	0.072	0.634	0.526
	Trip length by car in work purpose in km	0.048	0.012	0.317	4.029	0.000
	Trip length by car in education purpose in km	0.138	0.027	0.020	5.072	0.000
	Trip length by car in shopping purpose in km	0.255	0.017	0.398	14.993	0.000
	Trip length by car in recreation purpose in km	0.121	0.017	0.121	7.079	0.000

Dependent Variable: Number of Four-wheeler (car) trips per Household per day

5.3.10. Model 8: Multiple Regression Model for Two-wheeler trips

Multiple Regressions is attempted on Two-wheeler trips of travel characteristics of the surveyed households by considering number of two-wheeler trips per household per day as the dependent variable (y) and monthly income, family size, vehicle ownership, total trip length by two-wheeler, trip length by two-wheeler in work, education, shopping and recreation purposes are considered as independent variables. This model reveals that the all considered variables in this model are highly significant independent variables. The results (Coefficients) of this model are presented in Table 5.11. The multiple regression equation employed in this analysis is presented as below:

$y = f(x_1, x_2, x_3, \ldots x_n)$

The Multiple Regressions obtained by employing the above function is

$y = -1.398E\text{-}5x_1 + 1.225x_2 + 0.131x_3 + 0.039x_4 + 0.095x_5 + 0.261x_6 + 0.214\, x_7 + 0.074$

$r^2 = 1.000$

Whereas, y = Number of Two-wheeler Trips per Household per day

x_1 = Monthly Household Income in Rupees.

x_2 = Vehicle Ownership

x_3 = Family size

x_4 = Trip Length by Two-wheeler in Work purpose in km

x_5 = Trip Length by Two-wheeler in Education purpose in km

X_6 = Trip Length by Two-wheeler in Shopping purpose in km

X_7 = Trip Length by Two-wheeler in Recreation purpose in km

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	1.000	1.000	1.000	1.3154197

Predictors: (Constant), Monthly income in Rs., Family size, Vehicle ownership, Total trip length by two-wheeler in km, Trip length by two-wheeler in work purpose in km, Trip length by two-wheeler in education purpose in km, Trip length by two-wheeler in shopping purpose in km, Trip length by Two-wheeler in recreation purpose in km

Table No. 5.11: Coefficients of Model No. 8

Model		Unstandardized Coefficients		Standardized Coefficients		
		B	Std. Error	Beta	t	Sig.
1	(Constant)	-0.002	0.074		-0.027	0.979
	Monthly income in Rs.	-1.398E-5	0.000	-0.127	-3.893	0.000
	Vehicle ownership	1.225	0.197	0.270	6.235	0.000
	Family size	0.131	0.022	0.174	6.027	0.000
	Trip length by two-wheeler in work purpose in km	0.039	0.004	0.220	10.917	0.000
	Trip length by two-wheeler in education purpose in km	0.095	0.011	0.065	8.954	0.000
	Trip length by two-wheeler in shopping purpose in km	0.261	0.020	0.230	12.993	0.000
	Trip length by two-wheeler in recreation purpose in km	0.214	0.018	0.170	11.712	0.000

Dependent Variable: Number of Two-wheeler trips per Household per day

Excluded Variables

Model	Beta In	t	Sig.	Partial correlation	Collinearity statistics: Tolerance
1 Total Trip Length by two-wheeler in km	0.701	4.144	0.000	0.228	4.367E-5

5.3.11. Model 9: Multiple Regression Model for Three-wheeler trips (Auto rickshaw trips)

Multiple Regressions is attempted on Three-wheeler trips of travel characteristics of the surveyed households by considering number of three-wheeler trips per household per day as the dependent variable (y) and monthly income, family size, vehicle ownership, total trip length by three-wheeler, trip length by three-wheeler in work, education, shopping and recreation purposes are considered as independent variables. This model reveals that the family size, trip lengths by three-wheeler in work, education, shopping and recreational purpose variables are highly significant among the independent variables. The results (Coefficients) of this model are presented in Table 5.12. The multiple regression equation employed in this analysis is presented as below:

$y = f(x_1, x_2, x_3, \ldots . x_n)$

The Multiple Regressions obtained by employing the above function is

$y = 8.592E\text{-}7x_1 - 0.068x_2 + 0.020x_3 + 0.089x_4 + 0.198x_5 + 0.429x_6 + 0.250\, x_7 + 0.024$

$r^2 = 0.995$

Whereas, y = Number of Three-wheeler Trips per Household per day

x_1 = Monthly Household Income in Rupees.

x_2 = Vehicle Ownership

x_3 = Family size

x_4 = Trip Length by Three-wheeler in Work purpose in km

x_5 = Trip Length by Three-wheeler in Education purpose in km

X_6 = Trip Length by Three-wheeler in Shopping purpose in km

X_7 = Trip Length by Three-wheeler in Recreation purpose in km

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	0.997	0.995	0.995	0.4274827

Predictors: (Constant), Monthly income in Rs., Family size, Vehicle ownership, Total trip length by three-wheeler in km, Trip length by three-wheeler in work purpose in km, Trip length by three-wheeler in education purpose in km, Trip length by three-wheeler in shopping purpose in km, Trip length by three-wheeler in recreation purpose in km

Table No. 5.12: Coefficients of Model No. 9

Model		Unstandardized Coefficients		Standardized Coefficients		
		B	Std. Error	Beta	T	Sig.
1	(Constant)	0.001	0.024		0.026	0.980
	Monthly income in Rs.	8.592E-7	0.000	0.085	0.731	0.465
	Vehicle ownership	-0.068	0.054	-0.163	-1.264	0.207
	Family size	0.020	0.007	0.288	2.859	0.005
	Trip length by three-wheeler in work purpose in km	0.089	0.009	0.114	10.122	0.000
	Trip length by three-wheeler in education purpose in km	0.198	0.007	0.451	27.231	0.000
	Trip length by three-wheeler in shopping purpose in km	0.429	0.040	0.122	10.759	0.000
	Trip length by three-wheeler in recreation purpose in km	0.250	0.023	0.130	10.893	0.000

Dependent Variable: Number of Three-wheeler trips per Household per day

Excluded Variables

Model	Beta In	t	Sig.	Partial correlation	Collinearity statistics: Tolerance
1 Total trip length by three-wheeler in km	-20.480	-0.408	0.683	-0.023	6.484E-9

5.3.12. Model 10: Multiple Regression Model for Private Vehicle Trips

Multiple Regressions is attempted on private vehicle trips of travel characteristics of the surveyed households by considering number of private vehicle trips per household per day as the dependent variable (y) and monthly income, family size, vehicle ownership, total trip length by private vehicle, trip length by private vehicle in work and education purpose variables are considered as independent variables. This model reveals that the family sizes, trip length by private vehicle in work and education purpose are highly significant among the independent variables. The results (Coefficients) of this model are presented in Table 5.13. The multiple regression equation employed in this analysis is presented as below:

$y = f(x_1, x_2, x_3, \ldots\ldots x_n)$

The Multiple Regressions obtained by employing the above function is

$y = -1.467E\text{-}6x_1 - 0.015x_2 + 0.037x_3 + 0.052x_4 + 0.117x_5 + 0.040$

$r^2 = 0.996$

Whereas, y = Number of Private Vehicle Trips per Household per day

x_1 = Monthly Household Income in Rupees.

x_2 = Vehicle Ownership

x_3 = Family size

x_4 = Trip Length by Private vehicle in Work purpose in km

x_5 = Trip Length by Private vehicle in Education purpose in km

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	0.998	0.996	0.996	0.7187538

Predictors: (Constant), Monthly income in Rs., Family size, Vehicle ownership, Total trip length by Private Vehicle in km, Trip length by Private vehicle in work purpose in km, Trip length by Private vehicle in education purpose in km, Trip length by Private vehicle in shopping purpose in km, Trip length by Private vehicle in recreation purpose in km

Table No. 5.13: Coefficients of Model No. 10

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	0.000	0.040		0.011	0.991
	Monthly income in Rs.	-1.467E-6	0.000	-0.074	-0.739	0.461
	Vehicle ownership	-0.015	0.089	-0.019	-0.174	0.862
	Family size	0.037	0.011	0.277	3.305	0.001
	Trip length by Private vehicle in work purpose in km	0.052	0.004	0.213	13.120	0.000
	Trip length by Private vehicle in education purpose in km	0.117	0.004	0.608	26.239	0.000

Dependent Variable: Number of Private vehicle trips per Household per day

Excluded Variables

Model	Beta In	t	Sig.	Partial correlation	Collinearity statistics: Tolerance
1 Total trip length by Private Vehicle in km	-18.557	-0.318	0.751	-0.018	3.559E-9

5.3.13. Model 11: Multiple Regression Model for Work Purpose Trips (Weekday)

Multiple Regressions is attempted on work purpose trips of travel characteristics of the surveyed households by considering number of work purpose trips per household per day as the dependent variable (y) and monthly income, family size, vehicle ownership, working population, total trip length in work purpose, total travel time in work purpose, number of walking, bicycle, two-wheeler, three-wheeler, four-wheeler, public transport, and private transport trips in work purpose; trip length by walking, bicycle, two-wheeler, three-wheeler, four-wheeler, public transport and private vehicle in work purposes are considered as independent variables. This model reveals that the number of walking, bicycle, two-wheeler, three-wheeler, four-wheeler, public transport and private transport trips; trip length by walking, three-wheeler, public transport, and private transports are highly significant among the independent variables. The results (Coefficients) of this model are presented in Table 5.14. The multiple regression equation employed in this analysis is presented as below:

$y = f(x_1, x_2, x_3, \ldots .. x_n)$

The Multiple Regressions obtained by employing the above function is

$$y = 1.212E\text{-}7x_1 + 0.010x_2 - 0.005x_3 + 0.015x_4 + 0.013x_5 + 1.005x_6 + 0.998x_7 + 0.993x_8 + 0.998x_9 + 0.987x_{10} + 1.024x_{11} + 0.960x_{12} - 0.018x_{13} - 0.014x_{14} - 0.013x_{15} - 0.013x_{16} - 0.012x_{17} - 0.015x_{18} - 0.010x_{19} + 0.010$$

$r^2 = 1.000$

Whereas, y = Number of Work Purpose Trips per Household per day

x_1 = Monthly Household Income in Rs.

x_2 = Vehicle Ownership

x_3 = Family size

x_4 = Working population

x_5 = Trip Length in Work purpose in km

x_6 = No. of Walking Trips in work purpose

x_7 = No. of Bicycle Trips in work purpose

x_8 = No. of Two-wheeler Trips in work purpose

x_9 = No. of Three-wheeler Trips in work purpose

x_{10} = No. of Four-wheeler Trips in work purpose

x_{11} = No. of Public Transport Trips in work purpose

x_{12} = No. of Private Vehicle Trips in work purpose

x_{13} = Trip Length by Walking in work purpose in km

x_{14} = Trip Length by Bicycle in work purpose in km

x_{15} = Trip Length by Two-wheeler in work purpose in km

x_{16} = Trip Length by Three-wheeler in work purpose in km

x_{17} = Trip Length by Four-wheeler in work purpose in km

x_{18} = Trip Length by Public Transport in work purpose in km

x_{19} = Trip Length by Private Transport in work purpose in km

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	1.000	1.000	1.000	0.1783779

Predictors: (Constant), Monthly income in Rs., Family size, Vehicle ownership, Working population, Trip length in work purpose in km, Total travel time in work purpose in min, No. of walking trips in work purpose, No. of bicycle trips in work purpose, No. of two-wheeler trips in work purpose, No. of three-wheeler trips in work purpose, No. of car trips in work purpose, No. of public transport trips in work purpose, No. of private transport trips in work purpose, Trip length by walking in work purpose in km, Trip length by bicycle in work purpose in km, Trip length by two-wheeler in work purpose in km, Trip length by three-wheeler in work purpose in km, Trip length by car in work purpose in km, Trip length by public transport in work purpose in km, Trip length by private transport in work purpose in km.

Table No. 5.14: Coefficients of Model No. 11

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	0.000	0.010		-0.070	0.945
	Monthly income in Rs.	1.212E-7	0.000	0.001	0.197	0.844
	Vehicle ownership	0.010	0.026	0.002	0.385	0.700
	Family size	-0.005	0.005	-0.006	-1.055	0.292
	Working Population	0.015	0.026	0.008	0.556	0.579
	Trip length in work purpose in km	0.013	0.001	0.143	13.193	0.000
	No. of walking trips in work purpose	1.005	0.049	0.067	20.556	0.000
	No. of bicycle trips in work purpose	0.998	0.100	0.020	9.988	0.000
	No. of two-wheeler trips in work purpose	0.993	0.016	0.412	61.131	0.000
	No. of three-wheeler trips in work purpose	0.998	0.127	0.015	7.860	0.000
	No. of car trips in work purpose	0.987	0.026	0.167	37.634	0.000
	No. of public transport trips in work purpose	1.024	0.018	0.281	55.472	0.000
	No. of private transport trips in work purpose	0.960	0.050	0.041	19.044	0.000
	Trip length by walking in work purpose in km	-0.018	0.020	-0.003	-0.895	0.372
	Trip length by bicycle in work purpose in km	-0.014	0.018	-0.001	-0.769	0.443
	Trip length by two-wheeler in work purpose in km	-0.013	0.001	-0.065	-10.606	0.000
	Trip length by three-wheeler in work purpose in km	-0.013	0.018	-0.001	-0.716	0.475
	Trip length by car in work purpose in km	-0.012	0.002	-0.028	-6.788	0.000
	Trip length by public transport in work purpose in km	-0.015	0.002	-0.040	-9.403	0.000
	Trip length by private transport in work purpose in km	-0.010	0.003	-0.007	-3.485	0.001

Dependent Variable: Number of Work Purpose Trips per Household per day

Excluded Variables

Model	Beta In	t	Sig.	Partial correlation	Collinearity statistics: Tolerance
1 Total travel time in work purpose in min	0.008	0.554	0.580	0.032	8.807E-5

5.3.14. Model 12: Multiple Regression Model for Education Purpose Trips (Weekday)

Multiple Regressions is attempted on education purpose trips of travel characteristics of the surveyed households by considering number of education purpose trips per household per day as the dependent variable (y) and monthly income, family size, vehicle ownership, total trip length in education purpose, total travel time in education purpose, number of walking, bicycle, two-wheeler, three-wheeler, four-wheeler, public transport, and private transport trips in education purpose; trip length by walking, bicycle, two-wheeler, three-wheeler, four-wheeler, public transport and private vehicle in education purposes are considered as independent variables. This model reveals that the family size, travel time for education purpose, number of walking, bicycle, two-wheeler, three-wheeler, four-wheeler, public transport and private transport trips; trip length by two-wheeler, public transport, and private transports are highly significant independent variables. The results (Coefficients) of this model are presented in Table 5.15. The multiple regression equation employed in this analysis is presented as below:

$y = f(x_1, x_2, x_3, \ldots x_n)$

The Multiple Regressions obtained by employing the above function is

$y = 2.106E\text{-}8x_1 - 0.028x_2 + 0.028x_3 + 0.007x_4 + 0.784x_5 + 0.834x_6 + 0.907x_7 + 0.916x_8 + 0.783x_9 + 0.855x_{10} + 0.930x_{11} - 0.008x_{12} - 0.002x_{13} - 0.022x_{14} - 0.022x_{15} + 0.000x_{16} - 0.017x_{17} - 0.032x_{18} + 0.019$

$r^2 = 1.000$

Whereas, y = Number of Education Purpose Trips per Household per day

x_1 = Monthly Household Income in Rupees.

x_2 = Vehicle Ownership

x_3 = Family size

x_4 = Travel time in Education purpose in min

x_5 = No. of Walking Trips in Education purpose

x_6 = No. of Bicycle Trips in Education purpose

x_7 = No. of Two-wheeler Trips in Education purpose

x_8 = No. of Three-wheeler Trips in Education purpose

x_9 = No. of Four-wheeler Trips in Education purpose

x_{10} = No. of Public Transport Trips in Education purpose

x_{11} = No. of Private Vehicle Trips in Education purpose

x_{12} = Trip Length by Walking in Education purpose in km

x_{13} = Trip Length by Bicycle in Education purpose in km

x_{14} = Trip Length by Two-wheeler in Education purpose in km

x_{15} = Trip Length by Three-wheeler in Education purpose in km

x_{16} = Trip Length by Four-wheeler in Education purpose in km

x_{17} = Trip Length by Public Transport in Education purpose in km

x_{18} = Trip Length by Private Transport in Education purpose in km

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	1.000	1.000	1.000	0.3414553

Predictors: (Constant), Monthly income in Rs., Family size, Vehicle ownership, Trip length in Education purpose in km, Total time for Education purpose in min, No. of walking trips in Education purpose, No. of bicycle trips in Education purpose, No. of two-wheeler trips in Education purpose, No. of three-wheeler trips in Education purpose, No. of car trips in Education purpose, No. of public transport trips in Education purpose, No. of private transport trips in Education purpose, Trip length by walking in Education purpose in km, Trip length by bicycle in Education purpose in km, Trip length by two-wheeler in Education purpose in km, Trip length by three-wheeler in Education purpose in km, Trip length by car in Education purpose in km, Trip length by public transport in Education purpose in km, Trip length by private transport in Education purpose in km.

Table No. 5.15: Coefficients of Model No. 12

Model		Unstandardized Coefficients		Standardized Coefficients		
		B	Std. Error	Beta	t	Sig.
1	(Constant)	0.000	0.019		-0.030	0.976
	Monthly income in Rs.	2.106E-08	0.000	0.000	0.021	0.983
	Vehicle ownership	-0.028	0.044	-0.009	-0.637	0.524
	Family size	0.028	0.008	0.053	3.313	0.001
	Total time for Education purpose in min	0.007	0.001	0.204	7.823	0.000
	No. of walking trips in Education purpose	0.784	0.028	0.193	28.417	0.000
	No. of bicycle trips in Education purpose	0.834	0.085	0.031	9.846	0.000
	No. of two-wheeler trips in Education purpose	0.907	0.043	0.135	21.008	0.000
	No. of three-wheeler trips in Education purpose	0.916	0.061	0.070	15.097	0.000
	No. of car trips in Education purpose	0.783	0.115	0.015	6.786	0.000
	No. of public transport trips in Education purpose	0.855	0.029	0.257	29.484	0.000
	No. of private transport trips in Education purpose	0.930	0.034	0.176	27.231	0.000
	Trip length by walking in Education purpose in km	-0.008	0.007	-0.005	-1.162	0.246
	Trip length by bicycle in Education purpose in km	-0.002	0.024	0.000	-0.098	0.922
	Trip length by two-wheeler in Education purpose in km	-0.022	0.006	-0.022	-3.504	0.001
	Trip length by three-wheeler in Education purpose in km	-0.022	0.013	-0.007	-1.697	0.091
	Trip length by car in Education purpose in km	0.000	0.026	0.000	0.016	0.987
	Trip length by public transport in Education purpose in km	-0.017	0.004	-0.040	-4.548	0.000
	Trip length by private transport in Education purpose in km	-0.032	0.006	-0.042	-5.708	0.000

Dependent Variable: Number of Education Purpose Trips per Household per day

Excluded Variables

Model	Beta In	t	Sig.	Partial correlation	Collinearity statistics: Tolerance
1 Trip length in Education purpose in km	0.921	17.395	0.000	0.707	3.261E-5

5.3.15. Model 13: Multiple Regression Model for Shopping Purpose Trips (Weekday)

Multiple Regressions is attempted on shopping purpose trips of travel characteristics of the surveyed households by considering number of shopping purpose trips per household per day as the dependent variable (y) and monthly income, family size, vehicle ownership, total trip length in shopping purpose, total travel time in shopping purpose, number of walking, bicycle, two-wheeler, three-wheeler, four-wheeler, and public transport trips in shopping purpose; trip length by walking, bicycle, two-wheeler, three-wheeler, four-wheeler, and public transport trips in shopping purposes are considered as independent variables. This model reveals that family size, vehicle ownership, travel time for shopping purpose, number of walking, bicycle, two-wheeler, three-wheeler, four-wheeler, public transport and private transport trips in shopping purpose; trip length by walking and two-wheeler are highly significant among the independent variables. The results (Coefficients) of this model are presented in Table 5.16. The multiple regression equation employed in this analysis is presented as below:

$y = f(x_1, x_2, x_3, \ldots x_n)$

The Multiple Regressions obtained by employing the above function is

$y = 1.676E\text{-}6x_1 + 0.140x_2 - 0.013x_3 + 0.009x_4 + 1.075x_5 + 0.892x_6 + 0.835x_7 + 0.930x_8 + 0.900x_9 + 0.734x_{10} - 0.136x_{11} - 0.026x_{12} - 0.022x_{13} - 0.010x_{14} - 0.026x_{15} + 0.028x_{16} + 0.016$

$r^2 = 1.000$

Whereas, y = Number of Shopping Purpose Trips per Household per day

x_1 = Monthly Household Income in Rs.

x_2 = Vehicle Ownership

x_3 = Family size

x_4 = Trip Length in Shopping purpose in km

x_5 = Travel time in Shopping purpose in min

x_6 = No. of Walking Trips in Shopping purpose

x_7 = No. of Bicycle Trips in Shopping purpose

x_8 = No. of Two-wheeler Trips in Shopping purpose

x_9 = No. of Three-wheeler Trips in Shopping purpose

x_{10} = No. of Four-wheeler Trips in Shopping purpose

x_{11} = No. of Public Transport Trips in Shopping purpose

x_{12} = Trip Length by Walking in Shopping purpose in km

x_{13} = Trip Length by Bicycle in Shopping purpose in km

x_{14} = Trip Length by Two-wheeler in Shopping purpose in km

x_{15} = Trip Length by Three-wheeler in Shopping purpose in km

x_{16} = Trip Length by Four-wheeler in Shopping purpose in km

x_{17} = Trip Length by Public Transport in Shopping purpose in km

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	1.000	1.000	1.000	0.2866181

Predictors: (Constant), Monthly income in Rs., Family size, Vehicle ownership, Trip length in Shopping purpose in km, Travel time in Shopping purpose in min, No. of walking trips in Shopping purpose, No. of bicycle trips in Shopping purpose, No. of two-wheeler trips in Shopping purpose, No. of three-wheeler trips in Shopping purpose, No. of car trips in Shopping purpose, No. of public transport trips in Shopping purpose, No. of private transport trips in Shopping purpose, Trip length by walking in Shopping purpose in km, Trip length by bicycle in Shopping purpose in km, Trip length by two-wheeler in Shopping purpose in km, Trip length by three-wheeler in Shopping purpose in km, Trip length by car in Shopping purpose in km, Trip length by public transport in Shopping purpose in km, Trip length by private transport in Shopping purpose in km.

Table No. 5.16: Coefficients of Model No. 13

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	0.000	0.016		0.022	0.983
	Monthly income in Rs.	1.676E-6	0.000	0.022	1.879	0.061
	Vehicle ownership	0.140	0.050	0.044	2.790	0.006
	Family size	-0.013	0.006	-0.025	-2.132	0.034
	Travel time in Shopping purpose in min	0.009	0.001	0.155	6.690	0.000
	No. of walking trips in Shopping purpose	1.075	0.038	0.388	28.280	0.000
	No. of bicycle trips in Shopping purpose	0.892	0.121	0.039	7.368	0.000
	No. of two-wheeler trips in Shopping purpose	0.835	0.040	0.326	21.092	0.000
	No. of three-wheeler trips in Shopping purpose	0.930	0.157	0.017	5.922	0.000
	No. of car trips in Shopping purpose	0.900	0.082	0.153	11.041	0.000
	No. of public transport trips in Shopping purpose	0.734	0.154	0.012	4.770	0.000
	Trip length by walking in Shopping purpose in km	-0.136	0.023	-0.074	-5.962	0.000
	Trip length by bicycle in Shopping purpose in km	-0.026	0.046	-0.003	-0.572	0.567

Contd...in Page No. 276

Table No. 5.16: Coefficients of Model No. 13

Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
Trip length by two-wheeler in Shopping purpose in km	-0.022	0.009	-0.027	-2.452	0.015
Trip length by three-wheeler in Shopping purpose in km	-0.010	0.072	0.000	-0.133	0.894
Trip length by car in Shopping purpose in km	-0.026	0.016	-0.022	-1.653	0.099
Trip length by public transport in Shopping purpose in km	0.028	0.036	0.002	0.777	0.438

Dependent Variable: Number of Shopping Purpose Trips per Household per day

Excluded Variables

Model	Beta In	t	Sig.	Partial correlation	Collinearity statistics: Tolerance
1 Total Trip length in Shopping purpose in km	0.075	0.795	0.427	0.046	1.422E-5

5.3.16. Model 14: Multiple Regression Model for Recreational Purpose Trips (Weekday)

Multiple Regressions is attempted on recreational purpose trips of travel characteristics of the surveyed households by considering number of recreational purpose trips per household per day as the dependent variable (y) and monthly income, family size, vehicle ownership, total trip length in recreational purpose, total travel time in recreational purpose, number of walking, bicycle, two-wheeler, three-wheeler, four-wheeler, and public transport trips in recreational purpose; trip length by walking, bicycle, two-wheeler, three-wheeler, four-wheeler, and public transport in recreational purposes are considered as independent variables. This model reveals that the family size, number of walking, bicycle, two-wheeler, three-wheeler, four-wheeler and public transport trips in recreational purpose; trip length by two-wheeler, three-wheeler and four-wheeler are highly significant among the independent variables. The results (Coefficients) of this model are presented in Table 5.17. The multiple regression equation employed in this analysis is presented as below:

$y = f(x_1, x_2, x_3, \ldots x_n)$

The Multiple Regressions obtained by employing the above function is

$y = -1.033E\text{-}6x_1 - 0.134x_2 + 0.169x_3 + 0.753x_4 + 3.976x_5 + 1.530x_6 - 3.404x_7 + 1.018x_8 + 0.853x_9 + 0.051x_{10} - 0.881x_{11} - 0.122x_{12} + 1.120x_{13} - 0.010x_{14} + 0.000x_{15} + 0.010x_{16} - 0.049$

$r^2 = 1.000$

Whereas, y = Number of Recreational Purpose Trips per Household per day

x_1 = Monthly Household Income in Rupees.

x_2 = Vehicle Ownership

x_3 = Family size

x_4 = No. of Walking Trips in Recreational purpose

x_5 = No. of Bicycle Trips in Recreational purpose

x_6 = No. of Two-wheeler Trips in Recreational purpose

x_7 = No. of Three-wheeler Trips in Recreational purpose

x_8 = No. of Four-wheeler Trips in Recreational purpose

x_9 = No. of Public Transport Trips in Recreational purpose

x_{10} = Trip Length by Walking in Recreational purpose in km

x_{11} = Trip Length by Bicycle in Recreational purpose in km

x_{12} = Trip Length by Two-wheeler in Recreational purpose in km

x_{13} = Trip Length by Three-wheeler in Recreational purpose in km

x_{14} = Trip Length by Four-wheeler in Recreational purpose in km

x_{15} = Trip Length by Public Transport in Recreational purpose in km

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	1.000	1.000	1.000	0.8813308

Predictors: (Constant), Monthly income in Rs., Family size, Vehicle ownership, Trip length in Recreational purpose in km, Travel time in Recreational purpose in min, No. of walking trips in Recreational purpose, No. of bicycle trips in Recreational purpose, No. of two-wheeler trips in Recreational purpose, No. of three-wheeler trips in Recreational purpose, No. of car trips in Recreational purpose, No. of public transport trips in Recreational purpose, No. of private transport trips in Recreational purpose, Trip length by walking in Recreational purpose in km, Trip length by bicycle in Recreational purpose in km, Trip length by two-wheeler in Recreational purpose in km, Trip length by three-wheeler in Recreational purpose in km, Trip length by car in Recreational purpose in km, Trip length by public transport in Recreational purpose in km, Trip length by private transport in Recreational purpose in km

Table No. 5.17: Coefficients of Model No. 14

Model		Unstandardized Coefficients		Standardized Coefficients		
		B	Std. Error	Beta	t	Sig.
1	(Constant)	-0.001	0.049		-0.026	0.979
	Monthly income in Rs.	-9.802E-7	0.000	-0.009	-0.355	0.723
	Vehicle ownership	-0.158	0.131	-0.034	-1.206	0.229
	Family size	0.148	0.018	0.194	8.464	0.000
	No. of walking trips in Recreational purpose	0.738	0.082	0.527	8.957	0.000
	No. of bicycle trips in Recreational purpose	3.792	1.290	0.036	2.940	0.004
	No. of two-wheeler trips in Recreational purpose	1.534	0.205	0.277	7.490	0.000
	No. of three-wheeler trips in Recreational purpose	-3.317	0.561	-0.054	-5.911	0.000
	No. of car trips in Recreational purpose	0.993	0.285	0.074	3.484	0.001
	No. of public transport trips in Recreational purpose	0.927	0.563	0.012	1.646	0.101
	Trip length by walking in Recreational purpose in km	0.040	0.035	0.064	1.160	0.247
	Trip length by bicycle in Recreational purpose in km	-0.821	0.331	-0.037	-2.478	0.014
	Trip length by two-wheeler in Recreational purpose in km	-0.124	0.046	-0.097	-2.684	0.008
	Trip length by three-wheeler in Recreational purpose in km	1.095	0.160	0.052	6.855	0.000
	Trip length by car in Recreational purpose in km	-0.005	0.055	-0.002	-0.096	0.923
	Trip length by public transport in Recreational purpose in km	-0.028	0.130	-0.002	-0.212	0.832

Dependent Variable: Number of Recreational Purpose Trips per Household per day

Excluded Variables

Model	Beta In	t	Sig.	Partial correlation	Collinearity statistics: Tolerance
1 Total Trip length in Recreational purpose in km	0.654	5.062	0.000	0.278	3.143E-5
Travel time in Recreational purpose in min	0.364	4.053	0.000	0.220	6.688E-5

5.3.17. Model 15: Multiple Regression Model for Weekend day trips

Multiple Regressions is attempted on weekend day trips of travel characteristics of the surveyed households by considering number of weekend trips per household per day as the dependent variable (y) and monthly income, family size, vehicle ownership, number of shopping, recreational, entertainment, social-gathering purpose trips; number of walking, bicycle, two-wheeler, three-wheeler, four-wheeler, and public transport trips in weekend days; trip length by walking, bicycle, two-wheeler, three-wheeler, four-wheeler, and public transport in weekend days are considered as independent variables. This model reveals that the number of shopping, recreational, entertainment and social gathering trips of weekend days trips are highly significant among the independent variables considered in this model. The results (Coefficients) of this model are presented in Table 5.18. The multiple regression equation employed in this analysis is presented as below:

$y = f(x_1, x_2, x_3, \ldots x_n)$

The Multiple Regressions obtained by employing the above function is

$y = 4.937E\text{-}8x_1 - 0.004x_2 + 0.000x_3 + 0.999x_4 + 0.999x_5 + 0.999x_6 + 0.999x_7 + 0.024x_8 + 0.008x_9 + 0.002x_{10} + 0.002x_{11} + 0.001x_{12} + 0.000x_{13} - 0.009x_{14} - 0.002x_{15} - 5.152E\text{-}5x_{16} + 0.000x_{17} + 3.248E\text{-}5x_{18} + 6.312E\text{-}5x_{19} + 0.001$

$r^2 = 1.000$

Whereas, y = Number of Weekend Trips per Household per day

x_1 = Monthly Household Income in Rs.

x_2 = Vehicle Ownership

x_3 = Family size

x_4 = No. of Shopping purpose trips

x_5 = No. of Recreational purpose trips

x_6 = No. of Entertainment purpose trips

x_7 = No. of Social gathering purpose trips

x_8 = No. of Walking Trips

x_9 = No. of Two-wheeler Trips

x_{10} = No. of Three-wheeler Trips

x_{11} = No. of Four-wheeler Trips

x_{12} = No. of Public Transport Trips

x_{13} = Trip Length by Walking in km

x_{14} = Trip Length by Bicycle in km

x_{15} = Trip Length by Two-wheeler in km

x_{16} = Trip Length by Three-wheeler in km

x_{17} = Trip Length by Four-wheeler in km

x_{18} = Trip Length by Public Transport in km

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	1.000	1.000	1.000	0.0167974

Predictors: (Constant), Monthly income in Rs., Family size, Vehicle ownership, No. of shopping purpose trips, No. of recreational purpose trips, No. of entertainment purpose trips, No. of social gathering trips, No. walking trips, No. of bicycle trips, No. of two-wheeler trips, No. of three-wheeler trips, No. of four-wheeler trips, No. of public transport trips, Trip length by walking in km, Trip length by two-wheeler in km, Trip length by three-wheeler in km, Trip length by four-wheeler in km, Trip length by public transport in km

Table No. 5.18: Coefficients of Model No. 15

Model		Unstandardized Coefficients		Standardized Coefficients		
		B	Std. Error	Beta	t	Sig.
1	(Constant)	0.000	0.001		-0.967	0.334
	Monthly income in Rs.	4.937E-8	0.000	0.000	0.876	0.382
	Vehicle ownership	-0.004	0.003	0.000	-1.194	0.233
	Family size	0.000	0.000	0.000	0.427	0.670
	No. of shopping purpose trips	0.999	0.002	0.370	558.124	0.000
	No. of recreational purpose trips	0.999	0.002	0.231	590.964	0.000
	No. of entertainment purpose	0.999	0.001	0.165	690.224	0.000
	trips	0.999	0.002	0.235	591.052	0.000
	No. of Social gathering trips					
	No. walking trips	0.024	0.017	0.000	1.397	0.163
	No. of bicycle trips	0.008	0.009	0.000	0.934	0.351
	No. of two-wheeler trips	0.002	0.002	0.001	0.851	0.395
	No. of three-wheeler trips	0.002	0.004	0.000	0.485	0.628
	No. of four-wheeler trips	0.001	0.002	0.000	0.337	0.736
	No. of public transport trips	0.000	0.001	0.000	0.359	0.720
	Trip length by walking in km	-0.009	0.007	0.000	-1.320	0.188
	Trip length by bicycle in km	-0.002	0.002	0.000	-0.793	0.428
	Trip length by two-wheeler in km	-5.152E-5	0.000	0.000	-0.298	0.766
	Trip length by three-wheeler in km	0.000	0.001	0.000	-0.234	0.815
	Trip length by four-wheeler in km	3.248E-5	0.000	0.000	0.352	0.725
	Trip length by public transport in km	6.312E-5	0.000	0.000	0.263	0.793

Dependent Variable: Number of Weekend Trips per Household per day

The multiple regression models attempted give the relationship between monthly household income and most influential variables; between household travel characteristics and the most important variables responsible for transportation system in the system. This has helped to understand the control parameters, which influence the system. It is observed that it is not possible to measure good number of other variables that decide the functions of the system pertaining to transportation by employing multiple regression models. Therefore, System Dynamic Models have been developed and employed in this investigation to understand the functions of the system.

5.4. APPLICATION OF SYSTEM DYNAMICS THEORY

In this present investigation, the Investigator has employed Systems theory and System Dynamics Technique by considering the study area as a system. The Investigator observes that Transportation is not yet treated as in an integral part of the system for evolving policies, plans, programs, projects, etc., for the development of the system. In fact, whatever initiatives were taken by the State Government, the Central Government, and the Non-Governmental Organizations so far in Transportation Planning and Development are sporadic and isolated attempts. Therefore, the Investigator has attempted to establish Transportation is an integral part of the system, and function as a catalyst for inclusive development of the system.

In this investigation, attempts have been made to develop Dynamics Models by employing System Dynamics Techniques to understand the function of the system for evolving optimal strategies for integrated development of the system.

5.4.1. Systems Concept

The word 'System' has Greek origin and literally means 'to set together'. A *system* can thus be defined as an organized or connected group or set of objects, principles, or ideas related by some common function or belief [58].

The word system has been defined in different ways in literature. However, in essence 'a system is a collection of interacting sub-systems'. Some of the definitions are below:

- Webster's New International Dictionary: "A system is an aggregation or assemblage of objects united by some form of regular interaction or interdependence: a group of diverse units so combined by nature or art as to form an integral whole, and function operate, or move in unison, and often, in obedience to some form of control...".

- Ackoff, R. L. 1971: "A system is any entity, conceptual or physical, which consists of interdependent parts [5]."
- Coyle, R. G., 1977: System is a collection of parts organized for a purpose [41].
- Chadwick, G., 1971: A system is a set of object together with relationship between the objects, and between their attributes". A 'system' can be defined as a complex of elements standing in interactions [32].
- Wadhwa., and Agarwal, A., 1993: A system is defined as an aggregation or assemblage of objects joined in some regular interaction of inter-dependence. In a dynamic system, the interaction caste changes overtime [214].
- Bernad, H., Rudwick., 1964: "A system is a collection of interacting diverse human and machine elements integrated to achieve a common desired objective by manipulation and control of materials, information, energy and humans [25]" - System Science Symposium of the IEEE.
- William R. King., 1967, David I Cleland., William R. King., 1968: A system may be defined literally as "an organized or complex whole; an assemblage or combination of things or part forming a complex of unitary whole [221]". System concept has had a substantial impact on both the planning and the execution functions of management. This effect is best illustrated in the planning context by the increasing emphasis, which is being placed on the scientific analysis of managerial decisions.
- Katsuhiko, Ogate., 2004: A system is a combination of components acting together to perform a specific objective. A component is a single functioning unit of a system. By no means limited to the realm of the physical phenomena, the concept of a system can be extended to abstract dynamic phenomena, such as those encountered in economic, transportation, population growth and biology. A system is called dynamic if its present output depends on past input; if its current output depends only on current input, the system is known as static. The output does not change. The output of a static system remains constant if the input does

not change. The output changes only when the input changes. In a dynamic system, the output changes with time if the system is not in a state of equilibrium [120].

- United States American Standards Institute "A system is as assembly of procedures, processes, methods, routines or techniques united by some form of regulated interaction to form an organized whole."
- Bennet, R. J.,: A System is composed of a number of state variables which are related to one another by operators and are subjected to inputs to produce outputs."
- Hall and Fagen. 1956: A system is a set of objects together with relationships between the objects. This definition can be interpreted in such a way that one or more elements constitute an organized entity, and that the existence of one element is based on its relationship with another. This interrelation can be further extended by assuming that a system is an entity that is separable from the rest of the world by means of a physical or a conceptual boundary [Karnopp and Rosenberg. 1975]. In other words, the world encompasses a number of systems, and each system stands as one unit that interacts with the surrounding environment.
- Devadas, V., and Nand Kumar., 2007: A system functions as a whole with the interaction of several subsystems. All the sub-systems of the system are interconnected, and interdependent to each other, and form a system. If one of the sub-systems of the system is defunct or functions with higher degree (taking lead role during its function) or partly functions, its effects can be visualized in the entire system over a period of time. In some cases, the system may not function at all, while in some cases the system may function, but with lot of disturbances or smooth functions of the system may be paralysed [55].

5.4.1.1. System Characteristics

The various major characteristics of a system as postulated by Jenkins (1969) and various Scholars are [113]:

- A system is a complex grouping of human beings and machine.

- A system is an assembly of interconnected but separable and independent parts [87]. Each part has certain characteristics and can also be considered to be a system in itself.
- A system consists of many sub-systems, the amount of sub-systems detail depending on the problem being studied.
- The outputs from the given sub-system provide the inputs to the other sub-systems. Thus, a given sub-system interacts with the other sub-systems and hence cannot be studied in isolation.
- In function, a system must have an objective, but this is influenced by the wider system of which it forms a part. Usually, systems have multiple objectives, which are in conflict with one another, so that an overall objective is required which effects a compromise between these conflicting objectives.
- In function, it functions with maximum efficiency; a system must be designed in such a way that it is capable of achieving its overall objective in the best possible ways.

5.4.2. System Dynamics

Some of the System Dynamics definitions are presented as below:

David I. Cleland & William R. King – 1968: To understand the methodology called 'System Analysis', it is first necessary to have an understanding of problems, for the goal of systems analysis is the solution of the decision problems, which face the planner [45].

Forrester, J. W., 1961: System Dynamics is a computer-aided approach for analyzing and solving complex problems with a focus on policy analysis and design [72].

Forrester, J. W., 1961: "System Dynamics is the study of information and feed back characterization of industrial enterprise to show how structure, amplification and time delays interact of influence the success of the enterprises [72]".

Barlas and Dicker., 1996, Francis., 1995, Larson., 1997, Galbraith., 1998a & 1998b, Kennedy., 2000, Singh, et. al., 2000: System Dynamics is a methodology for analyzing the behavior of complex dynamic systems to show how system structure and the policies used in decisions making govern the behavior of the system [20].

Coyle ., 1977: System Dynamics is defined as "that branch of control theory, which deals with socio - economic systems and that branch of Management Science which deals with problems of controllability [41]".

Forrester., 1961 and Goodman., 1974: A System Dynamics approach is mainly adopted for investigating dynamic behavior of feedback systems. A system Dynamics model represents feedback systems by differential equations and simulates them to trace their dynamic and transient evolution [72, 86].

5.4.3. Systems Theory

Various forms of systems theories have been evolved over the years. The important ones among them are General System's theory, Cybernetics, Systems Approach, and System Dynamics Approach.

General System theory propounded first by a biologist Ludwig Von Bertalanffy based on original research of biological organisms (1920s and 1930s), and theory of open systems [26, 27], which was both supported and criticized by many Scholars [5,13,145]. The broad objectives of the theory [34] are to investigate the isomorphy of concepts, laws and models in various fields, and to help in useful transfers from one field to another, to encourage the development of adequate theoretical models in areas which lack them, to eliminate the duplication of theoretical efforts in different fields, and to promote the unity of science through improving communication between specialists. However, this theory has not properly emerged due to lack of methods capable of implementing it [222].

Cybernetics is proclaimed to be a theory of communication and control in animals, society, and machines [13, 22, 23, 219, 220]. The elements of the theory are feedback, self-regulation, control and information transmission. It uses the concept of entropy in communication theory and uses this as a measure of disorder, uncertainty or variety of systems. This theory has inspired to analyse the problems arise in social systems; however remains largely verbal, and often graphical rather than mathematical.

Systems Theory is an outgrowth of the concepts of General Systems Theory and Cybernetics. It is more of a practical philosophy of solving problems in societal systems. It suggests a holistic approach in defining the problem, defining the objectives of the system, designing the change, and evaluating the design and known as design methodology [85]. The characteristics of this theory are:

1. The problem of a system is defined in relation to super-ordinate systems to which it is related by a community of objectives.
2. The objectives of the system must be viewed in relation to these super-ordinate systems or the whole system.
3. Present design must be evaluated in terms of opportunity costs or the extent of divergence of the system from the optimum design.
4. The optimum design cannot usually be found incrementally nearby present adopted forms. It involves planning, evaluation, and implementation of new alternatives, which offer innovative and creative departures from the whole system.
5. System design involves processes of thinking, such as, induction and synthesis, which differ from deductive and reductive methods used in the scientific method of system improvement.
6. Planning is conceived as a process where planner assumes the role of a leader rather than that of a follower, so those problems are prevented from occurring rather than solved when they occur.
7. It is universally accepted that it is one of the most potent ways of undertaking a systematic inquiry. However, it does not recommend any specific methodology, which guides the actual employment of approach.

The System Dynamics approach, developed by Forrester, W. J., (1961), amalgamates ideas developed in various Systems Theories and is a result of cross-fertilization of ideas from traditional management, cybernetics, and computer simulation. It is a theory of structure and behaviour system [85]. It presents a very easy to use, intuitively appealing, and yet use mathematically sophisticated methodologies while undertaking practical systems enquiry. Moreover, System Dynamics has its genesis to Industrial Dynamics, where it is said to be the study of information and feedback characterization of industrial enterprises to show the interaction of structure, amplification and time delay to influence successes of an enterprise [72], and is adopted for investigating dynamic behaviour of feedback systems [72, 86]. It is applicable to other complex social systems other than industrial systems with problems of controllability [41], such as, urban systems [32, 34, 74, 75, 82, 94, 120, 130, 131, 144, 169], world systems [74, 75], tourism systems [111, 149, 160], which deal with socio-economic systems and management.

The theory has its inherent weaknesses and criticised for the limitations such as,

a) Scarce data was used to build models
b) Models were highly aggregated
c) Absence of quantitative validity
d) Practice of trial and error during policy design did not always give the best design.
e) Methods of judging parameters sensitivity of models were not fool-proof.

However, after a number of improvements, over the years, System Dynamics has emerged as one of the most powerful methodologies of social systems analysis and design at aggregate level for its ability to address itself to very important long term and short term issues of real system, its ability and simplicity to model complex, non linear relationships, its ability to model soft social and psychological variables, the ease with which the effects of alternative policy options can be tested, and the ease in communicating the model, the results and recommendations [99, 149].

5.4.4. Application of System Dynamics Theory

System Dynamics Theory has been employed to address practically every sort of feedback system. It includes works in Corporate planning and policy design [72, 135], economic behavior [186], pubic management and policy [101], biological and medical modeling [97], theory development in the natural and social sciences [59], dynamic decision modeling [185], complex non-linear dynamics [150], software engineering [2], supply chain management [10, 21, 200], tourism system dynamic model [44, 111], business systems [184], business and market modeling [141], ecological systems [89], socio-economic systems [74, 75, 143], agricultural systems [173], political decision making systems [153], and environmental systems [1, 90, 211, 212, 213, 223], river pollution control [47], population dynamics model [89, 100, 206, 215], integrated city development plans [55, 83, 169], solid waste management [139, 191, 228, 230], urban strategic planning [226], and transportation system planning and modeling [19, 48, 51, 52, 53, 54, 95, 96, 109, 122, 123, 131, 141, 172, 178, 203]. In transportation system, Verma, P., (2004), developed a system dynamic simulation model to analyse the congestion and emission abatement policies for an urban transportation system. Some of the important factors included in the model are vehicle population, vehicle size, vehicle travel, vehicle speed, transport infrastructure availability, behavioural response transport users to changes in transportation system in Delhi City [210]. Khanna, I. K., (1986) employed system dynamics model which considered the interactions between the socio-economic activities of the urban region, highways, passenger transportation, transportation fuel consumption, and air pollution in Delhi region [122]. Umadevi, G., (2007) developed a system dynamics model by considering three sectors on urban system, which include population, land use and transport in Chennai city, India [203]. Kim, K., (1998) developed system dynamics model by considering few subsystems which include demography subsystem, transportation subsystem, travel demand subsystem, regional economy subsystem, finance subsystem, pavement management subsystem, bridge management subsystem, functional subsystem and appraisal subsystem in the urban system to achieve sustainable development for the Commonwealth of Virginia [123]. Han, Ji., (2010) developed system dynamics model by considering the passenger transport system in Delhi City to achieve reduction of energy use and emissions of CO_2 in Delhi City [96].

In this present investigation, the study area is considered as a System by integrating all the six elements of Integrated Transportation System with various physical, social, economic, ecological, environmental, infrastructure and institutional subsystems, where Transportation System shall function as a catalyst for integrated development of the system.

5.4.5. System Dynamic Modelling

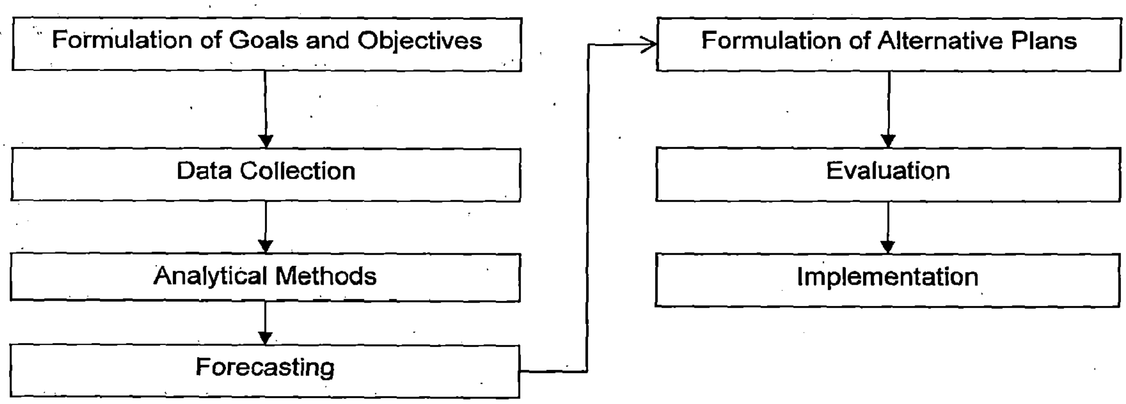
System dynamic modelling is one approach that can help the Planners and Managers to meet the challenges of decision-making and policy formulation for the development of a system. It represents the key feedback structures in the system. Simulating the model shows the effect of the system structures on policy interventions. It is a problem evaluation approach based on the premise that the structure of a system, that is the way essential components are connected, generates its behaviour [168, 184]. It is well suited to analysis of problems whose behaviour is governed by feed back relationships, have a long-term time horizon [208], and not suited to one-time decisions. The process of creating a simulation model helps clarify the resource management problem and makes modeller assumptions about the way the system works explicitly. The most important advantage of this model is once the model is built, it can be used to simulate the effect of proposed actions on the problem and the system as a whole. In this regard, Forrester (1987) noted that, this kind of tool is necessary because, while people are good at observing the local structure of the system, they are not good at predicting how the complex and interdependent the system will behave [77].

System Dynamics proceeds through several major steps [71, 168] and these are the same steps followed in any problem solving process. This is also an iterative process and results at any stage can feed back to previous steps. The various steps for developing and employing the System Dynamic models are:

1. Define the problem
2. Describe the system
3. Develop the model
4. Build confidence in the model (Validation)
5. Use the model for policy design and analysis
6. Use the model for public outreach.

The first five steps are used for building a model for decision support within an organization while the sixth step is used for public communication.

The system definitions and extensions of meaning concerning systems can be recognized in real-world situations, including specific scientific and engineering applications. These applications, using a systems viewpoint, are concerned with the operation of an overall system rather than with the operation of a separated system component. In order to apply systems analysis to a real problem, the systems approach should be utilized within a suitable framework. A simple framework suggested by Black (1981) provides seven steps, as shown in Fig. 5.1.



Source: Black, 1981

Fig. No. 5.1: Framework for a Systems Approach

5.4.5.1. Define the Problem/Problem Identification

The first step in System Dynamic modelling is to identify the key variable whose behaviour over time defines the problem. To recognize a problem that needs study through modeling is to identify it as the consequence of a system of interactions among large numbers of variables [149]. The interaction of these identified variables generates the dynamics of the system and work on feedback mechanisms. In identifying stage, it is important to interpret the problems and the causes thereof from the past behaviour of the system (reference mode). In a social complex system, it is difficult to build a reference mode and identify a problem. In such situations, the problem is identified through discussions with experts, interviews, questionnaire surveys, Delphi study for building up a rich picture of the situation and record multiple perspectives for a problem situation looking at the interactions from different angles [34, 134, 149]. In this present investigation, field observations, discussion with experts and survey methods have been employed to identify the problems of the system and are discussed in detail for each model in subsequent sections of model conceptualization.

5.4.5.2. Describe the System

Describing the system involves identifying the system structure that appears to be generating problematic trend. This entails extracting the essential elements and connections from the real system that produces the anticipated or observed behavior. Thus model aggregates and boundary are fixed at this stage [149]. All the factors relevant to the description of the problem phenomena under investigation need to be included at this stage. Therefore, a large number of variables those influence the system are brought within the system boundary for comprehensiveness. The final representation of important variables and causal links called dynamic hypothesis, which is the system structure, is thought to explain the dynamic behaviour of the system.

5.4.5.3. Developing the Model

A detailed model is developed based on the dynamic hypothesis, by representing through a set of stocks and flow diagrams, which takes into account the physical resources and information linkages at the time of their construction. Further, the variables are presented in different forms to identify them as Stocks or Levels (accumulation), Rates (decisions), Auxiliaries (algebraic subdivision of rates) or Converters and parameters. Model assumptions are also incorporated while developing the model.

5.4.5.4. Build Confidence (Model Validation)

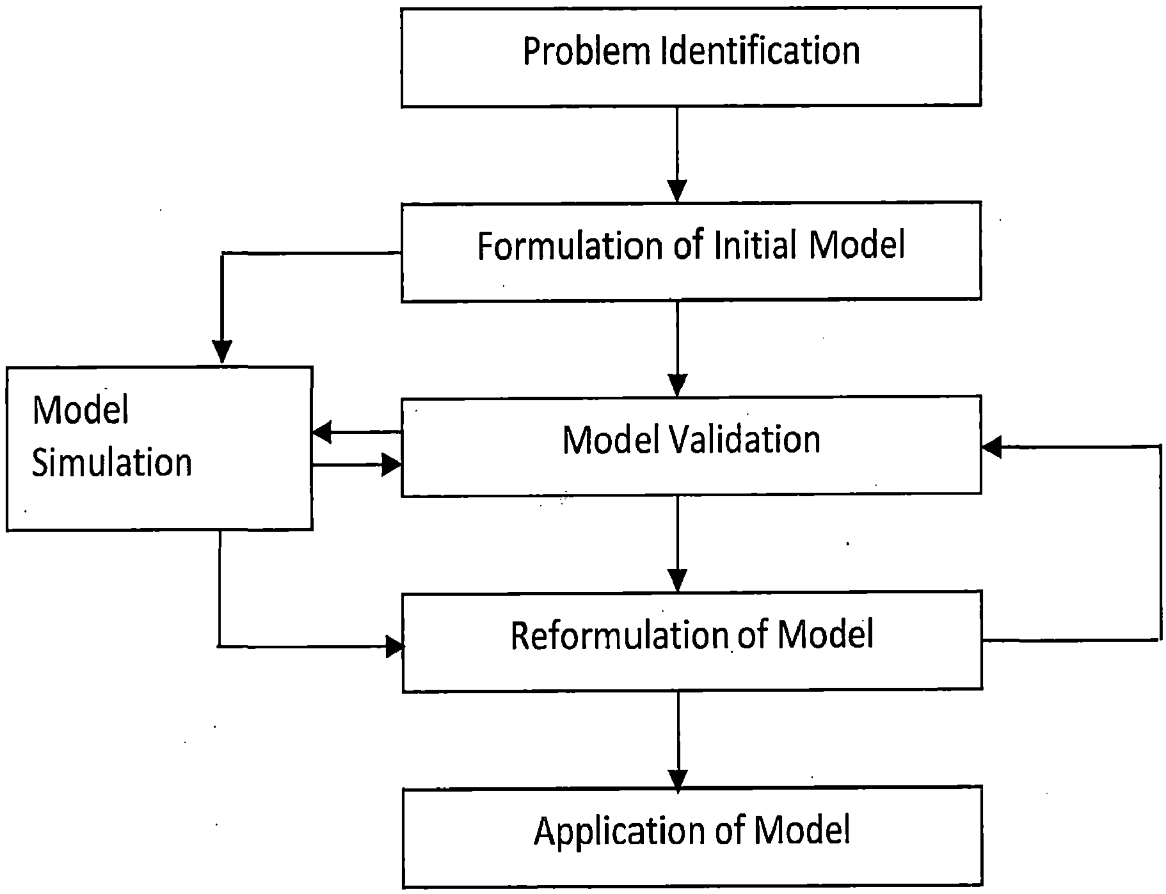
Before using the model to identify and test policy options, it must be validated against the observed or anticipated trend. The validity of a model is judged by its usefulness to serve the purpose for which it is designed. Validation in System Dynamics is a multi-test process and incorporates both statistical and modal-behaviour tests. Validity of a model is critical because the purpose of a system dynamic study is to evaluate alternative structures (strategies, policies) to improve the systems behavior. Accuracy of the model behaviour is meaningful only if there is sufficient confidence in the structure of the model. Validation needs to be applied at every stage of modelling. It is required to be validated against the observed or anticipated trend [73, 130, 131, 132, 149]. Sometimes individual tests, such as, structure oriented behaviour tests [20, 76], extreme condition, behaviour sensitivity and phase relationship tests [20] are used for detection of structural flaws in the model. If the model reproduces the trend and represents the real system as it actually works, then the model leads to accurate behaviour or else the modeler must go back to revise the dynamic hypothesis or model structure.

5.4.5.5. Use the Model for Policy Analysis

When the model is validated, it can be used to test the effects of policy interventions on the problem. It includes studying the model structure to identify policy levels, then simulating the effect of those changes. The effects of policies can be analysed both quantitatively and qualitatively. In the qualitative approach, the evaluation primarily predicts the effect, which improves or worsens the system behaviour, while in quantitative approach the evaluation is rigorous and uses precise numerical values.

5.4.5.6. Use the Model for Public Out-Reach

The model has the ability to involve the stakeholders, to make the models more effective for policies decisions [12, 40, 182, 208]; even when stakeholders are not directly involved in the model development process, a completed model can be an effectively used for public outreach. The use of the model not only helps public better understand the basis for management decisions, but also simulates discussion among group members, and can help build the consensus and support resource managers need to implement their decisions. The schematic diagram developed by Hamilton, et al. (1969) is presented in Fig. 5.2 showing the steps the model used for evolving in System Dynamic modelling [95].

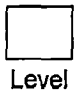


Source: Hamilton, et. al., 1969

Fig. No. 5.2: Model development as an iterative process

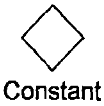
5.4.6. Notations and Equations Adopted in Modelling

The various variables used in System Dynamic models are the level, rate and auxiliary variables. They are:

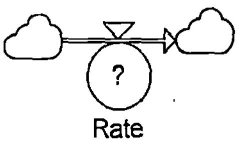


Level variable (L)

Auxiliary variable (A)



Constant (C)



Rate variable (R)

A level is the accumulation (or integration) of the flows that causes the level to change. Double arrows represent the flows, and the flow is controlled by a flow rate. An auxiliary is used to combine or reformulate information. It has no standard form; it is an algebraic computation of any combination of levels, flow rates, or other auxiliaries. Although auxiliary variables may appear to be accumulations, they have no memory, unlike levels. Constants are, unlike ordinary auxiliaries, constant over the time period of the simulation. A constant is defined by an initial value, and maintains this value throughout the simulation, unless the user changes the value manually.

A level variable depends only on a rate variable and presented as:

$\mathbf{L\ (t) = f_l\ (R\ (t))}$

A rate is depends on level variables and / or auxiliary variables, and on constants, and is presented in any of the forms depending on various variables used based on the requirements. The equations are as given below:

$\mathbf{R\ (t) = f_{r1}\ (L\ (t),\ C)}$

$\mathbf{R\ (t) = f_{r2}\ (A\ (t),\ C)}$

$R(t) = f_{r3}(L(t), A(t), C)$

An auxiliary variable can be a function of level and / or other auxiliary variables and constants, and is presented in any of the forms depending on the variables and used based on the requirements. The equations are as given below:

$A(t) = f_{a1}(L(t), C)$

$A(t) = f_{a2}(A(t), C)$

$A(t) = f_{a3}(L(t), A(t), C)$

The change in a level's value is determined by integration of the flows going in and out of the level.

The algorithm for numerical solutions by Euler integration of the System Dynamic model is presented as:

$L_i(t) = L_i(t\text{-}DT) + \Delta L_i(t\text{-}DT, t)$, for all i

$\Delta L_i(t\text{-}DT, t) = DT * d/dt\,(L_i(t\text{-}DT))$

Where, Li (t) = Level values at the end of the time step for all i

t = time period

DT= time step

5.5. INTEGRATED URBAN SYSTEM MODEL

In this investigation, the study area is considered as a system, and it has several subsystems. The various subsystems of the urban system are physical, social, economic, ecological, environmental, infrastructure, and institution. All these sub-systems are interlinked and interdependent to each other, and function as a whole. The dynamic functions of the urban system along with its different subsystems are presented in Fig. 5.3.

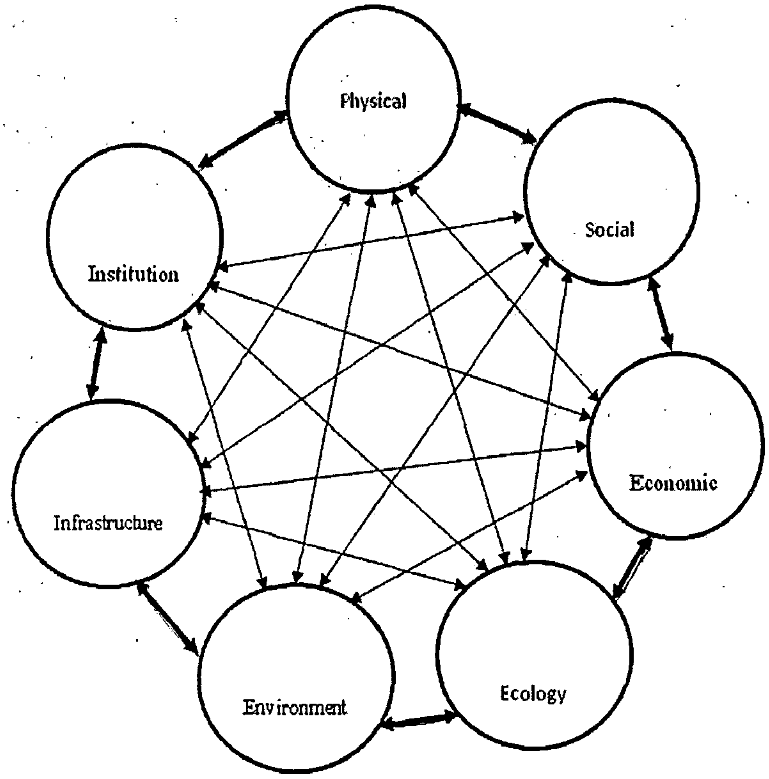


Fig. No. 5.3: Functions of the Urban system along with its sub systems.

5.6. CONCEPTUALISATION OF INTEGRATED TRANSPORTATION SYSTEM MODEL

Transportation subsystem plays a very crucial role in growth and development of any system. Transportation subsystem is a very complex in nature. Transportation subsystem is a function of several activities under various subsystems in the system (study area). The functions of the various subsystems of the system contribute to both positive and negative impacts on the development of transportation subsystem on one hand, and transportation subsystem contributes to overall development of the system on the other. The functions of various subsystems of the system, which contributes to the development of transportation subsystem are put under various individual and integrated domains, such as, population and population density; vehicle ownership; residential-parks & playgrounds-transportation land use area; vehicular population; modal split; total travel demand, and congestion.

The Investigator has conducted series of discussions with various experts who are working in the field of transportation in various organizations, which include Bangalore Development Authority (BDA), Bangalore Metropolitan Transport Corporation (BMTC), Bangalore Metropolitan Region Development Authority (BMRDA), Town Planning Department, Karnataka Urban Infrastructure and Development Finance Corporation (KUIDFC), Bangalore Metro Rail Corporation Limited (BMRCL), Regional Transport Department, Rail India Techno Economic Services Limited (RITES), Bangalore Water Supply and Sewerage Board (BWSSB), National Institute of Urban Affairs (NIUA), etc., for having more input about this present investigation.

The control parameters that decide the functions of transportation subsystem are identified and clubbed into eight subsystems, such as, population, population density, vehicle ownership, residential-parks & playgrounds-transportation land use, vehicular population, modal split, total travel demand and congestion. A schematic diagram indicating various subsystems and integrated transportation subsystem in the study area are presented in Fig. 5.4, and are discussed below in brief.

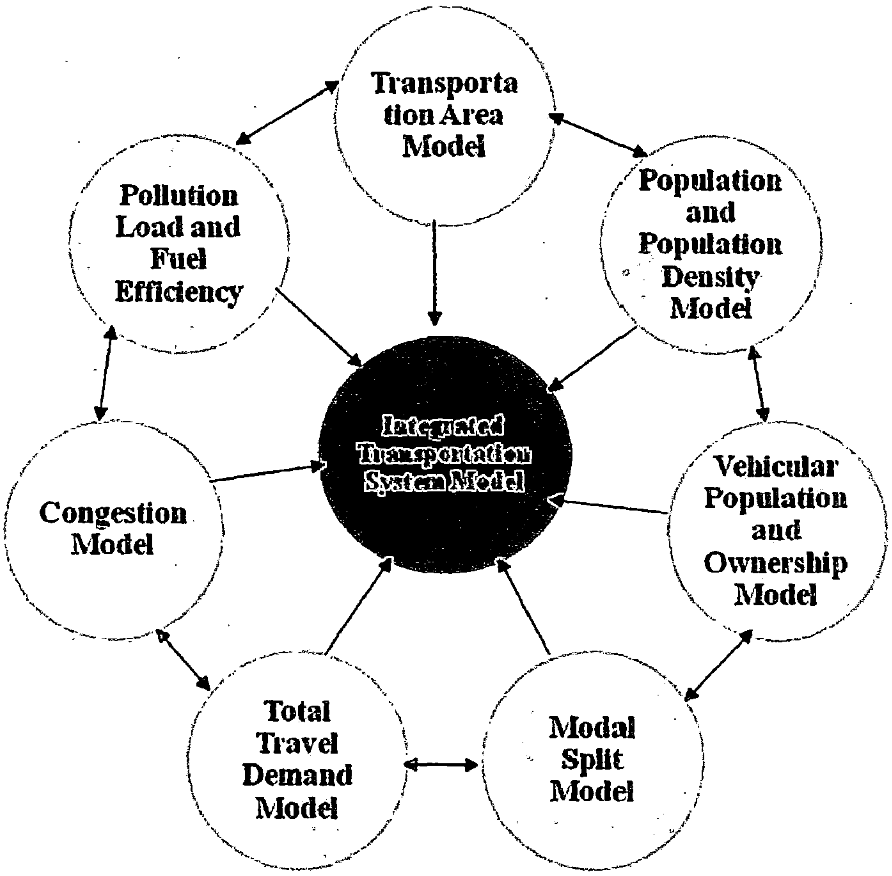


Fig. No. 5.4: Conceptualised Integrated Model for Transportation System in Bangalore City

5.6.1. Vehicle Ownership

Vehicle ownership is one of the important parameters in the transportation subsystem and a deciding factor for locational point of view. The vehicle ownership rate and having different varieties of vehicles in individual residents (households) are directly and indirectly having impact on transportation subsystem and other various subsystems of the system.

5.6.2. Residential-Parks & Playgrounds-Transportation Land use Area

Land use plays a very crucial role in planning in general and transportation system in particular. Integration of transportation land use with other land uses such as residential, commercial, industrial, public & semi-public, parks & playgrounds, water sheets, etc., is very much essential for inclusive development of the system. The judicious land use pattern of the city minimizes the travel distance, travel cost, travel time, consumption of fossil fuel and strengthens the mobility pattern of the system.

5.6.3. Vehicular Population

The increases in vehicular population growth and different composition of vehicles (heterogeneous) have direct impact on the transportation subsystem. Mobility and accessibility of people are important for inclusive development of the system. The vehicular population is a function of the transportation subsystem and decides the functions of the other subsystems in the urban system.

5.6.4. Modal Split

Modal split refers to the person trips by different mode of transport. The desirable modal split based on the population size of the urban system gives the desired mobility pattern in the system. Modal split decides the function of the transportation subsystem and also influences on the other subsystems of the urban system. According to various experts, public mass transportation is the only solution to the transportation problems across the globe. Desirable modal split plays a very crucial role to achieve efficient and effective public mass transportation in the system.

5.6.5. Travel demand

Travel demand is a function of various parameters, which include population, household income, trip length, per capita trip rate, modal split, commercial and industrial activities, manifold increase of household activities, etc. Travel demand of the system is interlinked and interdependent on the other subsystems of the system. Further, adoption of the compact city development concept, adoption of appropriate technology, innovative researches also reduces the travel demand of the city.

5.6.6. Fuel Consumption

The rapid growth of vehicular population and different composition of vehicles consume more quantity of fossil fuel in the system. The quantity of consumption of fossil fuel is depends on various parameters, which include the activity pattern of the residents, city form, functions of the city, etc. The consumption of fossil fuel, which decides the function of the transportation subsystem and also impact on the other subsystems of the system.

5.7. APPLICATION OF THE SYSTEM DYNAMIC MODEL

In this present investigation, the following control parameters, which include Population, Population Density, Households, Household Size, Household Vehicle Ownership, Residential-Parks & Playgrounds-Transportation Land Use Area, Total Vehicular Population, Modal Split, Vehicular Emission Load, Fuel consumption, Transport Demand and Congestion are considered for integrated development of the system. The detailed methods used for developing the System Dynamic models by subsystem wise are presented as below:

5.7.1. System Dynamics Model for Population and Population Density

Population and population density are considered as important parameters, which influence the system. A System Dynamic model is built to calculate population, and population density, by considering the influential variables such as, Birth Rate (BR), Death Rate (DR), Normal Birth Rate Fraction (NRBF), Normal Death Rate Fraction

(NDRF), In-migration Rate (IMR), In-migration Fraction (IMF), Out-migration Rate (OMR), Out-migration Fraction (OMF), and total area (A) of the system. In this model, population (P) is considered as a function of birth rate (BR), death rate (DR), in migration rate (IMR) and out migration rate (OMR) the system experiences in the past years. Population density (PD) refers as the number of persons available per Sq. km. of land area of the system, and is a function of population (P) and area (A) of the system. Population is considered as the level variable, whereas birth rate, death rate, in-migration and out migration rate are considered as rate variables. It is considered that the area of Bangalore Urban Agglomeration will increase from 534.08 Sq. Km. in the year 2001 to 863.12 Sq. Km. in the year 2031 (c.r.t.2.1, Chapter-2). In this investigation, the study area is considered as level variable, and the population density is considered as an auxiliary variable. The model, which is employed for computing the Population and Population density are presented in a functional flow diagram Fig. 5.5 and Fig. 5.6 and the functional relationships among the variables are presented below. The model equation used for the above purpose is presented in Appendix–3. The definitions of each variable and mathematical (algebraic) equation are described in the model equations are presented as below:

P = f (BR, DR, IMR, OMR)

PD = f (P, A)

BR = f (P, NBRF)

DR = f (P, NDRF)

IMR = f (P, IMF)

OMR = f (P, OMF)

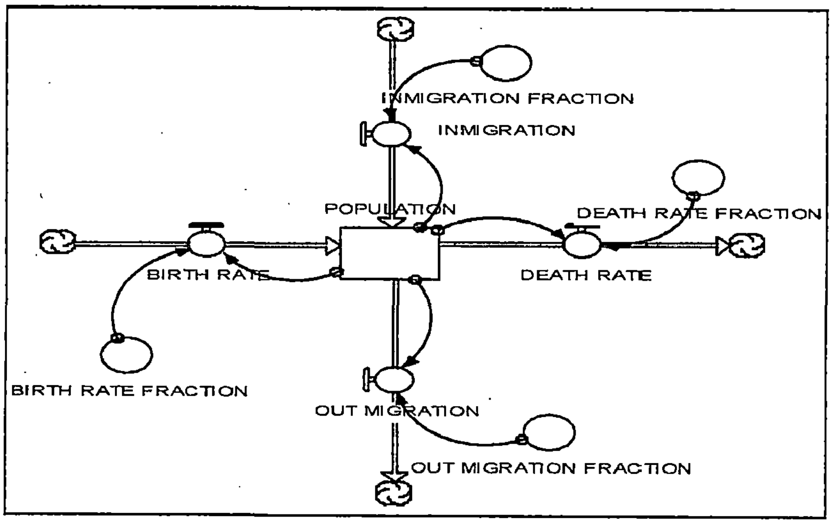


Fig. No. 5.5: System Dynamics Model for Population

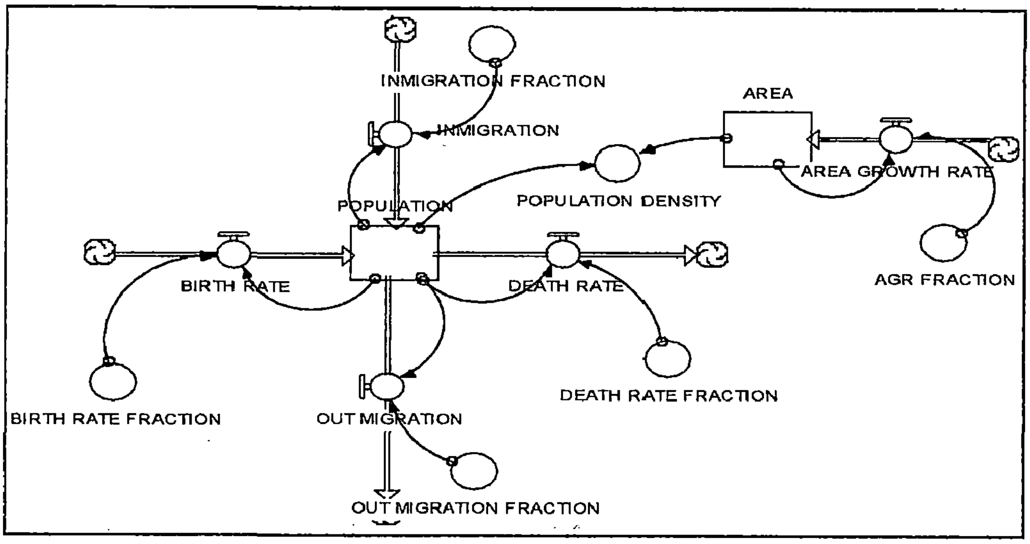


Fig. No. 5.6: System Dynamics Model for Population and Population Density

5.7.2. System Dynamics Model for Household Vehicle Ownership

Vehicle ownership is one of the important parameters in transportation subsystem, which influence the system. A System Dynamic model is built to calculate the vehicle ownership by considering the influential variables, such as, number of households, average household size and vehicle ownership growth rate, vehicle ownership growth rate fraction. In this model, population (P) is considered as the level variable, whereas vehicle ownership, number of households, average household size and vehicle ownership growth rate fraction are considered auxiliary variables. The model, which is employed for computing the household vehicle ownership, is presented in a functional flow diagram Fig. 5.7 and the functional relationships among the variables are presented below. The model equation used for the above purpose is presented in Appendix-3. The definitions of each variable and mathematical (algebraic) equation are described in the model equations are:

Vehicle Ownership = f (Number of Households, Vehicle Ownership Growth Rate, Average Household Size)

Vehicle Ownership Growth Rate = f (Vehicle Ownership, Vehicle OG Rate Fraction)

In this model development, vehicle ownership, number of households, average household size and vehicle ownership growth rate fraction are considered as auxiliary variables and population is considered as level variable. The functional model diagram for vehicle ownership in the study areas is presented in Fig. 5.7 as below and the model equations for the same are presented in the Appendix-3.

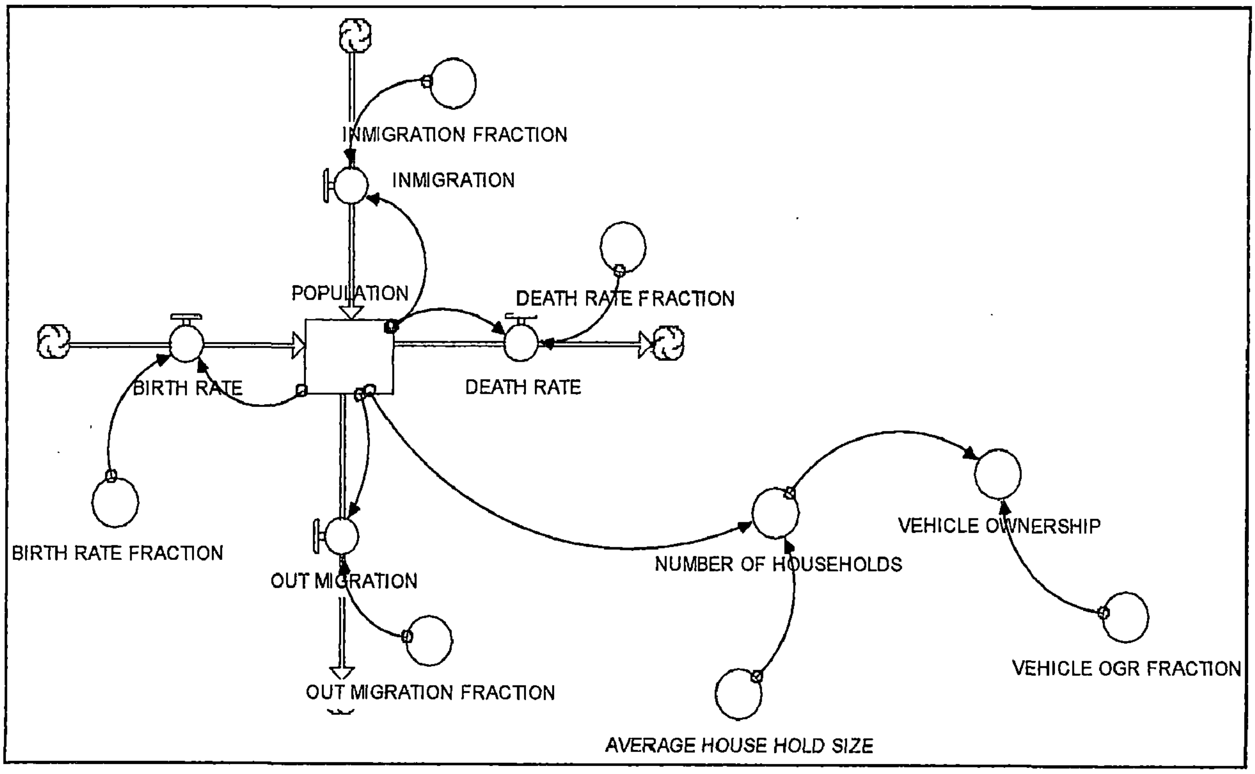


Fig. No. 5.7: System Dynamics Model for Household Vehicle Ownership in the Study Area

5.7.3. System Dynamics Model for Residential-Parks & Playgrounds-Transportation Land Use

Residential land use, parks & playgrounds land use and transportation land use area are considered as important parameters, which influence the system. A System Dynamic model is built to calculate residential land use, parks and playgrounds land use, and transportation land use areas, by considering the influential variables, such as,

Residential land use area = f (Residential Area Growth Rate, Population density)

Parks and Playgrounds land use area = f (Parks & playgrounds land use Area Growth Rate, Difference in park and playgrounds area)

Transportation area = f (Transportation Area Growth Rate, Vehicle density)

In this model development, residential land use area, parks & playgrounds land use area and transportation land use area are considered as level variables, residential land use area growth rate, parks & playgrounds land use area growth rate and transportation land use area growth rate are considered as rate variables and transportation land use area growth rate fraction, population density, parks & playground land use area growth rate fraction, difference in parks & playgrounds land use area, transportation land use area fraction, and vehicle density are considered as auxiliary variables. The functional model diagram for residential-parks & playgrounds-transportation land use area is presented in Fig. 5.8, as below, and the model equations for the same are presented in the Appendix-3.

5.7.4. System Dynamics Model for Vehicular Population

Vehicular population is one of the most important sub-systems in the transportation system, which gives different variety of vehicles available in the study area. A System Dynamic model is developed in order to compute number of two-wheelers, three-wheelers, cars, buses, other vehicles and total number of vehicles. Number of two-wheelers is a function of the total number of vehicles and fraction of two-wheelers; number of three-wheelers is a function of the total number of vehicles and fraction of three-wheelers; number of cars is a function of the total number of cars and fraction of cars; number of buses is a function of the total number of buses and fraction of buses;

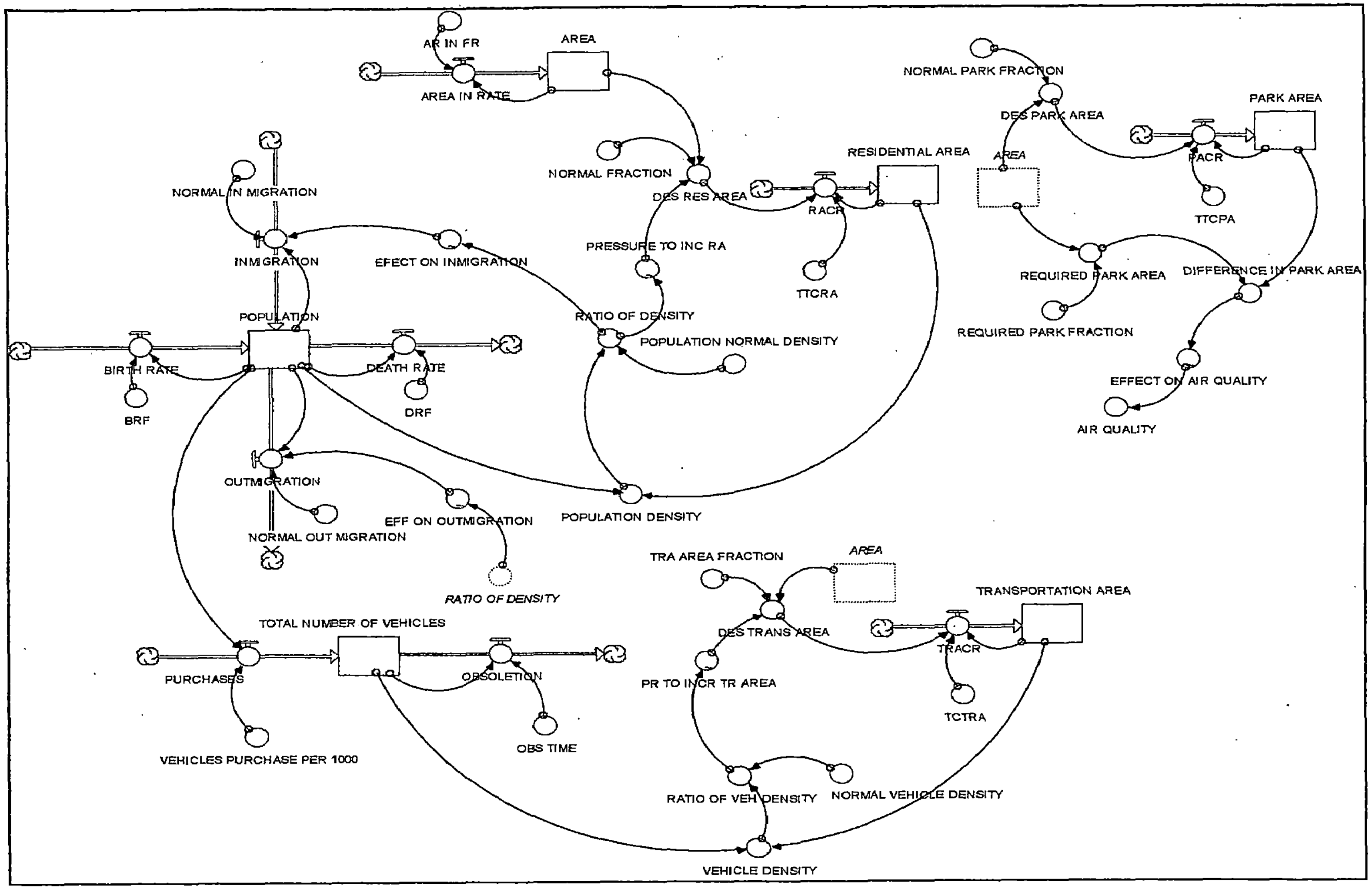


Fig. No. 5.8: System Dynamics Model for Residential-Parks & Playgrounds-Transportation Land Use

number of other vehicles is a function of the total number of other vehicles and fraction of other vehicles; total number of vehicles is a function of purchases, vehicles purchases per 1000 population, obsolete, etc.

Total number of vehicles = f (vehicles purchase per 1000 population, obsolete)

Number of two-wheeler = f (Total number of vehicles, fraction of two-wheelers)

Number of three-wheeler = f (Total number of vehicles, fraction of three-wheelers)

Number of cars = f (Total number of vehicles, fraction of cars)

Number of buses = f (Total number of vehicles, fraction of buses)

Number of other vehicles = f (Total number of vehicles, fraction of other vehicles)

In this model development, population, total number of vehicles are considered as level variables; purchases and vehicle purchase per 1000 population are considered as rate variables; obsolete, new industry, obsolete time, fraction of two-wheelers, fraction of three-wheelers, fraction of cars, fraction of buses, fraction of other vehicles are considered as auxiliary variables; number of two-wheelers, number of three-wheelers, number of cars, number of buses and number of other vehicles are considered as constants. The functional model diagram for vehicular population is presented in Fig. 5.9, as below, and the model equations for the same are presented in the Appendix-3.

5.7.5. System Dynamics Model for Modal Split

Modal split is one of the important sub-systems of the transportation system. A System Dynamics model is developed in order to compute total trips per day by different mode of transportation available in the system. The important control variables considered for developing the model are total trips per day, per capita trip rate, per capita trip rate fraction, bicycle trips, bicycle trip fraction, two-wheeler trips, two-wheeler trip fraction, three-wheeler trips, three-wheeler trip fraction, car trips, car trip fraction, bus trips, bus trip fraction, other vehicle trips and other vehicles trip fraction. Total trips per day is a function of bicycle trips, two-wheeler trips, three-wheeler trips, bus trips, other vehicle trips, per capita trip rate, per capita trip rate fraction; bicycle trips is a function of total trips per day, bicycle trip fraction; two-wheeler trips is a function of total trips per day, two-wheeler trip fraction; three-wheeler trips is a function of total trips per day, three-wheeler trip fraction; car trips is a function of total trips per day, car trip fraction; bus trips is a function of total trips per day, bus trip fraction; other vehicle trips is a function of total trips per day, other vehicles trip fraction.

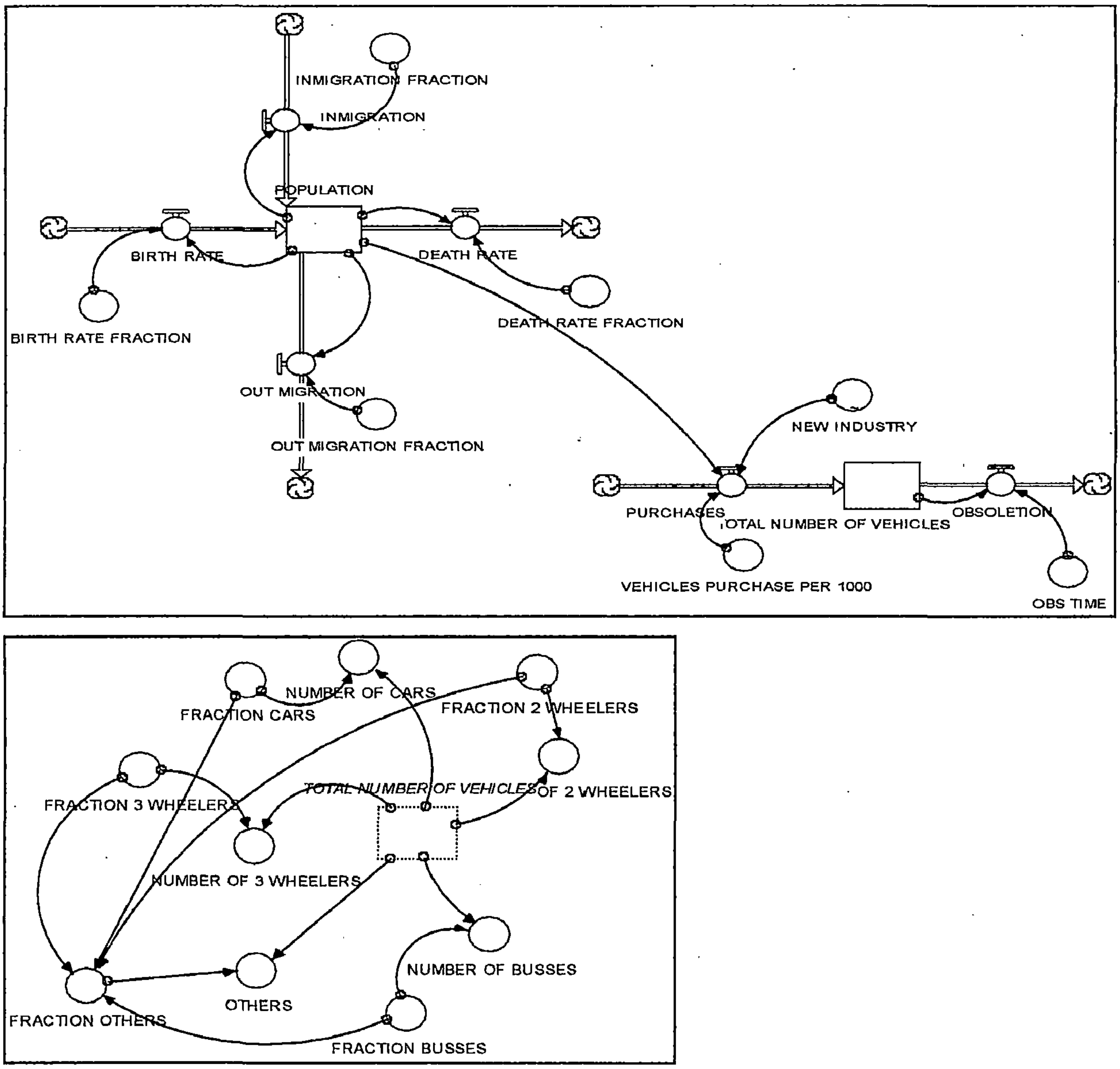


Fig. No. 5.9: System Dynamics Model for Vehicle Population in the Study Area

In this model, total trips per day is considered as level variable; per capita trips rate is considered as rate variables; per capita trip rate fraction, bicycle trip fraction, two-wheeler trip fraction, three-wheeler trip fraction, car trip fraction, bus trip fraction and other vehicles trip fraction are considered as auxiliary variables; bicycle trips, two-wheeler trips, three-wheeler trips, car trips, bus trips and other vehicle trips are considered as constants. The functional model diagram for modal split is presented in Fig. 5.10, as below and the model equations for the same are presented in Appendix-3.

Total trips per day = f (per capita trip rate, bicycle trips, two-wheeler trips, three-wheeler trips, car trips, bus trips, other vehicle trips)

Two-wheeler trips = f (Total trips per day, two-wheeler fraction)

Three-wheeler trips = f (Total trips per day, three-wheeler fraction)

Car trips = f (Total trips per day, car fraction)

Bus trips = f (Total trips per day, bus fraction)

Other vehicle trips = f (Total trips per day, other vehicle fraction)

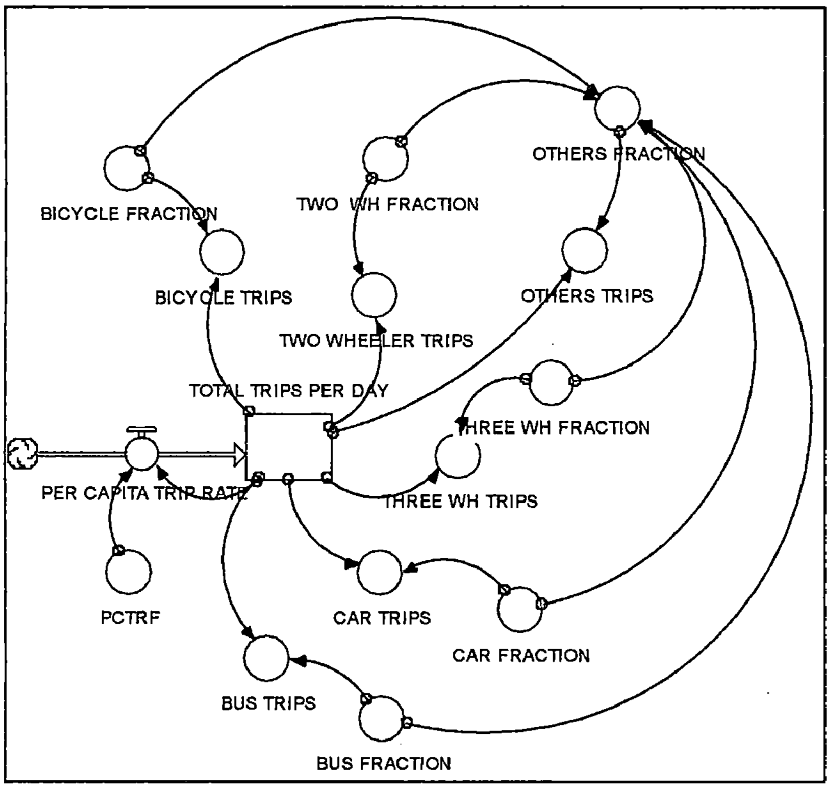


Fig. No. 5.10: System Dynamics Model for Modal Split in the Study Area

5.7.6. System Dynamics Model for Transport Demand

Transport demand is one of the important sub-systems of the transportation system. A System Dynamics model is developed in order to compute total travel demand in the study area. The important control variables considered for developing the model are total trips per day, bicycle travel demand, average trip length of bicycle, two-wheeler travel demand, average trip length of two-wheeler, three-wheeler travel demand, average trip length of three-wheeler, travel demand of car, average trip length of car, travel demand of bus and average trip length of bus. Total travel demand in the study area is a function of bicycle travel demand, two-wheeler travel demand, three-wheeler travel demand, car travel demand, and bus travel demand. The bicycle travel demand is a function of total trips per day, bicycle trip growth rate fraction, average trip length of bicycle; two-wheeler travel demand is a function of total trips per day, two-wheeler trips growth rate fraction, average trip length of two-wheelers; three-wheeler travel demand is a function of total trips per day, three-wheeler trips growth rate fraction, average trip length of three-wheelers; travel demand of car is a function of total trips per day, car trips growth rate fraction, average trip length of cars; travel demand of bus is a function of total trips per day, bus trips growth rate fraction, average trip length of buses.

In this model, a total trip per day is considered as the level variable. Bicycle travel demand, two-wheeler travel demand, three-wheeler travel demand, car travel demand and bus travel demand are the rate variables. Bicycle fraction, bicycle average trip length, two-wheeler fraction, two-wheeler average trip length, three-wheeler fraction, three-wheeler average trip length, car fraction, car average trip length, bus fraction, bus average trip length are considered as auxiliary variables. The functional model diagram for travel demand of the study area is presented in Fig. 5.11 and the model equations for the same are presented in Appendix-3.

Total Travel Demand = f (Bicycle travel demand, two-wheeler travel demand, three-wheeler travel demand, car travel demand, bus travel demand)

Bicycle travel demand = f (Total trips per day, bicycle average trip length, bicycle trips growth rate fraction)

Two-wheeler travel demand = f (Total trips per day, two-wheeler average trip length, two-wheeler trips growth rate fraction)

Three-wheeler travel demand = f (Total trips per day, three-wheeler average trip length, three-wheeler trips growth rate fraction)

Car travel demand = f (Total trips per day, car average trip length, car trips growth rate fraction)

Bus travel demand = f (Total trips per day, bus average trip length, bus trips growth rate fraction)

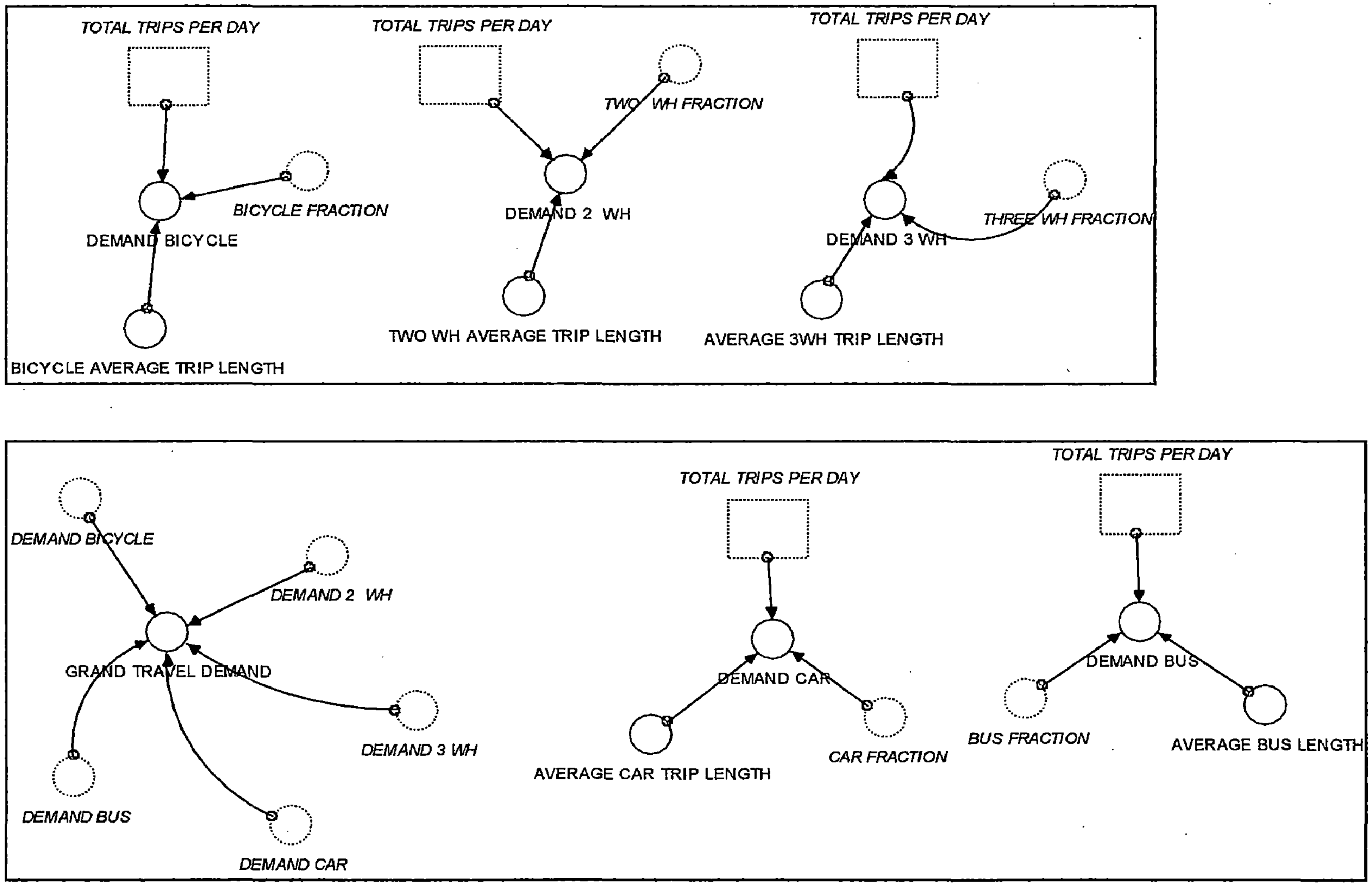


Fig. No. 5.11: System Dynamics Model for Transport Demand in the Study Area

5.7.7. System Dynamics Model for Road Congestion

Road congestion is one of the important subsystems of the transportation system. A System Dynamics model is developed in order to compute road congestion in the study area. The important control variables considered for developing the model are Population, area, transportation area, actual vehicle density, total trips per day, acceptable trips, and congestion. The congestion is the function of actual vehicle density, and acceptable trips.

In this model, transportation area and total trips per day are considered as level variables. Transportation area change growth rate is considered as rate variable. Congestion, effects of trips on congestion, actual vehicle density and acceptable trips are considered as auxiliary variables and time to change transportation area is considered as constant. The functional model diagram for road congestion of the study area is presented in Fig. 5.12 and the model equations for the same are presented in Appendix-3.

Congestion = f (Total trips per day, acceptable trips, actual vehicle density, effect of trips on congestion)

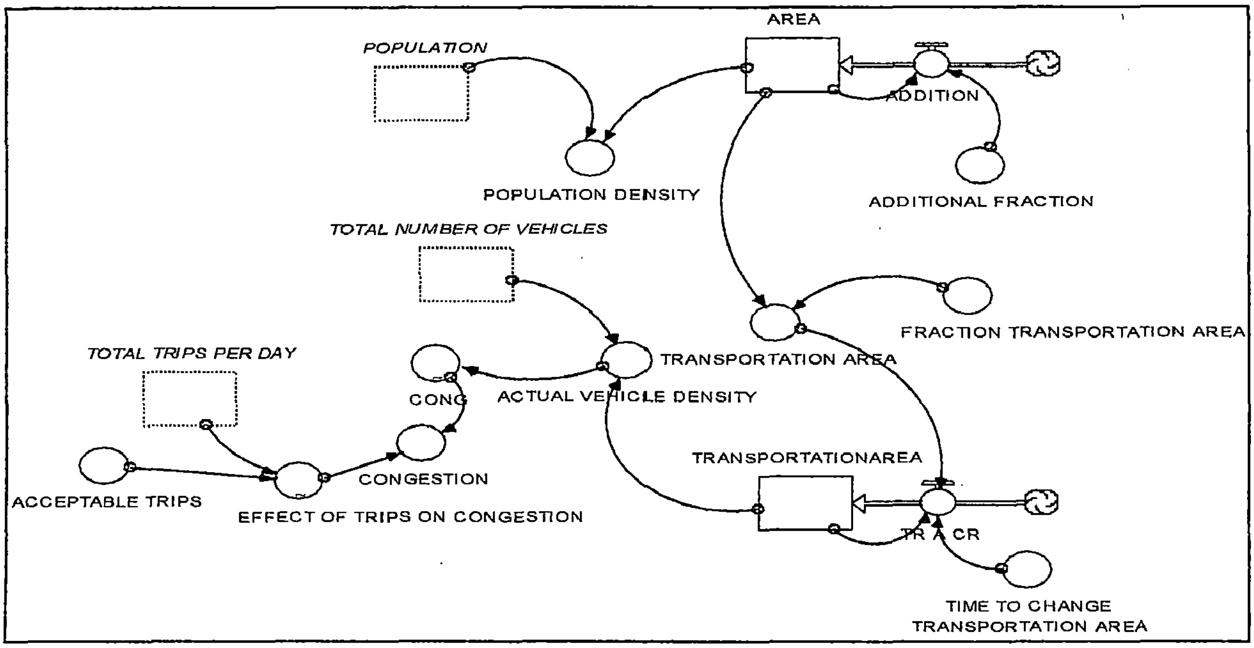


Fig. No. 5.12: System Dynamics Model for Road Congestion in the Study Area

5.7.8. System Dynamics Model for Fuel Efficiency (Fuel Consumption of Vehicles)

Total vehicular fuel consumption is one of the important subsystems of the transportation system. A System Dynamics model is developed in order to compute total vehicular fuel consumption in the system. The important control variables considered for developing the model are Total vehicular fuel consumption, two-wheeler fuel consumption, number of two-wheelers, efficiency per km of two-wheeler, average trip length of two-wheeler; three-wheeler fuel consumption, number of three-wheelers, efficiency per km of three-wheeler, average trip length of three-wheeler; car fuel consumption, number of cars, efficiency per km of cars, average trip length of car; bus fuel consumption, number of buses, efficiency per km of bus, average trip length of bus; other vehicle fuel consumption, number of other category vehicles, efficiency per km of other vehicles and average trip length of other vehicles. Total fuel consumption is the function of two-wheeler fuel consumption, three-wheeler fuel consumption, car fuel consumption, bus fuel consumption and other vehicles fuel consumption. Two-wheeler fuel consumption is the function of average trip length of two-wheeler, number of two-wheelers and efficiency per km trip length of two-wheelers; Three-wheeler fuel consumption is the function of average trip length of three-wheelers, number of three-wheelers and efficiency per km trip length of three-wheelers; car fuel consumption is the function of average trip length of car, number of cars and efficiency per km trip length of car; bus fuel consumption is the function of average trip length of bus, number of buses, efficiency per km trip length of bus; Other vehicles fuel consumption is the function of average trip length of other vehicles, number of other category vehicles, efficiency per km trip length of other category vehicles.

In this model, two-wheeler fuel consumption, average trip length of two-wheelers, efficiency per km trip length of two-wheelers are considered as auxiliary variables and number of two-wheelers is constant; three-wheeler fuel consumption, average trip length of three-wheelers, efficiency per km trip length of three-wheelers are considered as auxiliary variables and number of three-wheelers is constant; car fuel consumption, average trip length of cars, emission per km trip length of cars are considered as auxiliary variables and number of buses is constant; bus fuel consumption, average trip length of buses, efficiency per km trip length of buses are considered as auxiliary variables and number of buses is constant; other vehicle fuel consumption, average trip length of other vehicles, efficiency per km trip length of other vehicles are considered as auxiliary variables and other vehicles is constant. The functional model diagram for vehicular fuel consumption is presented in Fig. 5.13 and the model equations for the same are presented in Appendix-3.

Total fuel consumption = f (Two-wheeler fuel consumption, three-wheeler fuel consumption, car fuel consumption, bus fuel consumption, other vehicles fuel consumption)

Two-wheeler fuel consumption = f (Number of two-wheelers, average trip length of two-heelers, efficiency per km trip length of two-wheelers)

Three-wheeler fuel consumption = f (Number of three-wheelers, average trip length of three-wheelers, efficiency per km trip length of three-wheelers)

Car fuel consumption = f (Number of cars, average trip length of cars, efficiency per km trip length of cars)

Bus fuel consumption = f (Number of buses, average trip length of buses, efficiency per km trip length of buses)

Other fuel consumption = f (Number of other vehicles, average trip length of other vehicles, efficiency per km trip length of other vehicles)

5.7.9. System Dynamics Model for Vehicular Emission Load

Total vehicular emission load is one of the important subsystems of the transportation system. A System Dynamics model is developed in order to compute total vehicular emission load in the system. The important control variables considered for developing the model are total emission load, two-wheeler emission load, number of two-wheelers, emission per km of two-wheeler, average trip length of two-wheeler; three-wheeler emission load, number of three-wheelers, emission per km of three-wheeler, average trip length of three-wheeler; car emission load, number of cars, emission per km of cars, average trip length of car; bus emission load, number of buses, emission per km of bus, average trip length of bus; other vehicle emission load, number of other category vehicles, emission per km of other vehicles and average trip length of other vehicles. Total emission is the function of two-wheeler emission, three-wheelers emission, car emission, bus emission and other vehicles emission; Two-wheelers emission is the function of average trip length of two-wheeler, number of two-wheelers and emission per km trip length of two-wheelers; Three-wheeler emission is the function of average trip length of three-wheelers, number of three-wheelers and emission per km trip length of three-wheelers; car emission is the function of average trip length of car, number of cars and emission per km trip length of car; bus emission is the function of average trip length of bus, number of buses, emission per km trip length of bus; Other vehicles emission is the function of average trip length of other vehicles, number of other category vehicles, emission per km trip length of other category vehicles.

In this model, two-wheeler emission load, average trip length of two-wheelers, emission per km trip length of two-wheelers are considered as auxiliary variables and number of two-wheelers is constant (constant = application of direct values); three-wheeler emission load, average trip length of three-wheelers, emission per km trip length of three-wheelers are considered as auxiliary variables and number of three-wheelers is constant; car emission load, average trip length of cars, emission per km trip length of cars are considered as auxiliary variables and number of buses is constant; bus emission load, average trip length of buses, emission per km trip length of buses are considered as auxiliary variables and number of buses is constant; other vehicle emission load, average trip length of other vehicles, emission per km trip length of other vehicles are considered as auxiliary variables and other vehicles is constant. The functional model diagram for vehicular emission load is presented in Fig. 5.13 and the model equations for the same are presented in Appendix-3.

Total emission load = f (Two-wheeler emission load, three-wheeler emission load, car emission load, bus emission load, other vehicles emission load)

Two-wheeler emission load = f (Number of two-wheelers, average trip length of two-wheelers, emission per km trip length of two-wheelers)

Three-wheeler emission load = f (Number of three-wheelers, average trip length of three-wheelers, emission per km trip length of three-wheelers)

Car emission load = f (Number of cars, average trip length of cars, emission per km trip length of cars)

Bus emission load = f (Number of buses, average trip length of buses, emission per km trip length of buses)

Other emission load = f (Number of other vehicles, average trip length of other vehicles, emission per km trip length of other vehicles)

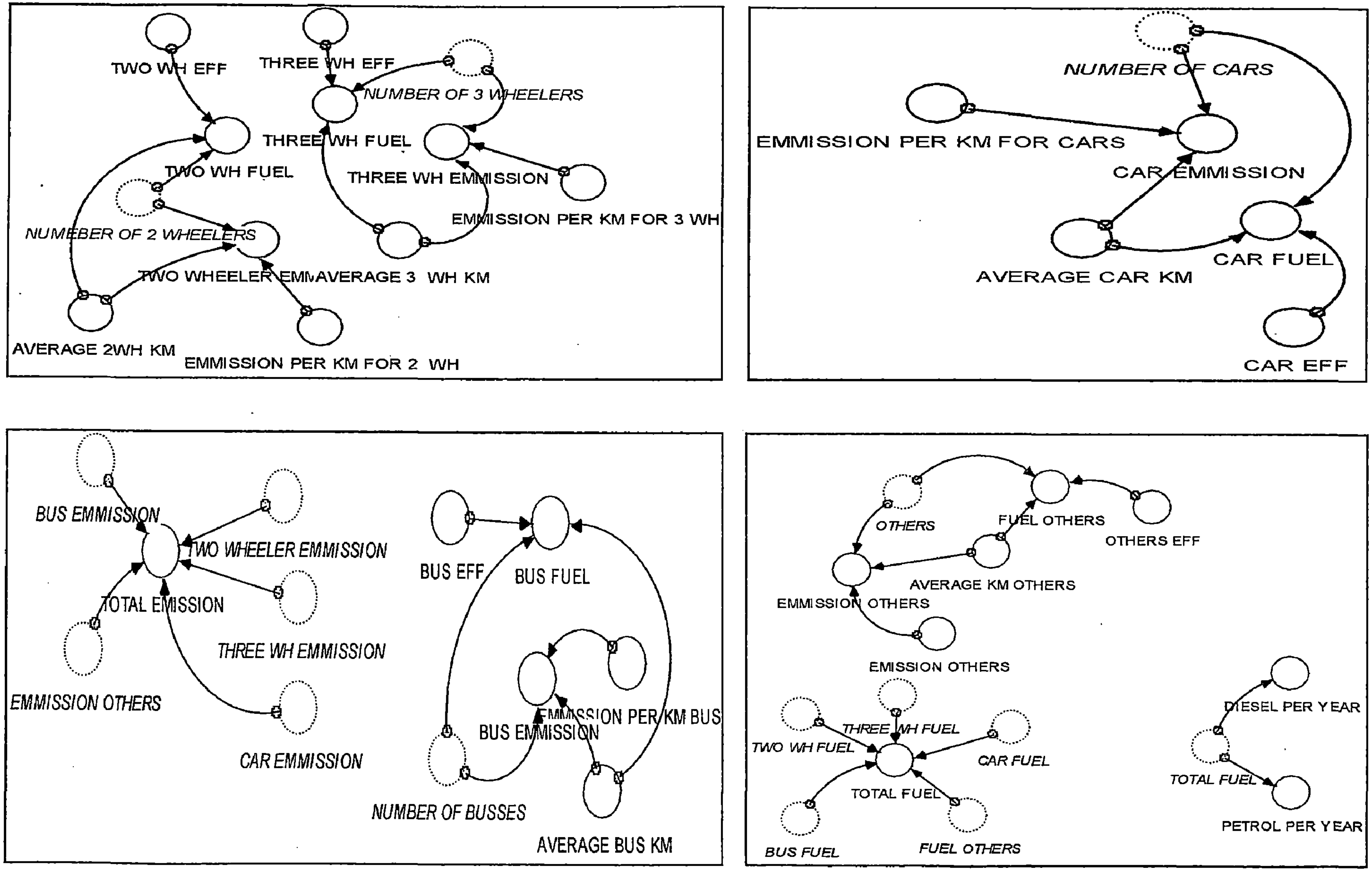


Fig. No. 5.13: System Dynamics Model for Vehicular Emission Load and Fuel Consumption in the Study Area

5.7.10. System Dynamics Model for Integrated Transportation System in Bangalore City

A System Dynamics model for Integrated Transportation System in the Study area has been developed by integrating the afore presented subsystem models, such as System Dynamics model for population, population density, vehicle ownership, residential-parks & playgrounds-transportation land use area, vehicular population, vehicular pollution load, vehicular fuel consumption, modal split, total travel demand and congestion is presented in Fig. 5.14. All sub-systems of the system are interlinked and interdependent and function as feedback loops among themselves, where effects of each sub-system are seen on the integrated Transportation system in the study area.

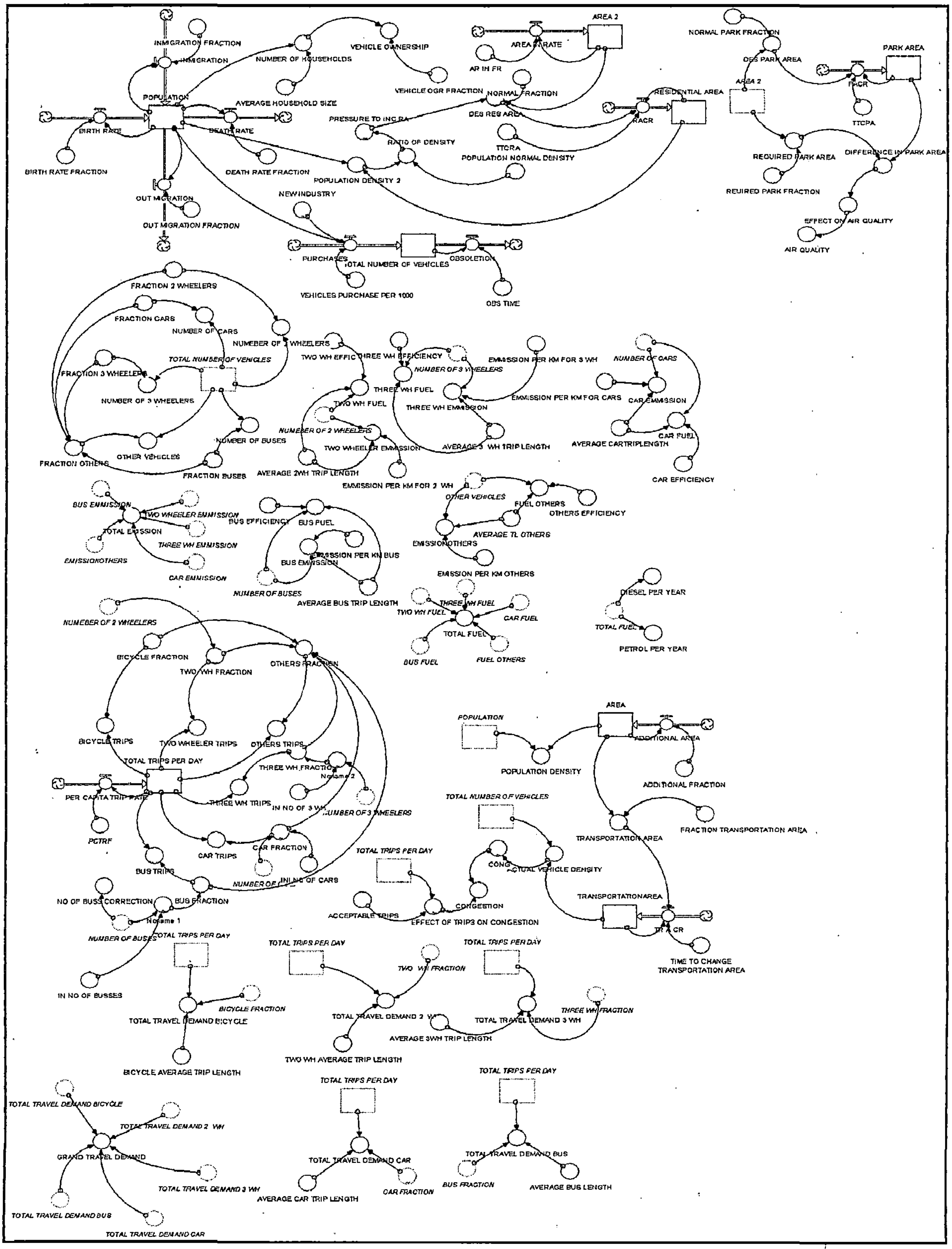


Fig. No. 5.14: System Dynamics Model for Integrated Transportation System in Bangalore City

5.8. BASE YEAR MODEL RESULTS-2001

The System Dynamic models developed in this investigation are employed to understand the functions of the system. In these models, year 2001 is considered as the base year to understand the functions of the system and its various subsystems together. The results of the various variables computed from the models considering year 2001 as the base year are population, population density, vehicle ownership, residential land use, parks & playgrounds land use, transportation land use, vehicular population, vehicular pollution load, fuel consumption, modal split, total travel demand and congestion. The results are presented in Table Nos. 5. 20 to 5.30.

The Table 5.20 clearly indicates that the population available in the study area is 5757020 having area 534.08 Sq. km and a population density of 10779 persons per sq. km in the year 2001. It is observed from the Table 5.21 that the number of households and vehicle ownership are 1290812 and 263213. The available residential land use area, parks & playgrounds and transportation land use area are 159.76, 21.31 and 108.68 Sq. km respectively to a total land area in the study area (system) of 537.08 Sq. km is presented in Table 5.22. The difference in parks and playground land use area and air quality are 0.65 and 44.92 respectively and is presented in Table 5.23. The available vehicular population in the study area which include two-wheelers, three-wheelers, cars, buses, other vehicles and total vehicular population are 1223187, 57853, 237034, 3008, 111740, and 1652956 respectively and is presented in Table 5.24. It is observed from the Table 5.25 that the bicycle trips, two-wheeler trips, three-wheeler trips, car trips, bus trips, other trips and total trips are 97828, 1412127, 316963, 240657, 1927214, 179323 and 4891405 respectively in the study area. The available vehicular emission load, which include two-wheeler, three-wheeler, cars, buses, other and total vehicles are 66843, 60863, 16589, 586, 30170 and 175051 tonnes per year in the study area is presented in Table 5.30. It is observed from the Table 5.28 that the fossil fuel consumption of different kind of vehicles, which include two-wheeler, three-wheeler, car, bus, others and total vehicles are 198156365, 68729910, 134398216, 51059728, 414331273 and 866675493 litres per year respectively in the study area. The diesel and petrol consumption in the study area were 182001854 and 684673640 litres per year respectively, and is presented in Table 5.29. It is observed from the Table No. 5.26 that the bicycle travel demand, two-wheeler travel demand, three-wheeler travel demand, car travel demand, bus travel demand and total travel demand are 0.44, 19.06, 38.04, 6.50, 381.59, and 445.63 million person kilometers per year in the study area. The actual vehicle density and congestion are 15209 and 1.25, and is presented in Table No. 5.27.

5.9. MODEL VALIDATION

The evolved integrated model is employed to compute outputs from a set of inputs for the year 2001, which is referred as the base year for the model in this investigation. The data available for some important parameters from the year 1971 to year 2001 are considered for model validation. The model results are closely examined and compared to the data available in the real system, and it is observed that the model results and real system data of various important parameters, such as, population, area, two-wheeler vehicles, three-wheeler vehicles, cars, buses, two-wheeler trips, car trips, and bus trips etc., are very closely matched with minimum variation, thus making both behavioural and *structural validity* of the models closely reflecting the real system. The model results and the comparison between model results and the real system data are presented in Fig. Nos. 5.15 to 5.23. The actual and modal results are also validated with using SPSS employed regression analysis and the results are presented in Table 5.19.

Table No. 5.19: Model Validation Results

Sl. No.	Actual and Model Results Validated with the Following Variables	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	Population	0.992	0.984	0.976	2.65499E5
2	Area	0.925	0.856	0.784	70.81173
3	Two-wheeler Vehicles	0.974	0.949	0.924	1.40595E5
4	Three-wheeler Vehicles	0.992	0.984	0.976	4095.67857
5	Number of Cars	0.985	0.971	0.956	19479.37907
6	Number of Buses	0.981	0.961	0.942	358.88568
7	Two-wheeler Trips	0.996	0.992	0.988	78879.88042
8	Car Trips	0.926	0.858	0.787	44020.45535
9	Bus Trips	0.916	0.839	0.758	3.59250E5

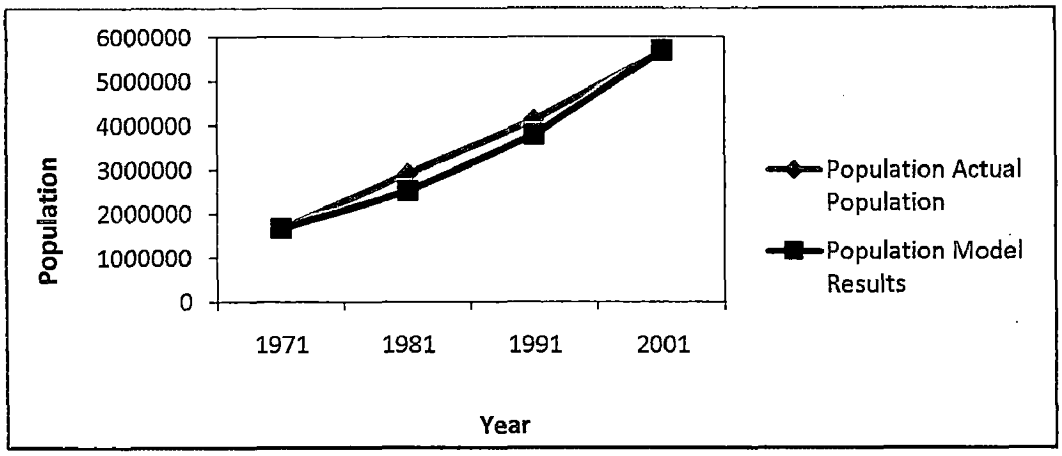


Fig. No. 5.15: Real and Model based Population in the Study Area

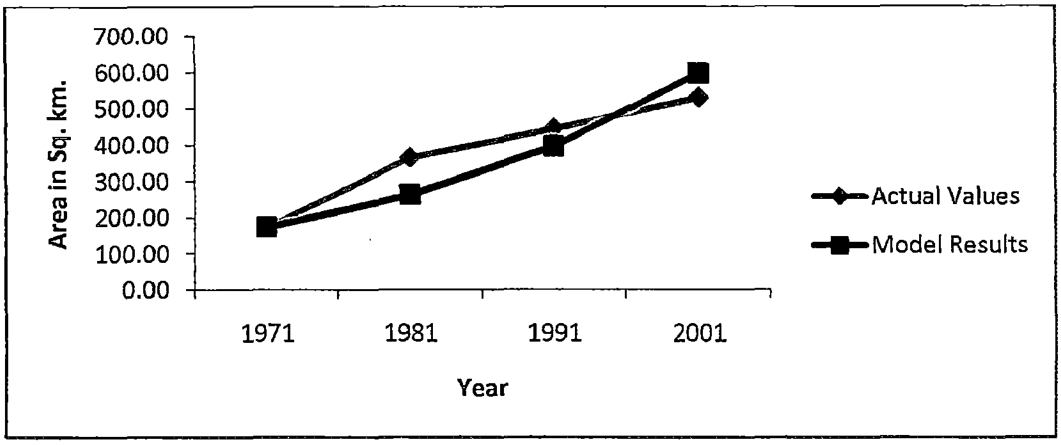


Fig. No. 5.16: Real and Model based Area in the Study Area

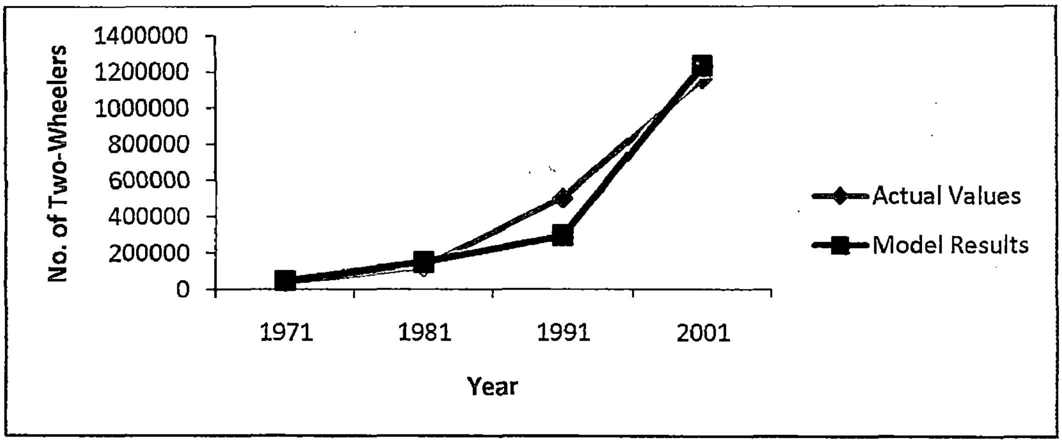


Fig. No. 5.17: Real and Model based No. of Two-wheeler Vehicles in the Study Area

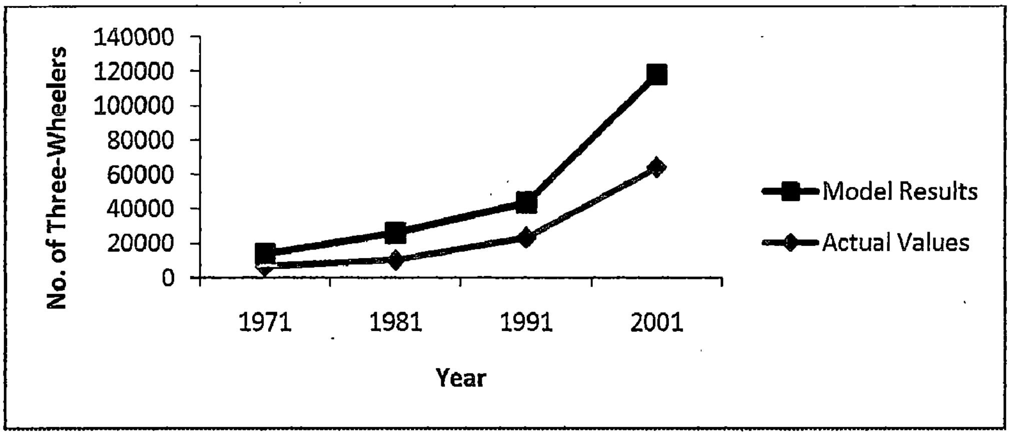


Fig. No. 5.18: Real and Model Based No. of Three-wheelers in the Study Area

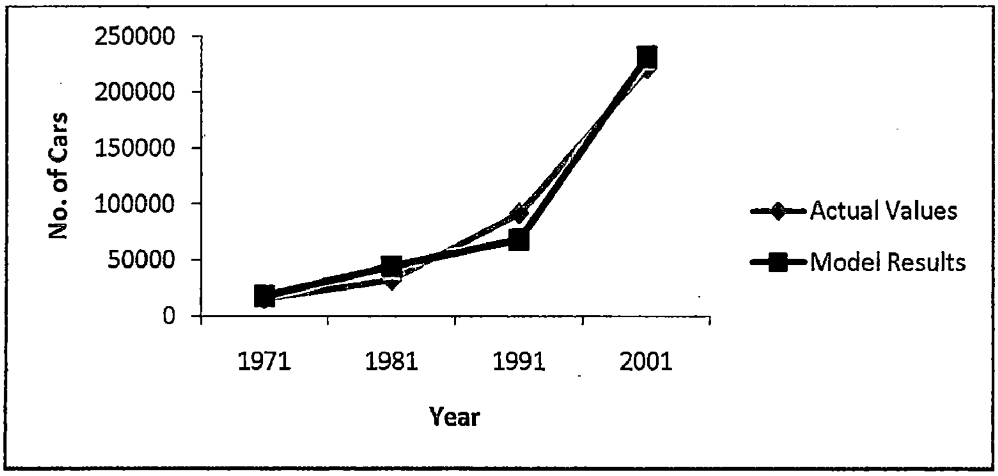


Fig. No. 5.19: Real and Model Based No. of Cars in the Study Area

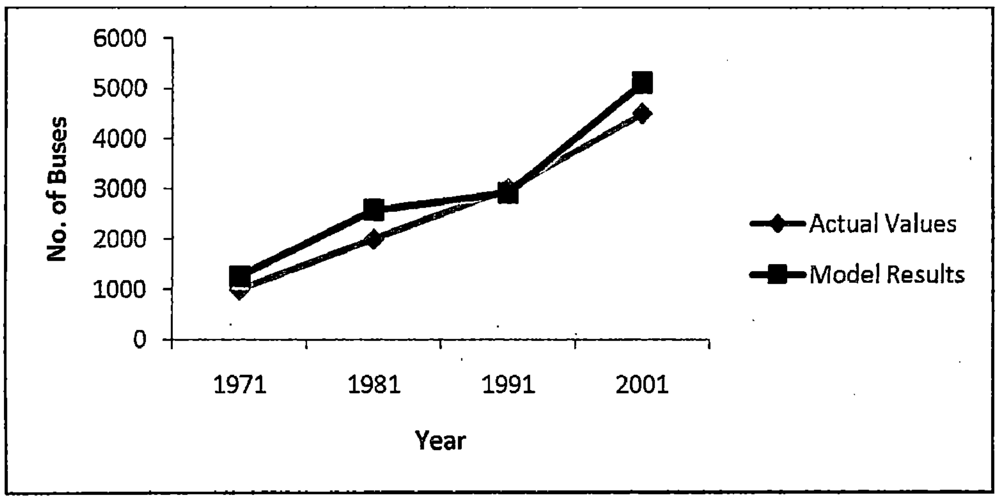


Fig. No. 5.20: Real and Model Based No. of Buses in the Study Area

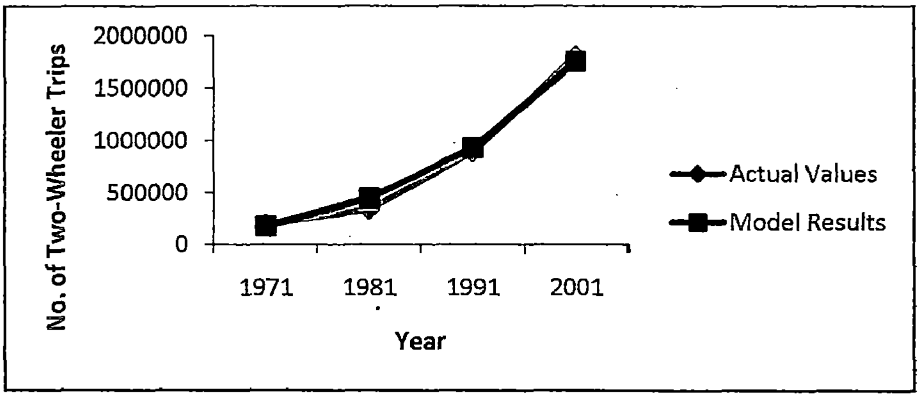


Fig. No. 5.21: Real and Model Based No. of Two-wheeler Trips in the Study Area

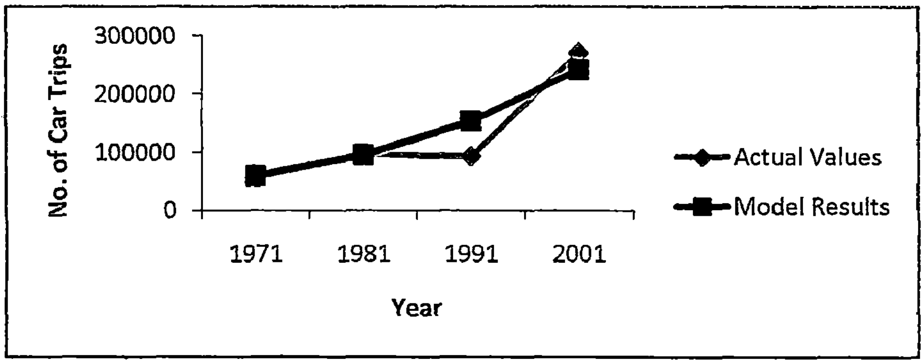


Fig. No. 5.22: Real and Model Based No. of Car Trips in the Study Area

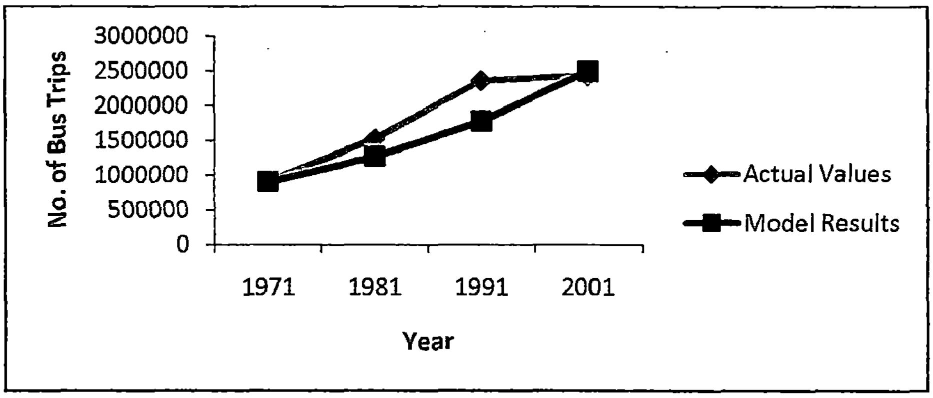


Fig. No. 5.23: Real and Model Based No. of Bus Trips in the Study Area

5.10. PROJECTIONS

In this present investigation, various control parameters of different subsystems of the system, which influence the functions of the system largely, such as, population, population density, vehicle ownership, residential-parks & playgrounds-transportation land use area, vehicular population, modal split, vehicular emission load, fuel efficiency, travel demand, and road congestion, etc., have been considered for projecting their value up to the year 2031 AD for strategic planning. Period of projections is considered up to 2031 AD by keeping in mind the very dynamic and volatile nature of transportation system. Projections were done in the validated integrated base year 2001 AD model by employing STELLA 9.1.4 software by considering the time series data available in the system.

5.11. PROJECTED YEAR 2031 AD MODEL RESULTS

The System Dynamics models developed in this investigation are employed to understand the functions of the system. In these models, year 2001 is considered as the base year to project the projected year 2031 A.D. model. The results of the projected year model is presented as below:

5.11.1. Population and Population Density

The projected population and the population density in the study area is presented in Table 5.20, and Fig. 5.24 to Fig. 26. The model results revealed that the population in the study area would be increased from 5757020 in 2001 to 10822416 in the year 2031 AD and the area of the city would be increased from 534.08 Sq. km to 863.11 Sq. km during the same period. The population density in the study area would be increased from 10779 persons per Sq. km in 2001 to 12538 persons per Sq. km in the year 2031 AD.

Table No. 5.20: Projected Population Growth and Population Density in the Year 2031 A.D.

Sl. No.	Year	Population	Area in Sq. km	Population Density in Persons/Sq.km
1	2001	5,757,020	534.08	10779.32
2	2006	6,395,662	578.56	11054.41
3	2011	7,105,150	626.75	11336.52
4	2016	7,893,343	678.95	11625.83
5	2021	8,768,973	735.50	11922.52
6	2026	9,741,739	796.75	12226.79
7	2031	10,822,416	863.11	12538.82

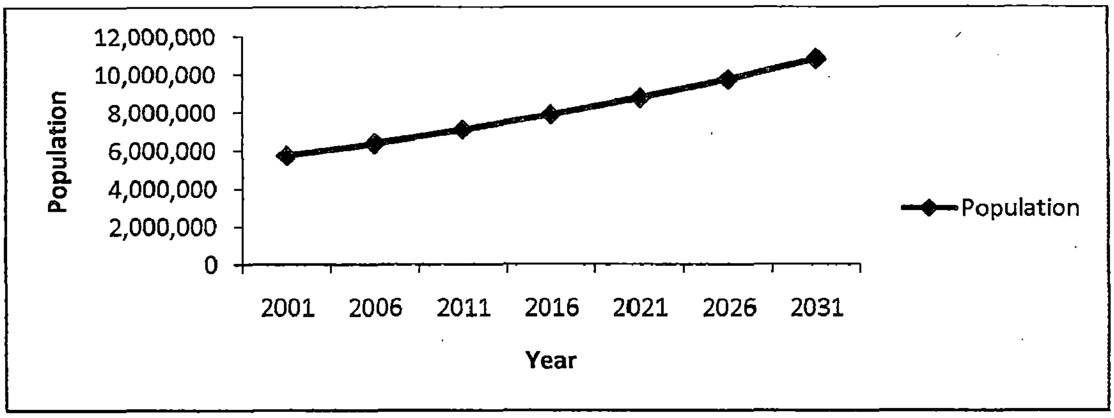


Fig. No. 5.24: Projected Population up to 2031 A.D.

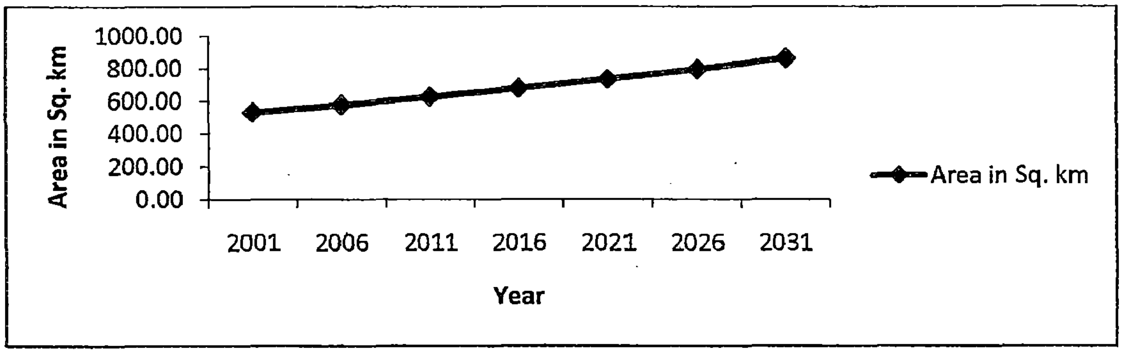


Fig. No. 5.25: Projected Area up to 2031 A.D.

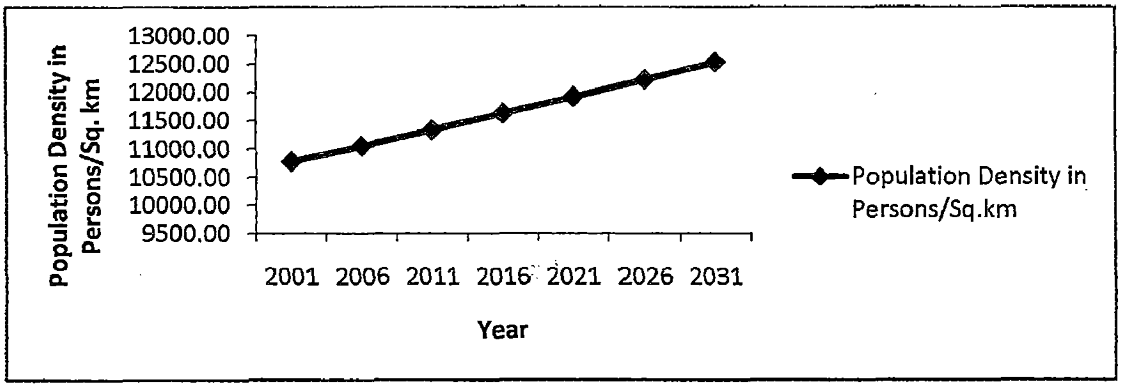


Fig. No. 5.26: Projected Population Density up to 2031 A.D.

5.11.2. Households and Vehicle Ownership

Number of households and vehicle ownership are the important control parameters, which influence the system. The results of the number of households and vehicle ownership have been presented in Table 5.21, in Fig. 5.27 and Fig. 5.28. It is observed that the number of households in the study area would be increased from 1290812 in 2001 to 2426551 in the year 2031 AD and the vehicle ownership in the study area would be increased from 263213 to 2184246 in the year 2031 AD. It is further observed that the vehicle ownership would be 1966137 in the year 2021 that would be equal to the number of household in the year 2021 AD in the study area.

Table No. 5.21: Projected Households-Vehicle Ownership in the Year 2031 A.D.

Sl. No.	Year	No. of Households	Vehicle Ownership
1	2001	1,290,812	263,213
2	2006	1,434,005	440,701
3	2011	1,593,083	737,871
4	2016	1,769,808	1,235,429
5	2021	1,966,137	1,966,137
6	2026	2,184,246	2,184,246
7	2031	2,426,551	2,426,551

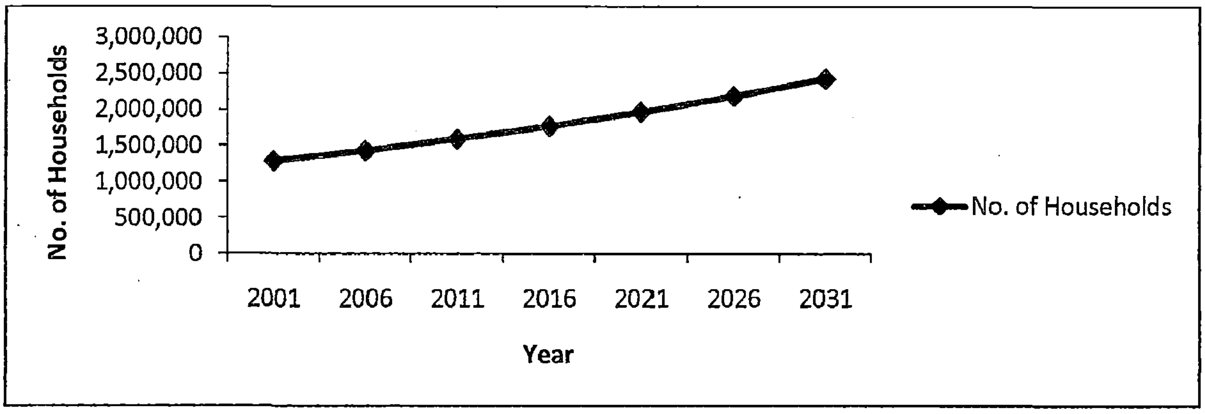


Fig. No. 5.27: Projected Households up to 2031 A.D.

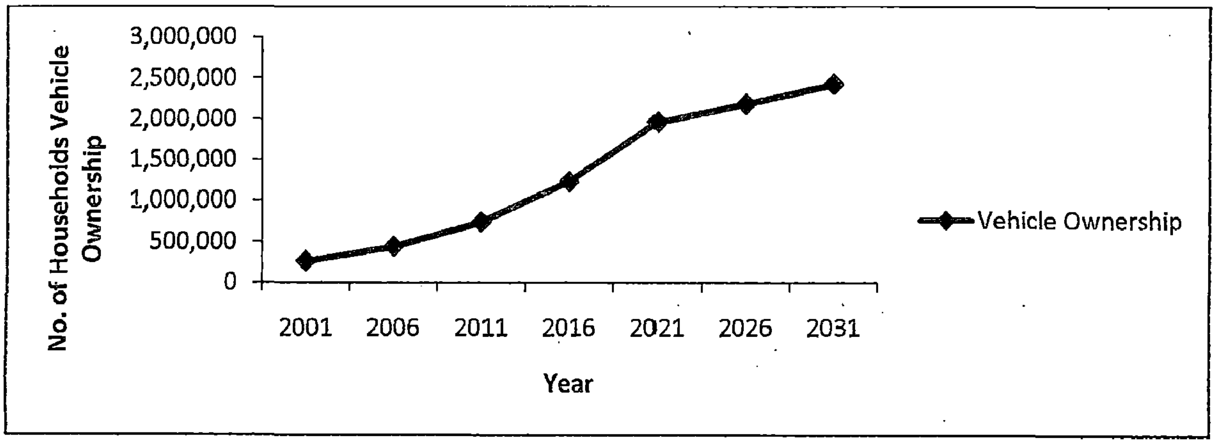


Fig. No. 5.28: Projected Vehicle Ownership up to 2031 A.D.

5.11.3. Residential-Parks & Playgrounds and Transportation Land Use Area in the Year 2031 A.D.

The results of residential land use, parks & playgrounds land use and transportation land use area are presented in Table 5.22 and Fig. 5.29. It is observed from the model result that the total area would be increase from 537.08 Sq. km in the year 2001 to 973.16 Sq. km in the year 2031 AD; residential land use area would be increased from 159.76 Sq. km in 2001 to 512.82 Sq. km in the year 2031 AD; parks & playground land use area would be increased from 21.32 Sq. km in the year 2001 to 34.51 Sq. km in the year 2031 AD; transportation land use area would be increased from 108.68 Sq. km in the year 2001 AD to 185.88 Sq. km in the year 2031 AD.

Table No. 5.22: Projected Area-Residential-Parks & Playgrounds-Transportation Land use Area in the Year 2031 A.D.

Sl. No.	Year	Area in Sq. km	Residential Area in Sq. km	Parks & Playgrounds Area in Sq. km	Transportation Area in Sq. km
1	2001	534.08	159.76	21.32	108.68
2	2006	590.25	266.39	21.83	108.74
3	2011	652.33	327.46	23.46	116.47
4	2016	720.93	374.06	25.68	132.32
5	2021	796.75	417.87	28.29	149.46
6	2026	880.55	463.47	31.24	167.27
7	2031	973.16	512.82	34.51	185.88

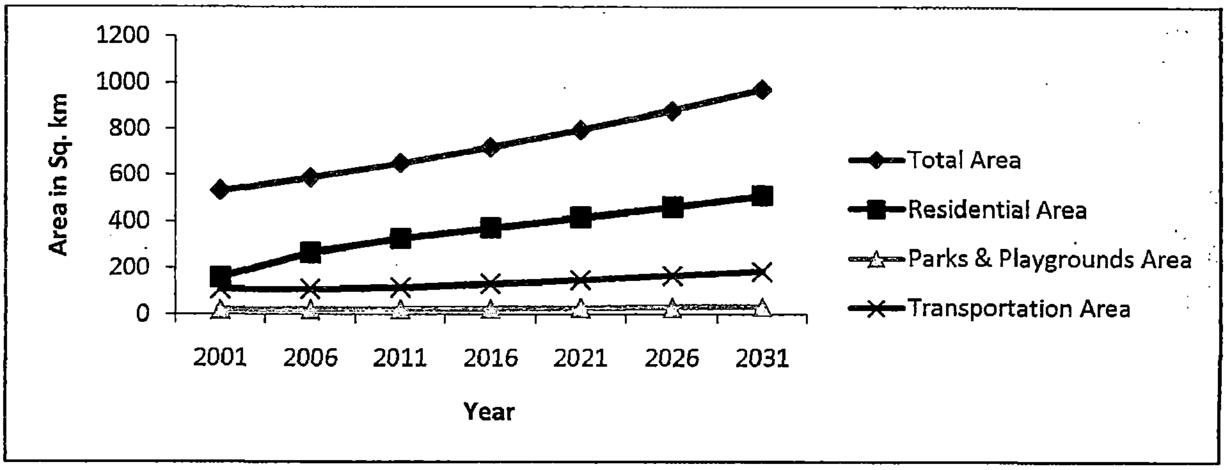


Fig. No. 5.29: Projected Area-Residential-Parks & Playgrounds-Transportation Land use Area in the Year 2031 A.D.

5.11.4. Air Quality in the Study Area in the Year 2031 A.D.

The results of difference in parks and playgrounds land use area and air quality in the study area are presented in Table 5.23 and Fig. 5.30. It is observed from the model result that the difference in parks and playgrounds area would be increased from 0.60 in 2001 to 0.65 in year 2031 AD and air quality would be decreased from 51.38 in the year 2001 to 44.92 in the year 2031 AD.

Table No. 5.23: Difference in Parks and Playgrounds Area and Air Quality in the Year 2031 A.D.

Sl. No.	Year	Difference in Parks and Playgrounds Area	Air Quality
1	2001	0.60	51.38
2	2006	0.63	47.12
3	2011	0.64	45.65
4	2016	0.64	45.15
5	2021	0.64	44.99
6	2026	0.65	44.94
7	2031	0.65	44.92

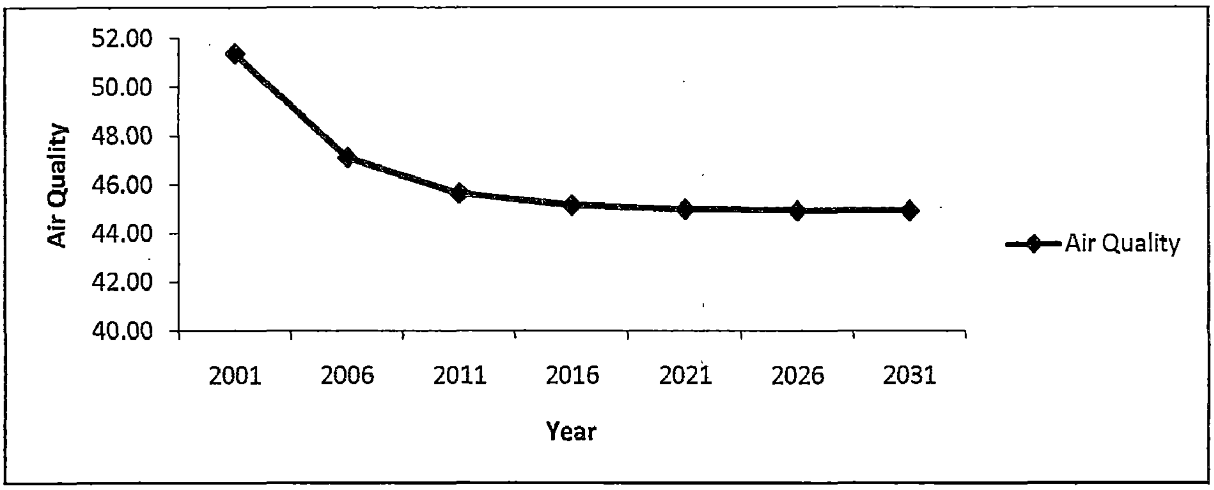


Fig. No. 5.30: Air Quality in the Study Area in the Year 2031 A.D.

5.11.5. Vehicular Population in the Study Area in the Year 2031 A.D.

The results of vehicular population in the study area are presented in Table No. 5.24 and in Fig. 5.31. It is observed from the model result that the number of two-wheeler vehicles would be increased from 1223187 in the year 2001 to 4402407 in the year 2031 AD; three-wheeler vehicles would be increased from 57853 in the year 2001 to 208222 in the year 2031 AD; number of cars would be increased from 237034 in the year 2001 to 832888 in the year 2031 AD; number of buses would be increased from 3008 in the year 2001 to 18562 in the year 2031; other vehicles would be increased from 111740 in the year 2001 to 362901 in the year 2031 AD; and the total number of vehicles would be increased from 1652956 in the year 2001 to 5949199 in the year 2031AD.

5.11.6. Modal Split in the Study Area in the Year 2031 A.D.

The results of modal split in the study area are presented in Table No. 5.25 and in Fig. 5.32. It is observed from the model result that the number of bicycle trips would be increased from 97828 in the year 2001 to 302236 in the year 2031 AD; number of two-wheeler trips would be increased from 1412127 in the year 2001 to 5804028 in the year 2031 AD; number of three-wheeler trips would be increased from 316963 in the year 2001 to 1128345 in the year 2031 AD; number of car trips would be increased from 240657 in the year 2001 to 866329 in the year 2031 AD; number of bus trips would be increased from 1927214 to 6606608 in the year 2031 AD; number of other vehicle trips would be increased from 179323 to 80854 in the year 2031 AD; total number of trips would be increased from 4891405 in the year 2001 to 15111816 in the year 2031 AD.

5.11.7. Projected Total Travel Demand by Different Mode of Transport in the Study Area in the Year 2031 A.D.

The results of total travel demand in the study area are presented in Table 5.26 and in Fig. 5.33. It is observed from the model result that the bicycle travel demand would be increased from 0.44 Million Persons Kilometres per year (MPK) in the year 2001 to 1.36 MPK/year in the year 2031 AD; the two-wheeler travel demand would be increased from 19.06 MPK/year in the year 2001 to 78.35 MPK/year in the year 2031 AD; the three-wheeler travel demand would be increased from 38.04 MPK/year in the year 2001 to 135.40 MPK/year; the car travel demand would be increased from 6.50 MPK/year in the year 2001 to 23.39 MPK/year in the year 2031 AD; the public bus travel demand would be increased from 381.59 MPK/year in the year 2001 to 1308.11 MPK/year in the year 2031 AD; the total travel demand in the study area would be increased from 445.63 MPK/year in the year 2001 to 1546.62 MPK/year in the year 2031 AD.

Table No. 5.24: Projected Vehicular Population in the Study Area in the Year 2031 A.D.

Sl. No.	Year	No. of Two-wheelers	No. of Three-wheelers	No. of Cars	No. of Buses	No. of Other Vehicles	Number of Total Vehicles
1	2001	1,223,187	57,853	237,034	3,008	111,740	1,652,956
2	2006	1,834,317	86,758	347,033	4,511	175,995	2,478,807
3	2011	2,378,470	112,495	449,981	10,028	196,063	3,214,149
4	2016	2,886,419	136,520	546,079	12,170	237,935	3,900,567
5	2021	3,381,523	159,937	639,748	14,257	278,747	4,569,626
6	2026	3,881,970	183,607	734,427	16,367	320,000	5,245,905
7	2031	4,402,407	208,222	832,888	18,562	487,120	5,949,199

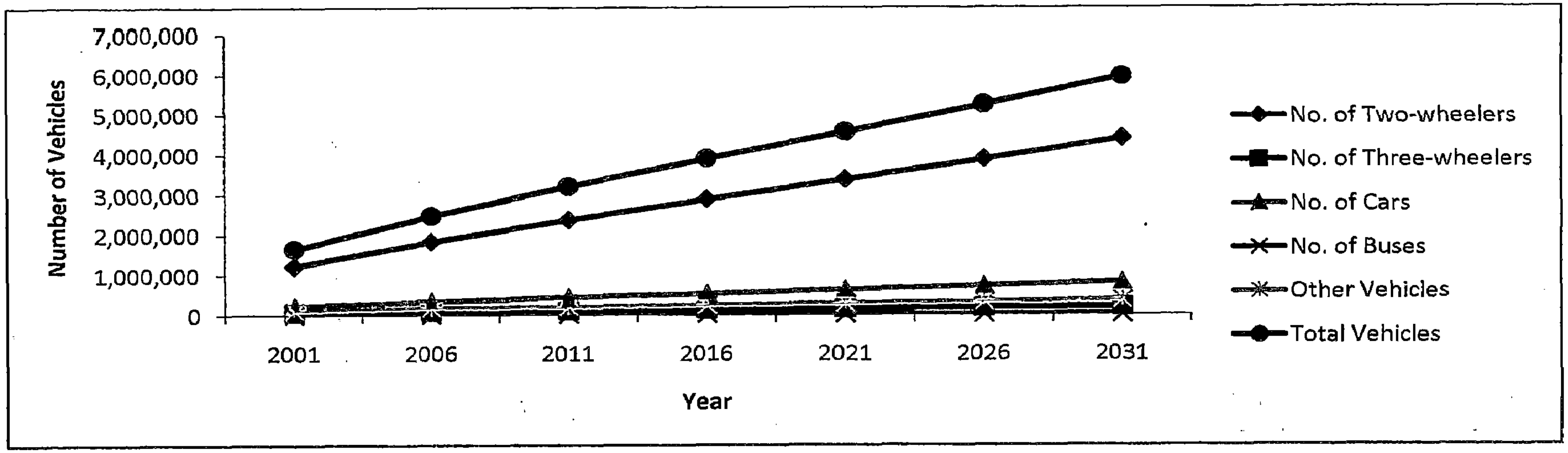


Fig. No. 5.31: Projected Vehicular Population in the Study Area in the Year 2031 A.D.

Table No. 5.25: Projected Modal Split in the Study Area in the Year 2031 A.D.

Sl. No.	Year	Bicycle Trips	Two-wheeler Trips	Three-wheeler Trips	Car Trips	Bus Trips	Other Trips	Total Trips
1	2001	97,828	1,412,127	316,963	240,657	1,927,214	179,323	4,891,405
2	2006	118,062	1,812,429	387,042	290,433	2,325,825	193,864	5,903,109
3	2011	142,481	2,303,596	478,898	352,545	2,890,090	191,291	7,124,067
4	2016	171,951	2,911,070	601,296	440,279	3,559,632	182,666	8,597,558
5	2021	207,516	3,667,288	753,397	548,132	4,421,258	155,645	10,375,817
6	2026	250,438	4,613,800	929,409	687,006	5,426,270	122,991	12,521,878
7	2031	302,236	5,804,028	1,128,345	866,329	6,606,608	404,270	15,111,816

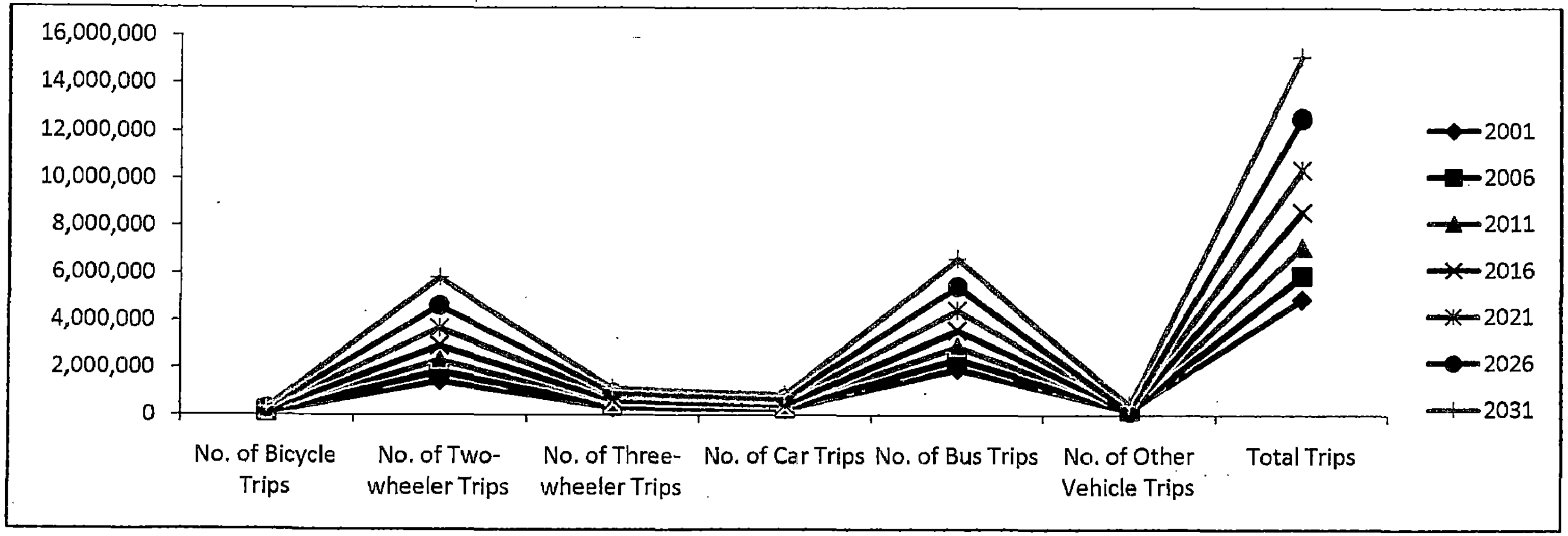


Fig. No. 5.32: Projected Modal Split in the Study Area in the Year 2031 A.D.

Table No. 5.26: Projected Total Travel Demand by Different Mode of Transport in the Study Area in the Year 2031 A.D.

Sl. No.	Year	Travel Demand in Million Persons Kilometers per Year					
		Bicycle Demand	Two-wheeler Demand	Three-wheeler Demand	Car Demand	Bus Demand	Total Travel Demand
1	2001	0.44	19.06	38.04	6.50	381.59	445.63
2	2006	0.53	24.47	46.45	7.84	460.51	539.80
3	2011	0.64	31.10	57.47	9.52	572.24	670.96
4	2016	0.77	39.30	72.16	11.89	704.81	828.92
5	2021	0.93	49.51	90.41	14.80	875.41	1,031.06
6	2026	1:13	62.29	111.53	18.55	1,074.40	1,267.89
7	2031	1.36	78.35	135.40	23.39	1,308.11	1,546.62

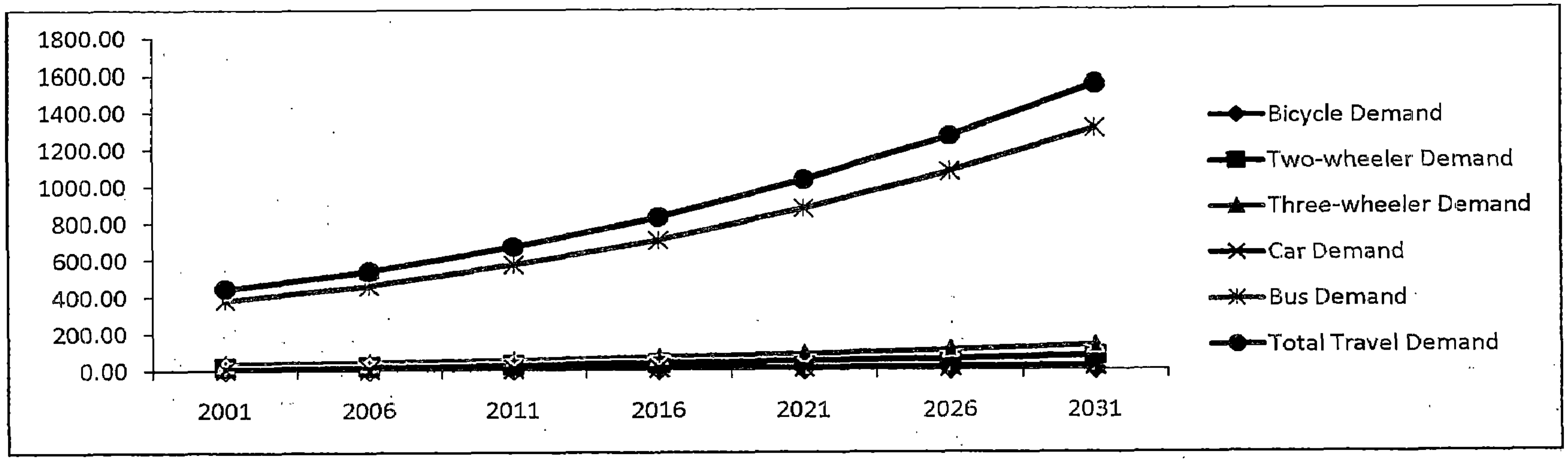


Fig. No. 5.33: Projected Total Travel Demand by Different Mode of Transport in the Study Area in the Year 2031 A.D.

5.11.8. Projected Vehicular Density and Congestion in the Study Area in the Year 2031 A.D.

The results of vehicular density and congestion level in the study area are presented in Table 5.27, Fig. 5.34 and Fig. 5.35. It is observed from the model result that the actual vehicle density would be increased from 15209 Vehicles per Transportation Area (VPTA) in the year 2001 to 33872.81 VPTA in the year 2031 AD and congestion level would be increased from 1.25 in the year 2001 to 5.37 in the year 2031 AD.

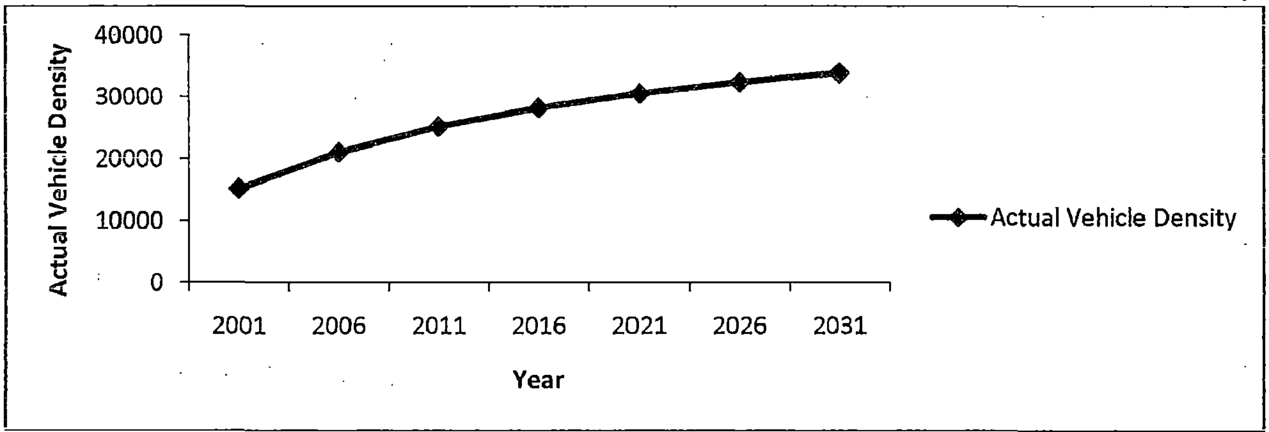


Fig. No. 5.34: Projected Actual Vehicle Density in the Study Area in the Year 2031 A.D.

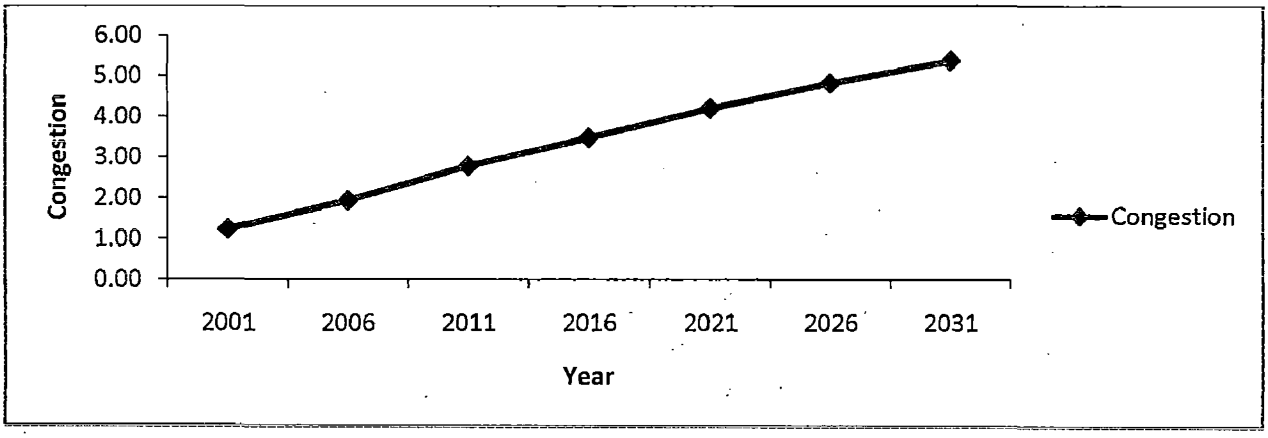


Fig. No. 5.35: Projected Congestion in the Study Area in the Year 2031 A.D.

Table No. 5.27: Projected Vehicular Density and Congestion in the Study Area in the Year 2031 A.D.

Sl. No.	Year	Transportation Area in Sq. km	Actual Vehicle Density in Vehicles per Transportation Area	Total No. of Trips per Day	No. of Acceptable Trips	Congestion
1	2001	108.68	15209	4891405	3000000	1.25
2	2006	117.73	21054	5903108	3000000	1.95
3	2011	127.54	25201	7124066	3000000	2.79
4	2016	138.16	28232	8597558	3000000	3.48
5	2021	149.66	30532	10375817	3000000	4.20
6	2026	162.13	32356	12521878	3000000	4.82
7	2031	175.63	33872	15111815	3000000	5.37

5.11.9. Projected Total Fuel Consumption in the Study Area in the Year 2031 A.D.

The results of total fuel consumption of vehicles in the study area are presented in Table 5.28 and in Fig. 5.36. It is observed from the model result that the two-wheeler fuel consumption would be increased from 198156365 litres per year in the year 2001 to 713189917 litres per year in the year 2031 AD; three-wheeler fuel consumption would be increased from 68729910 litres per year in the year 2001 to 247367674 litres per year in the year 2031 AD; car fuel consumption would be increased from 134398216 litres per year in the year 2001 to 472247378 litres per year in the year 2031 AD; bus fuel consumption would be increased from 51059728 litres per year in the year 2001 to 315035048 litres per year in the year 2031 AD; other vehicles fuel consumption would be increased 414331273 litres per year in the year 2001 to 1345637312 litres per year in the year 2031 AD. Total fuel consumption of vehicles in the study area would be increased from 866675493 litres per year in the year 2001 to 3093477329 litres per year in the year 2031 AD.

5.11.10. Projected Fossil Fuel Consumption in the Study Area in the Year 2031 A.D.

The results of diesel and petrol consumption in the study area are presented in Table 5.29 and in Fig. 5.37. It is observed from the model result that the diesel consumption in the study area would be increased from 182001854 litres per year in the year 2001 to 649630239 litres per year in the year 2031 AD and the petrol consumption in the study area would be increased from 684673640 litres per year in the year 2001 to 3093477329 litres per year in the year 2031 AD.

Table No. 5.28: Projected Total Fuel Consumption in the Study Area in the Year 2031 A.D.

Sl. No.	Year	Fossil Fuel Consumption in Litres per Year					
		Two-wheeler Fuel	Three-wheeler Fuel	Car Fuel	Bus Fuel	Other Vehicles Fuel	Total Fuel
1	2001	198,156,365	68,729,910	134,398,216	51,059,728	414,331,273	866,675,493
2	2006	297,159,371	103,068,791	196,767,692	76,570,221	652,590,536	1,326,156,611
3	2011	385,312,146	133,644,303	255,139,124	170,202,673	727,001,865	1,671,300,110
4	2016	467,599,948	162,185,568	309,626,993	206,551,394	882,261,403	2,028,225,306
5	2021	547,806,716	190,005,032	362,736,880	241,980,868	1,033,594,474	2,376,123,970
6	2026	628,879,102	218,124,733	416,419,946	277,792,707	1,186,560,779	2,727,777,267
7	2031	713,189,917	247,367,674	472,247,378	315,035,048	1,345,637,312	3,093,477,329

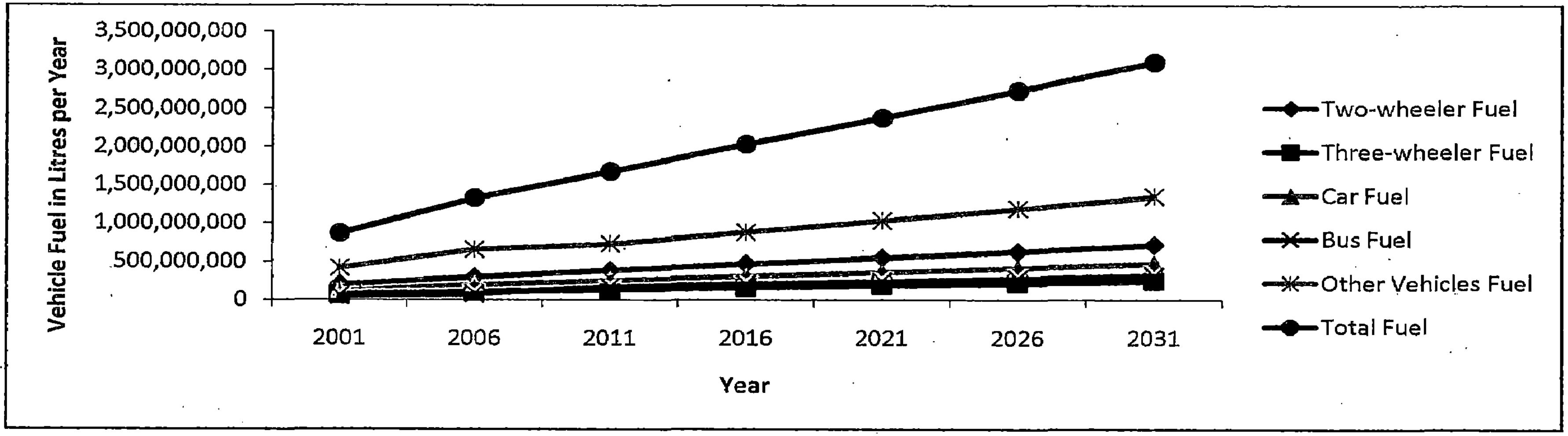


Fig. No. 5.36: Projected Total Fuel Consumption in the Study Area in the Year 2031 A.D.

Table No. 5.29: Projected Fossil Fuel Consumption in the Study Area in the Year 2031 A.D.

Sl. No.	Year	Fossil Fuel Consumption in Litres per Year		
		Diesel Per Year	Petrol Per Year	Total Fuel Per Year
1	2001	182,001,854	684,673,640	866,675,493
2	2006	278,492,888	1,047,663,723	1,326,156,611
3	2011	350,973,023	1,320,327,087	1,671,300,110
4	2016	425,927,314	1,602,297,992	2,028,225,306
5	2021	498,986,034	1,877,137,936	2,376,123,970
6	2026	572,833,226	2,154,944,041	2,727,777,267
7	2031	649,630,239	2,443,847,090	3,093,477,329

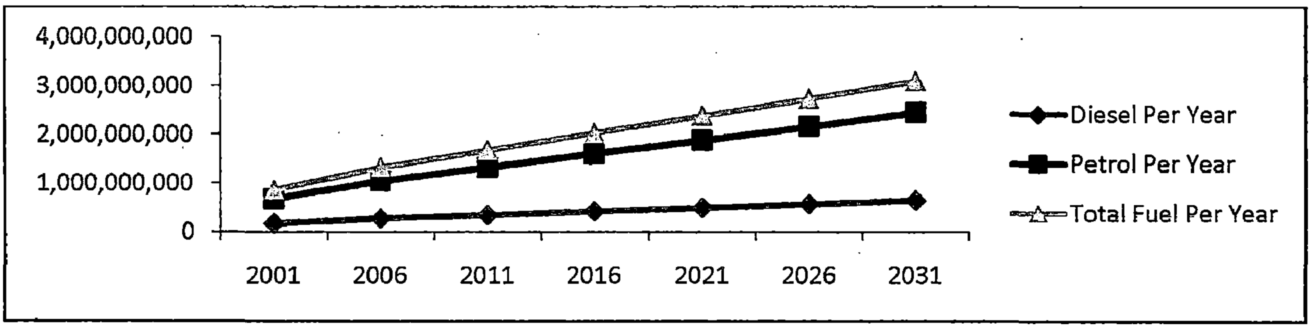


Fig. No. 5.37: Projected Fossil Fuel Consumption in the Study Area in the Year 2031 A.D.

5.11.11. Projected Vehicular Emission Load in the Study Area in the Year 2031 A.D.

The results of vehicular emission load in the study area are presented in Table 5.30 and in Fig. 5.38. It is observed from the model result that the two-wheeler emission load would be increased from 66843 tonnes per year in the year 2001 to 240577 tonnes per year in the year 2031 AD; three-wheeler emission load would be increased from 60863 tonnes per day in the year 2001 to 219055 tonnes per year in the year 2031 AD; car emission load would be increased from 16589 tonnes per year in the year 2001 to 58289 tonnes per year in the year 2031 AD; bus emission load would be increased from 586 tonnes per year in the year 2001 to 3617 tonnes per year in the year 2031 AD; other vehicles emission load would be increased from 30170 tonnes per year in the year 2001 to 97983 tonnes per year in the year 2031 AD; total vehicular emission load would be increased from 175051 tonnes per year in the year 2001 to 619521 tonnes per year in the year 2031 AD.

Table No. 5.30: Projected Vehicular Emission Load in the Study Area in the Year 2031 A.D.

Sl. No.	Year	Pollution Load in Tonnes per Year					
		Two-wheeler Emission Load	Three-wheeler Emission Load	Car Emission Load	Bus Emission Load	Other Vehicles Emission Load	Total Emission Load
1	2001	66843	60863	16589	586	30170	175051
2	2006	100239	91272	24287	879	47519	264196
3	2011	129975	118348	31491	1954	52937	334706
4	2016	157733	143623	38217	2371	64242	406186
5	2021	184789	168258	44772	2778	75262	475859
6	2026	212137	193159	51398	3189	86400	546283
7	2031	240577	219055	58289	3617	97983	619521

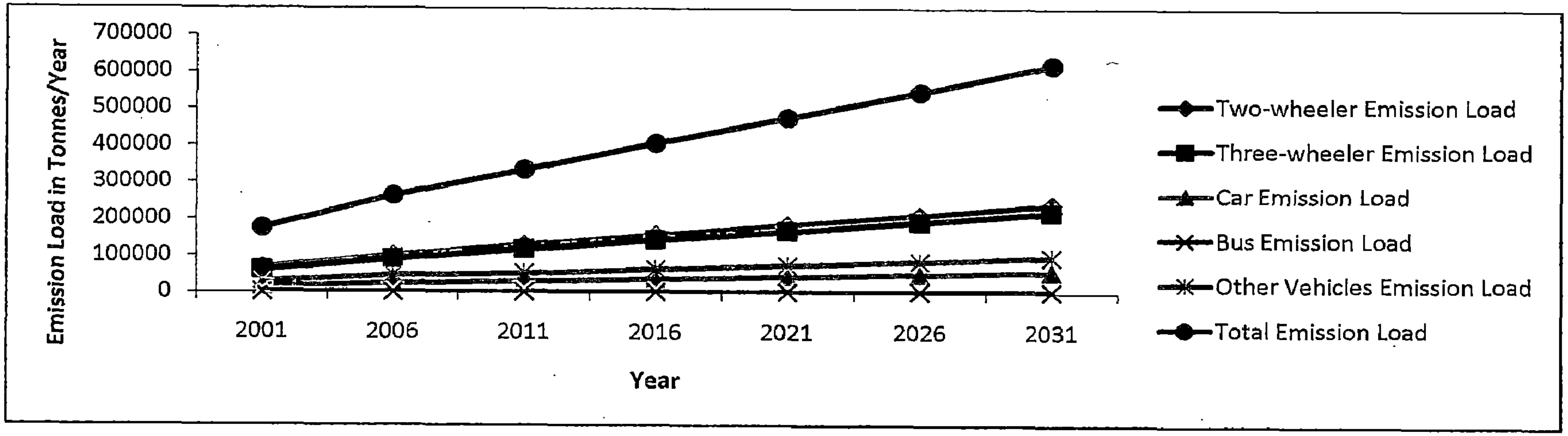


Fig. No. 5.38: Projected Vehicular Emission Load in the Study Area in the Year 2031 A.D.

5.12. SUMMARY RESULT

The results of the various socio-economic, transport characteristics of the study area have been summarized and presented in Table 5.31. The indicators considered for analysis are vehicle ownership, transportation area, vehicular population, vehicular pollution load, fuel consumption of vehicles, modal split, total travel demand and congestion. The Table reveals that the total vehicles in the study area would be increased by 259.91 per cent in the projected year 2031 AD from the base year 2001. The total trips in the study area would be increased by 208.95 per cent in the projected year 2031 AD from the base year 2001. The total emission load from vehicular population in the study area would be increased by 253.91 per cent in the projected year 2031 AD from the base year 2001. The total fuel consumption from the vehicles in the study area would be increased by 256.94 per cent in the projected year 2031 AD from the base year 2001. Diesel consumption and the petrol consumption from the vehicles in the study area would be increased by 256.94 per cent and 256.94 per cent respectively in the projected year 2031 AD from the base year 2001. The total travel demand in the study area would be increased by 247.06 MPK in the projected year 2031 AD from the base year 2001. The actual vehicle density and the congestion in the study area would be increased by 122.71 and 329.60 per cent in the projected year 2031 AD from the base year respectively.

Table No. 5.31: Summary Results

Sl. No.	Year	Population	Per cent Increase over year 2001	Area in Sq. km	Per cent Increase over year 2001	Population Density in Persons /Sq.km	Per cent Increase over year 2001	No. of Households	Per cent Increase over year 2001
1	2	3	4	5	6	7	8	9	10
1	2001	5,757,020	-	534.08	-	10779.32	-	1,290,812	-
2	2006	6,395,662	11.09	578.56	8.33	11054.41	2.55	1,434,005	11.09
3	2011	7,105,150	23.42	626.75	17.35	11336.52	5.17	1,593,083	23.42
4	2016	7,893,343	37.11	678.95	27.13	11625.83	7.85	1,769,808	37.11
5	2021	8,768,973	52.32	735.50	37.71	11922.52	10.61	1,966,137	52.32
6	2026	9,741,739	69.21	796.75	49.18	12226.79	13.43	2,184,246	69.21
7	2031	10,822,416	87.99	863.11	61.61	12538.82	16.32	2,426,551	87.99

Table No. 5.31: Summary Results

Sl. No.	Year	No. of Household Vehicle Ownership	Per cent Increase over year 2001	Reside-ntial Area in Sq. km	Per cent Increase over year 2001	Parks & Playgrounds Area in Sq. km	Per cent Increase over year 2001	Transpor-tation Area in Sq. km	Per cent Increase over year 2001
1	2	11	12	13	14	15	16	17	18
1	2001	263,213	-	159.76	-	21.32	-	108.68	-
2	2006	440,701	67.43	266.39	66.74	21.83	2.39	108.74	0.06
3	2011	737,871	180.33	327.46	104.97	23.46	10.04	116.47	7.17
4	2016	1,235,429	369.36	374.06	134.14	25.68	20.45	132.32	21.75
5	2021	1,966,137	646.98	417.87	161.56	28.29	32.69	149.46	37.52
6	2026	2,184,246	729.84	463.47	190.10	31.24	46.53	167.27	53.91
7	2031	2,426,551	821.90	512.82	220.99	34.51	61.87	185.88	71.03

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Table No. 5.31: Summary Results

Sl. No.	Year	No. of Two-wheelers	Per cent Increase over year 2001	No. of Three-wheelers	Per cent Increase over year 2001	No. of Cars	Per cent Increase over year 2001	No. of Buses	Per cent Increase over year 2001
1	2	19	20	21	22	23	24	25	26
1	2001	1,223,187	-	57,853	-	237,034	-	3,008	-
2	2006	1,834,317	49.96	86,758	49.96	347,033	46.41	4,511	49.96
3	2011	2,378,470	94.45	112,495	94.45	449,981	89.84	10,028	233.34
4	2016	2,886,419	135.98	136,520	135.98	546,079	130.38	12,170	304.53
5	2021	3,381,523	176.45	159,937	176.45	639,748	169.90	14,257	373.92
6	2026	3,881,970	217.37	183,607	217.37	734,427	209.84	16,367	444.05
7	2031	4,402,407	259.91	208,222	259.91	832,888	251.38	18,562	516.99

Table No. 5.31: Summary Results

Sl. No.	Year	No. of Other Vehicles	Per cent Increase over year 2001	Total No. of Vehicles	Per cent Increase over year 2001	No. of Bicycle Trips	Per cent Increase over year 2001	No. of Two-wheeler Trips	Per cent Increase over year 2001
1	2	27	28	29	30	31	32	33	34
1	2001	111,740	-	1,652,956	-	97,828	-	1,412,127	-
2	2006	175,995	57.50	2,478,807	49.96	118,062	20.68	1,812,429	28.35
3	2011	196,063	75.46	3,214,149	94.45	142,481	45.64	2,303,596	63.13
4	2016	237,935	112.94	3,900,567	135.98	171,951	75.77	2,911,070	106.15
5	2021	278,747	149.46	4,569,626	176.45	207,516	112.12	3,667,288	159.70
6	2026	320,000	186.38	5,245,905	217.37	250,438	156.00	4,613,800	226.73
7	2031	362,901	224.77	5,949,199	259.91	302,236	208.95	5,804,028	311.01

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Table No. 5.31: Summary Results

Sl. No.	Year	No. of Three-wheeler Trips	Per cent Increase over year 2001	No. of Car Trips	Per cent Increase over year 2001	No. of Bus Trips	Per cent Increase over year 2001	Total No. Trips	Per cent Increase over year 2001
1	2	35	36	37	38	39	40	41	42
1	2001	316,963	-	240,657	-	1,927,214	-	4,891,405	-
2	2006	387,042	22.11	290,433	20.68	2,325,825	20.68	5,903,109	20.68
3	2011	478,898	51.09	352,545	46.49	2,890,090	49.96	7,124,067	45.64
4	2016	601,296	89.71	440,279	82.95	3,559,632	84.70	8,597,558	75.77
5	2021	753,397	137.69	548,132	127.76	4,421,258	129.41	10,375,817	112.12
6	2026	929,409	193.22	687,006	185.47	5,426,270	181.56	12,521,878	156.00
7	2031	1,128,345	255.99	866,329	259.98	6,606,608	242.81	15,111,816	208.95

Table No. 5.31: Summary Results

Sl. No.	Year	Bicycle Demand	Per cent Increase over year 2001	Two-wheeler Demand	Per cent Increase over year 2001	Three-wheeler Demand	Per cent Increase over year 2001	Car Demand	Per cent Increase over year 2001
1	2	43	44	45	46	47	48	49	50
1	2001	0.44		19.06		38.04		6.50	
2	2006	0.53	20.45	24.47	28.38	46.45	22.11	7.84	20.62
3	2011	0.64	25.00	31.10	63.17	57.47	51.08	9.52	46.46
4	2016	0.77	29.55	39.30	106.19	72.16	89.70	11.89	82.92
5	2021	0.93	36.36	49.51	159.76	90.41	137.67	14.80	127.69
6	2026	1.13	45.45	62.29	226.81	111.53	193.19	18.55	185.38
7	2031	1.36	52.27	78.35	311.07	135.40	255.94	23.39	259.85

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Table No. 5.31: Summary Results

Sl. No.	Year	Bus Demand	Per cent Increase over year 2001	Total Travel Demand	Per cent Increase over year 2001	Actual Vehicle Density	Per cent Increase over year 2001	Congestion	Per cent Increase over year 2001
1	**2**	**51**	**52**	**53**	**54**	**55**	**56**	**57**	**58**
1	2001	381.59		445.63		15209		1.25	
2	2006	460.51	20.68	539.80	21.13	21055	38.43	1.95	56.00
3	2011	572.24	49.96	670.96	50.56	25202	65.70	2.79	123.20
4	2016	704.81	84.70	828.92	86.01	28233	85.63	3.48	178.40
5	2021	875.41	129.41	1031.06	131.37	30532	100.75	4.20	236.00
6	2026	1074.40	181.56	1267.89	184.52	32356	112.74	4.82	285.60
7	2031	1308.11	242.81	1546.62	247.06	33873	122.71	5.37	329.60

Table No. 5.31: Summary Results

Sl. No.	Year	Air Quality	Per cent Increase over year 2001	Two-wheeler Fuel	Per cent Increase over year 2001	Three-wheeler Fuel	Per cent Increase over year 2001	Car Fuel	Per cent Increase over year 2001
1	**2**	**59**	**60**	**61**	**62**	**63**	**64**	**65**	**66**
1	2001	51.38		198,156,365		68,729,910		134,398,216	
2	2006	47.12	-8.29	297,159,371	49.96	103,068,791	49.96	196,767,692	46.41
3	2011	45.65	-11.15	385,312,146	94.45	133,644,303	94.45	255,139,124	89.84
4	2016	45.15	-12.13	467,599,948	135.98	162,185,568	135.98	309,626,993	130.38
5	2021	44.99	-12.44	547,806,716	176.45	190,005,032	176.45	362,736,880	169.90
6	2026	44.94	-12.53	628,879,102	217.37	218,124,733	217.37	416,419,946	209.84
7	2031	44.92	-12.57	713,189,917	259.91	247,367,674	259.91	472,247,378	251.38

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Table No. 5.31: Summary Results

Sl. No.	Year	Bus Fuel	Per cent Increase over year 2001	Other Vehicles Fuel	Per cent Increase over year 2001	Total Fuel	Per cent Increase over year 2001	Diesel Per Year	Per cent Increase over year 2001
1	2	67	68	69	70	71	72	73	74
1	2001	51,059,728		414,331,273		866,675,493		182,001,854	
2	2006	76,570,221	49.96	652,590,536	57.50	1,326,156,611	53.02	278,492,888	53.02
3	2011	170,202,673	233.34	727,001,865	75.46	1,671,300,110	92.84	350,973,023	92.84
4	2016	206,551,394	304.53	882,261,403	112.94	2,028,225,306	134.02	425,927,314	134.02
5	2021	241,980,868	373.92	1,033,594,474	149.46	2,376,123,970	174.17	498,986,034	174.17
6	2026	277,792,707	444.05	1,186,560,779	186.38	2,727,777,267	214.74	572,833,226	214.74
7	2031	315,035,048	516.99	1,345,637,312	224.77	3,093,477,329	256.94	649,630,239	256.94

Table No. 5.31: Summary Results

Sl. No.	Year	Petrol Per Year	Per cent Increase over year 2001	Total Fuel Per Year	Per cent Increase over year 2001	Two-wheeler Emission Load	Per cent Increase over year 2001	Three-wheeler Emission Load	Per cent Increase over year 2001
1	2	75	76	77	78	79	80	81	82
1	2001	684,673,640		866,675,493		66843		60863	
2	2006	1,047,663,723	53.02	1,326,156,611	53.02	100239	-99.98	91272	-99.99
3	2011	1,320,327,087	92.84	1,671,300,110	92.84	129975	-99.97	118348	-99.99
4	2016	1,602,297,992	134.02	2,028,225,306	134.02	157733	-99.96	143623	-99.98
5	2021	1,877,137,936	174.17	2,376,123,970	174.17	184789	-99.96	168258	-99.98
6	2026	2,154,944,041	214.74	2,727,777,267	214.74	212137	-99.95	193159	-99.98
7	2031	2,443,847,090	256.94	3,093,477,329	256.94	240577	-99.94	219055	-99.97

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Table No. 5.31: Summary Results

Sl. No.	Year	Car Emission Load	Per cent Increase over year 2001	Bus Emission Load	Per cent Increase over year 2001	Other Vehicles Emission Load	Per cent Increase over year 2001	Total Emission Load	Per cent Increase over year 2001
1	**2**	**83**	**84**	**85**	**86**	**87**	**88**	**89**	**90**
1	2001	16589		586		30170		175051	
2	2006	24287	-99.99	879	49.96	47519	57.50	264196	50.93
3	2011	31491	-99.98	1954	233.34	52937	75.46	334706	91.20
4	2016	38217	-99.98	2371	304.53	64242	112.94	406186	132.04
5	2021	44772	-99.98	2778	373.91	75262	149.46	475859	171.84
6	2026	51398	-99.97	3189	444.05	86400	186.38	546283	212.07
7	2031	58289	-99.97	3617	516.99	97983	224.77	619521	253.91

5.13: SCENARIOS

A set of plausible scenarios are generated based on the prevailing trend in the system, aspirations of the local people, requirements of transportation subsystem in the system, and experts opinions in order to arrive at plausible decisions. The following control parameters are considered for developing the scenarios. They are:

1. Reduction in per cent of two-wheelers
2. Reduction in per cent of three-wheelers
3. Reduction in per cent of cars
4. Reduction in per cent of other vehicles
5. Increase in per cent of public transport buses
6. Increase in bicycle trips
7. Increase in transportation area
8. Increase in usage of Battery-powered public transport buses

A good number of policy runs are made by considering the above parameters individually and in combination of them by reducing increasing different per cent of the aforesaid parameters. It is observed that enhancement of individual parameters alone do not influence the transportation system, social capital and ecónomic capital of the system very much. However, a combination of different parameters yielded good results.

The scenarios, tested in this model are presented in Table 5.32. Of which the most important scenarios which yielded good results are presented as below:

5.13.1. Scenario 1: Decrease in two-wheelers by 5.00 per cent, decrease in three-wheelers by 5.00 per cent, decrease in cars by 5.00 per cent, decrease in other vehicles by 5.00 per cent, increase in buses by 1.00 per cent, increase in transportation area by 1.00 per cent and increase in bicycle trips by 1.00 per cent:

The above scenario was tested in the projected year model, and the results are presented in Table 5.32 and in Fig. 5.39 (A) to 5.39 (E). It has been observed from the table and the figure that the two-wheeler trips would decrease from 5804028 in the projected year model 2031 AD to 5704236 (-1.719%); three-wheeler trips would decrease from 1128345 to 1127438 (-0.08%); car trips would decrease from 866329 to 849045 (-1.99%); other vehicle trips would decrease from 404270 to 396225 (-1.99%); bus trips would increase from 6606608 to 6610660 (0.06%) and the total trips would decrease from

15111816 to 14992863 (-0.79%). Bicycle travel demand would increase from 1.36 to 1.37 Million Persons Kilometres /year (0.73%); two-wheeler travel demand would decrease from 78.35 to 77.01 MPK/year (-1.71%); three-wheeler travel demand would decrease from 135.40 to 135.29 MPK/year (-0.08%); car travel demand would decrease from 23.39 to 22.92 MPK/year (-2.00%); bus travel demand would increase from 1308.11 to 1308.91 MPK/year (0.06%) and the total travel demand would decrease from 1546.62 to 1545.51 MPK/year (-0.07%). Vehicle density would decrease from 33873 to 32451 vehicles per transportation area (vehicles per sq. km) (-4.19%) and the vehicle congestion level would decrease from 5.37 to 5.23 (-2.60%). Fuel consumption in two-wheeler would decrease from 713.18 to 677.53 Million Litres/year (-4.99%); fuel consumption in three-wheeler would decrease from 247.36 to 234.99 ML/year (-5.00%); fuel consumption in cars would decrease from 472.24 to 448.13 ML/year (-5.10%); fuel consumption in other vehicles would decrease from 1345.63 to 1278.48 ML/year (-4.99%); fuel consumption in buses would increase from 315.03 to 318.18 ML/year (0.99%) and the total fuel consumption would decrease from 3093.44 to 2957.31 ML/year (-4.40%). Two-wheeler emission load would decrease from 240577 to 228548 t/year (-5.49%); three-wheeler emission load would decrease from 219055 to 208103 t/year (-4.99%); car emission load would decrease from 58289 to 55312 t/year (-5.11%); other emission load would decrease from 97983 to 93094 t/year (-4.98%); bus emission load would increase from 3617 to 3653 t/year (0.99%) and the total emission load would decrease from 619521 to 588710 t/year (-4.97%).

5.13.2. Scenario 2: Decrease in two-wheelers by 10.00 per cent, decrease in three-wheelers by 10.00 per cent, decrease in cars by 10.00 per cent, decrease in other vehicles by 8.00 per cent, increase in buses by 2.00 per cent, increase in transportation area by 2.00 per cent and increase in bicycle trips by 2.00 per cent:

The above scenario was tested in the projected year model, and the results are presented in Table 5.32 and in Fig. 5.40 (A) to 5.40 (E). It has been observed from the table and the figure that the two-wheeler trips would decrease from 5804028 in the projected year model 2031 AD to 5604443 (-3.438%); three-wheeler trips would decrease from 1128345 to 1123293 (-0.45%); car trips would decrease from 866329 to 833453 (-3.79%); other vehicle trips would decrease from 404270 to 388140 (-4.00%); bus trips would increase from 6606608 to 6614505 (0.12%) and the total trips would decrease from 15111816 to 14866070 (-1.63%). Bicycle travel demand would increase from 1.36 to 1.39 Million Persons Kilometres /year (2.21%); two-wheeler travel demand would decrease from 78.35 to 75.66 MPK/year (-3.43%); three-wheeler travel demand would decrease from 135.40 to 134.80 MPK/year (-0.44%); car travel demand would decrease from 23.39 to 22.50 MPK/year (-3.81%); bus travel demand would increase from 1308.11 to 1309.67 MPK/year (0.12%) and the total travel demand would decrease from 1546.62 to 1544.03 MPK/year (-0.07%). Vehicle density would decrease from 33873 to 32451 vehicles per transportation area (vehicles per sq. km) (-4.19%) and the vehicle congestion level would decrease from 5.37 to 5.23 (-2.60%). Fuel consumption in two-wheeler would decrease from 713.18 to 641.87 Million Litres/year (-9.98%); fuel consumption in three-wheeler would decrease from 247.36 to 222.63 ML/year (-9.99%); fuel consumption in cars would decrease from 472.24 to 424.01 ML/year (-10.21%); fuel consumption in other vehicles would decrease from 1345.63 to 1211.20 ML/year (-9.99%); fuel consumption in buses would increase from 315.03 to 321.33 ML/year (1.99%) and the total fuel consumption would decrease from 3093.44 to 2821.04 ML/year (-8.81%). Two-wheeler emission load would decrease from 240577 to 216519 t/year (-10.00%); three-wheeler emission load would decrease from 219055 to 197150 t/year (-9.99%); car emission load would decrease from 58289 to 52335 t/year (-10.21%); other emission load would decrease from 97983to 88204 t/year (-9.98%); bus emission load would increase from 3617 to 3689 t/year (1.99%) and the total emission load would decrease from 619521 to 557897 t/year (-9.94%).

5.13.3. Scenario 3: Decrease in two-wheelers by 15.00 per cent, decrease in three-wheelers by 15.00 per cent, decrease in cars by 15.00 per cent, decrease in other vehicles by 15.00 per cent, increase in buses by 3.00 per cent, increase in transportation area by 3.00 per cent and increase in bicycle trips by 3.00 per cent:

The above scenario was tested in the projected year model, and the results are presented in Table 5.32 and in Fig. 5.41 (A) to 5.41 (E). It has been observed from the table and the figure that the two-wheeler trips would decrease from 5804028 in the projected year model 2031 AD to 5504651 (-5.158%); three-wheeler trips would decrease from 1128345 to 1117119 (-0.99%); car trips would decrease from 866329 to 819626(-

5.39%); other vehicle trips would decrease from 404270 to 382561 (-5.36%); bus trips would increase from 6606608 to 6618351 (0.17%) and the total trips would decrease from 15111816 to 14744544 (-2.43%). Bicycle travel demand would increase from 1.36 to 1.40 Million Persons Kilometres /year (2.94%); two-wheeler travel demand would decrease from 78.35 to 74.31 MPK/year (-5.15%); three-wheeler travel demand would decrease from 135.40 to 134.05 MPK/year (-0.99%); car travel demand would decrease from 23.39 to 22.13 MPK/year (-5.38%); bus travel demand would increase from 1308.11 to 1310.43 MPK/year (0.17%) and the total travel demand would decrease from 1546.62 to 1542.29 MPK/year (-0.28%). Vehicle density would decrease from 33873 to 32143 vehicles per transportation area (vehicles per sq. km) (-5.10%) and the vehicle congestion level would decrease from 5.37 to 5.20 (-3.16%). Fuel consumption in two-wheeler would decrease from 713.18 to 606.21 Million Litres/year (-14.99%); fuel consumption in three-wheeler would decrease from 247.36 to 210.26 ML/year (-14.99%); fuel consumption in cars would decrease from 472.24 to 399.89 ML/year (-15.32%); fuel consumption in other vehicles would decrease from 1345.63 to 1144.86 ML/year (-14.92%); fuel consumption in buses would increase from 315.03 to 324.48 ML/year (2.99%) and the total fuel consumption would decrease from 3093.44 to 2685.70 ML/year (-13.18%). Two-wheeler emission load would decrease from 240577 to 204490 t/year (-15.00%); three-wheeler emission load would decrease from 219055 to 186197 t/year (-14.99%); car emission load would decrease from 58289 to 49358 t/year (-15.32%); other emission load would decrease from 97983 to 83393 t/year (-14.89%); bus emission load would increase from 3617 to 3725 t/year (2.98%) and the total emission load would decrease from 619521 to 527163 t/year (-14.91%).

5.13.4. Scenario 4: Decrease in two-wheelers by 20.00 per cent, decrease in three-wheelers by 20.00 per cent, decrease in cars by 20.00 per cent, decrease in other vehicles by 20.00 per cent, increase in buses by 4.00 per cent, increase in transportation area by 4.00 per cent and increase in bicycle trips by 4.00 per cent:

The above scenario was tested in the projected year model, and the results are presented in Table 5.32 and in Fig. 5.42 (A) to 5.42 (E). It has been observed from the table and the figure that the two-wheeler trips would decrease from 5804028 in the projected year model 2031 AD to 5404858 (-6.877%); three-wheeler trips would decrease from 1128345 to 1105335 (-2.04%); car trips would decrease from 866329 to 805799 (-6.98%); other vehicle trips would decrease from 404270 to 376133 (-6.96%); bus trips would increase from 6606608 to 6622196 (0.24%) and the total trips would decrease from 15111816 to 14628647 (-3.19%). Bicycle travel demand would increase from 1.36 to 1.37 Million Persons Kilometres /year (0.73%); two-wheeler travel demand would decrease from 78.35 to 72.97 MPK/year (-6.86%); three-wheeler travel demand would decrease from 135.40 to 132.64 MPK/year (-2.04%); car travel demand would decrease from 23.39 to 21.76 MPK/year (-6.97%); bus travel demand would increase from 1308.11 to 1311.19 MPK/year (0.23%) and the total travel demand would decrease from 1546.62 to 1539.98 MPK/year (-0.43%). Vehicle density would decrease from 33873 to 31841 vehicles per transportation area (vehicles per sq. km) (-5.99%) and the vehicle congestion level would decrease from 5.37 to 5.17 (-3.72%). Fuel consumption in two-wheeler would decrease from 713.18 to 570.55 Million Litres/year (-19.99%); fuel consumption in three-wheeler would decrease from 247.36 to 197.89 ML/year (-19.99%); fuel consumption in cars would decrease from 472.24 to 375.77 ML/year (-20.42%); fuel consumption in other vehicles would decrease from 1345.63 to 1074.62 ML/year (-20.14%); fuel consumption in buses would increase from 315.03 to 327.63 ML/year (3.99%) and the total fuel consumption would decrease from 3093.44 to 2546.46 ML/year (-17.68%). Two-wheeler emission load would decrease from 240577 to 192461 t/year (-20.00%); three-wheeler emission load would decrease from 219055 to 175244 t/year (-20.00%); car emission load would decrease from 58289 to 46381 t/year (-20.43%); other emission load would decrease from 97983 to 78288 t/year (-20.10%); bus emission load would increase from 3617 to 3761 t/year (3.98%) and the total emission load would decrease from 619521 to 496135 t/year (-19.92%).

5.13.5. Scenario 5: Decrease in two-wheelers by 25.00 per cent, decrease in three-wheelers by 25.00 per cent, decrease in cars by 25.00 per cent, decrease in other vehicles by 25.00 per cent, increase in buses by 5.00 per cent, increase in transportation area by 5.00 per cent and increase in bicycle trips by 5.00 per cent:

The above scenario was tested in the projected year model, and the results are presented in Table 5.32 and in Fig. 5.43 (A) to 5.43 (E). It has been observed from the table and the figure that the two-wheeler trips would decrease from 5804028 in the projected year model 2031 AD to 5305066 (-8.596%); three-wheeler trips would decrease from 1128345 to 1092030 (-2.33%); car trips would decrease from 866329 to 791972 (-8.58%); other vehicle trips would decrease from 404270 to 369624 (-8.57%); bus trips would increase from 6606608 to 6626041 (0.29%) and the total trips would decrease from 15111816 to 14512081 (-3.97%). Bicycle travel demand would increase from 1.36 to 1.43 Million Persons Kilometres /year (5.14%); two-wheeler travel demand would decrease from 78.35 to 71.62 MPK/year (-8.59%); three-wheeler travel demand would decrease from 135.40 to 131.04 MPK/year (-3.22%); car travel demand would decrease from 23.39 to 21.38 MPK/year (-8.59%); bus travel demand would increase from 1308.11 to 1311.96 MPK/year (0.29%) and the total travel demand would decrease from 1546.62 to 1537.43 MPK/year (-0.59%). Vehicle density would decrease from 33873 to 31544 vehicles per transportation area (vehicles per sq. km) (-6.87%) and the vehicle congestion level would decrease from 5.37 to 5.14 (-4.28%). Fuel consumption in two-wheeler would decrease from 713.18 to 534.89 Million Litres/year (-24.99%); fuel consumption in three-wheeler would decrease from 247.36 to 185.52 ML/year (-25.00%); fuel consumption in cars would decrease from 472.24 to 351.66 ML/year (-25.53%); fuel consumption in other vehicles would decrease from 1345.63 to 1002.35 ML/year (-25.51%); fuel consumption in buses would increase from 315.03 to 330.78 ML/year (4.99%) and the total fuel consumption would decrease from 3093.44 to 2405.20 ML/year (-22.24%). Two-wheeler emission load would decrease from 240577 to 180433 t/year (-24.99%); three-wheeler emission load would decrease from 219055 to 164291 t/year (-25.00%); car emission load would decrease from 58289 to 43404 t/year (-25.53%); other emission load would decrease from 97983 to 72987 t/year (-25.51%); bus emission load would increase from 3617 to 3797 t/year (4.98%) and the total emission load would decrease from 619521 to 464912 t/year (-24.95%).

5.13.6. Scenario 6: Decrease in two-wheelers by 30.00 per cent, decrease in three-wheelers by 30.00 per cent, decrease in cars by 30.00 per cent, decrease in other vehicles by 30.00 per cent, increase in buses by 6.00 per cent, increase in transportation area by 6.00 per cent and increase in bicycle trips by 6.00 per cent:

The above scenario was tested in the projected year model, and the results are presented in Table 5.32 and in Fig. 5.44 (A) to 5.44 (E). It has been observed from the table and the figure that the two-wheeler trips would decrease from 5804028 in the projected year model 2031 AD to 5205273 (-10.316%); three-wheeler trips would decrease from 1128345 to 1077526 (-4.50%); car trips would decrease from 866329 to 781573 (-9.78%); other vehicle trips would decrease from 404270 to 364813 (-9.76%); bus trips would increase from 6606608 to 6629886 (0.35%) and the total trips would decrease from 15111816 to 14379441 (-4.84%). Bicycle travel demand would increase from 1.36 to 1.44 Million Persons Kilometres /year (5.88%); two-wheeler travel demand would decrease from 78.35 to 70.27 MPK/year (-10.32%); three-wheeler travel demand would decrease from 135.40 to 129.30 MPK/year (-4.51%); car travel demand would decrease from 23.39 to 21.10 MPK/year (-9.79%); bus travel demand would increase from 1308.11 to 1312.72 MPK/year (0.35%) and the total travel demand would decrease from 1546.62 to 1534.84 MPK/year (-0.76%). Vehicle density would decrease from 33873 to 31254 vehicles per transportation area (vehicles per sq. km) (-7.74%) and the vehicle congestion level would decrease from 5.37 to 5.11 (-4.84%). Fuel consumption in two-wheeler would decrease from 713.18 to 499.23 Million Litres/year (-29.99%); fuel consumption in three-wheeler would decrease from 247.36 to 173.15 ML/year (-30.00%); fuel consumption in cars would decrease from 472.24 to 327.54 ML/year (-30.63%); fuel consumption in other vehicles would decrease from 1345.63 to 940.32 ML/year (-30.12%); fuel consumption in buses would increase from 315.03 to 333.94 ML/year (6.00%) and the total fuel consumption would decrease from 3093.44 to 2274.18 ML/year (-26.48%). Two-wheeler emission load would decrease from 240577 to 168404 t/year (-29.99%); three-wheeler emission load would decrease from 219055 to 153339 t/year (-29.99%); car emission load would decrease from 58289 to 40427 t/year (-30.64%); other emission load would decrease from 97983 to 68412 t/year (-30.18%); bus emission load would increase from 3617 to 3834 t/year (5.99%) and the total emission load would decrease from 619521 to 434416 t/year (-29.88%).

5.13.7. Scenario 7: Decrease in two-wheelers by 35.00 per cent, decrease in three-wheelers by 35.00 per cent, decrease in cars by 35.00 per cent, decrease in other vehicles by 35.00 per cent, increase in buses by 7.00 per cent, increase in transportation area by 7.00 per cent and increase in bicycle trips by 7.00 per cent:

The above scenario was tested in the projected year model, and the results are presented in Table 5.32 and in Fig. 5.45 (A) to 5.45 (E). It has been observed from the table and the figure that the two-wheeler trips would decrease from 5804028 in the projected year model 2031 AD to 5105481 (-12.035%); three-wheeler trips would decrease from 1128345 to 1054126 (-6.57%); car trips would decrease from 866329 to 770362 (-11.07%); other vehicle trips would decrease from 404270 to 359679 (-11.03%); bus trips would increase from 6606608 to 6633732 (0.41%) and the total trips would decrease from 15111816 to 14246773 (-5.74%). Bicycle travel demand would increase from 1.36 to 1.46 Million Persons Kilometres /year (7.35%); two-wheeler travel demand would decrease from 78.35 to 68.92 MPK/year (-12.03 %); three-wheeler travel demand would decrease from 135.40 to 126.50 MPK/year (-6.57%); car travel demand would decrease from 23.39 to 20.80 MPK/year (-11.07%); bus travel demand would increase from 1308.11 to 1313.48 MPK/year (0.41%) and the total travel demand would decrease from 1546.62 to 1531.17 MPK/year (-0.99%). Vehicle density would decrease from 33873 to 30968 vehicles per transportation area (vehicles per sq. km) (-8.57%) and the vehicle congestion level would decrease from 5.37 to 5.08 (-5.40%). Fuel consumption in two-wheeler would decrease from 713.18 to 463.57 Million Litres/year (-34.99%); fuel consumption in three-wheeler would decrease from 247.36 to 160.78 ML/year (-35.00%); fuel consumption in cars would decrease from 472.24 to 303.42 ML/year (-35.74%); fuel consumption in other vehicles would decrease from 1345.63 to 865.11 ML/year (-35.71%); fuel consumption in buses would increase from 315.03 to 337.08 ML/year (6.99%) and the total fuel consumption would decrease from 3093.44 to 2129.96 ML/year (-31.14%). Two-wheeler emission load would decrease from 240577 to 156375 t/year (-35.00%); three-wheeler emission load would decrease from 219055 to 142386 t/year (-34.99%); car emission load would decrease from 58289 to 37451 t/year (-35.75%); other emission load would decrease from 97983 to 62993 t/year (-35.71%); bus emission load would increase from 3617 to 3870 t/year (6.99%) and the total emission load would decrease from 619521 to 403075 t/year (-34.93%).

5.13.8. Scenario 8: Decrease in two-wheelers by 40.00 per cent, decrease in three-wheelers by 40.00 per cent, decrease in cars by 40.00 per cent, decrease in other

vehicles by 40.00 per cent, increase in buses by 8.00 per cent, increase in transportation area by 8.00 per cent and increase in bicycle trips by 8.00 per cent:

The above scenario was tested in the projected year model, and the results are presented in Table 5.32 and in Fig. 5.46 (A) to 5.46 (E). It has been observed from the table and the figure that the two-wheeler trips would decrease from 5804028 in the projected year model 2031 AD to 5005688 (-13.750%); three-wheeler trips would decrease from 1128345 to 1032099 (-8.52%); car trips would decrease from 866329 to 756535 (-12.67%); other vehicle trips would decrease from 404270 to 353251 (-12.62%); bus trips would increase from 6606608 to 6637577 (0.47%) and the total trips would decrease from 15111816 to 14111565 (-6.62%). Bicycle travel demand would increase from 1.36 to 1.47 Million Persons Kilometres /year (8.08%); two-wheeler travel demand would decrease from 78.35 to 67.58 MPK/year (-13.74%); three-wheeler travel demand would decrease from 135.40 to 123.85 MPK/year (-8.53%); car travel demand would decrease from 23.39 to 20.43 MPK/year (-12.65%); bus travel demand would increase from 1308.11 to 1314.24 MPK/year (0.47%) and the total travel demand would decrease from 1546.62 to 1527.56 MPK/year (-1.23%). Vehicle density would decrease from 33873 to 30687 vehicles per transportation area (vehicles per sq. km) (-9.40%) and the vehicle congestion level would decrease from 5.37 to 5.06 (-5.77%). Fuel consumption in two-wheeler would decrease from 713.18 to 427.91 Million Litres/year (-39.99%); fuel consumption in three-wheeler would decrease from 247.36 to 148.42 ML/year (-39.98%); fuel consumption in cars would decrease from 472.24 to 279.30 ML/year (-40.85%); fuel consumption in other vehicles would decrease from 1345.63 to 805.76 ML/year (-40.12%); fuel consumption in buses would increase from 315.03 to 340.23 ML/year (7.99%) and the total fuel consumption would decrease from 3093.44 to 2001.62 ML/year (-35.29%). Two-wheeler emission load would decrease from 240577 to 144346 t/year (-40.00%); three-wheeler emission load would decrease from 219055 to 131433 t/year (-40.00%); car emission load would decrease from 58289 to 34474 t/year (-40.85%); other emission load would decrease from 97983 to 57996 t/year (-40.81%); bus emission load would increase from 3617 to 3906 t/year (7.99%) and the total emission load would decrease from 619521 to 372155 t/year (-39.93%).

5.13.9. Scenario 9: Decrease in two-wheelers by 45.00 per cent, decrease in three-wheelers by 45.00 per cent, decrease in cars by 45.00 per cent, decrease in other vehicles by 45.00 per cent, increase in buses by 9.00 per cent, increase in transportation area by 9.00 per cent and increase in bicycle trips by 9.00 per cent:

The above scenario was tested in the projected year model, and the results are presented in Table 5.32 and in Fig. 5.47 (A) to 5.47 (E). It has been observed from the table and the figure that the two-wheeler trips would decrease from 5804028 in the projected year model 2031 AD to 4905896 (-15.474%); three-wheeler trips would decrease from 1128345 to 1018501 (-9.73%); car trips would decrease from 866329 to 747837 (-13.67%); other vehicle trips would decrease from 404270 to 349248 (-13.61%); bus trips would increase from 6606608 to 6641422 (0.52%) and the total trips would decrease from 15111816 to 13992342 (-7.41%). Bicycle travel demand would increase from 1.36 to 1.48 Million Persons Kilometres /year (8.82%); two-wheeler travel demand would decrease from 78.35 to 66.23 MPK/year (-15.46%); three-wheeler travel demand would decrease from 135.40 to 122.22 MPK/year (-9.73%); car travel demand would decrease from 23.39 to 20.19 MPK/year (-13.68%); bus travel demand would increase from 1308.11 to 1315.00 MPK/year (0.52%) and the total travel demand would decrease from 1546.62 to 1525.13 MPK/year (-1.38%). Vehicle density would decrease from 33873 to 30412 vehicles per transportation area (vehicles per sq. km) (-10.21%) and the vehicle congestion level would decrease from 5.37 to 5.03 (-6.33%). Fuel consumption in two-wheeler would decrease from 713.18 to 392.25 Million Litres/year (-44.99%); fuel consumption in three-wheeler would decrease from 247.36 to 136.05 ML/year (-44.99%); fuel consumption in cars would decrease from 472.24 to 255.18 ML/year (-45.96%); fuel consumption in other vehicles would decrease from 1345.63 to 735.79 ML/year (-45.32%); fuel consumption in buses would increase from 315.03 to 343.38 ML/year (8.99%) and the total fuel consumption would decrease from 3093.44 to 1862.65 ML/year (-39.78%). Two-wheeler emission load would decrease from 240577 to 132317 t/year (-45.00%); three-wheeler emission load would decrease from 219055 to 120480 t/year (-45.00%); car emission load would decrease from 58289 to 31497 t/year (-45.96%); other emission load would decrease from 97983 to 52999 t/year (-45.91%); bus emission load would increase from 3617 to 3942 t/year (8.98%) and the total emission load would decrease from 619521 to 341235 t/year (-44.92%).

5.13.10. Scenario 10: Decrease in two-wheelers by 50.00 per cent, decrease in three-wheelers by 50.00 per cent, decrease in cars by 50.00 per cent, decrease in other vehicles by 50.00 per cent, increase in buses by 10.00 per cent, increase in transportation area by 10.00 per cent and increase in bicycle trips by 10.00 per cent:

The above scenario was tested in the projected year model, and the results are presented in Table 5.32 and in Fig. 5.48 (A) to 5.48 (E). It has been observed from the table and the figure that the two-wheeler trips would decrease from 5804028 in the projected year model 2031 AD to 4806103 (-17.193%); three-wheeler trips would decrease from 1128345 to 1006421 (-10.81%); car trips would decrease from 866329 to 744380 (-14.07%); other vehicle trips would decrease from 404270 to 347632 (-14.00%); bus trips would increase from 6606608 to 6645267 (0.58%) and the total trips would decrease from 15111816 to 13882263 (-8.13%). Bicycle travel demand would increase from 1.36 to 1.50 Million Persons Kilometres /year (10.29%); two-wheeler travel demand would decrease from 78.35 to 64.88 MPK/year (-17.19%); three-wheeler travel demand would decrease from 135.40 to 120.77 MPK/year (-10.81%); car travel demand would decrease from 23.39 to 20.10 MPK/year (-14.06%); bus travel demand would increase from 1308.11 to 1315.76 MPK/year (0.58%) and the total travel demand would decrease from 1546.62 to 1523.01 MPK/year (-1.52%). Vehicle density would decrease from 33873 to 30141 vehicles per transportation area (vehicles per sq. km) (-11.02%) and the vehicle congestion level would decrease from 5.37 to 4.99 (-7.07%). Fuel consumption in two-wheeler would decrease from 713.18 to 356.59 Million Litres/year (-50.00%); fuel consumption in three-wheeler would decrease from 247.36 to 123.68 ML/year (-50.00%); fuel consumption in cars would decrease from 472.24 to 231.06 ML/year (-51.07%); fuel consumption in other vehicles would decrease from 1345.63 to 671.61 ML/year (-50.00%); fuel consumption in buses would increase from 315.03 to 346.54 ML/year (10.00%) and the total fuel consumption would decrease from 3093.44 to 1729.48 ML/year (-44.09%). Two-wheeler emission load would decrease from 240577 to 120288 t/year (-50.00%); three-wheeler emission load would decrease from 219055 to 108529 t/year (-49.99%); car emission load would decrease from 58289 to 28520 t/year (-51.07%); other emission load would decrease from 97983 to 48002 t/year (-51.00%); bus emission load would increase from 3617 to 3978 t/year (9.07%) and the total emission load would decrease from 619521 to 310316 t/year (-49.91%).

5.13.11. *Scenario* 11: Decrease in two-wheelers by 55.00 per cent, decrease in three-wheelers by 55.00 per cent, decrease in cars by 55.00 per cent, decrease in other vehicles by 55.00 per cent, increase in buses by 11.00 per cent, increase in transportation area by 11.00 per cent and increase in bicycle trips by 11.00 per cent:

The above scenario was tested in the projected year model, and the results are presented in Table 5.32 and in Fig. 5.49 (A) to 5.49 (E). It has been observed from the table and the figure that the two-wheeler trips would decrease from 5804028 in the projected year model 2031 AD to 4706310 (-18.913%); three-wheeler trips would decrease from 1128345 to 995543 (-11.76%); car trips would decrease from 866329 to 743501 (-14.17%); other vehicle trips would decrease from 404270 to 347268 (-14.09%); bus trips would increase from 6606608 to 6649113 (0.64%) and the total trips would decrease from 15111816 to 13777217 (-8.83%). Bicycle travel demand would increase from 1.36 to 1.51 Million Persons Kilometres /year (11.03%); two-wheeler travel demand would decrease from 78.35 to 63.54 MPK/year (-18.90%); three-wheeler travel demand would decrease from 135.40 to 119.47 MPK/year (-11.76%); car travel demand would decrease from 23.39 to 20.07 MPK/year (-14.19%); bus travel demand would increase from 1308.11 to 1316.52 MPK/year (0.64%) and the total travel demand would decrease from 1546.62 to 1521.11 MPK/year (-1.64%). Vehicle density would decrease from 33873 to 29875 vehicles per transportation area (vehicles per sq. km) (-11.80%) and the vehicle congestion level would decrease from 5.37 to 4.96 (-7.63%). Fuel consumption in two-wheeler would decrease from 713.18 to 320.93 Million Litres/year (-55.00%); fuel consumption in three-wheeler would decrease from 247.36 to 111.31 ML/year (-55.00%); fuel consumption in cars would decrease from 472.24 to 206.94 ML/year (-56.18%); fuel consumption in other vehicles would decrease from 1345.63 to 604.18 ML/year (-55.10%); fuel consumption in buses would increase from 315.03 to 349.69 ML/year (11.00%) and the total fuel consumption would decrease from 3093.44 to 1593.05 ML/year (-48.50%). Two-wheeler emission load would decrease from 240577 to 108260 t/year (-54.99%); three-wheeler emission load would decrease from 219055 to 98575 t/year (-54.99%); car emission load would decrease from 58289 to 25543 t/year (-56.17%); other emission load would decrease from 97983 to 43926 t/year (-55.16%); bus emission load would increase from 3617 to 4014 t/year (10.97%) and the total emission load would decrease from 619521 to 280318 t/year (-54.75%).

5.13.12. Scenario 12: Decrease in two-wheelers by 60.00 per cent, decrease in three-wheelers by 60.00 per cent, decrease in cars by 60.00 per cent, decrease in other vehicles by 60.00 per cent, increase in buses by 12.00 per cent, increase in transportation area by 12.00 per cent and increase in bicycle trips by 12.00 per cent:

The above scenario was tested in the projected year model, and the results are presented in Table 5.32 and in Fig. 5.50 (A) to 5.50 (E). It has been observed from the table and the figure that the two-wheeler trips would decrease from 5804028 in the projected year model 2031 AD to 4606518 (-20.63%); three-wheeler trips would decrease from 1128345 to 988704 (-12.37%); car trips would decrease from 866329 to 742704 (-14.26%); other vehicle trips would decrease from 404270 to 346500 (-14.28%); bus trips would increase from 6606608 to 6652958 (0.70%) and the total trips would decrease from 15111816 to 13675889 (-9.50%). Bicycle travel demand would increase from 1.36 to 1.52 Million Persons Kilometres /year (11.76%); two-wheeler travel demand would decrease from 78.35 to 62.19 MPK/year (-20.62%); three-wheeler travel demand would decrease from 135.40 to 118.64 MPK/year (-12.37%); car travel demand would decrease from 23.39 to 20.03 MPK/year (-14.36%); bus travel demand would increase from 1308.11 to 1317.29 MPK/year (0.70%) and the total travel demand would decrease from 1546.62 to 1519.68 MPK/year (-1.74%). Vehicle density would decrease from 33873 to 29614 vehicles per transportation area (vehicles per sq. km) (-12.58%) and the vehicle congestion level would decrease from 5.37 to 4.98 (-8.38%). Fuel consumption in two-wheeler would decrease from 713.18 to 285.27 Million Litres/year (-60.00%); fuel consumption in three-wheeler would decrease from 247.36 to 98.94 ML/year (-60.00%); fuel consumption in cars would decrease from 472.24 to 182.82 ML/year (-61.28%); fuel consumption in other vehicles would decrease from 1345.63 to 536.63 ML/year (-60.12%); fuel consumption in buses would increase from 315.03 to 352.84 ML/year (12.00%) and the total fuel consumption would decrease from 3093.44 to 1456.50

ML/year (-52.92%). Two-wheeler emission load would decrease from 240577 to 96231 t/year (-59.99%); three-wheeler emission load would decrease from 219055 to 87622 t/year (-60.00%); car emission load would decrease from 58289 to 22566 t/year (-61.28%); other emission load would decrease from 97983 to 39203 t/year (-59.99%); bus emission load would increase from 3617 to 4051 t/year (11.99%) and the total emission load would decrease from 619521 to 249673 t/year (-59.69%).

5.13.13. Scenario 13: Decrease in two-wheelers by 65.00 per cent, decrease in three-wheelers by 65.00 per cent, decrease in cars by 65.00 per cent, decrease in other vehicles by 65.00 per cent, increase in buses by 13.00 per cent, increase in transportation area by 13.00 per cent and increase in bicycle trips by 13.00 per cent:

The above scenario was tested in the projected year model, and the results are presented in Table 5.32 and in Fig. 5.51 (A) to 5.51 (E). It has been observed from the table and the figure that the two-wheeler trips would decrease from 5804028 in the projected year model 2031 AD to 4506725 (-22.35%); three-wheeler trips would decrease from 1128345 to 983170 (-12.86%); car trips would decrease from 866329 to 741750 (-14.38%); other vehicle trips would decrease from 404270 to 346095 (-14.39%); bus trips would increase from 6606608 to 6656803 (0.76%) and the total trips would decrease from 15111816 to 13576070 (-10.16%). Bicycle travel demand would increase from 1.36 to 1.54 Million Persons Kilometres /year (13.23%); two-wheeler travel demand would decrease from 78.35 to 60.84 MPK/year (-22.34%); three-wheeler travel demand would decrease from 135.40 to 117.98 MPK/year (-12.86%); car travel demand would decrease from 23.39 to 20.00 MPK/year (-14.49%); bus travel demand would increase from 1308.11 to 1318.05 MPK/year (0.75%) and the total travel demand would decrease from 1546.62 to 1518.48 MPK/year (-1.82%). Vehicle density would decrease from 33873 to 29357 vehicles per transportation area (vehicles per sq. km) (-13.33%) and the vehicle congestion level would decrease from 5.37 to 4.89 (-8.94%). Fuel consumption in two-wheeler would decrease from 713.18 to 249.62 Million Litres/year (-64.99%); fuel consumption in three-wheeler would decrease from 247.36 to 86.58 ML/year (-64.99%); fuel consumption in cars would decrease from 472.24 to 158.71 ML/year (-66.39%); fuel consumption in other vehicles would decrease from 1345.63 to 468.41 ML/year (-

65.19%); fuel consumption in buses would increase from 315.03 to 355.98 ML/year (12.99%) and the total fuel consumption would decrease from 3093.44 to 1319.30 ML/year (-57.36%). Two-wheeler emission load would decrease from 240577 to 84202 t/year (-64.99%); three-wheeler emission load would decrease from 219055 to 76669 t/year (-65.00%); car emission load would decrease from 58289 to 19589 t/year (-66.36%); other emission load would decrease from 97983 to 34196t/year (-65.10%); bus emission load would increase from 3617 to 4087 t/year (12.99%) and the total emission load would decrease from 619521 to 218743 t/year (-64.69%).

5.13.14. Scenario 14: Decrease in two-wheelers by 70.00 per cent, decrease in three-wheelers by 70.00 per cent, decrease in cars by 70.00 per cent, decrease in other vehicles by 70.00 per cent, increase in buses by 14.00 per cent, increase in transportation area by 14.00 per cent and increase in bicycle trips by 14.00 per cent:

The above scenario was tested in the projected year model, and the results are presented in Table 5.32 and in Fig. 5.52 (A) to 5.52 (E). It has been observed from the table and the figure that the two-wheeler trips would decrease from 5804028 in the projected year model 2031 AD to 4406933 (-24.07%); three-wheeler trips would decrease from 1128345 to 980451 (-13.11%); car trips would decrease from 866329 to 740798 (-14.49%); other vehicle trips would decrease from 404270 to 345610 (-14.51%); bus trips would increase from 6606608 to 6660648 (0.82%) and the total trips would decrease from 15111816 to 13478989 (-10.80%). Bicycle travel demand would increase from 1.36 to 1.55 Million Persons Kilometres /year (13.97%); two-wheeler travel demand would decrease from 78.35 to 59.49 MPK/year (-24.07%); three-wheeler travel demand would decrease from 135.40 to 117.65 MPK/year (-13.11%); car travel demand would decrease from 23.39 to 19.97 MPK/year (-14.59%); bus travel demand would increase from 1308.11 to 1318.81 MPK/year (0.82%) and the total travel demand would decrease from 1546.62 to 1517.48 MPK/year (-1.88%). Vehicle density would decrease from 33873 to 29105 vehicles per transportation area (vehicles per sq. km) (-14.07%) and the vehicle congestion level would decrease from 5.37 to 4.85 (-9.68%). Fuel consumption in two-wheeler would decrease from 713.18 to 213.95 Million Litres/year (-70.00%); fuel consumption in three-wheeler would decrease from 247.36 to 74.21 ML/year (-69.99%);

fuel consumption in cars would decrease from 472.24 to 134.59 ML/year (-71.49%); fuel consumption in other vehicles would decrease from 1345.63 to 388.88 ML/year (-71.10%); fuel consumption in buses would increase from 315.03 to 359.14 ML/year (14.00%) and the total fuel consumption would decrease from 3093.44 to 1170.77 ML/year (-62.15%). Two-wheeler emission load would decrease from 240577 to 72173 t/year (-70.00%); three-wheeler emission load would decrease from 219055 to 65717 t/year (-69.99%); car emission load would decrease from 58289 to 16612 t/year (-71.50%); other emission load would decrease from 97983 to 29169 t/year (-70.23%); bus emission load would increase from 3617 to 4123 t/year (13.98%) and the total emission load would decrease from 619521 to 187794 t/year (-69.68%).

5.13.15. Scenario 15: Decrease in two-wheelers by 75.00 per cent, decrease in three-wheelers by 75.00 per cent, decrease in cars by 75.00 per cent, decrease in other vehicles by 75.00 per cent, increase in buses by 15.00 per cent, increase in transportation area by 15.00 per cent and increase in bicycle trips by 15.00 per cent:

The above scenario was tested in the projected year model, and the results are presented in Table 5.32 and in Fig. 5.53 (A) to 5.53 (E). It has been observed from the table and the figure that the two-wheeler trips would decrease from 5804028 in the projected year model 2031 AD to 4307140 (-25.79%); three-wheeler trips would decrease from 1128345 to 979246 (-13.21%); car trips would decrease from 866329 to 849045 (-14.18%); other vehicle trips would decrease from 404270 to 346904 (-14.19%); bus trips would increase from 6606608 to 6664494 (0.87%) and the total trips would decrease from 15111816 to 13388857 (-11.40%). Bicycle travel demand would increase from 1.36 to 1.56 Million Persons Kilometres /year (14.70%); two-wheeler travel demand would decrease from 78.35 to 58.15 MPK/year (-25.78%); three-wheeler travel demand would decrease from 135.40 to 117.51 MPK/year (-13.21%); car travel demand would decrease from 23.39 to 19.95 MPK/year (-14.19%); bus travel demand would increase from 1308.11 to 1319.57 MPK/year (0.87%) and the total travel demand would decrease from 1546.62 to 1516.75 MPK/year (-1.93%). Vehicle density would decrease from 33873 to 28857 vehicles per transportation area (vehicles per sq. km) (-14.81%) and the vehicle congestion level would decrease from 5.37 to 4.82 (-2.60%). Fuel consumption in two-wheeler would decrease from 713.18 to 178.29 Million Litres/year (-75.00%); fuel consumption in three-wheeler would decrease from 247.36 to 61.84 ML/year (-75.00%); fuel consumption in cars would decrease from 472.24 to 110.47 ML/year (-76.60%); fuel consumption in other vehicles would decrease from 1345.63 to 333.31 ML/year (-75.23%); fuel consumption in buses would increase from 315.03 to 362.29 ML/year (15.00%) and the total fuel consumption would decrease from 3093.44 to 1046.20 ML/year (-66.18%). Two-wheeler emission load would decrease from 240577 to 60144 t/year (-75.00%); three-wheeler emission load would decrease from 219055 to 54764 t/year (-74.99%); car emission load would decrease from 58289 to 13635 t/year (-76.60%); other emission load would decrease from 97983 to 24182 t/year (-75.32%); bus emission load would increase from 3617 to 4159 t/year (14.98%) and the total emission load would decrease from 619521 to 156884 t/year (-74.67%).

5.13.16. Scenario 16: Decrease in two-wheelers by 80.00 per cent, decrease in three-wheelers by 80.00 per cent, decrease in cars by 80.00 per cent, decrease in other vehicles by 80.00 per cent, increase in buses by 16.00 per cent, increase in transportation area by 16.00 per cent and increase in bicycle trips by 16.00 per cent:

The above scenario was tested in the projected year model, and the results are presented in Table 5.32 and in Fig. 5.54 (A) to 5.54 (E). It has been observed from the table and the figure that the two-wheeler trips would decrease from 5804028 in the projected year model 2031 AD to 4207348 (-27.51%); three-wheeler trips would decrease from 1128345 to 977824 (-13.34%); car trips would decrease from 866329 to 745043 (-14.00%); other vehicle trips would decrease from 404270 to 347672 (-14.00%); bus trips would increase from 6606608 to 6668339 (0.94%) and the total trips would decrease from 15111816 to 13296820 (-12.01%). Bicycle travel demand would increase from 1.36 to 1.58 Million Persons Kilometres /year (16.17%); two-wheeler travel demand would decrease from 78.35 to 56.80 MPK/year (-27.50%); three-wheeler travel demand would decrease from 135.40 to 117.37 MPK/year (-13.31%); car travel demand would decrease from 23.39 to 20.07 MPK/year (-14.19%); bus travel demand would increase from 1308.11 to 1320.33 MPK/year (0.93%) and the total travel demand would decrease from 1546.62 to 1516.16 MPK/year (-1.96%). Vehicle density would decrease from 33873 to

28613 vehicles per transportation area (vehicles per sq. km) (-15.52%) and the vehicle congestion level would decrease from 5.37 to 4.79 (-10.80%). Fuel consumption in two-wheeler would decrease from 713.18 to 14.63 Million Litres/year (-80.00%); fuel consumption in three-wheeler would decrease from 247.36 to 49.47 ML/year (-80.00%); fuel consumption in cars would decrease from 472.24 to 86.35 ML/year (-81.71%); fuel consumption in other vehicles would decrease from 1345.63 to 267.78 ML/year (-80.10%); fuel consumption in buses would increase from 315.03 to 365.44 ML/year (16.00%) and the total fuel consumption would decrease from 3093.44 to 911.67 ML/year (-70.52%). Two-wheeler emission load would decrease from 240577 to 48115 t/year (-80.00%); three-wheeler emission load would decrease from 219055 to 43811 t/year (-80.00%); car emission load would decrease from 58289 to 10659 t/year (-81.71%); other emission load would decrease from 97983 to 19596 t/year (-80.00%); bus emission load would increase from 3617 to 4195 t/year (15.98%) and the total emission load would decrease from 619521 to 126376 t/year (-79.60%).

5.13.17. Scenario 17: Nine Scenarios were tested for public transport buses conversion from diesel driven vehicles into battery-powered operated in the study area i.e., from 10.00 to 90.00 per cent.

The above said scenarios were tested in the projected year model one by one and the results are presented in Table 5.33. It has been observed that conversion of public transport buses by 10.00 per cent result into in fuel consumption in buses would decrease from 315.03 ML/year in the projected year model 2031 A.D. to 283.53 ML/year (1.02% to total); emission load per year would decrease from 3617 to 3255 t/year (0.058% to total); The conversion of public transport buses by 20.00 per cent results into fuel consumption in buses would decrease from 315.03 to 252.02 ML/year (2.04% to total); emission load per year would decrease from 3617 to 2893 t/year (0.117% to total). The conversion of public transport buses by 30.00 per cent results into fuel consumption in buses would decrease from 315.03 to 220.52 ML/year (3.06% to total); emission load per year would decrease from 3617 to 2531 t/year (0.175% to total). The conversion of public transport buses by 40.00 per cent results into fuel consumption in buses would decrease from 315.03 to 189.02 ML/year (4.07% to total); emission load per year would decrease from 3617 to 2170 t/year (0.234% to total). The conversion of public transport buses by 50.00

per cent results into fuel consumption in buses would decrease from 315.03 to 157.51 ML/year (5.09% to total); emission load per year would decrease from 3617 to 1809 t/year (0.292% to total). The conversion of public transport buses by 60.00 per cent results into fuel consumption in buses would decrease from 315.03 to 126.01 ML/year (6.11% to total); emission load per year would decrease from 3617 to 1447 t/year (0.35% to total). The conversion of public transport buses by 70.00 per cent results into fuel consumption in buses would decrease from 315.03 to 94.51 ML/year (7.13% to total); emission load per year would decrease from 3617 to 1085 t/year (0.409% to total). The conversion of public transport buses by 80.00 per cent results into fuel consumption in buses would decrease from 315.03 to 63.00 ML/year (8.15% to total); emission load per year would decrease from 3617 to 723 t/year (0.467% to total). The conversion of public transport buses by 90.00 per cent results into fuel consumption in buses would decrease from 315.03 to 31.50 ML/year (9.17% to total); emission load per year would decrease from 3617 to 362 t/year (0.525% to total).

Table No. 5.32: Scenario Results

Sl. No.	Scenario	Scenarios with Growth Rate of Control Parameters (in Per cent)	Total No. of Vehicles	Per cent Variation
1	2	3	4	5
1	S	Projected Year Results: Population in the Projected Year 2031 A. D.:10822416	5949199	
1	S1	2W-05%, 3W-05%, CAR-05% OTHERS-05%, BUS+01%, TA+01% and BICYCLE TRIPS+01%	5651739	-5.00
2	S2	2W-10%, 3W-10%, CAR-10% OTHERS-10%, BUS+02%, TA+02% and BICYCLE TRIPS+02%	5354279	-10.00
3	S3	2W-15%, 3W-15%, CAR-15% OTHERS-15%, BUS+03%, TA+03% and BICYCLE TRIPS+03%	5056819	-15.00
4	S4	2W-20%, 3W-20%, CAR-20% OTHERS-20%, BUS+04%, TA+04% and BICYCLE TRIPS+04%	4760245	-19.99
5	S5	2W-25%, 3W-25%, CAR-25% OTHERS-25%, BUS+05%, TA+05% and BICYCLE TRIPS+05%	4463005	-24.98
6	S6	2W-30%, 3W-30%, CAR-30% OTHERS-30%, BUS+06%, TA+06% and BICYCLE TRIPS+06%	4165767	-29.98
7	S7	2W-35%, 3W-35%, CAR-35% OTHERS-35%, BUS+07%, TA+07% and BICYCLE TRIPS+07%	3868528	-34.97
8	S8	2W-40%, 3W-40%, CAR-40% OTHERS-40%, BUS+08%, TA+08% and BICYCLE TRIPS+08%	3571290	-39.97
9	S9	2W-45%, 3W-45%, CAR-45% OTHERS-45%, BUS+09%, TA+09% and BICYCLE TRIPS+09%	3274052	-44.97
10	S10	2W-50%, 3W-50%, CAR-50% OTHERS-50%, BUS+10%, TA+10% and BICYCLE TRIPS+10%	2976813	-49.96
11	S11	2W-55%, 3W-55%, CAR-55% OTHERS-55%, BUS+11%, TA+11% and BICYCLE TRIPS+11%	2679574	-54.96
12	S12	2W-60%, 3W-60%, CAR-60% OTHERS-60%, BUS+12%, TA+12% and BICYCLE TRIPS+12%	2382336	-59.96
13	S13	2W-65%, 3W-65%, CAR-65% OTHERS-65%, BUS+13%, TA+13% and BICYCLE TRIPS+13%	2085097	-64.95
14	S14	2W-70%, 3W-70%, CAR-70% OTHERS-70%, BUS+14%, TA+14% and BICYCLE TRIPS+14%	1787859	-69.95
15	S15	2W-75%, 3W-75%, CAR-75% OTHERS-75%, BUS+15%, TA+15% and BICYCLE TRIPS+15%	1490619	-74.94
16	S16	2W-80%, 3W-80%, CAR-80% OTHERS-80%, BUS+16%, TA+16% and BICYCLE TRIPS+16%	1193380	-79.94

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Table No. 5.32: Scenario Results

Sl. No.	Scenario	No. of Bicycle Trips	Per cent Variation	No. of Two-wheeler Trips	Per cent Variation	No. of Three-wheeler Trips	Per cent Variation	No. of Car Trips	Per cent Variation
1	2	6	7	8	9	10	11	12	13
1	S	302236		5804028		1128345		866329	
1	S1	305258	1.00	5704236	-1.719	1127438	-0.08	849045	-1.99
2	S2	308281	2.00	5604443	-3.438	1123293	-0.45	833453	-3.79
3	S3	311303	3.00	5504651	-5.158	1117119	-0.99	819626	-5.39
4	S4	314325	4.00	5404858	-6.877	1105335	-2.04	805799	-6.98
5	S5	317348	5.00	5305066	-8.596	1092030	-2.33	791972	-8.58
6	S6	320370	5.99	5205273	-10.316	1077526	-4.50	781573	-9.78
7	S7	323393	7.00	5105481	-12.035	1054126	-6.57	770362	-11.07
8	S8	326415	8.00	5005688	-13.750	1032099	-8.52	756535	-12.67
9	S9	329437	9.00	4905896	-15.474	1018501	-9.73	747837	-13.67
10	S10	332460	10.00	4806103	-17.193	1006421	-10.81	744380	-14.07
11	S11	335482	11.00	4706310	-18.913	995543	-11.76	743501	-14.17
12	S12	338504	12.00	4606518	-20.630	988704	-12.37	742704	-14.26
13	S13	341527	13.00	4506725	-22.350	983170	-12.86	741750	-14.38
14	S14	344549	14.00	4406933	-24.070	980451	-13.11	740798	-14.49
15	S15	347571	15.00	4307140	-25.790	979246	-13.21	743501	-14.18
16	S16	350594	16.00	4207348	-27.510	977824	-13.34	745043	-14.00

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Table No. 5.32: Scenario Results

Sl. No.	Scenario	No. of Other Vehicle Trips	Per cent Variation	No. of Bus Trips	Per cent Variation	Total No. of Trips	Per cent Variation
1	2	14	15	16	17	18	19
1	S	404270		6606608		15111816	
1	S1	396225	-1.99	6610660	0.06	14992863	-0.79
2	S2	388140	-4.00	6614505	0.12	14866070	-1.63
3	S3	382561	-5.36	6618351	0.17	14744544	-2.43
4	S4	376133	-6.96	6622196	0.24	14628647	-3.19
5	S5	369624	-8.57	6626041	0.29	14512081	-3.97
6	S6	364813	-9.76	6629886	0.35	14379441	-4.84
7	S7	359679	-11.03	6633732	0.41	14246773	-5.74
8	S8	353251	-12.62	6637577	0.47	14111565	-6.62
9	S9	349248	-13.61	6641422	0.52	13992342	-7.41
10	S10	347632	-14.00	6645267	0.58	13882263	-8.13
11	S11	347268	-14.09	6649113	0.64	13777217	-8.83
12	S12	346500	-14.28	6652958	0.70	13675889	-9.50
13	S13	346095	-14.39	6656803	0.76	13576070	-10.16
14	S14	345610	-14.51	6660648	0.82	13478989	-10.80
15	S15	346904	-14.19	6664494	0.87	13388857	-11.40
16	S16	347672	14.00	6668339	0.94	13296820	-12.01

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Table No. 5.32: Scenario Results

Sl. No.	Scenario	Bicycle Travel Demand in MPK/Year	Per cent Variation	Two-wheeler Travel Demand in MPK/year	Per cent Variation	Three-wheeler Travel Demand in MPK/year	Per cent Variation	Car Travel Demand in MPK/year	Per cent Variation
1	2	20	21	22	23	24	25	26	27
1	S	1.36		78.35		135.40		23.39	
1	S1	1.37	0.73	77.01	-1.71	135.29	-0.08	22.92	-2.00
2	S2	1.39	2.21	75.66	-3.43	134.80	-0.44	22.50	-3.81
3	S3	1.40	2.94	74.31	-5.15	134.05	-0.99	22.13	-5.38
4	S4	1.41	3.67	72.97	-6.86	132.64	-2.04	21.76	-6.97
5	S5	1.43	5.14	71.62	-8.59	131.04	-3.22	21.38	-8.59
6	S6	1.44	5.88	70.27	-10.32	129.30	-4.51	21.10	-9.79
7	S7	1.46	7.35	68.92	-12.03	126.50	-6.57	20.80	-11.07
8	S8	1.47	8.08	67.58	-13.74	123.85	-8.53	20.43	-12.65
9	S9	1.48	8.82	66.23	-15.46	122.22	-9.73	20.19	-13.68
10	S10	1.50	10.29	64.88	-17.19	120.77	-10.81	20.10	-14.06
11	S11	1.51	11.03	63.54	-18.90	119.47	-11.76	20.07	-14.19
12	S12	1.52	11.76	62.19	-20.62	118.64	-12.37	20.03	-14.36
13	S13	1.54	13.23	60.84	-22.34	117.98	-12.86	20.00	-14.49
14	S14	1.55	13.97	59.49	-24.07	117.65	-13.11	19.97	-14.59
15	S15	1.56	14.70	58.15	-25.78	117.51	-13.21	19.95	-14.70
16	S16	1.58	16.17	56.80	-27.50	117.37	-13.31	20.07	-14.19

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Table No. 5.32: Scenario Results

Sl. No.	Scenario	Bus Travel Demand in MPK/year	Per cent Variation	Total Travel Demand in MPK/year	Per cent Variation	Transportation Area in Sq. km	Per cent Variation	Vehicle Density in No. of Vehicles per Transportation Area	Per cent Variation	Congestion	Per cent Variation
1	2	28	29	30	31	32	33	34	35	36	37
1	S	1308.11		1546.62		185.57		33873		5.37	
1	S1	1308.91	0.06	1545.51	-0.07	187.38	0.97	32451	-4.19	5.23	-2.60
2	S2	1309.67	0.12	1544.03	-0.17	189.19	1.95	32451	-4.19	5.23	-2.60
3	S3	1310.43	0.17	1542.29	-0.28	191.01	2.93	32143	-5.10	5.20	-3.16
4	S4	1311.19	0.23	1539.98	-0.43	192.82	3.91	31841	-5.99	5.17	-3.72
5	S5	1311.96	0.29	1537.43	-0.59	194.63	4.88	31544	-6.87	5.14	-4.28
6	S6	1312.72	0.35	1534.84	-0.76	196.44	5.85	31254	-7.74	5.11	-4.84
7	S7	1313.48	0.41	1531.17	-0.99	198.26	6.83	30968	-8.57	5.08	-5.40
8	S8	1314.24	0.47	1527.56	-1.23	200.07	7.81	30687	-9.40	5.06	-5.77
9	S9	1315.00	0.52	1525.13	-1.38	201.88	8.08	30412	-10.21	5.03	-6.33
10	S10	1315.76	0.58	1523.01	-1.52	203.69	9.76	30141	-11.02	4.99	-7.07
11	S11	1316.52	0.64	1521.11	-1.64	205.51	10.74	29875	-11.80	4.96	-7.63
12	S12	1317.29	0.70	1519.68	-1.74	207.32	11.72	29614	-12.58	4.92	-8.38
13	S13	1318.05	0.75	1518.48	-1.82	209.13	12.69	29357	-13.33	4.89	-8.94
14	S14	1318.81	0.82	1517.48	-1.88	210.94	13.67	29105	-14.07	4.85	-9.68
15	S15	1319.57	0.87	1516.75	-1.93	212.76	14.65	28857	-14.81	4.82	-10.24
16	S16	1320.33	0.93	1516.16	-1.96	214.57	15.63	28613	-15.52	4.79	-10.80

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Table No. 5.32: Scenario Results

Sl. No.	Scenario	Two-wheeler Fuel in ML per year	Per cent Variation	Three-wheeler Fuel in ML per year	Per cent Variation	Car Fuel in ML per year	Per cent Variation	Other Vehicles Fuel in ML per year	Per cent Variation
1	2	38	39	40	41	42	43	44	45
1	S	713.18		247.36		472.24		1345.63	
1	S1	677.53	-4.99	234.99	-5.00	448.13	-5.10	1278.48	-4.99
2	S2	641.87	-9.98	222.63	-9.99	424.01	-10.21	1211.20	-9.99
3	S3	606.21	-14.99	210.26	-14.99	399.89	-15.32	1144.86	-14.92
4	S4	570.55	-19.99	197.89	-19.99	375.77	-20.42	1074.62	-20.14
5	S5	534.89	-24.99	185.52	-25.00	351.66	-25.53	1002.35	-25.51
6	S6	499.23	-29.99	173.15	-30.00	327.54	-30.63	940.32	-30.12
7	S7	463.57	-34.99	160.78	-35.00	303.42	-35.74	865.11	-35.71
8	S8	427.91	-39.99	148.42	-39.98	279.30	-40.85	805.76	-40.12
9	S9	392.25	-44.99	136.05	-44.99	255.18	-45.96	735.79	-45.32
10	S10	356.59	-50.00	123.68	-50.00	231.06	-51.07	671.61	-50.00
11	S11	320.93	-55.00	111.31	-55.00	206.94	-56.18	604.18	-55.10
12	S12	285.27	-60.00	98.94	-60.00	182.82	-61.28	536.63	-60.12
13	S13	249.62	-64.99	86.58	-64.99	158.71	-66.39	468.41	-65.19
14	S14	213.95	-70.00	74.21	-69.99	134.59	-71.49	388.88	-71.10
15	S15	178.29	-75.00	61.84	-75.00	110.47	-76.60	333.31	-75.23
16	S16	142.63	-80.00	49.47	-80.00	86.35	-81.71	267.78	80.10

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Table No. 5.32: Scenario Results

Sl. No.	Scenario	Bus Fuel in ML per year	Per cent Variation	Total Fuel in ML per year	Per cent Variation
1	2	46	47	48	49
1	S	315.03		3093.44	
1	S1	318.18	0.99	2957.31	-4.40
2	S2	321.33	1.99	2821.04	-8.81
3	S3	324.48	2.99	2685.70	-13.18
4	S4	327.63	3.99	2546.46	-17.68
5	S5	330.78	4.99	2405.20	-22.24
6	S6	333.94	6.00	2274.18	-26.48
7	S7	337.08	6.99	2129.96	-31.14
8	S8	340.23	7.99	2001.62	-35.29
9	S9	343.38	8.99	1862.65	-39.78
10	S10	346.54	10.00	1729.48	-44.09
11	S11	349.69	11.00	1593.05	-48.50
12	S12	352.84	12.00	1456.50	-52.92
13	S13	355.98	12.99	1319.30	-57.36
14	S14	359.14	14.00	1170.77	-62.15
15	S15	362.29	15.00	1046.20	-66.18
16	S16	365.44	16.00	911.67	-70.52

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Table No. 5.32: Scenario Results

Sl. No.	Scenario	Two-wheeler Emission Load in t/year	Per cent Variation	Three-wheeler Emission Load in t/year	Per cent Variation	Car Emission Load in t/year	Per cent Variation	Other Vehicle Emission Load in t/year	Per cent Variation
1	2	50	51	52	53	54	55	56	57
1	S	240577		219055		58289		97983	
1	S1	228548	-5.49	208103	-4.99	55312	-5.11	93094	-4.98
2	S2	216519	-10.00	197150	-9.99	52335	-10.21	88204	-9.98
3	S3	204490	-15.00	186197	-14.99	49358	-15.32	83393	-14.89
4	S4	192461	-20.00	175244	-20.00	46381	-20.43	78288	-20.10
5	S5	180433	-24.99	164291	-25.00	43404	-25.53	72987	-25.51
6	S6	168404	-29.99	153339	-29.99	40427	-30.64	68412	-30.18
7	S7	156375	-35.00	142386	-34.99	37451	-35.75	62993	-35.71
8	S8	144346	-40.00	131433	-40.00	34474	-40.85	57996	-40.81
9	S9	132317	-45.00	120480	-45.00	31497	-45.96	52999	-45.91
10	S10	120288	-50.00	108529	-49.99	28520	-51.07	48002	-51.00
11	S11	108260	-54.99	98575	-54.99	25543	-56.17	43926	-55.16
12	S12	96231	-59.99	87622	-60.00	22566	-61.28	39203	-59.99
13	S13	84202	-64.99	76669	-65.00	19589	-66.36	34196	-65.10
14	S14	72173	-70.00	65717	-69.99	16612	-71.50	29169	-70.23
15	S15	60144	-75.00	54764	-74.99	13635	-76.60	24182	-75.32
16	S16	48115	-80.00	43811	-80.00	10659	-81.71	19596	-80.00

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Table No. 5.32: Scenario Results

Sl. No.	Scenario	Bus Emission Load in t/year	Per cent Variation	Total Emission Load in t/year	Per cent Variation
1	**2**	**58**	**59**	**60**	**61**
1	S	3617		619521	
1	S1	3653	0.99	588710	-4.97
2	S2	3689	1.99	557897	-9.94
3	S3	3725	2.98	527163	-14.91
4	S4	3761	3.98	496135	-19.92
5	S5	3797	4.98	464912	-24.95
6	S6	3834	5.99	434416	-29.88
7	S7	3870	6.99	403075	-34.93
8	S8	3906	7.99	372155	-39.93
9	S9	3942	8.98	341235	-44.92
10	S10	3978	9.07	310316	-49.91
11	S11	4014	10.97	280318	-54.75
12	S12	4051	11.99	249673	-59.69
13	S13	4087	12.99	218743	-64.69
14	S14	4123	13.98	187794	-69.68
15	S15	4159	14.98	156884	-74.67
16	S16	4195	15.98	126376	-79.60

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Table No. 5.33: Scenario Results

Sl. No.		Bus Emission Load t/year	Per cent to Total Emission Load 619521 t/year	Bus Fuel in ML/year	Per cent to Total Fuel Consumption 3093.44 ML/year
1	**Projected Year Results**	**3617**		**315.03**	
2	S1-BPBUSES-10%	3255	0.058	283.53	1.02
3	S2-BPBUSES-20%	2893	0.117	252.02	2.04
4	S3-BPBUSES-30%	2531	0.175	220.52	3.06
5	S4-BPBUSES-40%	2170	0.234	189.02	4.07
6	S5-BPBUSES-50%	1808	0.292	157.51	5.09
7	S6-BPBUSES-60%	1447	0.350	126.01	6.11
8	S7-BPBUSES-70%	1085	0.409	94.51	7.13
9	S8-BPBUSES-80%	723	0.467	63.00	8.15
10	S9-BPBUSES-90%	362	0.525	31.50	9.17

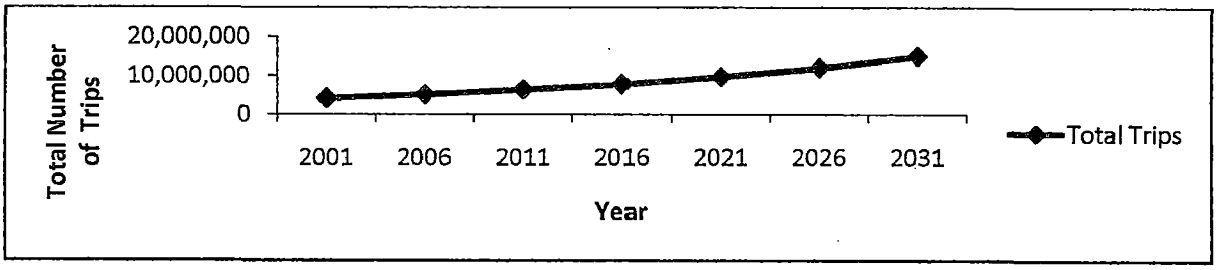

Fig. No. 5.39 (A): Scenario-1-Total Number of Trips

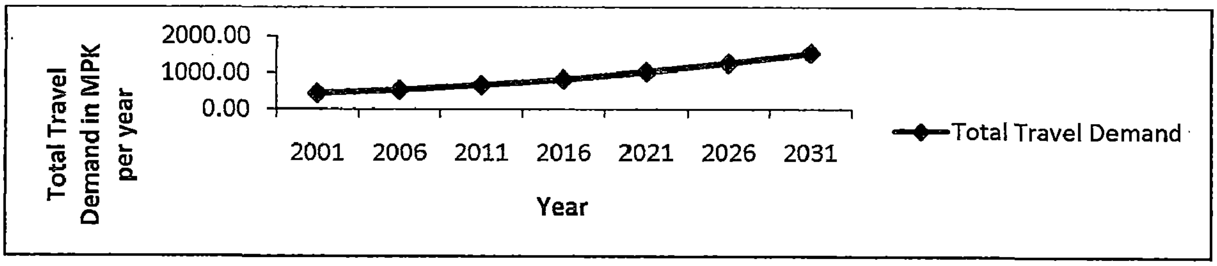

Fig. No. 5.39 (B): Scenario-1-Total Travel Demand

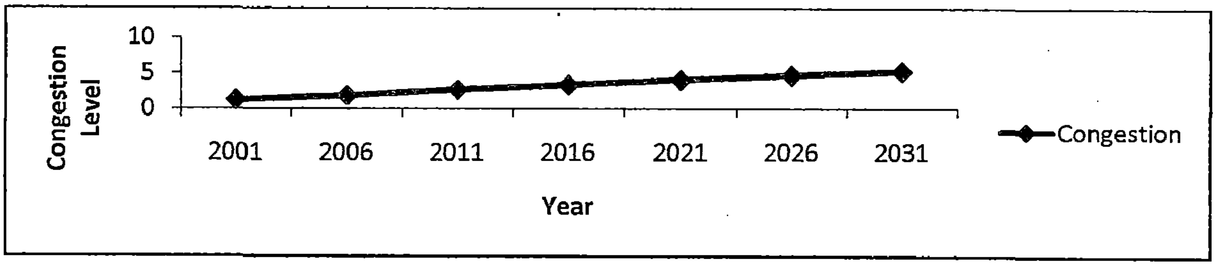

Fig. No. 5.39 (C): Scenario-1-Congestion Level

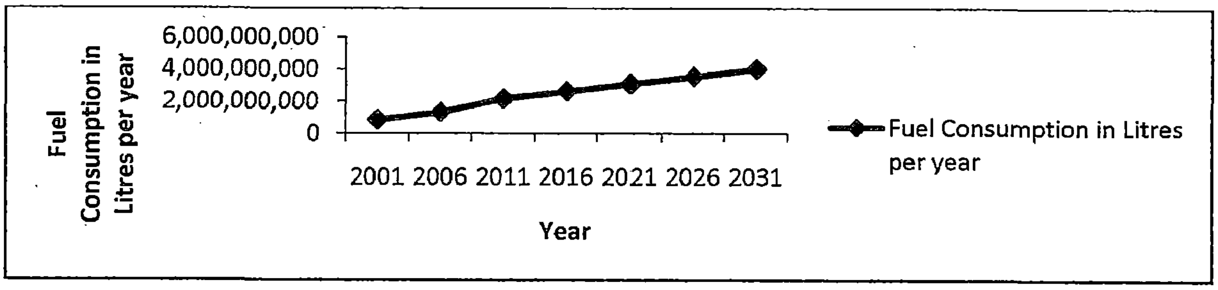

Fig. No. 5.39 (D): Scenario-1-Fuel Consumption

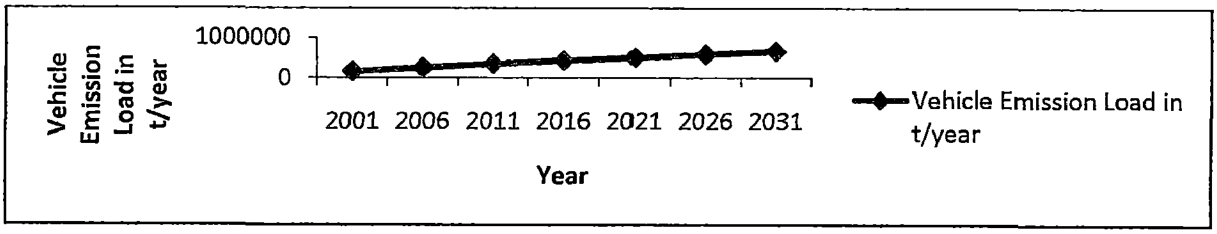

Fig. No. 5.39 (E): Scenario-1-Vehicle Emission Load

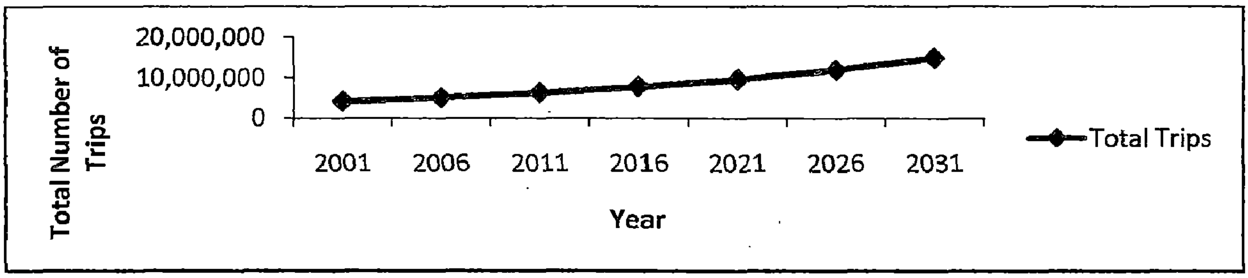

Fig. No. 5.40 (A): Scenario-2-Total Number of Trips

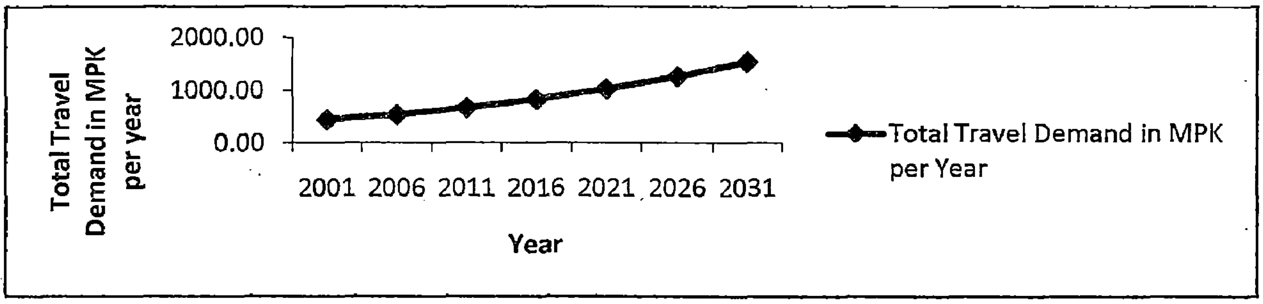

Fig. No. 5.40 (B): Scenario-2-Total Travel Demand

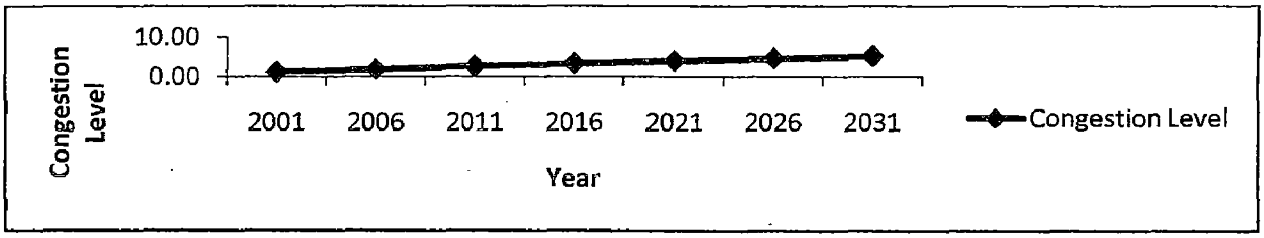

Fig. No. 5.40 (C): Scenario-2-Congestion Level

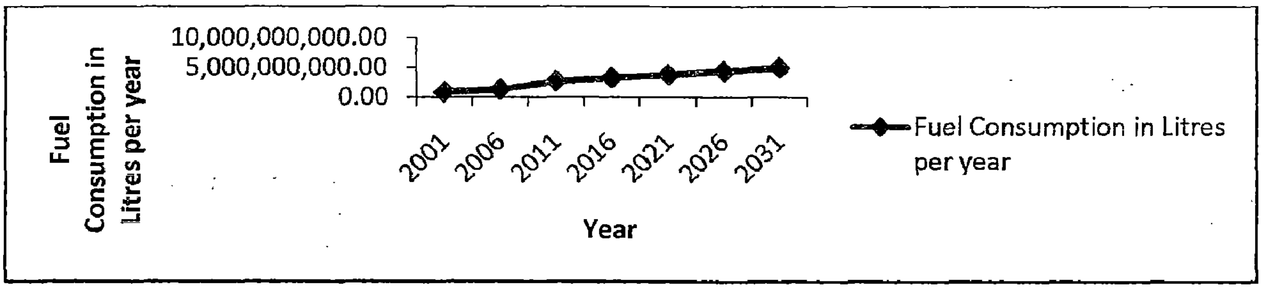

Fig. No. 5.40 (D): Scenario-2-Fuel Consumption

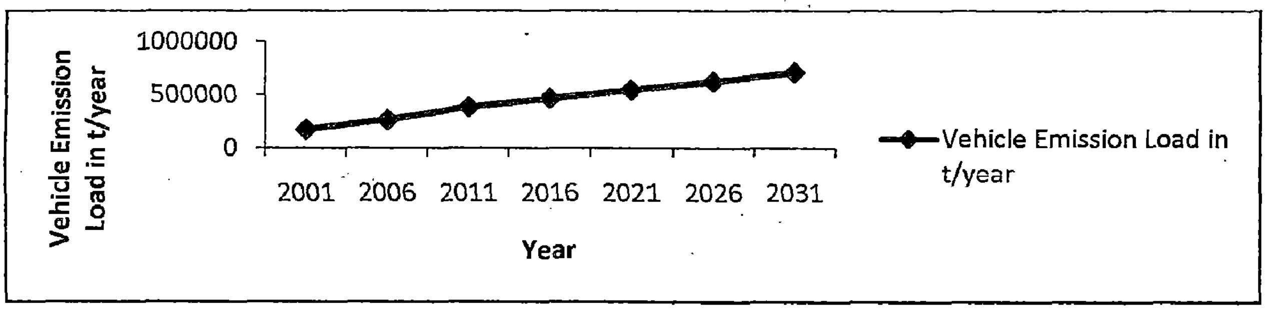

Fig. No. 5.40 (E): Scenario-2-Vehicle Emission Load

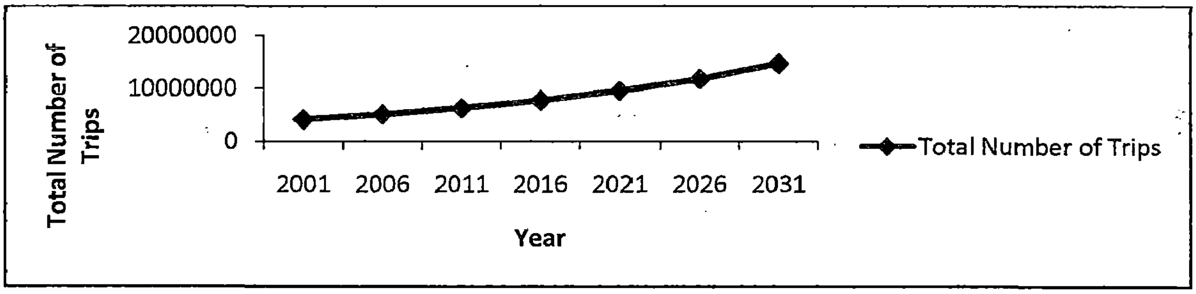

Fig. No. 5.41 (A): Scenario-3-Total Number of Trips

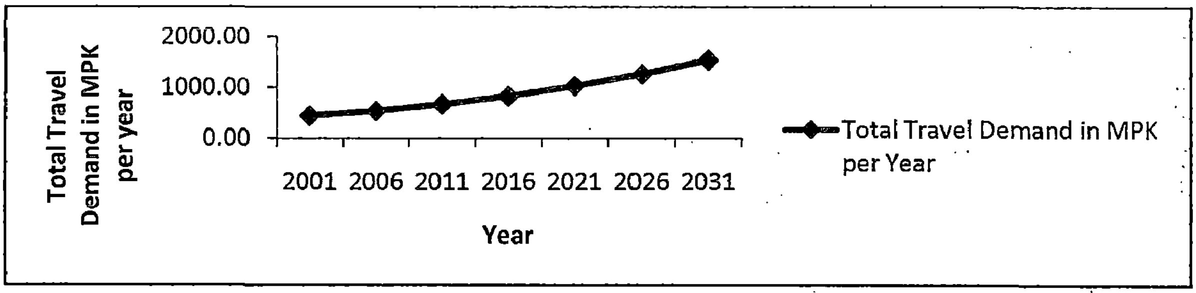

Fig. No. 5.41 (B): Scenario-3-Total Travel Demand

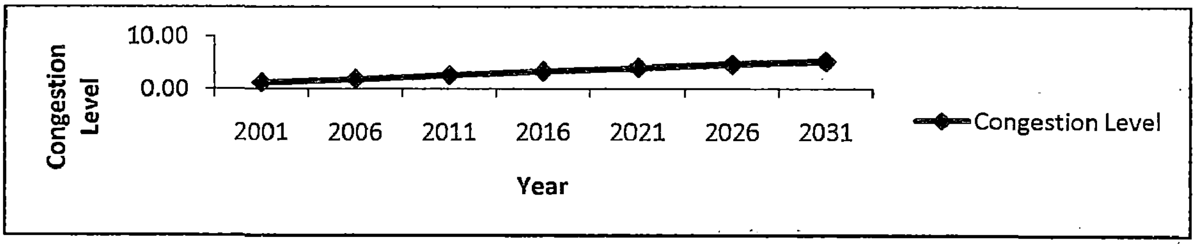

Fig. No. 5.41 (C): Scenario-3-Congestion Level

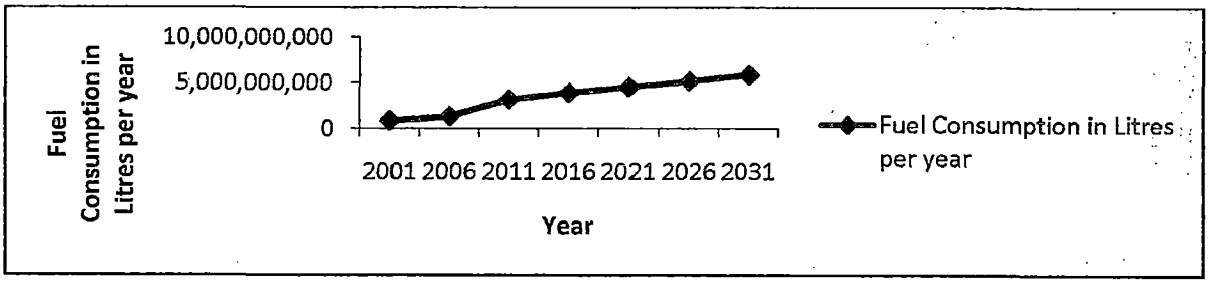

Fig. No. 5.41 (D): Scenario-3-Fuel Consumption

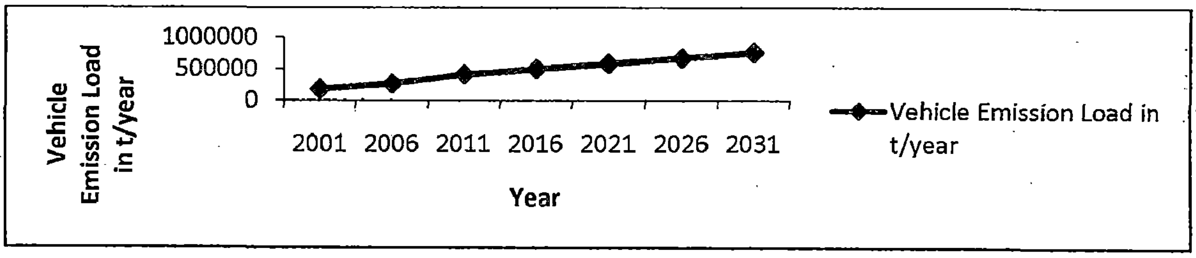

Fig. No. 5.41 (E): Scenario-3-Vehicle Emission Load

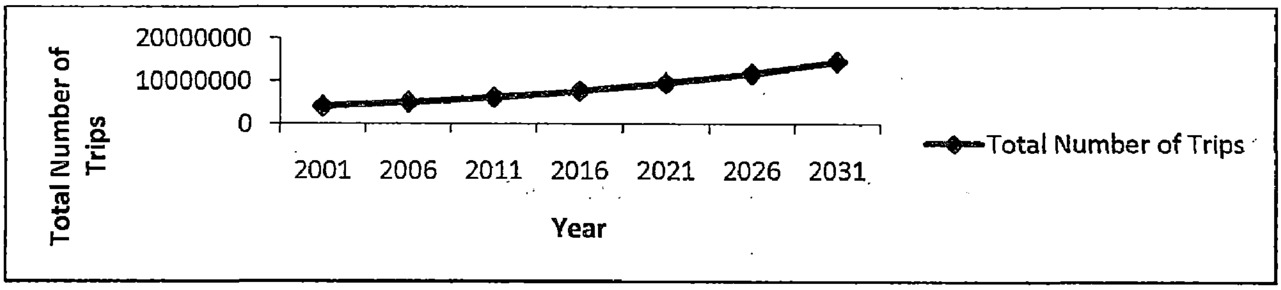

Fig. No. 5.42 (A): Scenario-4-Total Number of Trips

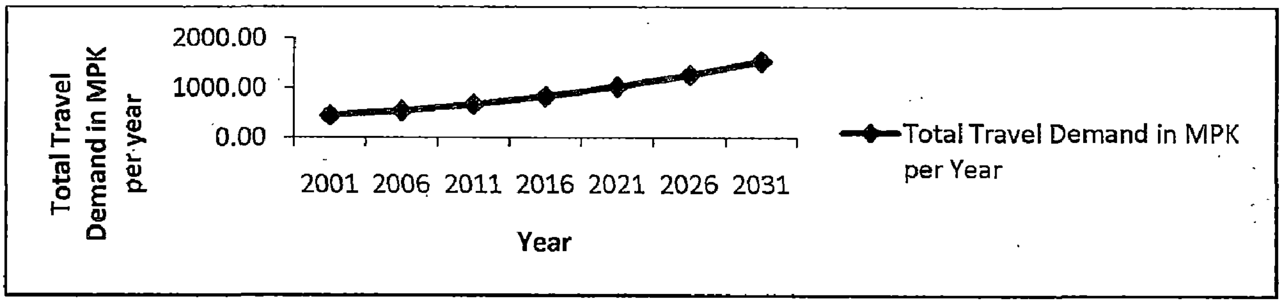

Fig. No. 5.42 (B): Scenario-4-Total Travel Demand

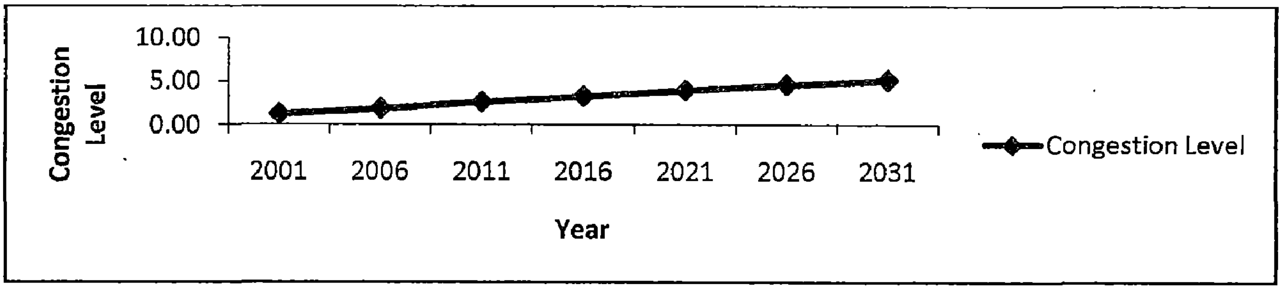

Fig. No. 5.42(C): Scenario-4-Congestion Level

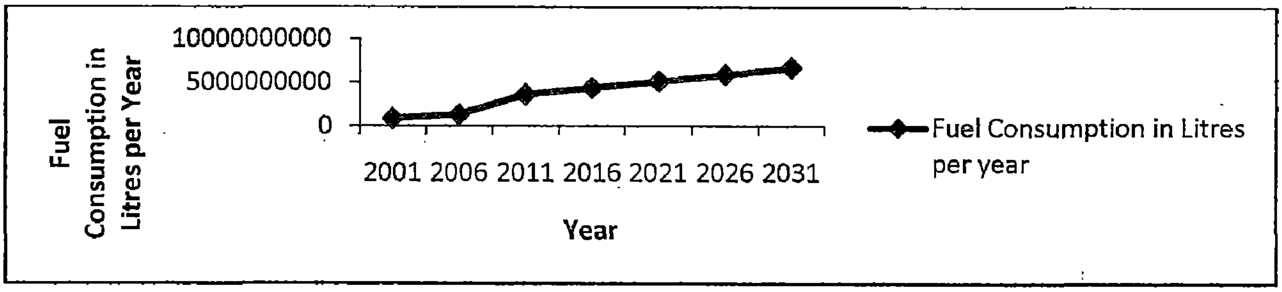

Fig. No. 5.42 (D): Scenario-4-Fuel Consumption

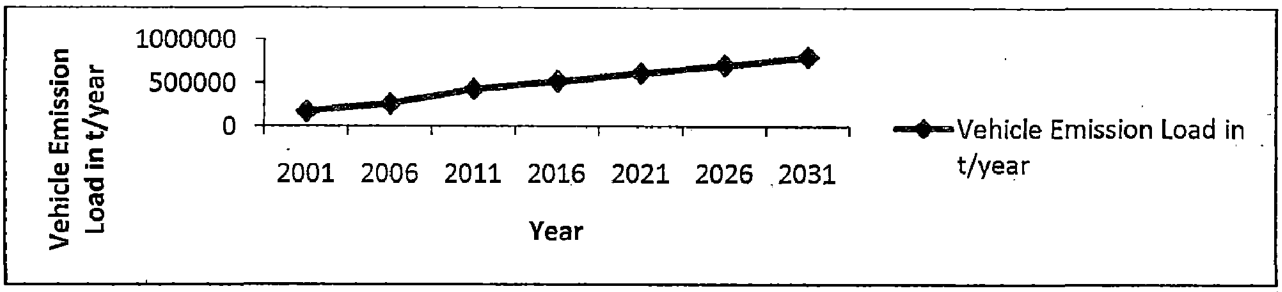

Fig. No. 5.42 (E): Scenario-4-Vehicle Emission Load

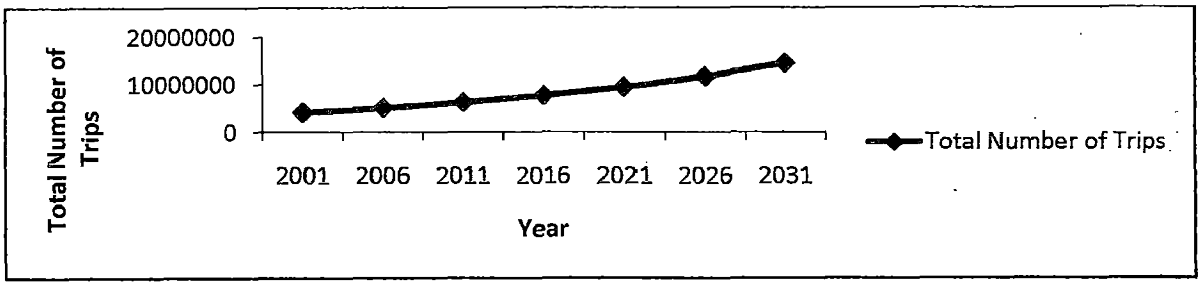

Fig. No. 5.43 (A): Scenario-5-Total Number of Trips

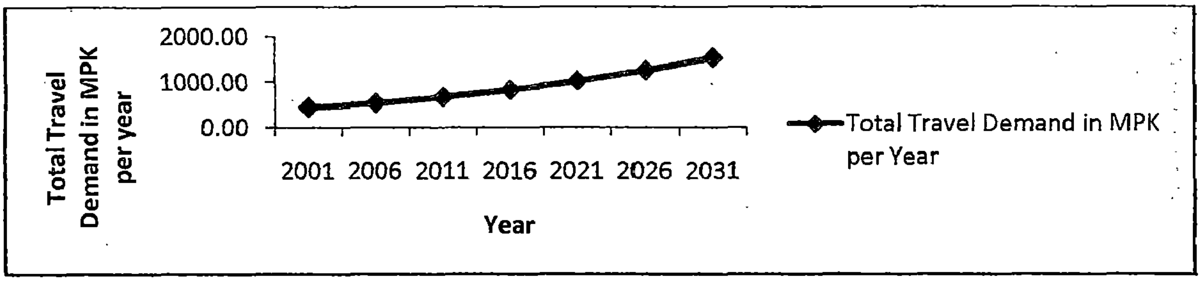

Fig. No. 5.43 (B): Scenario-5-Total Travel Demand

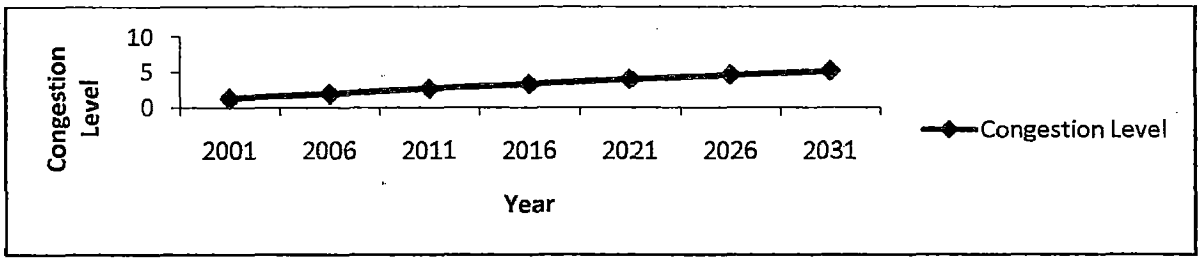

Fig. No. 5.43 (C): Scenario-5-Congestion Level

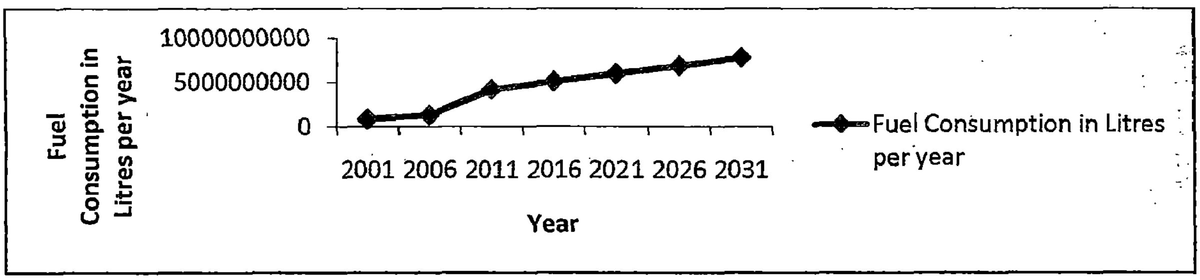

Fig. No. 5.43 (D): Scenario-5-Fuel Consumption

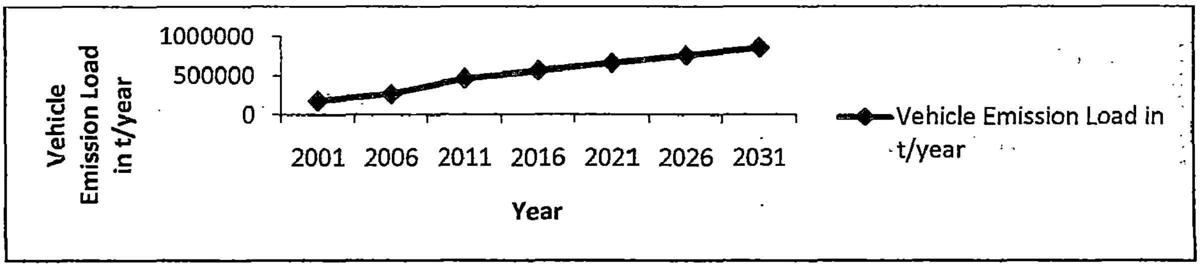

Fig. No. 5.43 (E): Scenario-5-Vehicle Emission Load

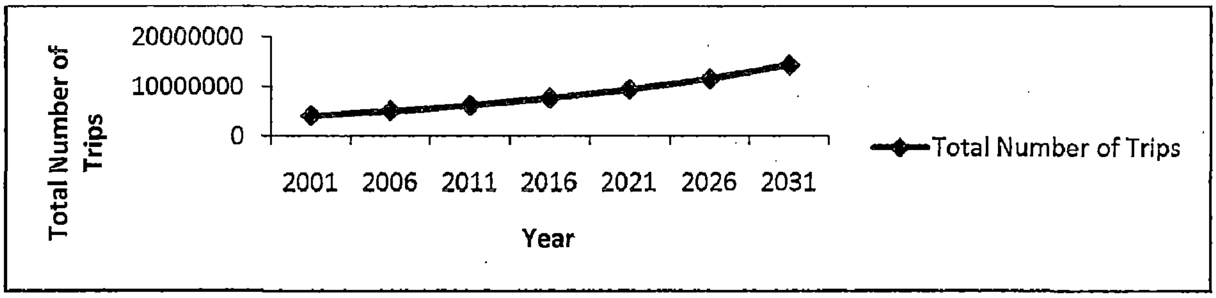

Fig. No. 5.44 (A): Scenario-6-Total Number of Trips

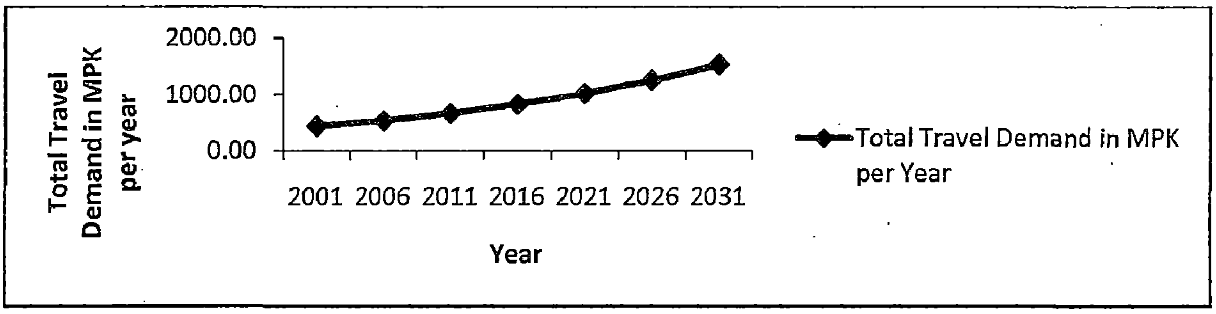

Fig. No. 5.44 (B): Scenario-6-Total Travel Demand

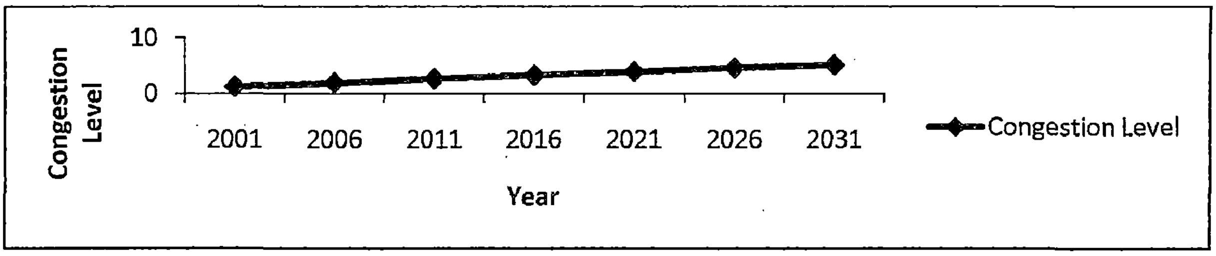

Fig. No. 5.44 (C): Scenario-6-Congestion Level

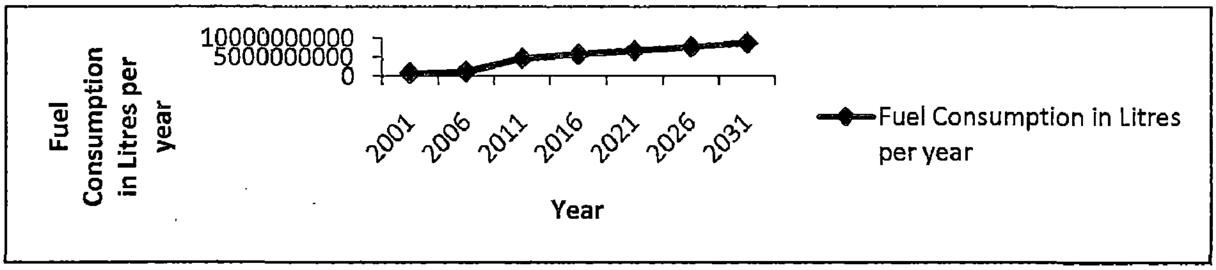

Fig. No. 5.44 (D): Scenario-6-Fuel Consumption

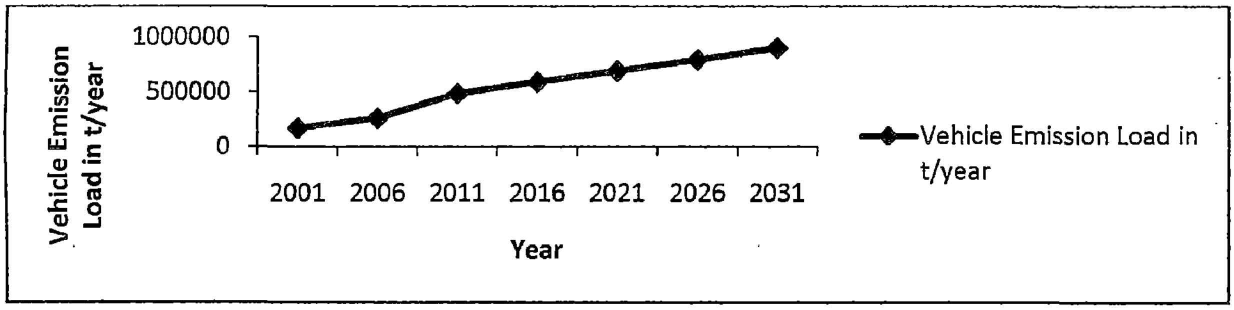

Fig. No. 5.44 (E): Scenario-6-Vehicle Emission Load

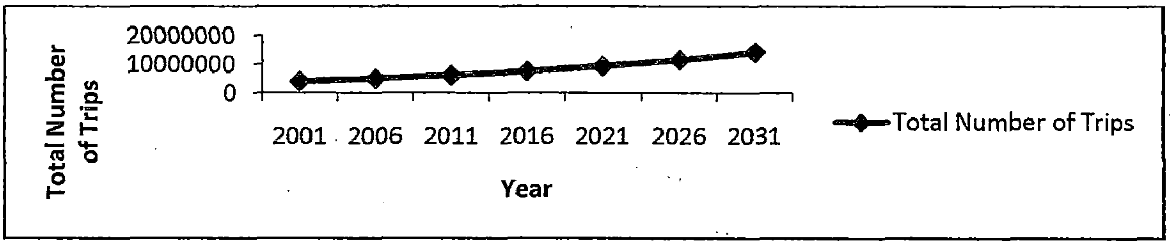

Fig. No. 5.45 (A): Scenario-7-Total Number of Trips

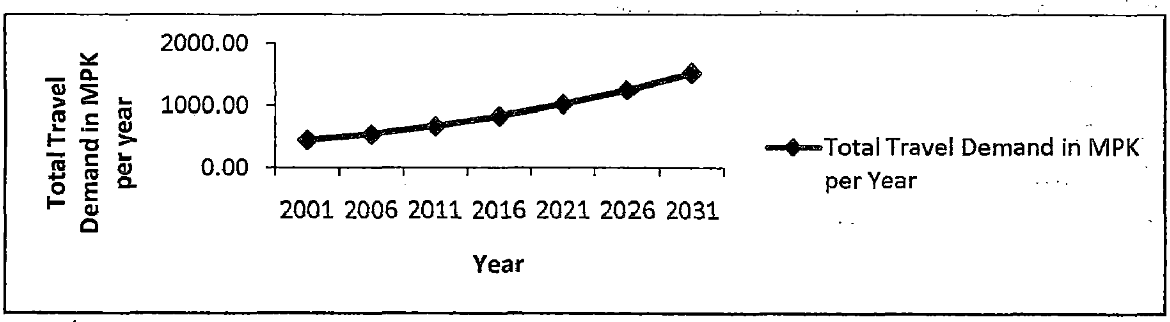

Fig. No. 5.45 (B): Scenario-7-Total Travel Demand

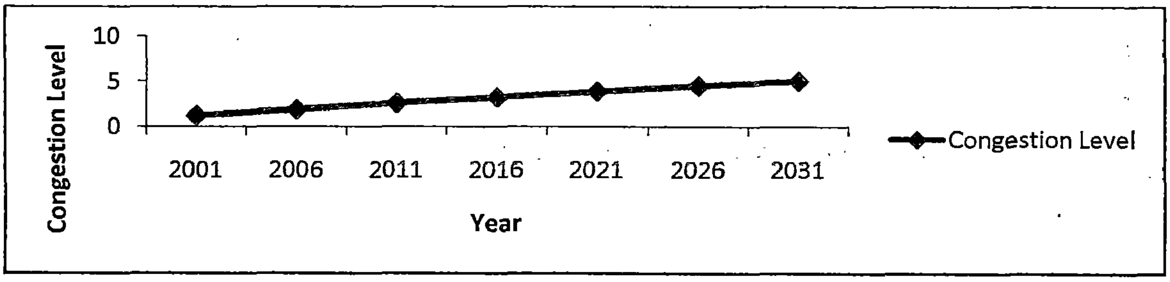

Fig. No. 5.45 (C): Scenario-7-Congestion Level

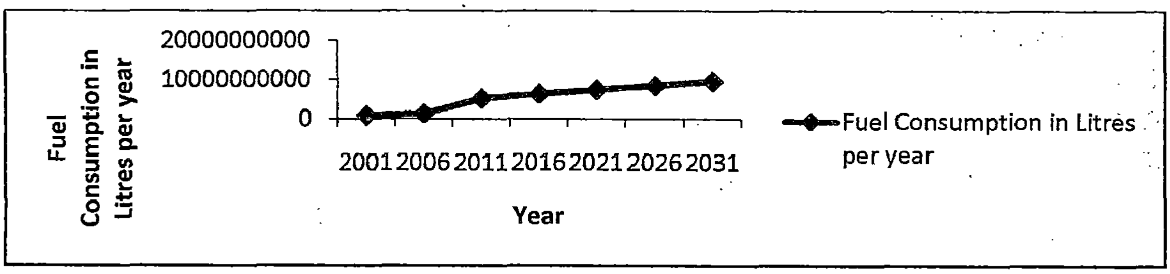

Fig. No. 5.45 (D): Scenario-6-Fuel Consumption

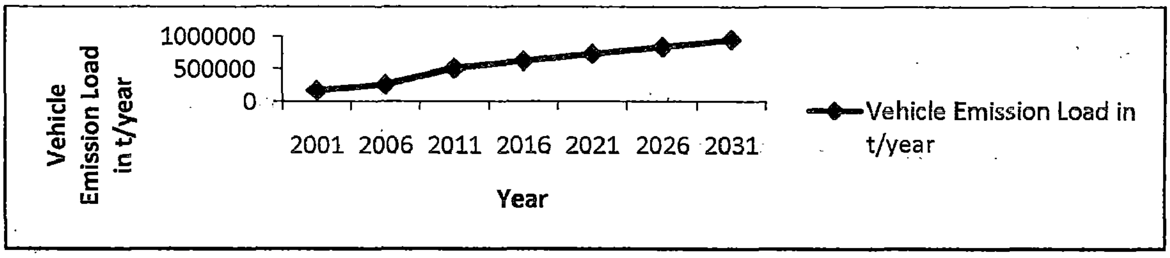

Fig. No. 5.45 (E): Scenario-7-Vehicle Emission Load

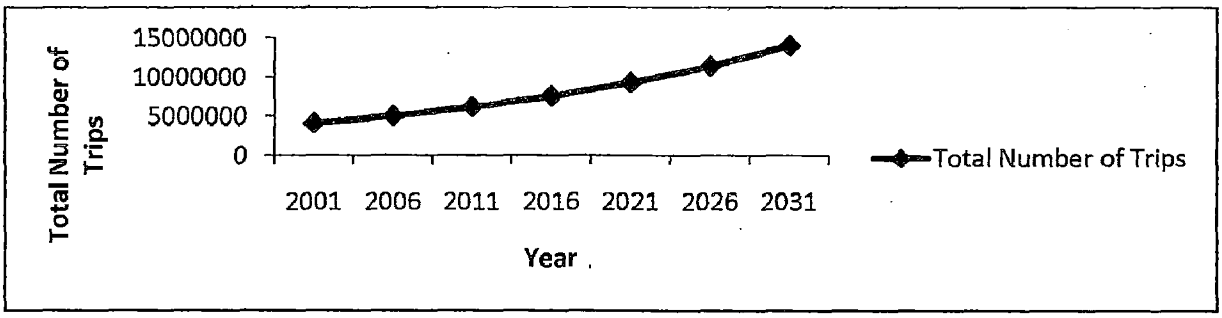

Fig. No. 5.46 (A): Scenario-8-Total Number of Trips

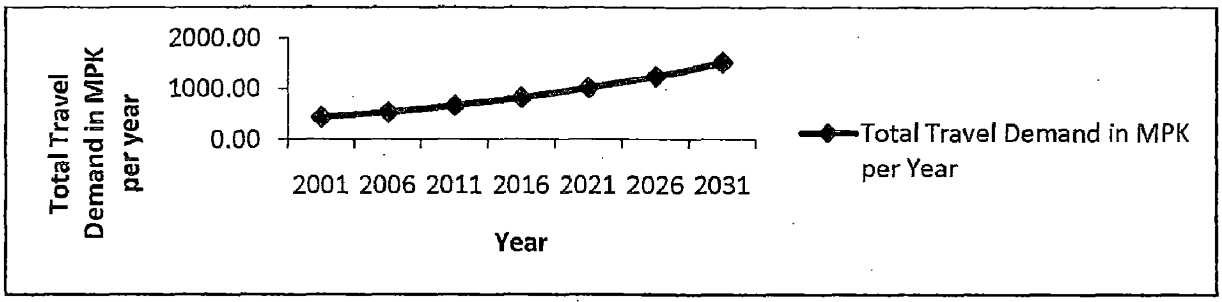

Fig. No. 5.46 (B): Scenario-8-Total Travel Demand

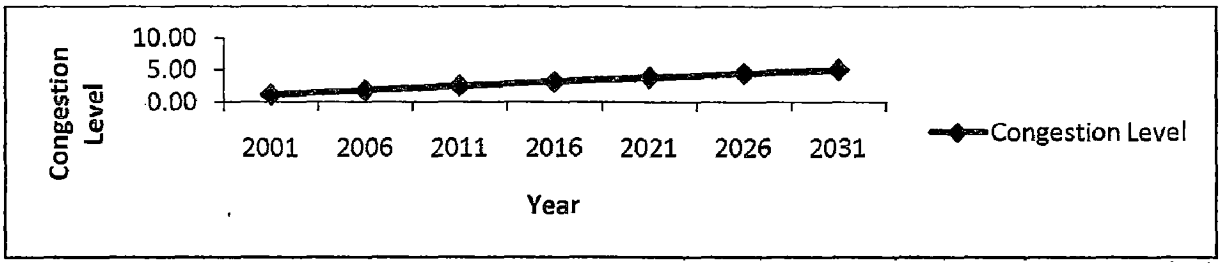

Fig. No. 5.46 (C): Scenario-8-Congestion Level

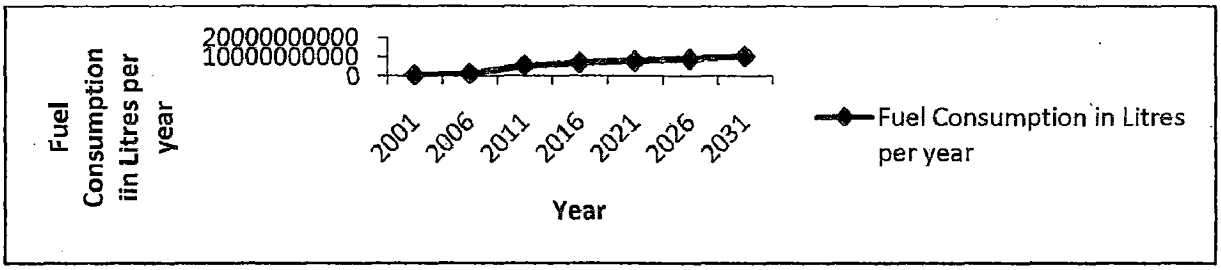

Fig. No. 5.46 (D): Scenario-8-Fuel Consumption

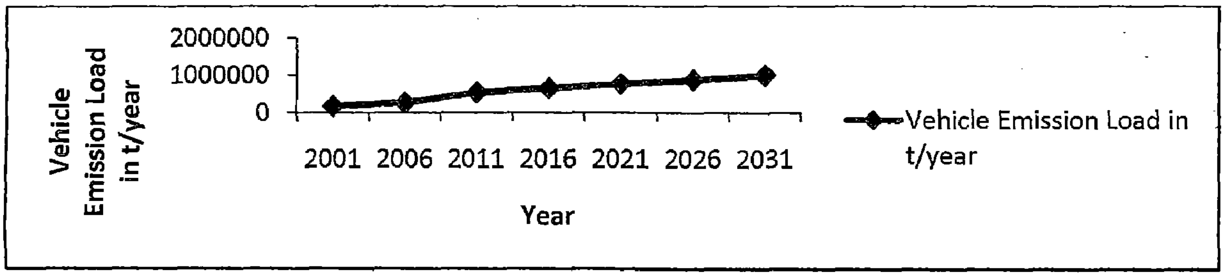

Fig. No. 5.46 (E): Scenario-8-Vehicle Emission Load

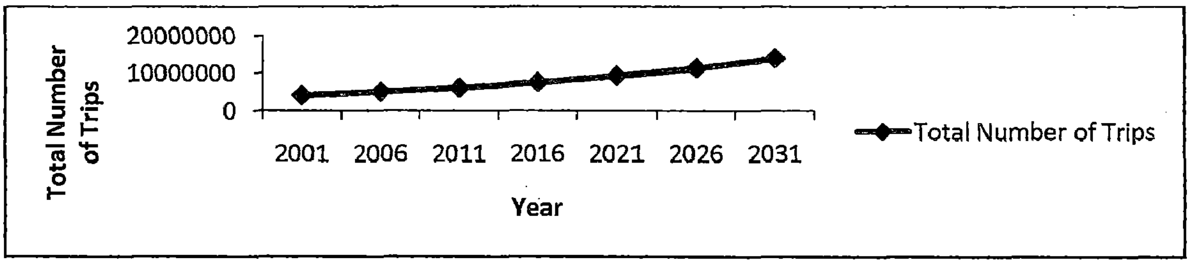

Fig. No. 5.47 (A): Scenario-9-Total Number of Trips

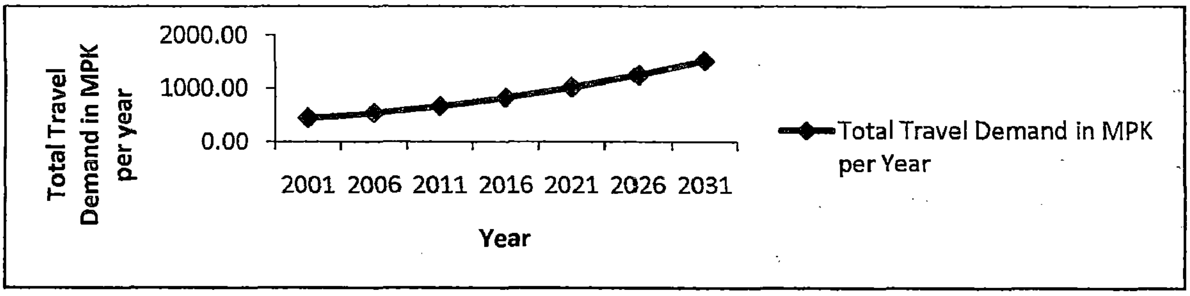

Fig. No. 5.47 (B): Scenario-9-Total Travel Demand

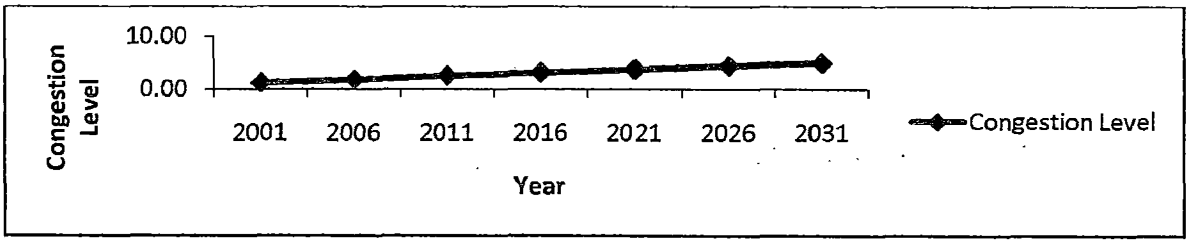

Fig. No. 5.47 (C): Scenario-9-Congestion Level

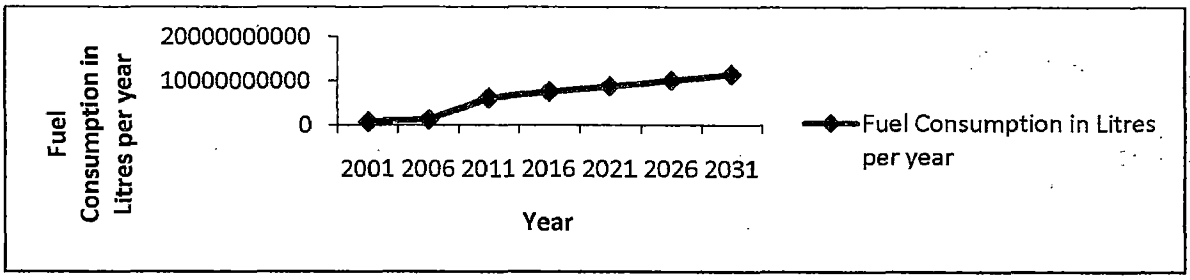

Fig. No. 5.47 (D): Scenario-9-Fuel Consumption

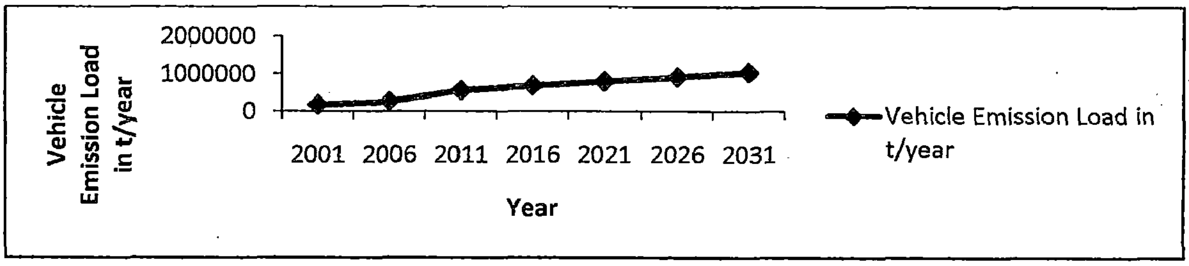

Fig. No. 5.47 (E): Scenario-9-Vehicle Emission Load

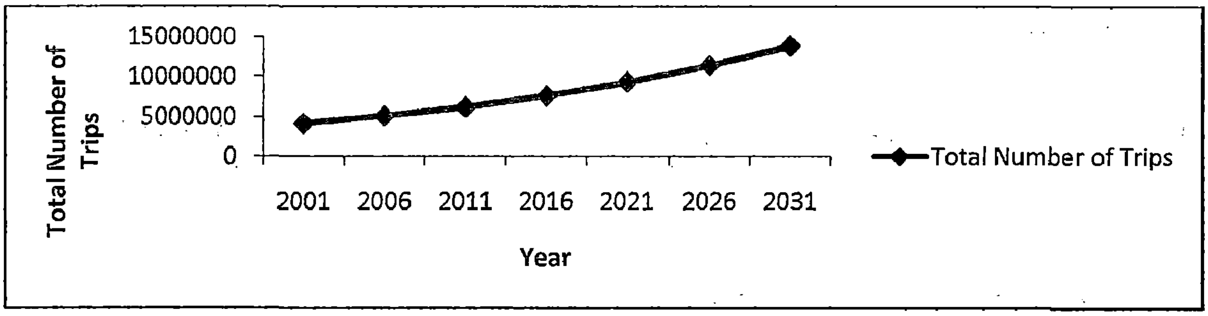

Fig. No. 5.48 (A): Scenario-10-Total Number of Trips

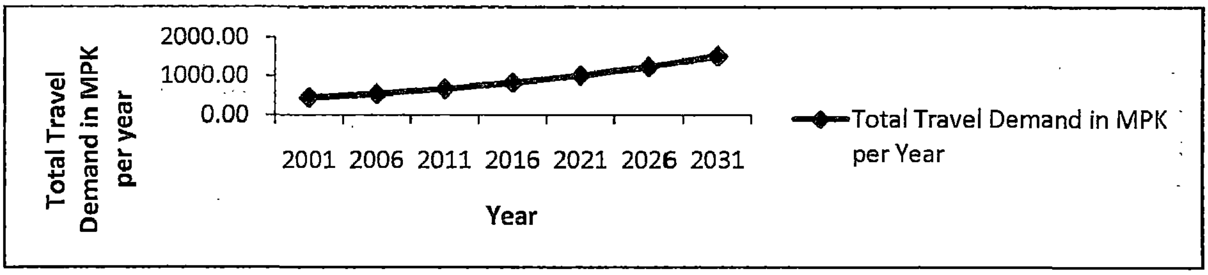

Fig. No. 5.48 (B): Scenario-10-Total Travel Demand

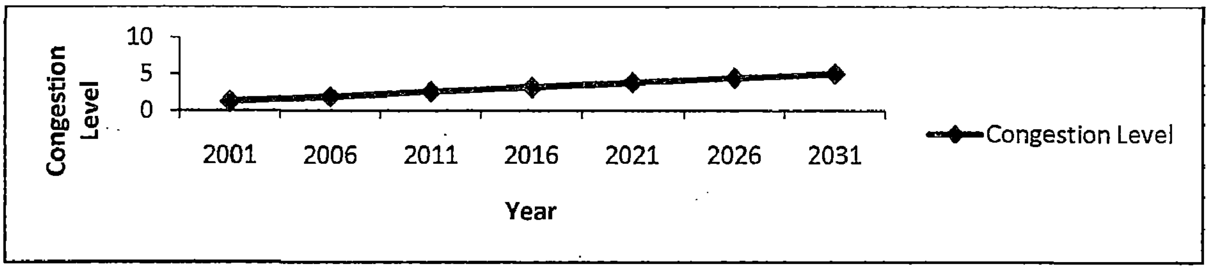

Fig. No. 5.48 (C): Scenario-10-Congestion Level

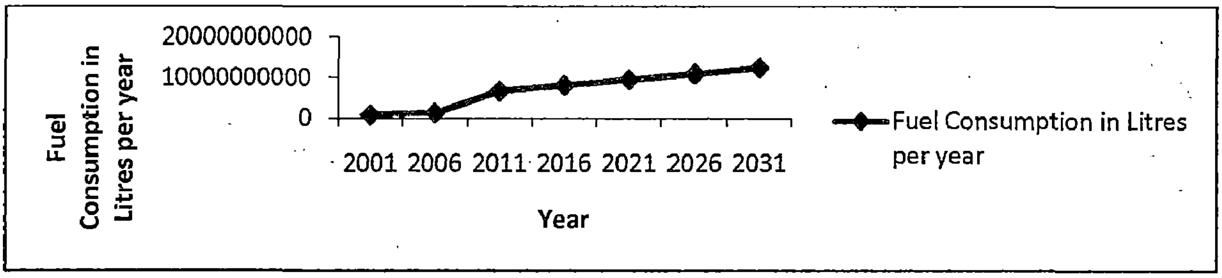

Fig. No. 5.48 (D): Scenario-10-Fuel Consumption

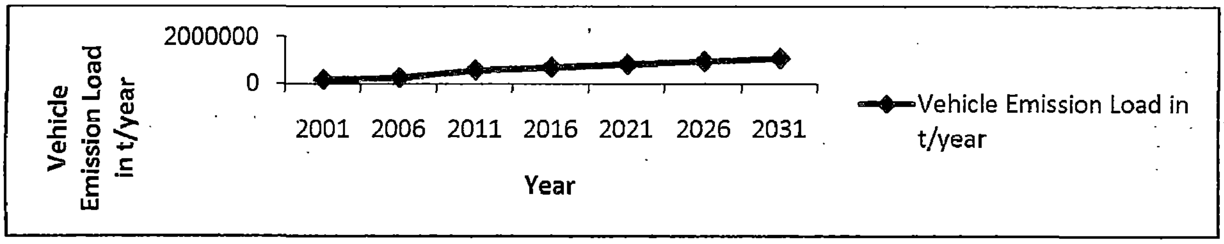

Fig. No. 5.48 (E): Scenario-10-Vehicle Emission Load

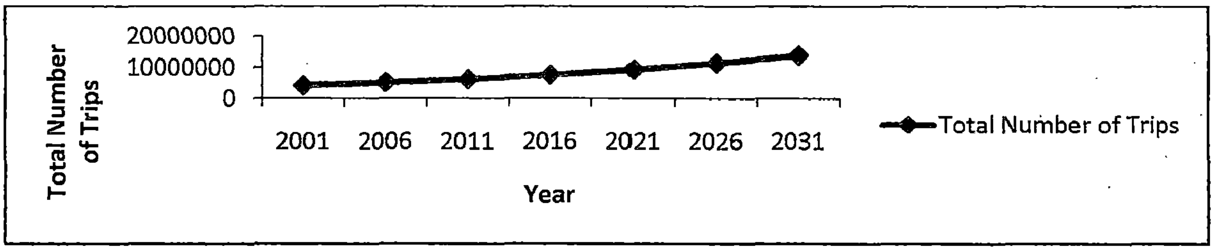

Fig. No. 5.49 (A): Scenario-11-Total Number of Trips

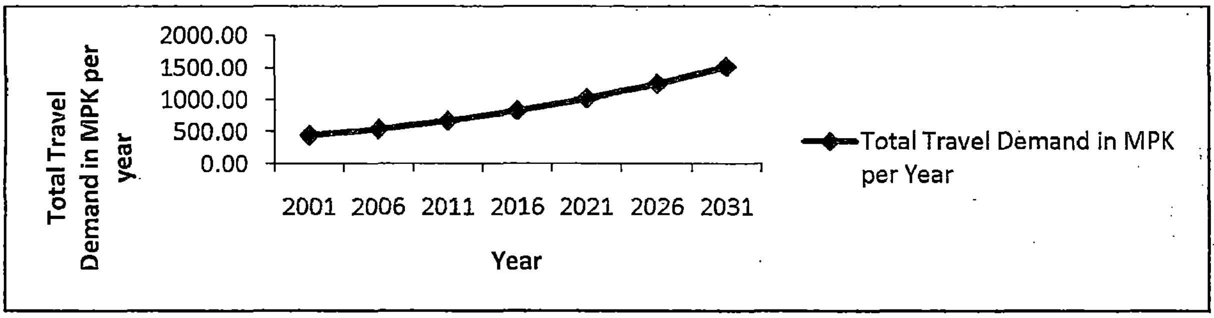

Fig. No. 5.49 (B): Scenario-11-Total Travel Demand

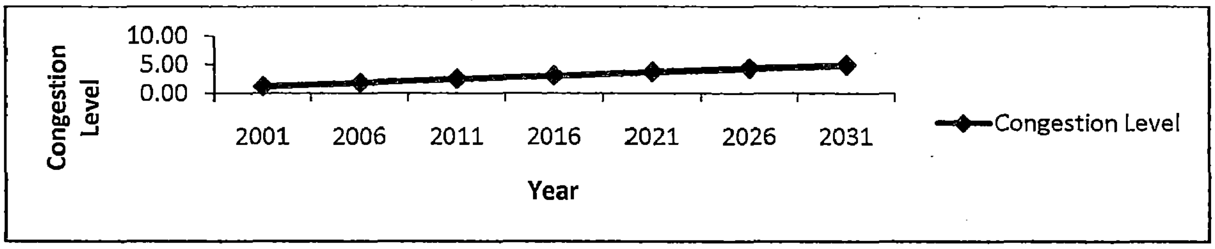

Fig. No. 5.49 (C): Scenario-11-Congestion Level

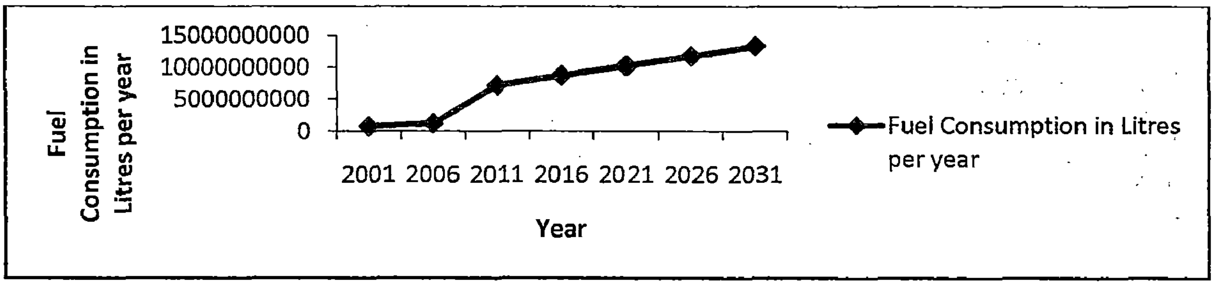

Fig. No. 5.49 (D): Scenario-11-Fuel Consumption

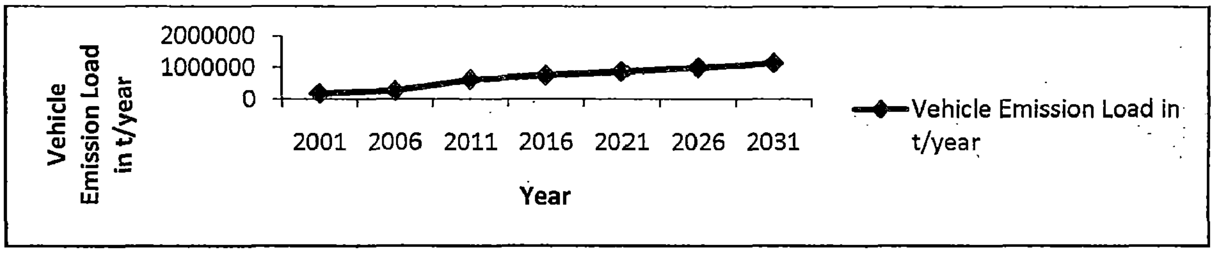

Fig. No. 5.49 (E): Scenario-11-Vehicle Emission Load

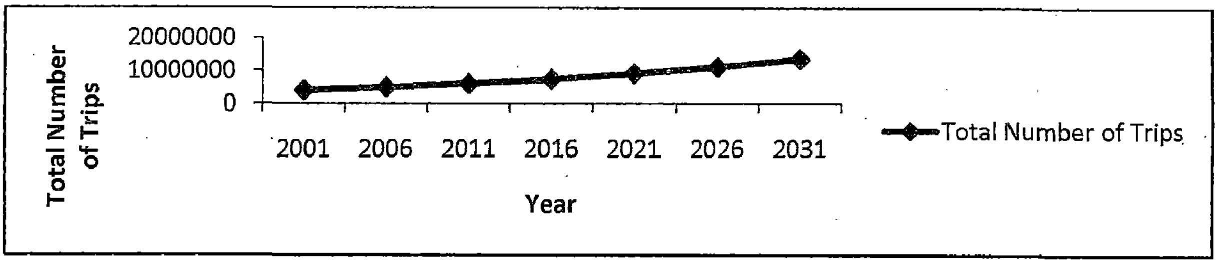

Fig. No. 5.50 (A): Scenario-12-Total Number of Trips

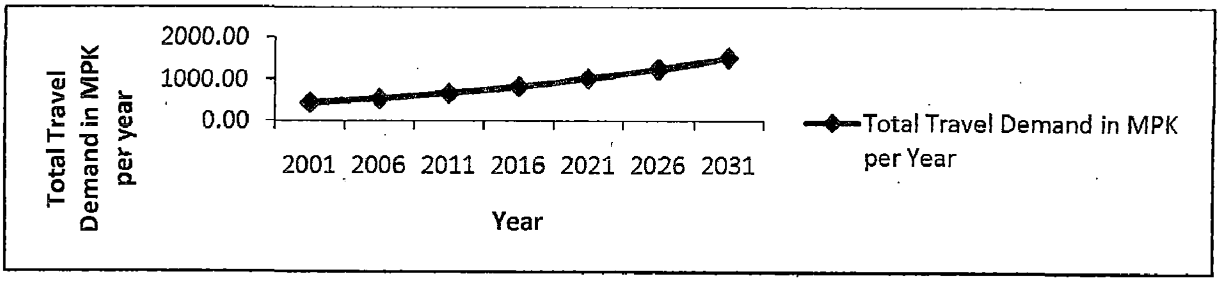

Fig. No. 5.50 (B): Scenario-12-Total Travel Demand

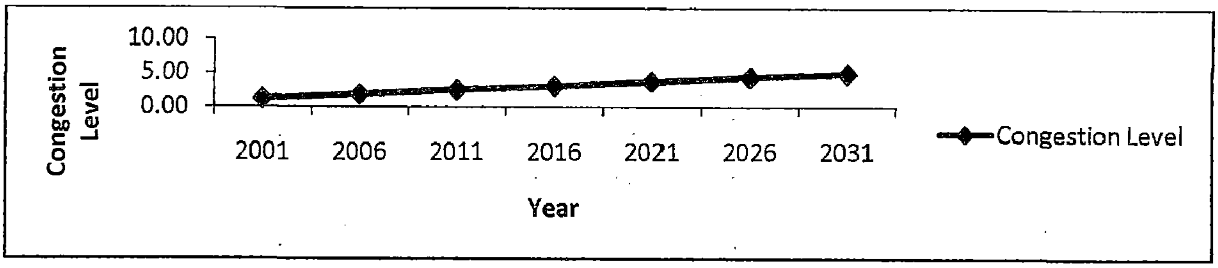

Fig. No. 5.50 (C): Scenario-12-Congestion Level

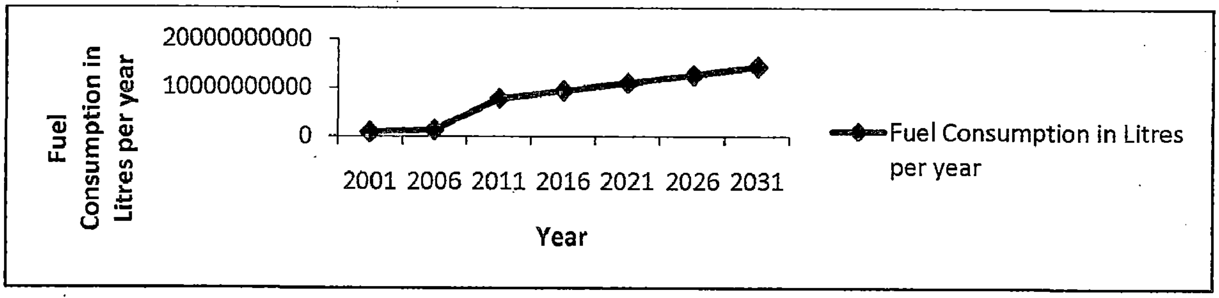

Fig. No. 5.50 (D): Scenario-12-Fuel Consumption

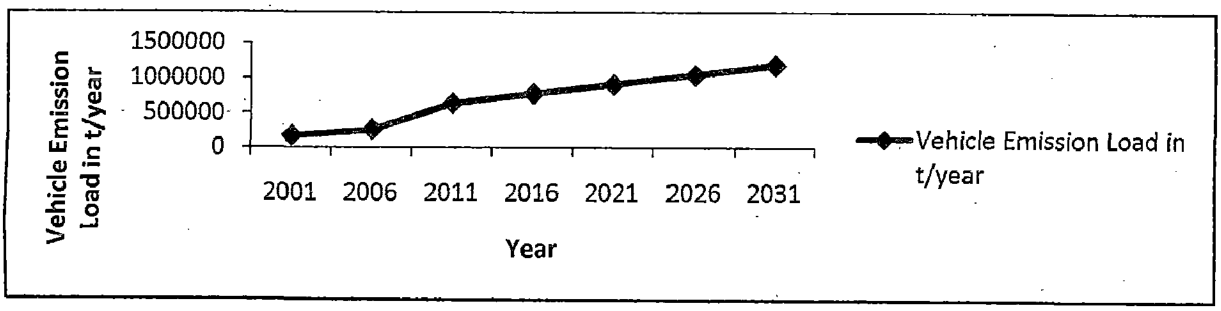

Fig. No. 5.50 (E): Scenario-12-Vehicle Emission Load

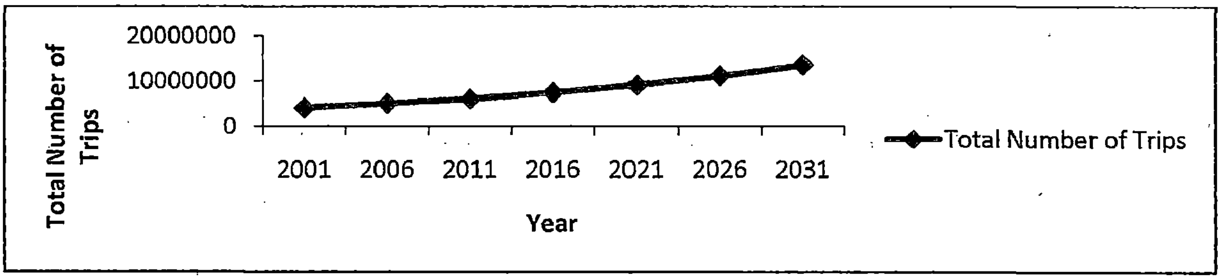

Fig. No. 5.51 (A): Scenario-13-Total Number of Trips

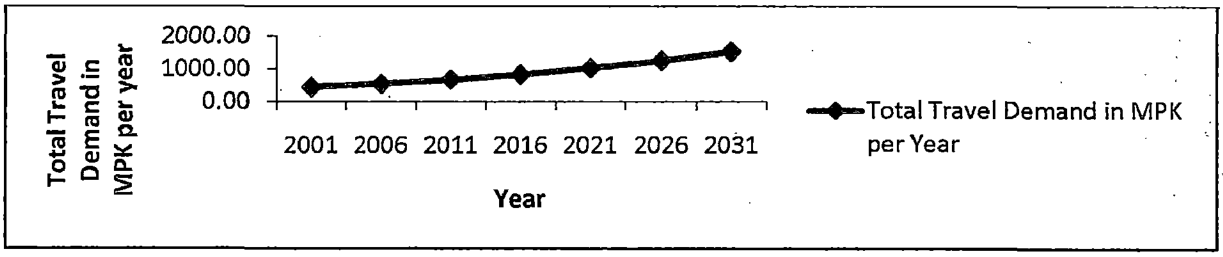

Fig. No. 5.51 (B): Scenario-13-Total Travel Demand

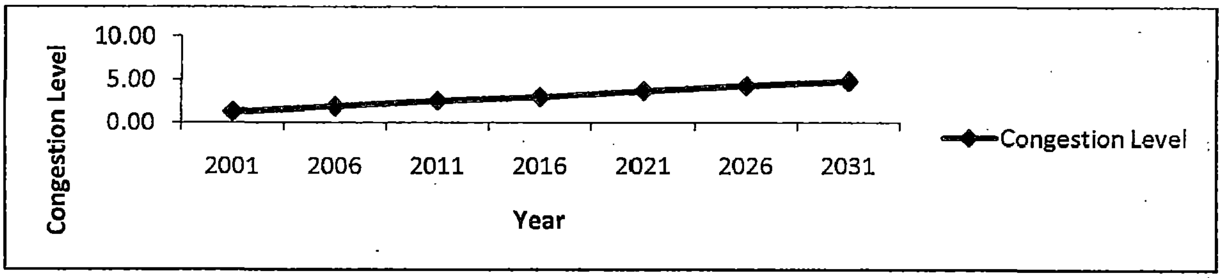

Fig. No. 5.51 (C): Scenario-13-Congestion Level

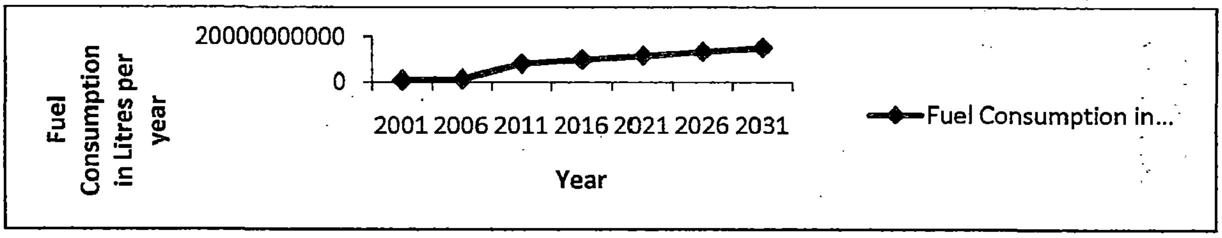

Fig. No. 5.51 (D): Scenario-13-Fuel Consumption

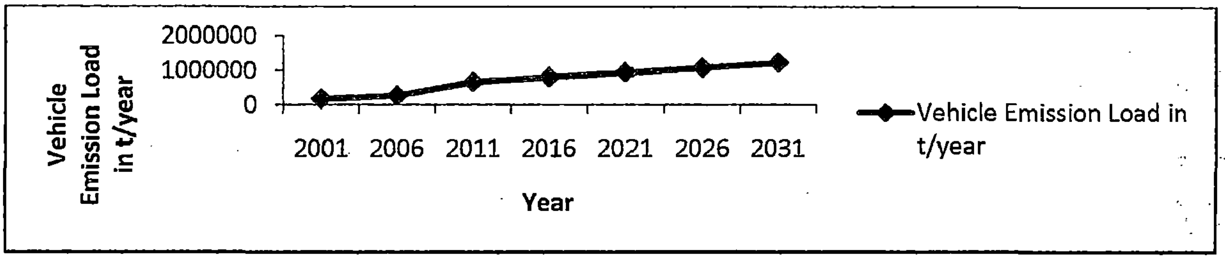

Fig. No. 5.51 (E): Scenario-13-Vehicle Emission Load

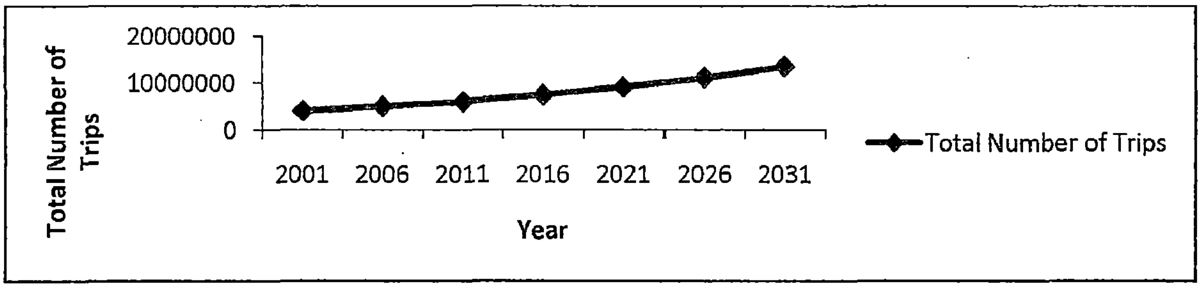

Fig. No. 5.52 (A): Scenario-14-Total Number of Trips

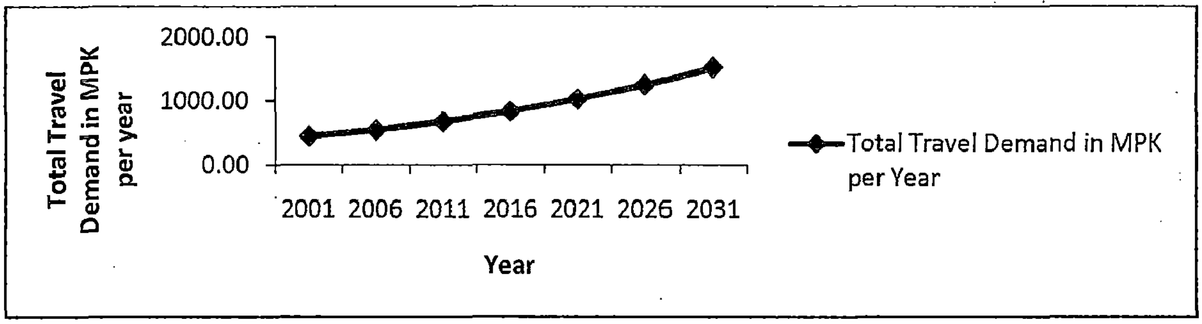

Fig. No. 5.52 (B): Scenario-14-Total Travel Demand

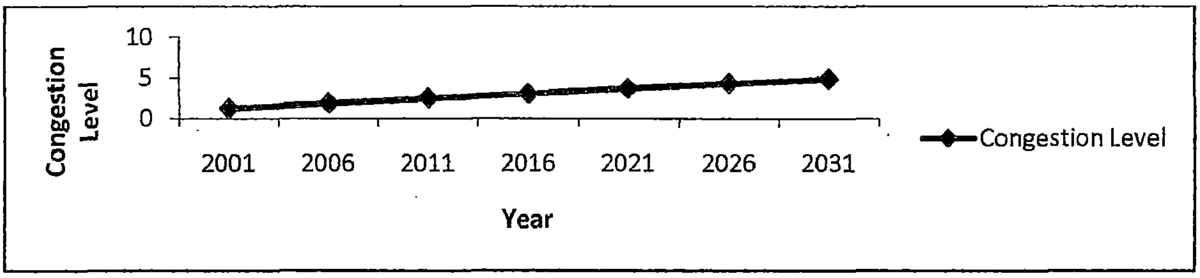

Fig. No. 5.52 (C): Scenario-14-Congestion Level

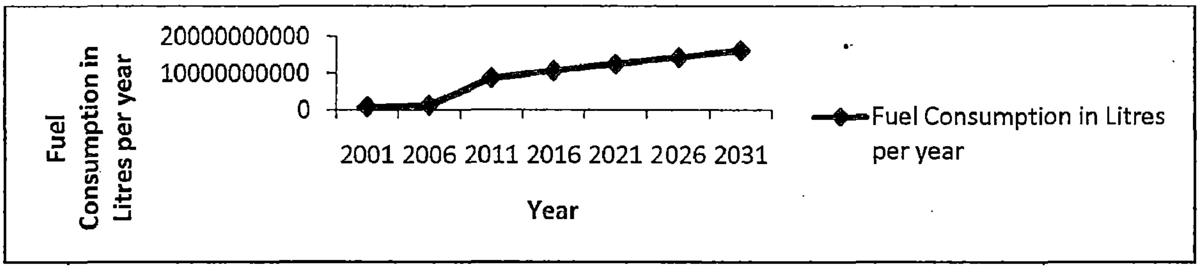

Fig. No. 5.52 (D): Scenario-14-Fuel Consumption

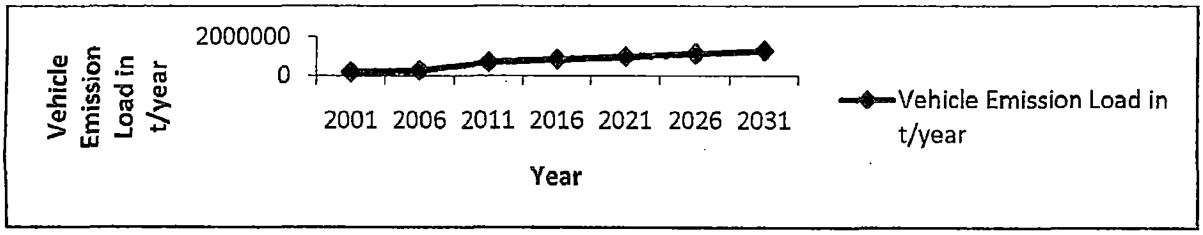

Fig. No. 5.52 (E): Scenario-14-Vehicle Emission Load

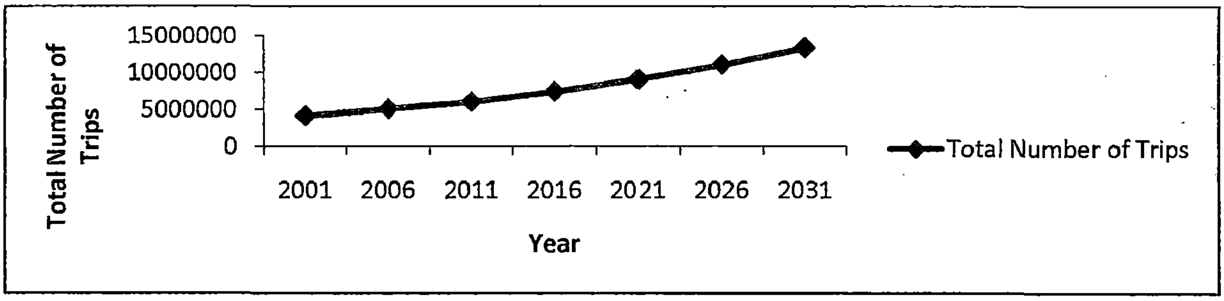

Fig. No. 5.53 (A): Scenario-15-Total Number of Trips

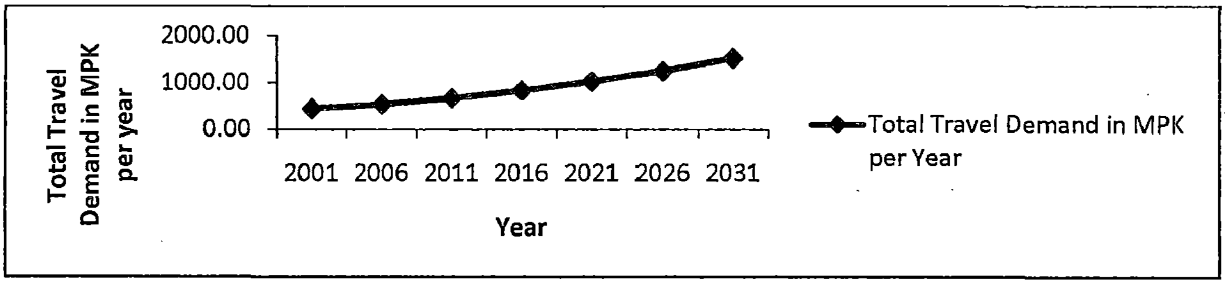

Fig. No. 5.53 (B): Scenario-15-Total Travel Demand

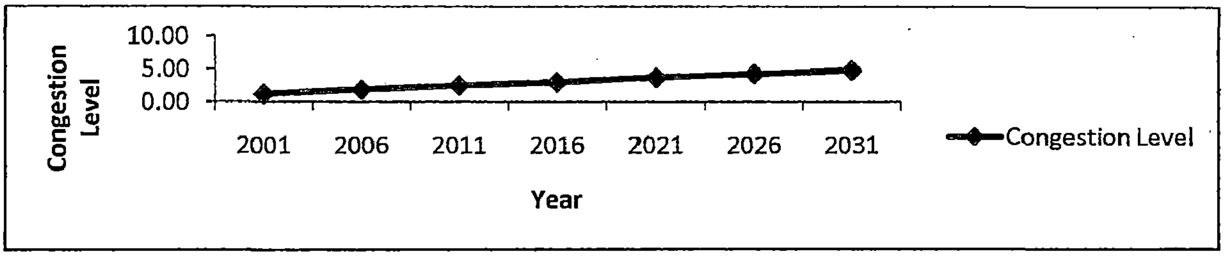

Fig. No. 5.53 (C): Scenario-15-Congestion Level

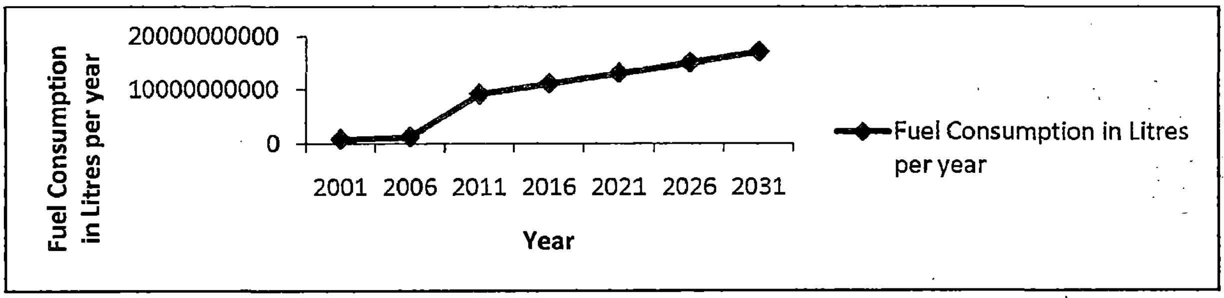

Fig. No. 5.53 (D): Scenario-15-Fuel Consumption

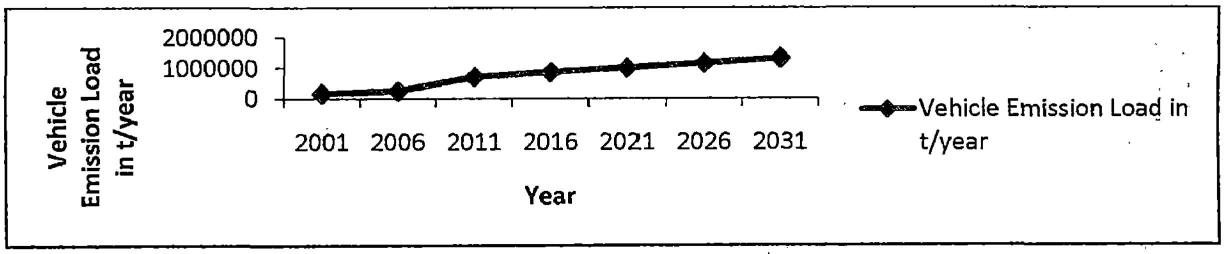

Fig. No. 5.53 (E): Scenario-15-Vehicle Emission Load

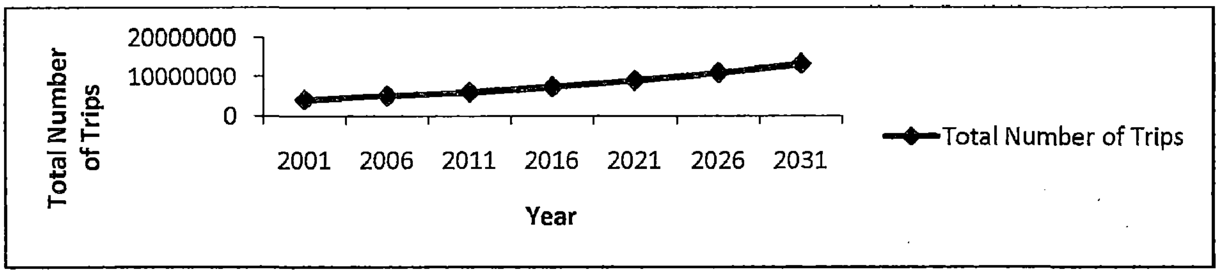

Fig. No. 5.54 (A): Scenario-16-Total Number of Trips

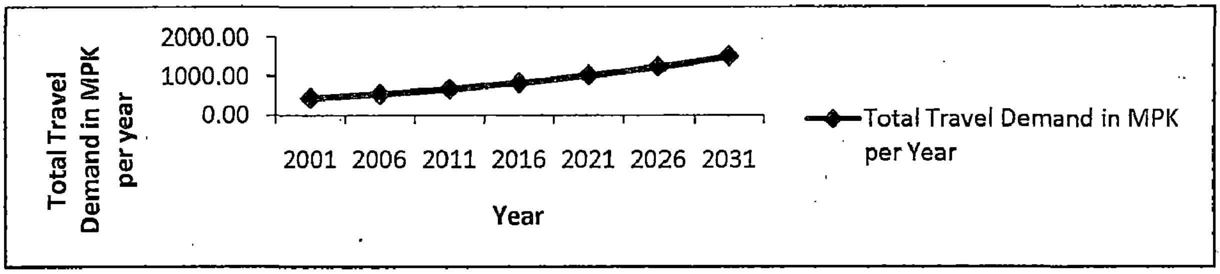

Fig. No. 5.54 (B): Scenario-16-Total Travel Demand

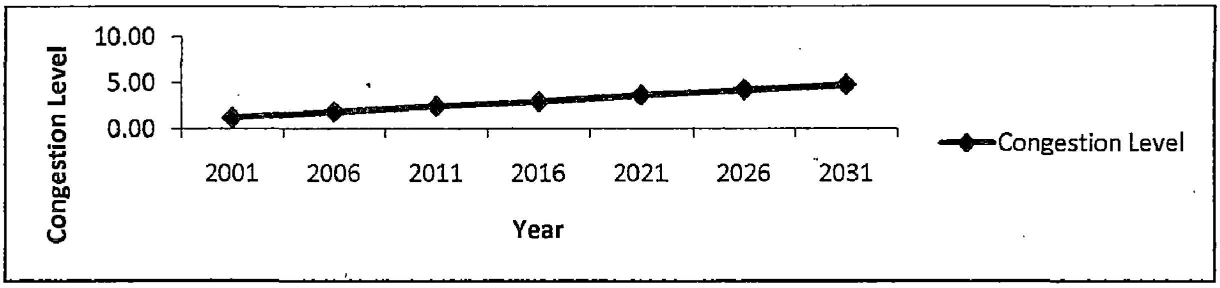

Fig. No. 5.54 (C): Scenario-16-Congestion Level

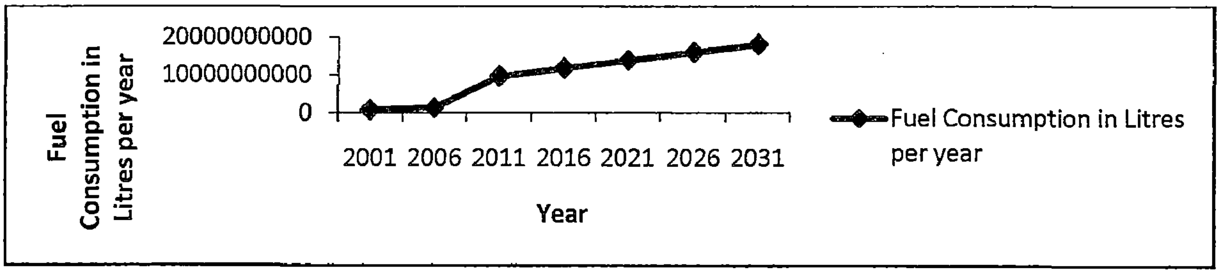

Fig. No. 5.54 (D): Scenario-16-Fuel Consumption

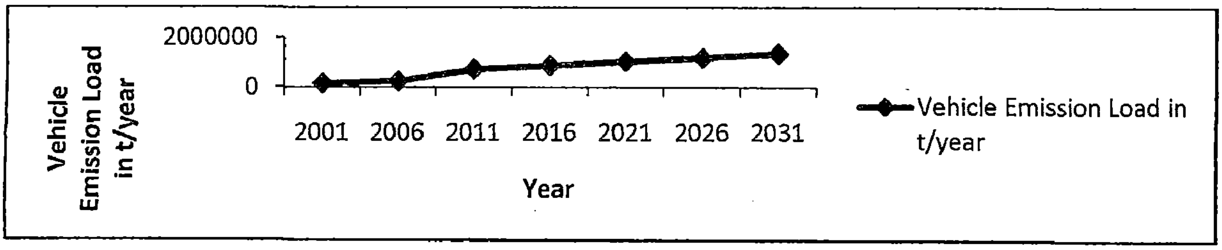

Fig. No. 5.54 (E): Scenario-16-Vehicle Emission Load

5.14. CONCLUSIONS

In this Chapter, the Investigator has identified the control parameters, which decide the functions of the system. Correlation and multiple regression techniques have been employed to understand the parameters, which directly influence the expenditure pattern of the household and the travel characteristics of the households at weekdays, weekend days by different income groups in the study area. Thereafter, System Dynamics model for Integrated Transportation System has been developed representing the existing transportation system in the study area. Subsequently, the developed model was successfully validated. The validated model is used to develop a projected year model for the year 2031 A.D. This projected year model is employed for analytical work. Subsequently, plausible scenarios were developed and tested in the projected year model. The results are presented in the subsequent chapter-6.

RESULTS, DISCUSSION AND FINDINGS

6.0. INTRODUCTION

In this present investigation, different kinds of analysis are made at various stages, such as review of literature, analysis of secondary data, analysis of primary household survey data, analysis of household travel survey in weekdays and weekend days, correlation analysis, multiple regression analysis and analysis of System Dynamics model results. The results of the analysis are thoroughly discussed in this chapter to arrive at inferences. The inferences derived from the results are grouped into five categories, such as inferences based on literature and primary household surveys, inferences based on field observations and inferences based on System Dynamics model analysis, which have been used for evolving policies and plausible recommendations for integrated solid waste management of the system and are presented in the subsequent sections as below.

6.1. FINDINGS BASED ON THE STUDY AREA PROFILE

1. The Bangalore city has transformed from a tiny village to metropolis over the years. The city has grown about 53 times from 9.98 Sq. km in the year 1889 to 531.00 Sq. km in 2001. The city has witnessed to change from textile; manufacturing industries to knowledge-based industries and has become one of the fastest growing cities in Asia.
2. Bangalore Metropolitan Area is divided into forty-seven Planning Districts. The population density of the Planning Districts varies from below 10,000 persons per Sq. km to above 30,000 persons per Sq. km in different Planning Districts of the city.
3. The land use pattern of Bangalore city in the year 2003 reveals that about 88.31 Sq. km land was used for transportation, i.e., about 20.96 per cent of the total land use in the study area.

4. The land under parks, playgrounds and open spaces has been decreased by 2.21 per cent in last three decades in the study area.
5. The entire Bangalore city was classified into five major zones, which include, the core area, peri-urban area, recent extensions on both sides of the outer ring road, new layout on the outskirts of the city, and green belt and the agricultural belt on the outskirts of the city.
6. The city is situated in the heart of South Deccan of Peninsular India. It has grown on a ridge-top running through the middle of Mysore plateau from West to East, at an average elevation of 3021 ft (about 1000.00 m above the mean sea level). The city has salubrious climate throughout the year.
7. The study area has the richest cultural and religious background because of the settlement started with the good number of temples and tanks with the surrounding places.
8. The Bangalore city is an integral part of the Bangalore Urban Agglomeration, which is a heterogeneous combination of Bruhat Bangalore Mahanagara Palike (BBMP) Area, Seven City Municipal Council Areas and one Town Municipal Council Area.
9. The city was the sixteenth largest city in the country in the year 1941, grew rapidly and stood eighth in 1941, became the sixth largest city in the country in the year 1961 became the fifth largest city in the country by the year 1981.
10. The decadal growth rate of population in the study area is phenomenal. The city has witnessed the higher growth rate between the year 1941-1951 and 1971-1981, i.e., about 94.90 and 76.20 per cent respectively. Further, it has been observed that the growth rate of population was gradually declined from the year 1981 to 1991 and 1991 to 2001, and the corresponding values are 41.36 and 37.69 per cent respectively, compared to previous decades.
11. The population density of Bangalore Urban Agglomeration was 10196 persons per Sq. km. The population density found to vary among the various settlement of the study area. It ranges from 1249 persons per Sq. km to 19489 persons per Sq. km. It has been observed that the higher concentration of population in the core area of the city, i.e., Central Business District (CBD), because of available transportation facilities, employment opportunities, and intense economic activities, etc.

12. Bangalore city and its Urban Agglomeration have an average household size of 4.46. The maximum and the minimum household size in the study area are 4.84 and 3.92 respectively.
13. The study are contributes about one-fourth (22.00 per cent) of the State's economy.
14. The study area contributes about three-fourth of the corporate tax collections, four-fifth of sales tax collections and nine-tenth of luxury tax collections in the State.
15. The city attracts more than one-tenth of the FDI in the country, which ranks next to Delhi and Mumbai as an investment destination.
16. The city has more than 512 multinational corporations and more than 1550 Information and Communications Technology (ICT) industries.
17. The city contributes two-fifth of National production in high-technology industrial sectors.
18. The city accounts for almost one-third of the software employment and exports in the country.
19. The city has blessed with good number of tanks and lakes. The total numbers of lakes available are 608 in the study area. The area of the tank/lake varies from less than 2 hectare to more than 50 hectares.
20. The Peenya Industrial Area, which is part of the Bangalore city and its Urban Agglomeration is claimed to be one of the largest industrial area in Asia.
21. The vehicle emissions from the transport sector contribute 51221 tonnes of carbon monoxide (CO), and about 2467 tonnes of particulate matter (PM) annually in the study area.
22. In Air Quality Index, in almost all areas are far beyond the permissible limits in the strategic locations of the study area except some residential areas.
23. About 1000 MLD sewage is generated in the city daily. Of which, about 40.00 per cent is collected and treated by the Bangalore Water Supply and Sewerage Board (BWSSB).
24. The levels of noise pollution in almost all strategic locations are far beyond the permissible limits.
25. Per capita availability of water in the study area was 76 Litres Per Capita per Day (LPCD) in the year 2007, which was far below the prescribed standard.

26. The study area is generating about 3395 tonnes of Municipal Solid Waste (MSW) per day.
27. The Index like Gross Domestic Income (GDI), Human Development Index (HDI), Health Index, Gender Index, Education Index and Income index, and their corresponding values are 0.592, 0.623, 0.663, 0.592, 0.757 and 0.449 respectively in the study area.
28. The City Development Index of Bangalore city is 58.00, city product is 51.10, infrastructure is 82.20, waste generation is 31.30, and the health is 76.50.

6.2. FINDING BASED ON EXISTING TRANSPORTATION SYSTEM IN BANGALORE CITY

1. The total road network of the city is 5900 km. Of which above nine-tenth (93.00 per cent) of the total road lengths are ordinary roads, above one-twentieth (5.94 per cent) of them are arterial and sub-arterial roads and a very meager of 1.06 per cent of them are outer ring roads. The National highways (NH) and State highways (SH) passing through this city, and are account for about 100 km of the total city roads in the study area.
2. The total vehicular population has increased from 51987 in the year 1971 to 1687728 in 2001, which was about 33 times. Further, it has been observed that the total vehicular population has increased 75.00 per cent from the year 2001 to 2006, i.e., from 1687728 in the year 2001 to 2967701 in 2006.
3. The ratio of total vehicle to total population was 1:32 in the year 1971, 1:14.80 in the year 1981, 1:6.88 in the year 1991, 1: 3.7 in the year 2001 and 1: 2.35 in the year 2006, which also shows that the number of vehicular population is increasing in the study area over the years.
4. The total vehicular population in the year 2006 was 2967701. Of which, about three-fourth (72.83 per cent) of them were two-wheelers, about one-seventh (14.00 per cent) of them were cars, less than one-twentieth (3.67 per cent) of them were trucks, about (3.18 per cent) of them were three-wheelers, and about a very meager per cent of them (1.46, 1.32, 1.10, 1.04, 0.66, 0.52, and 0.22 per cent)

belonged to other categories including buses, tractors, trailers, taxies, maxi cabs, and jeeps respectively in the study area.

5. The vehicles including cars and two-wheelers account for about nine-tenth (86.83 per cent) of the total vehicles in the study area.
6. On an average annual growth of vehicular population which includes maxi cabs, taxis, others, trucks, cars, two-wheelers, buses, and three-wheelers and their corresponding values are 43.91, 36.08, 32.76, 25.76, 17.52, 17.20, 14.00, and 9.56 per cent respectively in the study area.
7. The other category vehicles, two-wheelers, trailers, tractors, cars, taxis, trucks, buses, three-wheelers and jeeps were increased about 75, 35, 28, 23, 19, 19, 18, 11, 11 and 3 times respectively between the year 1976 and 2006.
8. The cumulative per cent increase of vehicular population which include two-wheelers, three-wheelers, cars, jeeps, taxies, buses, trucks, tractors, trailers, maxi cabs and other category vehicles and their corresponding values are 493.07, 327.33, 384.54, 122.01, 420.10, 354.16, 390.00, 835.00, 863.85, 311.24, and 836.95 per cent between the period 1976 and 2006 respectively in the study area.
9. The cumulative per cent increase of consumption of fossil fuel like petrol and diesel are 35.27 and 24.96 per cent between the year 1998-1999 and 2002-2003 respectively in the study area.
10. The per cent of work purpose trips reduced from 81.80 per cent to 58.50 per cent between the year 1965 and 2006, whereas education trips were increased from 4.20 to 23.50 per cent, and for the other category purpose remain constant during the same period.
11. The total trips performed by the public transport buses are 2634471. Of which, above half (54.27 per cent) of them covered maximum trip length in the range of 10-15 km; the total trips performed by car are 416304. Of which, above one-third (36.61 per cent) of them covered trip length in the range of 10-15 km; the total trips performed by two-wheeler are 1845476. Of which about two-fifth (39.29 per cent) of them covered trip length in the range of 5-10 km; the total trips performed by three-wheeler are 726425. Of which about two-fifth (38.53 per cent) of them covered trip length in the range of 2-5 km. The total trips covered by bicycle are 139407. Of which above two-fifth (42.42 per cent) of them covered trip length in the

range of 0-2 km; the total trips performed by walking are 523597.Of which, about cent per cent (99.52 per cent) of them covered the trip length in the range of 0-2 km in the study area.

12. Per capita trip rate is 0.924. The per capita trip rate for work, education, others, non-home based and employer business purpose trips are 0.542, 0.218, 0.122, 0.014 and 0.002 respectively in the study area
13. The minimum and maximum pedestrian volumes are 2114 to 19168 in different major junctions of the city.
14. The Bangalore Metropolitan Transport Corporation (BMTC) operates 3531 schedules per day with 4812 buses covering the 1726 routes in the study area. The total services operated by the Bangalore Metropolitan Transport Corporation (BMTC) are 3957. Of which, about two-third (64.24 per cent) of them are suburban services and more than one-fourth (27.84 per cent) of them are city services, and about 7.92 per cent of the total services are done by Pushpak and Volvo buses in the study area.
15. The Bangalore Metropolitan Transport Corporation was operating about 65,121 trips per day and carried about half of the total population, i.e., 37.00 lakh passengers per day in the study area. The Bangalore Metropolitan Transport Corporation (BMTC) buses alone fulfill above two-fifth (41.92 per cent) of the travel demand in the study area (c.ref. table 3.13). The daily average schedule kilometers operated by the Bangalore Metropolitan Transport Corporation buses were 9.33 lakhs in the year 2006-07. The accident rate in Bangalore Metropolitan Transport Corporation buses were 0.16 per lakh km coverage. The other characteristics of Bangalore Metropolitan Transport Corporation (BMTC) buses are average life of the bus is 4.47 years; fuel efficiency is 4.66 litres per km, staff/bus ratio is 4.78, vehicle productivity was 218 km/bus/day, total gross revenue Rs. 687 crore, and the net profit was 113 crore in the year 2006.
16. The walking mode of transport was totally ignored by the concerned authorities in 1994 and in 2002 plan. In 2006, walking mode of transport share was about 8.32 per cent of the total travel in the study area.

17. The bicycle mode of transport was shared about one-tenth (9.05 per cent) of the total travel demand in the year 1994, and further it was gradually declined to 2.22 per cent of the total travel demand in the year 2006.
18. The two-wheeler mode of transport accounted for above one-fifth (22.45 per cent) of the total travel demand in the year 1994, and it was further increased to more than one-third (36.31 per cent) of the total travel demand in the year 2002. Further, it has also been observed that the travel demand by the two-wheeler gradually declined from 36.31 per cent to 29.36 per cent between the year 2002 and 2006, whereas the two-wheelers accounted for about three-fourth (72.83 per cent) of the total vehicular population in the study area.
19. The Intermediate Public Transport (auto-rickshaws) shared about 5.28 per cent of the total travel demand in the year 1994. Further, it was observed that the travel demand was increased from 5.28 to 11.55 per cent between the year 1994 and 2006, whereas the fleet strength of three-wheelers accounted for 3.18 per cent of the total vehicles in the year 2006.
20. The car mode of transport shared about 2.38 per cent of the total travel demand in the year 1994 and gradually increased from 2.38 to 5.44 per cent between the year 1994 and 2002. Further, it has also been observed that the travel demand by car increased from 5.44 to 6.64 per cent between the year 2002 and 2006 whereas the available total fleet strength of cars was 14.00 per cent of the total vehicles in the year 2006.
21. The public transport buses shared more than three-fifth (60.19 per cent) of the total travel demand in the year 1994. It has been observed that there was declined trend from 60.19 per cent to 48.91 per cent between the year 1994 and 2002. Further, it has also been observed that there was a decrease from 48.91 per cent to 41.91 per cent between the year 2002 and 2006. It is interesting to note that public transport buses accounts for about 1.32 per cent of the total vehicles, but fulfills more than two-fifth (41.91 per cent) of the total travel demand in the study area.
22. The volume to capacity ratio is far above the limit and in some cases this ratio is more than 2.00 and 3.00. This clearly indicates that the exacerbated increase of personalized vehicles, inadequate public transportation system, absence of mass

transportation system, inefficient traffic management system, heterogeneous traffic, absence of urban transport policies, lack of planning, etc., in the study area, which is responsible for peak hours of congested traffic in the study area. The road network of the study area is unable to carry the increase in current traffic volume, and mean while it is observed that about 900 new vehicles are registered per day in the study area.

23. The study area is blessed with five railway lines from five different directions, and has about 62 km length of surface rail track. At present, these railway lines are used for intercity transportation and these lines are well connected and served the commuters of nearby satellite centre, district and taluk headquarters, which include Tumkur, Chikaballapur, Bangarpet, Hosur and Mandya.
24. The study area is blessed with an International Airport, located at Devanahally from 35 kilometers from the city centre. The Airport is well connected to the city and provided public transportation exclusively for this purpose. Few private airlines like Air Deccan and Kingfisher Airlines have their headquarters in this city. At present, it is the fourth busiest airport in India in terms of passenger traffic and the number of air traffic movements (ATMs) with about 280 per day.
25. The total road accidents occurred was 13093 in the year 2006. Of which, about half (46.22 per cent) of them were non-fatal. Followed by, above two-fifth (41.68 per cent) of them were injured, about 6.18 per cent and 5.93 per cent of them were killed and fatal respectively in the study area. The study area ranked fifth among India's fourteen major cities in terms of road traffic injuries (RTI) with annual rate of almost 13 road traffic injury deaths per 100,000 population
26. More than 90.00 per cent of people had a journey time longer than 60 minutes.

6.3. FINDINGS BASED ON PRIMARY SURVEY

1. The survey was conducted in 360 households spread across the study area, and 320 schedules were considered for analysis and is having the population of 1535 persons with an average household size of 4.80 persons per households. The maximum household size among the surveyed households is 5.04 and the minimum household size is 4.44 in the study area.

2. Of the total households, above three-fourth (75.32 per cent) of them is confined in the first two income groups category, i.e., below Rs. 20,000/- and Rs. 20,000-40,000. A marginally above 15.00 per cent of them are confined in the income group of Rs. 40,000.00-60,000 and the rest 5.00 per cent, and 4.38 per cent of them are confined to monthly income group of Rs. 60,000- 80,000 and above Rs. 80,000/- per month respectively.
3. The average household size of the surveyed households is 4.80. The least income group, and the monthly income group of Rs. 60,000-80,000, are having the household size, i.e., 4.62 and 4.44 respectively, whereas the other income groups are having above the average household size, i.e., 4.80.
4. Of the total surveyed population, more than half (51.99 per cent) of them are male and the rest (48.01 per cent) are female in the study area.
5. Of the total surveyed population, above one-fourth (26.51 per cent) of them confined in age group of 25-40 years, above one-fifth (21.17 per cent) of them confined in age group of 40-60 years, about one-fifth (18.44 per cent) confined in the age group of 18-25, above one-sixth (16.87 per cent) of them belong to age group of 5-18 years, and a meager (5.34 per cent, 5.67 per cent and 5.99 per cent) of them confined in age group of 60-65 years, below 5 years and above 65 years in the study area.
6. Of the total surveyed population, above half (55.90 per cent) of them is married and above two-fifth (40.59 per cent) of them is unmarried. Only a meager (1.50 per cent and 2.02 per cent) of them are widows and widowers in the study area.
7. Of the total population, about cent per cent (98.82 per cent) of them are literate in the study area. It is hardly about 1.18 per cent of them are illiterate, In educational qualification, about one-fifth (19.15 per cent) of them qualified up to HSC and about one-third (30.16 per cent) of them qualified up to PUC, above one-fifth (22.93 per cent) of them qualified UG and above one-fifteenth (6.71 per cent) of them qualified technical degree, less than one-twentieth (4.30 per cent) of them qualified PG, 4.17 per cent of them qualified diploma, and a very meager (0.91 per cent) and (1.17 per cent) of them qualified medical and others category.
8. Of the total working households, above half (53.97 per cent) of them are confined in the tertiary sector occupation, and above two-fifth (43.63 per cent) of them are

confined in the secondary sector occupation. Further, a very meager (2.40 per cent) of them are confined in the primary sector.

9. Of the total surveyed population, above two-fifth (43.65 per cent) of them are employed in the study area.
10. Of the total surveyed working population, above two-fifth (43.03 per cent) of them confined to 25-40 years of age group, about one-sixth (15.89 per cent) of them confined below 25 years of age group, about one-sixth (15.14 per cent) and above one-eighth (13.94 per cent) of them confined in the age group of 40-50 and 50-60 years, and the considerable, i.e., about one-eighth (11.99 per cent) of them confined in above 60 years of age group.
11. Of the total households, about four-fifth (79.06 per cent) of them are using public water supply system, above one-fifth (20.94 per cent) of them have their own source of water supply system, and about one-sixth (15.94 per cent) of them have both (public water supply system and own source) in the study area.
12. Of the total households, above four-fifth (83.44 per cent) of them had sewer line facility for sanitation, about one-fourteenth (6.88 per cent) of them have soak pit for sanitary facility, less than one-twentieth (4.38 per cent) of them had septic tank, and above one-twentieth (5.31 per cent) of them confined 'no facility category, in the study area.
13. Of the total households, about half (48.44 per cent) of them have open drainage system, about half (44.69 per cent) of them have covered drainage system, and only a meager percentage of population, i.e., about one-fourteenth (6.88 per cent) do not have proper drains in their locality in the study area.
14. Of the total households, about nine-tenth (85.94 per cent) of them disposed household level waste by using dustbin, about one-fifteenth (6.56 per cent) of them are burning their waste, only a meager (4.06 per cent) of them throwing in public places, and further a meager (3.44 per cent) of them have storage container for waste disposal in the study area.
15. Drinking water is good in the system in general; Of the surveyed households, above half (54.06 per cent) of them opinioned that they have access to good quality of drinking water, above one-third (36.25 per cent) has access to moderate quality of drinking water, above one-fourteenth (7.19 per cent) of them have

access to poor quality of drinking water, and only a meager (2.50 per cent) of them have access to very good quality of drinking water in the study area.

16. Air quality in the system is worse in general; Of the surveyed households, above one-third (37.81 per cent) of them opinioned that they have moderate air quality, about one-third (31.56 per cent) of them opinioned that they have poor air qualities, above one-fourth (28.75 per cent) of them opinioned that they have good quality of air, and only a meager (1.68 per cent) of them opinioned that they have very good quality of air in the system.
17. The land quality in the system is good in general; Of the surveyed households, above half (55.00 per cent) of them opinioned that they have good quality of land, above one-fourth (28.44 per cent) of them opinioned that the land quality is moderate, about one-eighth (12.19 per cent) of them opinioned that they have poor quality of land, and only a meager (4.38 per cent) of them opinioned that they have very good quality of land in the study area.
18. The noise pollution is worse in the system in general; Of the surveyed households, about half (46.56 per cent) of them opinioned that they feel moderate noise pollution, above two-fifth (40.31 per cent) of them opinioned that they feel high noise pollution, one-tenth (10.00 per cent) of them opinioned that they feel very high noise pollution, and only a meager (3.13 per cent) of them opinioned that they feel low noise pollution area in the study area.
19. Of the total households, above two-fifth (43.13 per cent) of them had opinioned that the road conditions is moderate, above one-fourth (27.50 per cent) of them opinioned that the road condition is good, above one-eighth (13.13 per cent) of them opinioned that the road condition is poor, less than one-tenth (9.06 per cent) of them opinioned that the road condition is very poor, and above one-fourteenth (7.19 per cent) of them opinioned that the road condition is worse in the study area.
20. Of the total households, above two-fifth (40.31 per cent) of them opinioned that the road maintenance is moderate, above one-fifth (22.19 per cent) of them opinioned that the road maintenance is poor, above one-seventh (15.31 per cent) of them opinioned that the road maintenance is good, above one-tenth (11.25 per cent) of them opinioned that the road maintenance is very poor, and above one-tenth

(10.94 per cent) of them opinioned that the road maintenance is worse in the study area.

21. Lower income groups spend a higher share of their income on food. Of the total households, about half (46.88 per cent) of them spend Rs. 5000-7000, above one-fifth (22.19 per cent) of them spend up to Rs. 5000/- per month, one-fifth (20 per cent) of them spend Rs. 7000-9000, and a very meager (5.31 per cent and 5.63 per cent) of them spend Rs. 9000-11000, and above Rs. 11000/- per month towards food respectively.
22. Of the total households, about one-third (32.81 per cent) of them spend Rs. 400-800 per month, above one-fourth (26.56 per cent) of them spend up to Rs. 400/- per month, above one-fifth (21.56 per cent) of them spend Rs. 800-1200 per month, above one-tenth (10.94 per cent) of them spend Rs. 1200-1600 per month, and about one-twelfth (8.13 per cent) of them spend above Rs. 1600/- per month on clothes.
23. Of the total households, about two-fifth (38.99 per cent) of them spend up to Rs. 1000/- per month, above one-fourth (27.98 per cent) of them spend Rs. 1000-2000 per month, about one-eighth (11.47 per cent) of them spend Rs. 2000-3000 per month, about one-tenth (9.63 per cent) of them spend Rs. 3000-4000 per month, about one-fifteenth (6.42 per cent) of them spend Rs. 4000-5000 per month, and about one-seventeenth (5.50 per cent) of them spend above Rs. 5000/- per month on education in the study area.
24. Of the total households, above one-third (37.50 per cent) of them spend Rs. 400-800 per month, above one-third (34.69 per cent) of them spend up to Rs. 400/- per month, about three-fourth (72.19 per cent) of them spend up to Rs. 800/- per month, about one-sixth (15.63 per cent) of them spend Rs. 800-1200 per month. Further, it is observed that a meager (4.06 per cent, 4.38 per cent, and 3.75 per cent) of them spend Rs. 1200-1600 per month, Rs. 1600-2000, and above Rs. 2000/- per month on health respectively.
25. Of the total households, about one-third (31.88 per cent) of them spend Rs. 300-600 per month, about one-fourth (23.19 per cent) of them spend up to Rs. 300/- per month, above one-fifth (22.10 per cent) of them spend Rs. 900-1200 per month, above one-eighth (12.68 per cent) of them spend of Rs. 600-900 per

month. Further it is observed that a meager (5.07 per cent, and 5.07 per cent) of them spend Rs. 1200-1500, and above Rs. 1500 per month on public transportation in the study area.

26. Of the total households, about half (46.23 per cent) of them spends up to Rs. 2000/- per month, about one-fourth (24.53 per cent) of them spend Rs. 1000-2000, one-twelfth (8.49 per cent) of them spend Rs. 3000-4000 per month, about one-thirteenth (7.55 per cent) of them spend Rs. 4000-5000 per month, about one-fifteenth (6.60 per cent) of them spend Rs. 5000-6000 per month, and about one-fifteenth (6.60 per cent) of them spend above Rs. 6000.00 per month on house rent in the study area.
27. Of the total households, about half (48.44 per cent) of them spend up to Rs. 200/- per month, above one-third (34.06 per cent) of them spend Rs. 200-400 per month, one-tenth (10.00 per cent) of them spend Rs. 400-600 per month, and about one-thirteen (7.50 per cent) of them spend above Rs. 600/- per month towards water tariff in the study area.
28. Of the total households, about one-fifth (18.13 per cent) of them spend up to Rs. 1000/- per month, above one-seventh (15.00 per cent) of them spend Rs. 2000-2500 per month, about one-sixth (15.63 per cent) of them spend between and Rs. 2500-3000 per month, above one-seventh (14.69 per cent) of them spend above Rs. 4000/- per month, about (14.38 per cent) of them spend 3500-4000 per month, about one-tenth (9.69 per cent) of them spend Rs. 1500-2000 per month, about one-twelfth (8.13 per cent) of them spend Rs. 3500-4000 per month, and about one-twentieth (4.38 per cent) of them spend Rs. 1000-1500 per month towards energy in the study area.
29. Of the total households, about half (48.03 per cent) of them spend up to Rs. 1000/- per month, about one-third (30.31 per cent) of them spend Rs. 1000-2000 per month, about one-tenth (9.84 per cent) of them spend up to Rs.1000/- per month, about one-fourteenth (7.09 per cent) of them spend Rs. 3000-4000 per month, and about (4.72 per cent) of them spend above Rs. 4000 per month towards petrol consumption in the study area.
30. Of the total households, above one-third (34.65 per cent) of them spend Rs. 200-400 per month, above one-third (33.86 per cent) of them spend up to Rs. 200 per

month, about one-fourth (24.41 per cent) of them spend up to Rs. 600/- per month, and only a meager, i.e., about one-fourteenth (7.09 per cent) of them spend above Rs. 600/- per month towards parking costs in the study area.

31. Of the total households, about one-fourth (24.37 per cent) of them had loan for different purposes, but majority of them avail loan for housing. Of which, one-third (33.33 per cent) of them spend above Rs. 6000/- per month, about one-sixth (16.67 per cent) of them spend up to Rs. 1000/- per month, above one-seventh (15.38 per cent) of them are spend Rs. 1000-2000 per month, about one-fifteenth (6.41 per cent) of them spend Rs. 2000-3000 per month, and about one-fifteenth (6.41 per cent) of them spend Rs. 3000-4000 per month towards loan repayment in the study area.

32. Of the total households, about one-fourth (24.06 per cent) of them spend Rs. 400-800 per month, about one-sixth (15.94 per cent) of them spend Rs. 1200-1600 per month, above one-seventh (14.38 per cent) of them spend Rs. 800-1200 per month, about one-seventh (14.38 per cent) of them spend Rs. 1600-2000 per month, above one-tenth (11.56 per cent) of them spend Rs. 2000-2400 per month, above one-tenth (10.31 per cent) of them spend above Rs. 2400/- per month, and about one-tenth (9.38 per cent) of them spend up to Rs. 400/- per month on recreation and entertainment in the study area.

33. Of the total households, above nine-tenth (94.38 per cent) of them had telephone-cell phone connection. Of which, above one-third (33.44 per cent) of them spend up to Rs. 1000/- per month, above one-eighth (12.58 per cent) of them spend Rs. 2500-3000 per month, above one-tenth (10.60 per cent) of them spend Rs. 3500-4000 per month, about one-tenth (9.93 per cent) of them spend Rs. 2000-2500 per month, another a set of about one-tenth (9.27 per cent) of them spend Rs. 1500-2000 per month and above Rs. 4000/- per month, above one-twelfth (8.94 per cent) of them spend and Rs. 1000-1500 per month, and a meager (5.96 per cent) of them spend Rs. 3000-3500 per month towards telecommunication in the study area.

34. Of the total households, above two-fifth (40.96 per cent) of them save up to Rs. 3000/- per month, about one-eighth (11.95 per cent) of the save above Rs. 30,000 per month, above one-eighth (12.63 per cent) of them save Rs. 3000-6000, above

one-twelfth (8.87 per cent) of them save Rs. 9000-12,000 per month, above one-fifteenth (6.83 per cent) of them save Rs. 6000-9000, and about one-eighteenth (5.46 per cent) of them save Rs. 12,000-15,000 per month. Further it is observed that a meager of 4.78 per cent, 3.75 per cent, 2.39 per cent, 1.37 per cent and 1.02 per cent save good amount and their corresponding values are 24,000-27,000, 18,000-21,000, 21,000-24,000, 15,000-18,000 and 27,000-30,000 per month respectively.

35. Of the total vehicle owners, about three-fifth (59.06 per cent) of them are having two-wheelers and about one-third (33.07 per cent) of them are having both two-wheelers and cars in the study area.
36. The surveyed households have the total numbers of 496 vehicles. The available number of vehicles per household is 1.55 and the per capita available vehicles are 0.33. Of the total vehicles, about three-fourth (71.77 per cent) of them are motorized two-wheeler vehicles, above one-fourth (27.62 per cent) of them are cars, and the rest of them (0.60 per cent) are three-wheelers.
37. Of the total surveyed households, about one-tenth (9.69 per cent) of them have their own bicycles. Of which above nine-tenth (93.55 per cent) of them had one bicycle and the rest (6.45 per cent) of them have two bicycles.
38. Of the total surveyed households, half of them opinioned that they have adequate parking facility at work place, and the rest of them opinioned that they have inadequate parking facility at work place.
39. Of the total households, above three-fourth (77.95 per cent) of them opinioned that the parking is inadequate at shopping area and rest of them (22.05 per cent) opinioned that parking is adequate at shopping areas in the study area.
40. Of the total households, about cent per cent (97.64 per cent) of them opinioned that parking is inadequate on roads whereas a very meager (2.36 per cent) of them opinioned that parking is adequate on road.
41. Total number of trips generated from the members of surveyed households is 2914. The per capita trip rate is 1.89 (average number of trips per person). Of the total trips, above two-fifth (43.10 per cent) of them performed for work purposes, above one-fourth (27.52 per cent) of them performed for education purposes,

above one-sixth (17.71 per cent) of them performed for shopping purposes, and about one-eighth (11.67 per cent) of them performed for recreation purposes.

42. Of the total trips performed by the surveyed population, above two-fifth (43.57 per cent) of them performed by two-wheelers, about one-fourth (23.03 per cent) of them performed by public transport buses (BMTC bus), above one-sixth (16.72 per cent) of them performed by car trips, above one-thirteenth (7.79 per cent) of them are performed by private vehicles, about (3.97 per cent) of them performed by auto-rickshaw, and a meager (1.29 per cent) of them performed by shared two-wheelers.

43. Of the total work purpose trips, above two-fifth (41.40 per cent) of them performed by two-wheelers., above one-fifth (27.38 per cent) of them performed by public transportation buses (Bangalore Metropolitan Transport Corporation buses BMTC), above one-sixth (16.88 per cent) of them performed by car, above one-sixteenth (6.36 per cent) of them performed by walking, about (4.14 per cent) of them are performed company vans/buses, about (1.92 per cent) of them performed by bicycles, about (1.44 per cent) of them performed by three-wheelers, and a meager (0.48 per cent) of them performed by Karnataka State Road Transport Corporation (KSRTC) buses.

44. Of the total educational purpose trips, about three-tenth (29.67 per cent) of them performed by public transport (Bangalore Metropolitan Transport Corporation buses), about one-fourth (23.94 per cent) of them performed by walking mode, about one-fifth (18.70 per cent) of them performed by school buses/vans, above one-seventh (14.72 per cent) of them were performed by two-wheeler trips, about one-thirteenth (7.48 per cent) of them performed by the three-wheelers, about (3.49 per cent) of them performed by bicycles, and a meager (2.00 per cent) of them performed by the cars.

45. Of the total shopping purpose trips, above three-fifth (60.85 per cent) of them performed by the two-wheelers, above one-fourth (26.36 per cent) of them performed by the cars, about (6.59 per cent) of the performed by bicycle, about (3.88 per cent) of them performed by three-wheeler, and a very meager (2.33 per cent) of them performed by the public transport.

46. Of the total recreational purpose trips, above three-fifth (62.35 per cent) of them performed by the two-wheelers, above one-fourth (25.29 per cent) of them performed by car mode of transport, about (5.29 per cent) of them performed by three-wheelers, about (4.12 per cent) of them performed by public transport, and only a meager (2.9 per cent) of them performed by bicycle.
47. Of the total households, above half (55.63 per cent) of them performed 8-12 trips per household per day, about one-fourth (24.06 per cent) of them performed 12-16 trips per household per day, above one-tenth (10.31 per cent) of them performed up to 8 trips per household per day, above one-twentieth (5.63 per cent) of them performed 16-20 number of trips per household per day, and only a meager one-twentieth (4.38 per cent) of them performed above 20 number of trips per household per day in the study area.
48. Of the total households, about half (44.69 per cent) of them performed 2-4 number of trips per household per day for work purpose, above one-third (36.56 per cent) of them performed up to two trips per household per day for work purpose, one-tenth (10.00 per cent) of them performed 4-6 number of trip per household per day for work purpose, one-twentieth (5.00 per cent) of them performed 6-8 number of trips per household per day for work purpose, and a very meager (3.75 per cent) of them performed above 8 number of work purpose trips per household per day for work purpose.
49. Of the total households, above one-third (33.75 per cent) of them performed 6-8 number of non-work purpose trips per household per day, above one-fifth (21.56 per cent) of them performed 4-6 number of non-work purpose trips per household per day, above one-fifth (20.63 per cent) of them performed 8-10 number of non-work purpose trips per day, about one-tenth (9.38 per cent) of them performed 10-12 number of non-work purpose trips per household per day, about one-fourteenth (7.19 per cent) of them performed up to 4 number of non-work purpose trips per household per day, and one-thirteenth (7.50 per cent) of them performed above 12 number of non-work purpose trips per household per day.
50. Of the total households, about one-third (30.63 per cent) of them performed 50-75 km trip length per household per day, just above one-fourth (25.94 per cent) of

them performed 75-100 km trip length per household per day, about one-fourth (24.38 per cent) of them performed less than 50 km trip length per household per day, about one-tenth (9.38 per cent) of them performed 100-125 km trip length per household per day, about (5.31 per cent) of them performed more than 150 km trip length per household per day, and a very meager (4.38 per cent) of them performed 125-150 km per household per day in the study area.

51. Of the total households, about one-third (30.31 per cent) of them performed 40-60 km trip length per household per day for work purpose, above one-fourth (26.56 per cent) of them performed 20-40 km trip length per household per day for work purpose, about one-fourth (24.38 per cent) of them performed up to 20 km trip length per household per day for work purpose, above one-tenth (10.31 per cent) of them performed 40-60 km trip length per household per day for work purpose, about (5.00 per cent) of them performed above 100 km trip length per household per day for work purpose, and a meager (3.44 per cent) of them performed 80-100 km trip length per household per day for work purpose.

52. Of the total households, above two-fifth (43.44 per cent) of them performed 20-40 km trip length per household per day for non-work purpose, about one-third (31.25 per cent) of them performed up to 20 km trip length per household per day for non-work purose, above one-sixth (17.19 per cent) of them performed 40-60 km trip length per household per day for non-work purpose, and about one-twelfth (8.13 per cent) of them perrformed above 60 km trip length per household per day for non-work purpsose.

53. Of the total public transport trips, about three-tenth (29.06 per cent) of them performed 3-6 km trip length per day, above one-fourth (27.91 per cent) of them performed 6-9 km of trip length per day, about one-fourth (22.99 per cent) of them performed 9-12 km trip length per day, about one-twelfth (8.21 per cent) of them performed 12-15 km trip length per day, about (6.24 per cent) of them performed up to 3 km trip length per day, and a meager, i.e., (5.58 per cent) of them performed above 15 km trip length per day.

54. Of the total households, above one-fourth (27.19 per cent) of them performed 1-2 hr travel time per household per day for work purpose, above one-fourth (25.94 per cent) of them performed 2-3 hr travel time per household per day for work purpose,

above one-fifth (22.81 per cent) of them performed 3-4 hr travel time per household per day for work purpose, about one-tenth (9.06 per cent) of them spent 4-5 hr travel time per household per day for work purpose, about one-thirteenth (7.50 per cent) of them spent less than one hour travel time per household per day for work purpose, and one-thirteenth (7.50 per cent) of them performed above 5 hours per household per day for work purpose.

55. Of the total households, above one-third (35.63 per cent) of them spent 2-3 hr per household per day for non-work purpose, above one-fifth (20.94 per cent) of them spend 3-4 hr per household per day for non-work purpose, one-fifth (20.00 per cent) of them spend up to 2 hr per household per day for non-work purpose, above one-eighth (12.81 per cent) of them spend 4-5 hr per household per day for non-work purpose, and above one-tenth (10.63 per cent) of them spend above 5 hr per household per day for non-work purpose.
56. Per capita trip rate for work, education, shopping, recreation, non-work purpose trips and total are 0.82, 0.52, 0.53, 0.77, 1.81 and 2.63 respectively. It clearly shows that the per capita trip rate of work purpose is higher among the other purpose of trips. The non-work purpose trip is the sum of education, shopping and recreation purpose trips. On an average the per capita trip rate is 1.89 in the study area.
57. Per capita trip rate of motorized and non-motorized trips are 1.66 and 0.97, and the total (motorized and non-motorized) is 2.63 respectively in the study area.
58. Per capita trip rate for with walking trips and without walking trips are 2.63 and 1.72 in the study area. The per capita trip rate of walking, bicycle, two-wheeler, shared two-wheeler, three-wheeler, car, public transport and private transport are 0.91, 0.06, 0.75, 0.02, 0.07, 0.29, 0.40, and 0.13 respectively.
59. Per capita trip length is 15.36 km. Per capita trip length in work purpose is 9.22 km. and per capita trip length in non-work purpose is 6.14 km in the study area.
60. Per capita time spends in total trips is 1.27 hr. Per capita time spends in motorized and non-motorized trips are 0.94 hr and 0.33 hr respectively in the study area.
61. The total number of trips performed by the surveyed households in weekend days is 1292. Per capita trip rate at weekend days is 0.84. Of the total weekend trips, about two-fifth (37.00 per cent) of them were done for shopping purpose, about

one-fourth (23.53 per cent) of them were done for social gathering, about one-fourth (23.07 per cent) of them were done for recreational purpose, and about one-sixth (16.41 per cent) of them were done for entertainment purpose in the study area.

62. Per capita trip rate at weekend trips is 0.84. Per capita trip rate for different purpose which include, shopping, recreational, entertainment, social gathering are 0.31, 0.19, 0.14 and 0.20 respectively. The per capita trip rate of shopping purpose is higher among the other purpose of weekend day's trips in the study area.

6.4. FINDINGS BASED ON STATISTICAL TECHNIQUES

6.4.1. Correlation Techniques based Findings

1. Occupation in tertiary sector of the economy and monthly household income has more correlation coefficient, followed by occupation in secondary and primary sectors of the economy.
2. Higher correlation coefficient is observed between monthly household income and female population. It is also observed that the female populations are trying to acquire higher qualification and employed in technical jobs in the system.
3. Correlation coefficient of Under Graduate Educational Qualification is higher among the educational qualification with monthly household income in the system.
4. Correlation coefficient of expenditure on food is higher among the basic expenditure parameters with monthly household income in the system.
5. Correlation coefficient for expenditure on telecommunication is higher among the non-basic expenditure parameters with monthly household income in the system.
6. Correlation coefficient of motorized trips is higher compared to non-motorized trips and total trips with monthly household income in the system.
7. Correlation coefficient of motorized trip length is higher compared to non-motorized trip length and total trip length with monthly household income in the system.
8. Correlation coefficient of travel time in motorized vehicles is higher compared to time spent in non-motorized vehicles, and total travel time with the monthly household income in the system.

9. Correlation coefficient of car trips with monthly household income is higher among the available different mode of transport in the system.
10. Correlation coefficient of recreational purpose trips in weekdays with monthly household income is higher among the other purpose of trips in weekdays in the system.
11. It is observed that the correlation coefficient of total trip length with monthly household income is higher compared to trip length in work and non-work purpose in the system. Obviously people are giving their importance for both work and non-work purpose in the system.
12. Correlation coefficient of total travel time with monthly household income is higher compared to travel time in work and non-work purpose in the system.
13. Correlation coefficient of shopping purpose trips in weekend days with monthly household income is higher among different purpose of trips in weekend days in the system.

6.4.2. Regression Model based Findings

There are 15 multiple regression models constructed in this present investigation. Of which monthly household income 'y' considered as dependent variable for three models. They are basic expenditures, non-basic expenditures, and motorized-non-motorized trips-trip length-travel time models. The independent variables (x) associated with models were considered for constructing the same and constant (r^2) value for same are 0.999. 1.000 and 0.999 respectively. Further, 12 more multiple regression models were constructed by having different dependent variables 'y' with their corresponding independent variables 'x'. They are walking trips; bicycle trips; public transport trips; four-wheeler (car trips) trips; two-wheeler trips; three-wheeler (auto rickshaws); private vehicle trips; work purpose trips; educational trips; shopping purpose trips; recreational trips; and weekend day trips are analysed and their corresponding values are observed as 1.000, 0.997, 0.999, 0.999, 1.000, 0.995, 0.996, 1.000, 1.000, 1.000, 1.000 and 1.000 respectively. The independent variables used for each above regression model are presented in Chapter-5.

6.5. SYSTEM DYNAMICS MODEL BASED FINDINGS

1. The System Dynamics Model results revealed that the population in the study area would be increased from 5757020 in the year 2001 to 10822416 in the year 2031 A.D, i.e., there would be an increase of population 87.99 per cent, and the area would be increased from 534.08 Sq. km in the year 2001 to 863.11 Sq. km in the year 2031 AD, the population density in the study area would be increased from 10779.32 in the year 2001 to 12538.82 persons per Sq. km in the year 2031.
2. The number of households in the study area would be increased from 1290812 in the year 2001 to 2426551 in the year 2031 AD, i.e., there would be an increase of 87.99 per cent of households.
3. The vehicle ownership would be increased from 263213 in the year 2001 to 2426551 in the year 2031 AD, i.e., there would be an increase of 821.90 per cent.
4. The residential land use area, parks & playgrounds land use area and transportation land use area would be increased from 159.76, 21.32 and 108.68 Sq. km in the year 2001 to 512.82, 34.51 and 185.88 Sq. km in the year 2031 respectively, i.e., there would be increase of 220.99, 61.87 and 71.03 per cent of area for the aforesaid parameters respectively.
5. The two-wheeler, three-wheeler (auto-rickshaw), cars, buses, other vehicles, and the total number of vehicles would be increased from 1223187, 57853, 237034, 3008, 111740, and 1652956 in the year 2001 to 4402407, 208222, 832888, 18562, 362901 and 5949199 in the year 2031 respectively, i.e., there would be an increase of 259.91, 259.91, 251.38, 516.99, 224.77, 259.91 per cent respectively.
6. The number of bicycle trips, two-wheeler trips, three-wheeler trips, car trips, bus trips, and the total trips would be increased from 97828, 1412127, 316963, 240657, 1927214, and 4891405 in the year 2001 to 302236, 5804028, 1128345, 866329, 6606608, and 15111816 in the year 2031 AD respectively, i.e., there would be an increase of 208.95, 311.01, 255.99, 259.98, 242.81 and 208.95 per cent respectively.
7. The two-wheeler emission load, three-wheeler emission load, car emission load, bus emission load, other vehicles emission load, and the total emission load would be increased from 66843, 60863, 16589, 586, 30170, and 175051 tonnes per year

in the year 2001 to 240577, 219055, 58289, 3617, 97983 and 619521 tonnes per year in the year 2031 AD, i.e., there would be an increase of 259.91, 259.91, 251.38, 516.99, 224.77, and 253.91 per cent respectively.

8. The two-wheeler fuel, three-wheeler fuel, car fuel, bus fuel, other vehicles fuel, and the total fuel demand would be increased from 198156, 68729, 134398, 51059, 414331 and 866675 million litres per year in the year 2001 to 713189, 247367, 472247, 315035, 1345637, and 3093477 million litres per year in the year 2031 AD, i.e., there would be an increase of 259.91, 259.91, 251.38, 516.99, 224.77 and 256.94 per cent respectively.
9. The diesel and petrol consumption would be increased from 182001 and 684673 million litres per year to 649630 and 2443847 litres per year in the year 2031 AD respectively, i.e., there would be an increase of 256.94 per cent, each, respectively.
10. The two-wheeler travel demand, three-wheeler travel demand, car travel demand, bus travel demand, and the total travel demand would be increased from 19.06, 38.04, 6.50, 381.59, and 445.63 million persons kilometers per year in the year 2001 to 78.35, 135.40, 23.39, 1308.11, and 1546.62 million persons kilometers per year in the year 2031 AD, i.e., there would be an increase of 311.07, 255.94, 259.85, 242.81 and 247.06 per cent respectively.
11. The actual vehicle density would be increased from 15209 vehicles per Sq. km of transportation area in the year 2001 to 33873 vehicles per Sq. km in the year 2031 AD, i.e., there would be an increase of 122.71 per cen.
12. The congestion would be increased from 1.25 in the year 2001 to 5.37 in the year 2031 AD, i.e., there would be an increase of 329.60 per cent.
13. The air quality would be decreased from 51.38 in the year 2001 to 44.92 in the year 2031 AD, i.e., there would be an decrease of 12.57 per cent.
14. A policy run with decrease in two-wheelers by 5.00 per cent, decrease in three-wheelers by 5.00 per cent, decrease in cars by 5.00 per cent, decrease in other vehicles by 5.00 per cent, increase in buses by 1.00 per cent, increase in transportation area by 1.00 per cent and increase in bicycle trips by 1.00 per cent reveals that the total trips would decrease from 15111816 to 149992863 (-0.79 %); total travel demand would decrease from 1546.62 to 1545.51 MPK/year (-0.07%);

vehicle density would decrease from 33873 to 32451 vehicles per area (-4.19%); vehicle congestion level would decrease from 5.37 to 5.23 (-2.60%); total fuel consumption would decrease from 3093.44 to 2957.31 ML/year (-4.40%) and total emission load would decrease from 619521 to 588710 t/year (-4.97%).

15. A policy run with decrease in two-wheelers by 10.00 per cent, decrease in three-wheelers by 10.00 per cent, decrease in cars by 10.00 per cent, decrease in other vehicles by 8.00 per cent, increase in buses by 2.00 per cent, increase in transportation area by 2.00 per cent and increase in bicycle trips by 2.00 per cent reveals that the total trips would decrease from 15111816 to 14866070 (-1.63 %); total travel demand would decrease from 1546.62 to 1544.03 MPK/year (-0.07%); vehicle density would decrease from 33873 to 32451 vehicles per area (-4.19%); vehicle congestion level would decrease from 5.37 to 5.23 (-2.60%); total fuel consumption would decrease from 3093.44 to 2821.04 ML/year (-8.81%) and total emission load would decrease from 619521 to 557897t/year (-9.94%).

16. A policy run with decrease in two-wheelers by 15.00 per cent, decrease in three-wheelers by 15.00 per cent, decrease in cars by 15.00 per cent, decrease in other vehicles by 15.00 per cent, increase in buses by 3.00 per cent, increase in transportation area by 3.00 per cent and increase in bicycle trips by 3.00 per cent reveals that the total trips would decrease from 15111816 to 14744544 (-2.43%); total travel demand would decrease from 1546.62 to 1542.29 MPK/year (-0.28%); vehicle density would decrease from 33873 to 32143 vehicles per area (-5.10%); vehicle congestion level would decrease from 5.37 to 5.20 (-3.16%); total fuel consumption would decrease from 3093.44 to 2685.70 ML/year (-13.18%) and total emission load would decrease from 619521 to 527163 t/year (-14.91%).

17. A policy run with decrease in two-wheelers by 20.00 per cent, decrease in three-wheelers by 20.00 per cent, decrease in cars by 20.00 per cent, decrease in other vehicles by 20.00 per cent, increase in buses by 4.00 per cent, increase in transportation area by 4.00 per cent and increase in bicycle trips by 4.00 per cent reveals that the total trips would decrease from 15111816 to 14628647 (-3.19%); total travel demand would decrease from 1546.62 to 1539.98 MPK/year (-0.43%); vehicle density would decrease from 33873 to 31841 vehicles per area (-5.99%); vehicle congestion level would decrease from 5.37 to 5.17 (-3.72%); total fuel

consumption would decrease from 3093.44 to 2546.46 ML/year (-17.68%) and total emission load would decrease from 619521 to 496135 t/year (-19.92%).

18. A policy run with decrease in two-wheelers by 25.00 per cent, decrease in three-wheelers by 25.00 per cent, decrease in cars by 25.00 per cent, decrease in other vehicles by 25.00 per cent, increase in buses by 5.00 per cent, increase in transportation area by 5.00 per cent and increase in bicycle trips by 5.00 per cent reveals that the total trips would decrease from 15111816 to 14512081 (-3.97%); total travel demand would decrease from 1546.62 to 1537.43 MPK/year (-0.59%); vehicle density would decrease from 33873 to 31544 vehicles per area (-6.87%); vehicle congestion level would decrease from 5.37 to 5.14 (-4.28%); total fuel consumption would decrease from 3093.44 to 2405.20 ML/year (-22.24%) and total emission load would decrease from 619521 to 464912 t/year (-24.95%).
19. A policy run with decrease in two-wheelers by 30.00 per cent, decrease in three-wheelers by 30.00 per cent, decrease in cars by 30.00 per cent, decrease in other vehicles by 30.00 per cent, increase in buses by 6.00 per cent, increase in transportation area by 6.00 per cent and increase in bicycle trips by 6.00 per cent reveals that the total trips would decrease from 15111816 to 14379441 (-4.84%); total travel demand would decrease from 1546.62 to 1534.84 MPK/year (-0.76%); vehicle density would decrease from 33873 to 31254 vehicles per area (-7.74%); vehicle congestion level would decrease from 5.37 to 5.11 (-4.84%); total fuel consumption would decrease from 3093.44 to 2274.18 ML/year (-26.48%) and total emission load would decrease from 619521 to 434416 t/year (-29.88%).
20. A policy run with decrease in two-wheelers by 35.00 per cent, decrease in three-wheelers by 35.00 per cent, decrease in cars by 35.00 per cent, decrease in other vehicles by 35.00 per cent, increase in buses by 7.00 per cent, increase in transportation area by 7.00 per cent and increase in bicycle trips by 7.00 per cent reveals that the total trips would decrease from 15111816 to 14246773 (-5.74%); total travel demand would decrease from 1546.62 to 1531.17 MPK/year (-0.99%); vehicle density would decrease from 33873 to 30968 vehicles per area (-8.57%); vehicle congestion level would decrease from 5.37 to 5.08 (-5.40%); total fuel consumption would decrease from 3093.44 to 2129.96 ML/year (-31.14%) and total emission load would decrease from 619521 to 403075 t/year (-34.93%).

21. A policy run with decrease in two-wheelers by 40.00 per cent, decrease in three-wheelers by 40.00 per cent, decrease in cars by 40.00 per cent, decrease in other vehicles by 40.00 per cent, increase in buses by 8.00 per cent, increase in transportation area by 8.00 per cent and increase in bicycle trips by 8.00 per cent reveals that the total trips would decrease from 15111816 to 14111565 (-6.62%); total travel demand would decrease from 1546.62 to 1527.56 MPK/year (-1.23%); vehicle density would decrease from 33873 to 30687 vehicles per area (-9.40%); vehicle congestion level would decrease from 5.37 to 5.06 (-5.77%); total fuel consumption would decrease from 3093.44 to 2001.62 ML/year (-35.29%) and total emission load would decrease from 619521 to 372155 t/year (-39.93%).
22. A policy run with decrease in two-wheelers by 45.00 per cent, decrease in three-wheelers by 45.00 per cent, decrease in cars by 45.00 per cent, decrease in other vehicles by 45.00 per cent, increase in buses by 9.00 per cent, increase in transportation area by 9.00 per cent and increase in bicycle trips by 9.00 per cent reveals that the total trips would decrease from 15111816 to 13992342 (-7.41%); total travel demand would decrease from 1546.62 to 1525.13 MPK/year (-1.38%); vehicle density would decrease from 33873 to 30412 vehicles per area (-10.21%); vehicle congestion level would decrease from 5.37 to 5.03 (-6.33%); total fuel consumption would decrease from 3093.44 to 1862.65 ML/year (-39.78%) and total emission load would decrease from 619521 to 341235 t/year (-44.92%).
23. A policy run with decrease in two-wheelers by 50.00 per cent, decrease in three-wheelers by 50.00 per cent, decrease in cars by 50.00 per cent, decrease in other vehicles by 50.00 per cent, increase in buses by 10.00 per cent, increase in transportation area by 10.00 per cent and increase in bicycle trips by 10.00 per cent reveals that the total trips would decrease from 15111816 to 13882263 (-8.13%); total travel demand would decrease from 1546.62 to 1523.01 MPK/year (-1.52%); vehicle density would decrease from 33873 to 30141 vehicles per area (-11.02%); vehicle congestion level would decrease from 5.37 to 4.99 (-7.07%); total fuel consumption would decrease from 3093.44 to 1729.48 ML/year (-44.09%) and total emission load would decrease from 619521 to 310316 t/year (-49.91%).
24. A policy run with decrease in two-wheelers by 55.00 per cent, decrease in three-wheelers by 55.00 per cent, decrease in cars by 55.00 per cent, decrease in other

vehicles by 55.00 per cent, increase in buses by 11.00 per cent, increase in transportation area by 11.00 per cent and increase in bicycle trips by 11.00 per cent reveals that the total trips would decrease from 15111816 to 13777217 (-8.83%); total travel demand would decrease from 1546.62 to 1521.11 MPK/year (-1.64%); vehicle density would decrease from 33873 to 29875 vehicles per area (-11.80%); vehicle congestion level would decrease from 5.37 to 4.96 (-7.63%); total fuel consumption would decrease from 3093.44 to 1593.05 ML/year (-48.50%) and total emission load would decrease from 619521 to 280318 t/year (-54.75%).

25. A policy run with decrease in two-wheelers by 60.00 per cent, decrease in three-wheelers by 60.00 per cent, decrease in cars by 60.00 per cent, decrease in other vehicles by 60.00 per cent, increase in buses by 12.00 per cent, increase in transportation area by 12.00 per cent and increase in bicycle trips by 12.00 per cent reveals that the total trips would decrease from 15111816 to 13675889 (-9.50%); total travel demand would decrease from 1546.62 to 1519.68 MPK/year (-1.74%); vehicle density would decrease from 33873 to 29614 vehicles per area (-12.58%); vehicle congestion level would decrease from 5.37 to 4.98 (-8.38%); total fuel consumption would decrease from 3093.44 to 1456.50 ML/year (-52.92%) and total emission load would decrease from 619521 to 249673 t/year (-59.69%).
26. A policy run with decrease in two-wheelers by 65.00 per cent, decrease in three-wheelers by 65.00 per cent, decrease in cars by 65.00 per cent, decrease in other vehicles by 65.00 per cent, increase in buses by 13.00 per cent, increase in transportation area by 13.00 per cent and increase in bicycle trips by 13.00 per cent reveals that the total trips would decrease from 15111816 to 13576070 (-10.16 %); total travel demand would decrease from 1546.62 to 1518.48 MPK/year (-1.82%); vehicle density would decrease from 33873 to 29357 vehicles per area (-13.13%); vehicle congestion level would decrease from 5.37 to 4.89 (-8.94%); total fuel consumption would decrease from 3093.44 to 1319.30 ML/year (-57.36%) and total emission load would decrease from 619521 to 218743 t/year (-64.69%).
27. A policy run with decrease in two-wheelers by 70.00 per cent, decrease in three-wheelers by 70.00 per cent, decrease in cars by 70.00 per cent, decrease in other vehicles by 70.00 per cent, increase in buses by 14.00 per cent, increase in transportation area by 14.00 per cent and increase in bicycle trips by 14.00 per

cent reveals that the total trips would decrease from 15111816 to 13478989 (-10.80 %); total travel demand would decrease from 1546.62 to 1517.48 MPK/year (-1.88%); vehicle density would decrease from 33873 to 29105 vehicles per area (-14.07%); vehicle congestion level would decrease from 5.37 to 4.85 (-9.68%); total fuel consumption would decrease from 3093.44 to 1170.77 ML/year (-62.15%) and total emission load would decrease from 619521 to 187794 t/year (-69.68%).

28. A policy run with decrease in two-wheelers by 75.00 per cent, decrease in three-wheelers by 75.00 per cent, decrease in cars by 75.00 per cent, decrease in other vehicles by 75.00 per cent, increase in buses by 15.00 per cent, increase in transportation area by 15.00 per cent and increase in bicycle trips by 15.00 per cent reveals that the total trips would decrease from 15111816 to 13388857 (-11.40 %); total travel demand would decrease from 1546.62 to 1516.75 MPK/year (-1.93%); vehicle density would decrease from 33873 to 28857 vehicles per area (-14.81%); vehicle congestion level would decrease from 5.37 to 4.82 (-10.24); total fuel consumption would decrease from 3093.44 to 2957.31 ML/year (-4.40%) and total emission load would decrease from 619521 to 156884 t/year (-74.67%).
29. A policy run with decrease in two-wheelers by 80.00 per cent, decrease in three-wheelers by 80.00 per cent, decrease in cars by 80.00 per cent, decrease in other vehicles by 80.00 per cent, increase in buses by 16.00 per cent, increase in transportation area by 16.00 per cent and increase in bicycle trips by 16.00 per cent reveals that the total trips would decrease from 15111816 to 13296820 (-12.01%); total travel demand would decrease from 1546.62 to 1516.16 MPK/year (-1.96%); vehicle density would decrease from 33873 to 28613 vehicles per area (-15.52%); vehicle congestion level would decrease from 5.37 to 4.79 (-10.80%); total fuel consumption would decrease from 3093.44 to 911.67 ML/year (-70.52%) and total emission load would decrease from 619521 to 126376 t/year (-79.60%).
30. A policy run for public transport buses conversion from diesel driven vehicles into battery-powered operated in the study area i.e., from 10.00 to 90.00 per cent reveals that the conversion of public transport buses by 10.00 per cent result into fuel consumption in buses would decrease from 315.03 ML/year in the projected year model 2031 A.D. to 283.53 ML/year (1.02% to total); emission load per year would decrease from 3617 to 3255 t/year (0.058% to total); The conversion of

public transport buses by 20.00 per cent results into fuel consumption in buses would decrease from 315.03 to 252.02 ML/year (2.04% to total); emission load per year would decrease from 3617 to 2893 t/year (0.117% to total). The conversion of public transport buses by 30.00 per cent results into fuel consumption in buses would decrease from 315.03 to 220.52 ML/year (3.06% to total); emission load per year would decrease from 3617 to 2531 t/year (0.175% to total). The conversion of public transport buses by 40.00 per cent results into fuel consumption in buses would decrease from 315.03 to 189.02 ML/year (4.07% to total); emission load per year would decrease from 3617 to 2170 t/year (0.234% to total). The conversion of public transport buses by 50.00 per cent results into fuel consumption in buses would decrease from 315.03 to 157.51 ML/year (5.09% to total); emission load per year would decrease from 3617 to 1809 t/year (0.292% to total). The conversion of public transport buses by 60.00 per cent results into fuel consumption in buses would decrease from 315.03 to 126.01 ML/year (6.11% to total); emission load per year would decrease from 3617 to 1447 t/year (0.35% to total). The conversion of public transport buses by 70.00 per cent results into fuel consumption in buses would decrease from 315.03 to 94.51 ML/year (7.13% to total); emission load per year would decrease from 3617 to 1085 t/year (0.409% to total). The conversion of public transport buses by 80.00 per cent results into fuel consumption in buses would decrease from 315.03 to 63.00 ML/year (8.15% to total); emission load per year would decrease from 3617 to 723 t/year (0.467% to total). The conversion of public transport buses by 90.00 per cent results into fuel consumption in buses would decrease from 315.03 to 31.50 ML/year (9.17% to total); emission load per year would decrease from 3617 to 362 t/year (0.525% to total).

6.6. CONCLUSION

In this chapter, an attempt has been made to present the findings of the investigation, based on the findings from literature survey results, field observations, primary household survey results, Correlation model, Multiple Regression model, and System Dynamic model results before evolving a set of policy guidelines, and also evolving plausible recommendations for the development of Transportation System in the system and the total development of the system as a whole. Further, plausible policies are evolved and recommended based on the aforesaid findings for the development of the system and are presented in the subsequent chapter-7.

CHAPTER-7

POLICIES, RECOMMENDATIONS AND CONCLUSION

7.0 INTRODUCTION

This city is facing inadequate infrastructure, which is not commensurate with the increase in population, and vehicular population. The study area has been undergoing transportation problems, which include poor public transportation services, absence of mass transportation system, absence of dedicated lanes for different vehicles, inadequate non-motorized infrastructure, absence of urban transport policies, etc. The study area, thus, is facing traffic congestion, overcrowding of buses, traffic jams, traffic delays, long journey hours, heavy consumption of fossil fuel, etc. The situation is bound to worsen if there is immediate measures are taken in short term and long term, and will eventually affect the socio-economic and environmental health of the city and its inhabitants. In this situation, it is felt inevitable to develop and implement a strategic integrated transportation system plan in the city (study area).

7.1. CONCEPT

The control parameters, which decide the functions of the system (study area) to the larger extent related to fuel consumption, emission load, vehicle density and congestion level at the aggregate level its various vehicles in the system, which include two-wheelers, three-wheelers, cars and other vehicles and mean time gradually increased public transport infrastructure (buses) in the vehicular population, transportation area in the total area of the system and non-motorized trips in the modal split in the study area, etc., were considered. This investigation reveals that enhancement of transportation area, public transport buses and bicycle trips, and decrease in two-wheelers, three-wheelers, cars, and other vehicles, etc., are the main controlling parameters, which influence transportation system in the study area. It is also observed that Institutional support at various levels, such as, National level, State level, Local level, etc., in the form of policy reforms, incentives, etc., are required for the development of the system. Besides these, transportation linkages at International, National and State level by air, road and rail transport; and communication linkages in terms of bandwidth connectivity, conducive environment enriched with social, cultural, leisure, recreational, etc., and presence of educational and Research and Development (R & D) institutions are the key elements in overall development of the system.

A set of policy guidelines and plausible recommendations are made based on the in-depth investigation done, i.e., model results, survey findings, observations made during the investigation at the grassroots level and discussions with experts, administrators in the field of transportation system.

In order to develop a set of policy guidelines and evolving plausible recommendations, the following strategies have been considered. They are:

1. Gradual reduction in per cent of two-wheelers from minimum 5.00 per cent to maximum 80.00 per cent by the year 2031 A. D. in the study area.
2. Gradual reduction in per cent of three-wheelers from minimum 5.00 per cent to maximum 80.00 per cent by the year 2031 A. D. in the study area.
3. Gradual reduction in per cent of cars from minimum 5.00 per cent to maximum 80.00 per cent by the year 2031 A. D. in the study area.
4. Gradual reduction in per cent of other vehicles from minimum 5.00 per cent to maximum 80.00 per cent by the year 2031 A. D. in the study area.
5. Gradual increase in per cent of buses from minimum 1.00 per cent to maximum 16.00 per cent by the year 2031 A. D. in the study area.
6. Gradual increase in per cent of bicycle trips from minimum 1.00 per cent to maximum 16.00 per cent by the year 2031 A. D. in the study area.
7. Gradual increase in per cent of transportation area from minimum 1.00 per cent to maximum 16.00 per cent by the year 2031 A. D. in the study area.
8. Gradual increase in per cent usage of battery-powered public transport buses from minimum 10.00 per cent to maximum 90.00 per cent by the year 2031 A. D. in the study area.
9. Composite scenarios were tried with the combination of two or more than two control parameters to develop alternative policies.
10. Further, the various important transport infrastructures and related parameters, such as, travel demand, emission load, fuel consumption, vehicle density and congestion, etc., in 2031 A. D., are calculated based on the model results and

policy run results (scenarios) and are presented in Table 7.1, and various alternative policies are formulated and their results are presented in Table 5.32.

7.2. POLICY OPTIONS

A good number of policy scenarios have been evolved based on the scenarios developed in the projected year 2031 A.D. by considering the parameters those have direct bearings in the system and the results are presented as below:

7.2.1. Policy-1

A policy has been developed by decrease in two-wheelers by 5.00 per cent, decrease in three-wheelers by 5.00 per cent, decrease in cars by 5.00 per cent, decrease in other vehicles by 5.00 per cent, increase in buses by 1.00 per cent, increase in transportation area by 1.00 per cent and increase in bicycle trips by 1.00 per cent in the projected year model 2031 A. D. It results that the two-wheeler trips would decrease from 5804028 in the projected year model 2031 AD to 5704236 (-1.719%); three-wheeler trips would decrease from 1128345 to 1127438 (-0.08%); car trips would decrease from 866329 to 849045 (-1.99%); other vehicle trips would decrease from 404270 to 396225 (-1.99%); bus trips would increase from 6606608 to 6610660 (0.06%) and the total trips would decrease from 15111816 to 14992863 (-0.79%). Bicycle travel demand would increase from 1.36 to 1.37 Million Persons Kilometres /year (0.73%); two-wheeler travel demand would decrease from 78.35 to 77.01 MPK/year (-1.71%); three-wheeler travel demand would decrease from 135.40 to 135.29 MPK/year (-0.08%); car travel demand would decrease from 23.39 to 22.92 MPK/year (-2.00%); bus travel demand would increase from 1308.11 to 1308.91 MPK/year (0.06%) and the total travel demand would decrease from 1546.62 to 1545.51 MPK/year (-0.07%). Vehicle density would decrease from 33873 to 32451 vehicles per transportation area (vehicles per sq. km) (-4.19%) and the vehicle congestion level would decrease from 5.37 to 5.23 (-2.60%). Fuel consumption in two-wheeler would decrease from 713.18 to 677.53 Million Litres/year (-4.99%); fuel consumption in three-wheeler would decrease from 247.36 to 234.99 ML/year (-5.00%); fuel consumption in cars would decrease from 472.24 to 448.13 ML/year (-5.10%); fuel consumption in other vehicles would decrease from 1345.63 to

1278.48 ML/year (-4.99%); fuel consumption in buses would increase from 315.03 to 318.18 ML/year (0.99%) and the total fuel consumption would decrease from 3093.44 to 2957.31 ML/year (-4.40%). Two-wheeler emission load would decrease from 240577 to 228548 t/year (-5.49%); three-wheeler emission load would decrease from 219055 to 208103 t/year (-4.99%); car emission load would decrease from 58289 to 55312 t/year (-5.11%); other emission load would decrease from 97983 to 93094 t/year (-4.98%); bus emission load would increase from 3617 to 3653 t/year (0.99%) and the total emission load would decrease from 619521 to 588710 t/year (-4.97%).

7.2.2. Policy-2

A policy has been developed by decrease in two-wheelers by 10.00 per cent, decrease in three-wheelers by 10.00 per cent, decrease in cars by 10.00 per cent, decrease in other vehicles by 8.00 per cent, increase in buses by 2.00 per cent, increase in transportation area by 2.00 per cent and increase in bicycle trips by 2.00 per cent in the projected year model 2031 A. D. It results that the two-wheeler trips would decrease from 5804028 in the projected year model 2031 AD to 5604443 (-3.438%); three-wheeler trips would decrease from 1128345 to 1123293 (-0.45%); car trips would decrease from 866329 to 833453 (-3.79%); other vehicle trips would decrease from 404270 to 388140 (-4.00%); bus trips would increase from 6606608 to 6614505 (0.12%) and the total trips would decrease from 15111816 to 14866070 (-1.63%). Bicycle travel demand would increase from 1.36 to 1.39 Million Persons Kilometres /year (2.21%); two-wheeler travel demand would decrease from 78.35 to 75.66 MPK/year (-3.43%); three-wheeler travel demand would decrease from 135.40 to 134.80 MPK/year (-0.44%); car travel demand would decrease from 23.39 to 22.50 MPK/year (-3.81%); bus travel demand would increase from 1308.11 to 1309.67 MPK/year (0.12%) and the total travel demand would decrease from 1546.62 to 1544.03 MPK/year (-0.07%). Vehicle density would decrease from 33873 to 32451 vehicles per transportation area (vehicles per sq. km) (-4.19%) and the vehicle congestion level would decrease from 5.37 to 5.23 (-2.60%). Fuel consumption in two-wheeler would decrease from 713.18 to 641.87 Million Litres/year (-9.98%); fuel consumption in three-wheeler would decrease from 247.36 to 222.63 ML/year (-9.99%); fuel consumption in cars would decrease from 472.24 to 424.01

ML/year (-10.21%); fuel consumption in other vehicles would decrease from 1345.63 to 1211.20 ML/year (-9.99%); fuel consumption in buses would increase from 315.03 to 321.33 ML/year (1.99%) and the total fuel consumption would decrease from 3093.44 to 2821.04 ML/year (-8.81%). Two-wheeler emission load would decrease from 240577 to 216519 t/year (-10.00%); three-wheeler emission load would decrease from 219055 to 197150 t/year (-9.99%); car emission load would decrease from 58289 to 52335 t/year (-10.21%); other emission load would decrease from 97983to 88204 t/year (-9.98%); bus emission load would increase from 3617 to 3689 t/year (1.99%) and the total emission load would decrease from 619521 to 557897 t/year (-9.94%).

7.2.3. Policy-3

A policy has been developed by decrease in two-wheelers by 15.00 per cent, decrease in three-wheelers by 15.00 per cent, decrease in cars by 15.00 per cent, decrease in other vehicles by 15.00 per cent, increase in buses by 3.00 per cent, increase in transportation area by 3.00 per cent and increase in bicycle trips by 3.00 per cent in the projected year model 2031 A. D. It results that the two-wheeler trips would decrease from 5804028 in the projected year model 2031 AD to 5504651 (-5.158%); three-wheeler trips would decrease from 1128345 to 1117119 (-0.99%); car trips would decrease from 866329 to 819626(-5.39%); other vehicle trips would decrease from 404270 to 382561 (-5.36%); bus trips would increase from 6606608 to 6618351 (0.17%) and the total trips would decrease from 15111816 to 14744544 (-2.43%). Bicycle travel demand would increase from 1.36 to 1.40 Million Persons Kilometres /year (2.94%); two-wheeler travel demand would decrease from 78.35 to 74.31 MPK/year (-5.15%); three-wheeler travel demand would decrease from 135.40 to 134.05 MPK/year (-0.99%); car travel demand would decrease from 23.39 to 22.13 MPK/year (-5.38%); bus travel demand would increase from 1308.11 to 1310.43 MPK/year (0.17%) and the total travel demand would decrease from 1546.62 to 1542.29 MPK/year (-0.28%). Vehicle density would decrease from 33873 to 32143 vehicles per transportation area (vehicles per sq. km) (-5.10%) and the vehicle congestion level would decrease from 5.37 to 5.20 (-3.16%). Fuel consumption in two-wheeler would decrease from 713.18 to 606.21 Million Litres/year (-14.99%); fuel consumption in three-wheeler would decrease from 247.36 to 210.26

ML/year (-14.99%); fuel consumption in cars would decrease from 472.24 to 399.89 ML/year (-15.32%); fuel consumption in other vehicles would decrease from 1345.63 to 1144.86 ML/year (-14.92%); fuel consumption in buses would increase from 315.03 to 324.48 ML/year (2.99%) and the total fuel consumption would decrease from 3093.44 to 2685.70 ML/year (-13.18%). Two-wheeler emission load would decrease from 240577 to 204490 t/year (-15.00%); three-wheeler emission load would decrease from 219055 to 186197 t/year (-14.99%); car emission load would decrease from 58289 to 49358 t/year (-15.32%); other emission load would decrease from 97983 to 83393 t/year (-14.89%); bus emission load would increase from 3617 to 3725 t/year (2.98%) and the total emission load would decrease from 619521 to 527163 t/year (-14.91%).

7.2.4. Policy-4

A policy has been developed by decrease in two-wheelers by 20.00 per cent, decrease in three-wheelers by 20.00 per cent, decrease in cars by 20.00 per cent, decrease in other vehicles by 20.00 per cent, increase in buses by 4.00 per cent, increase in transportation area by 4.00 per cent and increase in bicycle trips by 4.00 per cent in the projected year model 2031 A. D. It results that the two-wheeler trips would decrease from 5804028 in the projected year model 2031 AD to 5404858 (-6.877%); three-wheeler trips would decrease from 1128345 to 1105335 (-2.04%); car trips would decrease from 866329 to 805799 (-6.98%); other vehicle trips would decrease from 404270 to 376133 (-6.96%); bus trips would increase from 6606608 to 6622196 (0.24%) and the total trips would decrease from 15111816 to 14628647 (-3.19%). Bicycle travel demand would increase from 1.36 to 1.37 Million Persons Kilometres /year (0.73%); two-wheeler travel demand would decrease from 78.35 to 72.97 MPK/year (-6.86%); three-wheeler travel demand would decrease from 135.40 to 132.64 MPK/year (-2.04%); car travel demand would decrease from 23.39 to 21.76 MPK/year (-6.97%); bus travel demand would increase from 1308.11 to 1311.19 MPK/year (0.23%) and the total travel demand would decrease from 1546.62 to 1539.98 MPK/year (-0.43%). Vehicle density would decrease from 33873 to 31841 vehicles per transportation area (vehicles per sq. km) (-5.99%) and the vehicle congestion level would decrease from 5.37 to 5.17 (-3.72%). Fuel consumption in two-wheeler would decrease from 713.18 to 570.55 Million Litres/year (-

19.99%); fuel consumption in three-wheeler would decrease from 247.36 to 197.89 ML/year (-19.99%); fuel consumption in cars would decrease from 472.24 to 375.77 ML/year (-20.42%); fuel consumption in other vehicles would decrease from 1345.63 to 1074.62 ML/year (-20.14%); fuel consumption in buses would increase from 315.03 to 327.63 ML/year (3.99%) and the total fuel consumption would decrease from 3093.44 to 2546.46 ML/year (-17.68%). Two-wheeler emission load would decrease from 240577 to 192461 t/year (-20.00%); three-wheeler emission load would decrease from 219055 to 175244 t/year (-20.00%); car emission load would decrease from 58289 to 46381 t/year (-20.43%); other emission load would decrease from 97983 to 78288 t/year (-20.10%); bus emission load would increase from 3617 to 3761 t/year (3.98%) and the total emission load would decrease from 619521 to 496135 t/year (-19.92%).

7.2.5. Policy-5

A policy has been developed by decrease in two-wheelers by 25.00 per cent, decrease in three-wheelers by 25.00 per cent, decrease in cars by 25.00 per cent, decrease in other vehicles by 25.00 per cent, increase in buses by 5.00 per cent, increase in transportation area by 5.00 per cent and increase in bicycle trips by 5.00 per cent in the projected year model 2031 A. D. It results that the decrease in two-wheelers by 25.00 per cent, decrease in three-wheelers by 25.00 per cent, decrease in cars by 25.00 per cent, decrease in other vehicles by 25.00 per cent, increase in buses by 5.00 per cent, increase in transportation area by 5.00 per cent and increase in bicycle trips by 5.00 per cent two-wheeler trips would decrease from 5804028 in the projected year model 2031 AD to 5305066 (-8.596%); three-wheeler trips would decrease from 1128345 to 1092030 (-2.33%); car trips would decrease from 866329 to 791972 (-8.58%); other vehicle trips would decrease from 404270 to 369624 (-8.57%); bus trips would increase from 6606608 to 6626041 (0.29%) and the total trips would decrease from 15111816 to 14512081 (-3.97%). Bicycle travel demand would increase from 1.36 to 1.43 Million Persons Kilometres /year (5.14%); two-wheeler travel demand would decrease from 78.35 to 71.62 MPK/year (-8.59%); three-wheeler travel demand would decrease from 135.40 to 131.04 MPK/year (-3.22%); car travel demand would decrease from 23.39 to 21.38 MPK/year (-8.59%); bus travel demand would increase from 1308.11 to 1311.96

MPK/year (0.29%) and the total travel demand would decrease from 1546.62 to 1537.43 MPK/year (-0.59%). Vehicle density would decrease from 33873 to 31544 vehicles per transportation area (vehicles per sq. km) (-6.87%) and the vehicle congestion level would decrease from 5.37 to 5.14 (-4.28%). Fuel consumption in two-wheeler would decrease from 713.18 to 534.89 Million Litres/year (-24.99%); fuel consumption in three-wheeler would decrease from 247.36 to 185.52 ML/year (-25.00%); fuel consumption in cars would decrease from 472.24 to 351.66 ML/year (-25.53%); fuel consumption in other vehicles would decrease from 1345.63 to 1002.35 ML/year (-25.51%); fuel consumption in buses would increase from 315.03 to 330.78 ML/year (4.99%) and the total fuel consumption would decrease from 3093.44 to 2405.20 ML/year (-22.24%). Two-wheeler emission load would decrease from 240577 to 180433 t/year (-24.99%); three-wheeler emission load would decrease from 219055 to 164291 t/year (-25.00%); car emission load would decrease from 58289 to 43404 t/year (-25.53%); other emission load would decrease from 97983 to 72987 t/year (-25.51%); bus emission load would increase from 3617 to 3797 t/year (4.98%) and the total emission load would decrease from 619521 to 464912 t/year (-24.95%).

7.2.6. Policy-6

A policy has been developed by decrease in two-wheelers by 30.00 per cent, decrease in three-wheelers by 30.00 per cent, decrease in cars by 30.00 per cent, decrease in other vehicles by 30.00 per cent, increase in buses by 6.00 per cent, increase in transportation area by 6.00 per cent and increase in bicycle trips by 6.00 per cent in the projected year model 2031 A. D. It results that the two-wheeler trips would decrease from 5804028 in the projected year model 2031 AD to 5205273 (-10.316%); three-wheeler trips would decrease from 1128345 to 1077526 (-4.50%); car trips would decrease from 866329 to 781573 (-9.78%); other vehicle trips would decrease from 404270 to 364813 (-9.76%); bus trips would increase from 6606608 to 6629886 (0.35%) and the total trips would decrease from 15111816 to 14379441 (-4.84%). Bicycle travel demand would increase from 1.36 to 1.44 Million Persons Kilometres /year (5.88%); two-wheeler travel demand would decrease from 78.35 to 70.27 MPK/year (-10.32%); three-wheeler travel demand would decrease from 135.40 to 129.30 MPK/year (-4.51%); car travel demand would decrease from 23.39 to 21.10 MPK/year (-9.79%); bus travel demand would increase from 1308.11 to 1312.72 MPK/year (0.35%) and the total travel demand would decrease from 1546.62 to 1534.84 MPK/year (-0.76%). Vehicle density would decrease from 33873 to 31254 vehicles per transportation area (vehicles per sq. km) (-7.74%) and the vehicle congestion level would decrease from 5.37 to 5.11 (-4.84%). Fuel consumption in two-wheeler would decrease from 713.18 to 499.23 Million Litres/year (-29.99%); fuel consumption in three-wheeler would decrease from 247.36 to 173.15 ML/year (-30.00%); fuel consumption in cars would decrease from 472.24 to 327.54 ML/year (-30.63%); fuel consumption in other vehicles would decrease from 1345.63 to 940.32 ML/year (-30.12%); fuel consumption in buses would increase from 315.03 to 333.94 ML/year (6.00%) and the total fuel consumption would decrease from 3093.44 to 2274.18 ML/year (-26.48%). Two-wheeler emission load would decrease from 240577 to 168404 t/year (-29.99%); three-wheeler emission load would decrease from 219055 to 153339 t/year (-29.99%); car emission load would decrease from 58289 to 40427 t/year (-30.64%); other emission load would decrease from 97983 to 68412 t/year (-30.18%); bus emission load would increase from 3617 to 3834 t/year (5.99%) and the total emission load would decrease from 619521 to 434416 t/year (-29.88%).

7.2.7. Policy-7

A policy has been developed by decrease in two-wheelers by 35.00 per cent, decrease in three-wheelers by 35.00 per cent, decrease in cars by 35.00 per cent, decrease in other vehicles by 35.00 per cent, increase in buses by 7.00 per cent, increase in transportation area by 7.00 per cent and increase in bicycle trips by 7.00 per cent in the projected year model 2031 A. D. It results that the two-wheeler trips would decrease from 5804028 in the projected year model 2031 AD to 5105481 (-12.035%); three-wheeler trips would decrease from 1128345 to 1054126 (-6.57%); car trips would decrease from 866329 to 770362 (-11.07%); other vehicle trips would decrease from 404270 to 359679 (-11.03%); bus trips would increase from 6606608 to 6633732 (0.41%) and the total trips would decrease from 15111816 to 14246773 (-5.74%). Bicycle travel demand would increase from 1.36 to 1.46 Million Persons Kilometres /year (7.35%); two-wheeler travel demand would decrease from 78.35 to 68.92 MPK/year (-12.03 %); three-wheeler travel demand would decrease from 135.40 to 126.50 MPK/year (-6.57%); car travel demand would decrease from 23.39 to 20.80 MPK/year (-11.07%); bus travel demand would increase from 1308.11 to 1313.48 MPK/year (0.41%) and the total travel demand would decrease from 1546.62 to 1531.17 MPK/year (-0.99%). Vehicle density would decrease from 33873 to 30968 vehicles per transportation area (vehicles per sq. km) (-8.57%) and the vehicle congestion level would decrease from 5.37 to 5.08 (-5.40%). Fuel consumption in two-wheeler would decrease from 713.18 to 463.57 Million Litres/year (-34.99%); fuel consumption in three-wheeler would decrease from 247.36 to 160.78 ML/year (-35.00%); fuel consumption in cars would decrease from 472.24 to 303.42 ML/year (-35.74%); fuel consumption in other vehicles would decrease from 1345.63 to 865.11 ML/year (-35.71%); fuel consumption in buses would increase from 315.03 to 337.08 ML/year (6.99%) and the total fuel consumption would decrease from 3093.44 to 2129.96 ML/year (-31.14%). Two-wheeler emission load would decrease from 240577 to 156375 t/year (-35.00%); three-wheeler emission load would decrease from 219055 to 142386 t/year (-34.99%); car emission load would decrease from 58289 to 37451 t/year (-35.75%); other emission load would decrease from 97983 to 62993 t/year (-35.71%); bus emission load would increase from 3617 to 3870 t/year (6.99%) and the total emission load would decrease from 619521 to 403075 t/year (-34.93%).

7.2.8. Policy-8

A policy has been developed by decrease in two-wheelers by 40.00 per cent, decrease in three-wheelers by 40.00 per cent, decrease in cars by 40.00 per cent, decrease in other vehicles by 40.00 per cent, increase in buses by 8.00 per cent, increase in transportation area by 8.00 per cent and increase in bicycle trips by 8.00 per cent in the projected year model 2031 A. D. It results that the two-wheeler trips would decrease from 5804028 in the projected year model 2031 AD to 5005688 (-13.750%); three-wheeler trips would decrease from 1128345 to 1032099 (-8.52%); car trips would decrease from 866329 to 756535 (-12.67%); other vehicle trips would decrease from 404270 to 353251 (-12.62%); bus trips would increase from 6606608 to 6637577 (0.47%) and the total trips would decrease from 15111816 to 14111565 (-6.62%). Bicycle travel demand would increase from 1.36 to 1.47 Million Persons Kilometres /year (8.08%); two-wheeler travel demand would decrease from 78.35 to 67.58 MPK/year (-13.74%); three-wheeler travel demand would decrease from 135.40 to 123.85 MPK/year (-8.53%); car travel demand would decrease from 23.39 to 20.43 MPK/year (-12.65%); bus travel demand would increase from 1308.11 to 1314.24 MPK/year (0.47%) and the total travel demand would decrease from 1546.62 to 1527.56 MPK/year (-1.23%). Vehicle density would decrease from 33873 to 30687 vehicles per transportation area (vehicles per sq. km) (-9.40%) and the vehicle congestion level would decrease from 5.37 to 5.06 (-5.77%). Fuel consumption in two-wheeler would decrease from 713.18 to 427.91 Million Litres/year (-39.99%); fuel consumption in three-wheeler would decrease from 247.36 to 148.42 ML/year (-39.98%); fuel consumption in cars would decrease from 472.24 to 279.30 ML/year (-40.85%); fuel consumption in other vehicles would decrease from 1345.63 to 805.76 ML/year (-40.12%); fuel consumption in buses would increase from 315.03 to 340.23 ML/year (7.99%) and the total fuel consumption would decrease from 3093.44 to 2001.62 ML/year (-35.29%). Two-wheeler emission load would decrease from 240577 to 144346 t/year (-40.00%); three-wheeler emission load would decrease from 219055 to 131433 t/year (-40.00%); car emission load would decrease from 58289 to 34474 t/year (-40.85%); other emission load would decrease from 97983 to 57996 t/year (-40.81%); bus emission load would increase from 3617 to 3906 t/year (7.99%) and the total emission load would decrease from 619521 to 372155 t/year (-39.93%).

7.2.9. Policy-9

A policy has been developed by decrease in two-wheelers by 45.00 per cent, decrease in three-wheelers by 45.00 per cent, decrease in cars by 45.00 per cent, decrease in other vehicles by 45.00 per cent, increase in buses by 9.00 per cent, increase in transportation area by 9.00 per cent and increase in bicycle trips by 9.00 per cent in the projected year model 2031 A. D. It results that the two-wheeler trips would decrease from 5804028 in the projected year model 2031 AD to 4905896 (-15.474%); three-wheeler trips would decrease from 1128345 to 1018501 (-9.73%); car trips would decrease from 866329 to 747837 (-13.67%); other vehicle trips would decrease from 404270 to 349248 (-13.61%); bus trips would increase from 6606608 to 6641422 (0.52%) and the total trips would decrease from 15111816 to 13992342 (-7.41%). Bicycle travel demand would increase from 1.36 to 1.48 Million Persons Kilometres /year (8.82%); two-wheeler travel demand would decrease from 78.35 to 66.23 MPK/year (-15.46%); three-wheeler travel demand would decrease from 135.40 to 122.22 MPK/year (-9.73%); car travel demand would decrease from 23.39 to 20.19 MPK/year (-13.68%); bus travel demand would increase from 1308.11 to 1315.00 MPK/year (0.52%) and the total travel demand would decrease from 1546.62 to 1525.13 MPK/year (-1.38%). Vehicle density would decrease from 33873 to 30412 vehicles per transportation area (vehicles per sq. km) (-10.21%) and the vehicle congestion level would decrease from 5.37 to 5.03 (-6.33%). Fuel consumption in two-wheeler would decrease from 713.18 to 392.25 Million Litres/year (-44.99%); fuel consumption in three-wheeler would decrease from 247.36 to 136.05 ML/year (-44.99%); fuel consumption in cars would decrease from 472.24 to 255.18 ML/year (-45.96%); fuel consumption in other vehicles would decrease from 1345.63 to 735.79 ML/year (-45.32%); fuel consumption in buses would increase from 315.03 to 343.38 ML/year (8.99%) and the total fuel consumption would decrease from 3093.44 to 1862.65 ML/year (-39.78%). Two-wheeler emission load would decrease from 240577 to 132317 t/year (-45.00%); three-wheeler emission load would decrease from 219055 to 120480 t/year (-45.00%); car emission load would decrease from 58289 to 31497 t/year (-45.96%); other emission load would decrease from 97983 to 52999 t/year (-45.91%); bus emission load would increase from 3617 to 3942 t/year (8.98%) and the total emission load would decrease from 619521 to 341235 t/year (-44.92%).

7.2.10. Policy-10

A policy has been developed by decrease in two-wheelers by 50.00 per cent, decrease in three-wheelers by 50.00 per cent, decrease in cars by 50.00 per cent, decrease in other vehicles by 50.00 per cent, increase in buses by 10.00 per cent, increase in transportation area by 10.00 per cent and increase in bicycle trips by 10.00 per cent in the projected year model 2031 A. D. It results that the two-wheeler trips would decrease from 5804028 in the projected year model 2031 AD to 4806103 (-17.193%); three-wheeler trips would decrease from 1128345 to 1006421 (-10.81%); car trips would decrease from 866329 to 744380 (-14.07%); other vehicle trips would decrease from 404270 to 347632 (-14.00%); bus trips would increase from 6606608 to 6645267 (0.58%)

and the total trips would decrease from 15111816 to 13882263 (-8.13%). Bicycle travel demand would increase from 1.36 to 1.50 Million Persons Kilometres /year (10.29%); two-wheeler travel demand would decrease from 78.35 to 64.88 MPK/year (-17.19%); three-wheeler travel demand would decrease from 135.40 to 120.77 MPK/year (-10.81%); car travel demand would decrease from 23.39 to 20.10 MPK/year (-14.06%); bus travel demand would increase from 1308.11 to 1315.76 MPK/year (0.58%) and the total travel demand would decrease from 1546.62 to 1523.01 MPK/year (-1.52%). Vehicle density would decrease from 33873 to 30141 vehicles per transportation area (vehicles per sq. km) (-11.02%) and the vehicle congestion level would decrease from 5.37 to 4.99 (-7.07%). Fuel consumption in two-wheeler would decrease from 713.18 to 356.59 Million Litres/year (-50.00%); fuel consumption in three-wheeler would decrease from 247.36 to 123.68 ML/year (-50.00%); fuel consumption in cars would decrease from 472.24 to 231.06 ML/year (-51.07%); fuel consumption in other vehicles would decrease from 1345.63 to 671.61 ML/year (-50.00%); fuel consumption in buses would increase from 315.03 to 346.54 ML/year (10.00%) and the total fuel consumption would decrease from 3093.44 to 1729.48 ML/year (-44.09%). Two-wheeler emission load would decrease from 240577 to 120288 t/year (-50.00%); three-wheeler emission load would decrease from 219055 to 108529 t/year (-49.99%); car emission load would decrease from 58289 to 28520 t/year (-51.07%); other emission load would decrease from 97983 to 48002 t/year (-51.00%); bus emission load would increase from 3617 to 3978 t/year (9.07%) and the total emission load would decrease from 619521 to 310316 t/year (-49.91%).

7.2.11. Policy-11

A policy has been developed by decrease in two-wheelers by 55.00 per cent, decrease in three-wheelers by 55.00 per cent, decrease in cars by 55.00 per cent, decrease in other vehicles by 55.00 per cent, increase in buses by 11.00 per cent, increase in transportation area by 11.00 per cent and increase in bicycle trips by 11.00 per cent in the projected year model 2031 A. D. It results that the two-wheeler trips would decrease from 5804028 in the projected year model 2031 AD to 4706310 (-18.913%); three-wheeler trips would decrease from 1128345 to 995543 (-11.76%); car trips would decrease from 866329 to 743501 (-14.17%); other vehicle trips would decrease from

404270 to 347268 (-14.09%); bus trips would increase from 6606608 to 6649113 (0.64%) and the total trips would decrease from 15111816 to 13777217 (-8.83%). Bicycle travel demand would increase from 1.36 to 1.51 Million Persons Kilometres /year (11.03%); two-wheeler travel demand would decrease from 78.35 to 63.54 MPK/year (-18.90%); three-wheeler travel demand would decrease from 135.40 to 119.47 MPK/year (-11.76%); car travel demand would decrease from 23.39 to 20.07 MPK/year (-14.19%); bus travel demand would increase from 1308.11 to 1316.52 MPK/year (0.64%) and the total travel demand would decrease from 1546.62 to 1521.11 MPK/year (-1.64%). Vehicle density would decrease from 33873 to 29875 vehicles per transportation area (vehicles per sq. km) (-11.80%) and the vehicle congestion level would decrease from 5.37 to 4.96 (-7.63%). Fuel consumption in two-wheeler would decrease from 713.18 to 320.93 Million Litres/year (-55.00%); fuel consumption in three-wheeler would decrease from 247.36 to 111.31 ML/year (-55.00%); fuel consumption in cars would decrease from 472.24 to 206.94 ML/year (-56.18%); fuel consumption in other vehicles would decrease from 1345.63 to 604.18 ML/year (-55.10%); fuel consumption in buses would increase from 315.03 to 349.69 ML/year (11.00%) and the total fuel consumption would decrease from 3093.44 to 1593.05 ML/year (-48.50%). Two-wheeler emission load would decrease from 240577 to 108260 t/year (-54.99%); three-wheeler emission load would decrease from 219055 to 98575 t/year (-54.99%); car emission load would decrease from 58289 to 25543 t/year (-56.17%); other emission load would decrease from 97983 to 43926 t/year (-55.16%); bus emission load would increase from 3617 to 4014 t/year (10.97%) and the total emission load would decrease from 619521 to 280318 t/year (-54.75%).

7.2.12. Policy-12

A policy has been developed by decrease in two-wheelers by 60.00 per cent, decrease in three-wheelers by 60.00 per cent, decrease in cars by 60.00 per cent, decrease in other vehicles by 60.00 per cent, increase in buses by 12.00 per cent, increase in transportation area by 12.00 per cent and increase in bicycle trips by 12.00 per cent in the projected year model 2031 A. D. It results that the two-wheeler trips would decrease from 5804028 in the projected year model 2031 AD to 4606518 (-20.63%); three-wheeler trips would decrease from 1128345 to 988704 (-12.37%); car trips would decrease from 866329 to 742704 (-14.26%); other vehicle trips would decrease from 404270 to 346500 (-14.28%); bus trips would increase from 6606608 to 6652958 (0.70%) and the total trips would decrease from 15111816 to 13675889 (-9.50%). Bicycle travel demand would increase from 1.36 to 1.52 Million Persons Kilometres /year (11.76%); two-wheeler travel demand would decrease from 78.35 to 62.19 MPK/year (-20.62%); three-wheeler travel demand would decrease from 135.40 to 118.64 MPK/year (-12.37%); car travel demand would decrease from 23.39 to 20.03 MPK/year (-14.36%); bus travel demand would increase from 1308.11 to 1317.29 MPK/year (0.70%) and the total travel demand would decrease from 1546.62 to 1519.68 MPK/year (-1.74%). Vehicle density would decrease from 33873 to 29614 vehicles per transportation area (vehicles per sq. km) (-12.58%) and the vehicle congestion level would decrease from 5.37 to 4.98 (-8.38%). Fuel consumption in two-wheeler would decrease from 713.18 to 285.27 Million Litres/year (-60.00%); fuel consumption in three-wheeler would decrease from 247.36 to 98.94 ML/year (-60.00%); fuel consumption in cars would decrease from 472.24 to 182.82 ML/year (-61.28%); fuel consumption in other vehicles would decrease from 1345.63 to 536.63 ML/year (-60.12%); fuel consumption in buses would increase from 315.03 to 352.84 ML/year (12.00%) and the total fuel consumption would decrease from 3093.44 to 1456.50 ML/year (-52.92%). Two-wheeler emission load would decrease from 240577 to 96231 t/year (-59.99%); three-wheeler emission load would decrease from 219055 to 87622 t/year (-60.00%); car emission load would decrease from 58289 to 22566 t/year (-61.28%); other emission load would decrease from 97983 to 39203 t/year (-59.99%); bus emission load would increase from 3617 to 4051 t/year (11.99%) and the total emission load would decrease from 619521 to 249673 t/year (-59.69%).

7.2.13. Policy-13

A policy has been developed by decrease in two-wheelers by 65.00 per cent, decrease in three-wheelers by 65.00 per cent, decrease in cars by 65.00 per cent, decrease in other vehicles by 65.00 per cent, increase in buses by 13.00 per cent, increase in transportation area by 13.00 per cent and increase in bicycle trips by 13.00 per cent in the projected year model 2031 A. D. It results that the two-wheeler trips would decrease from 5804028 in the projected year model 2031 AD to 4506725 (-22.35%);

three-wheeler trips would decrease from 1128345 to 983170 (-12.86%); car trips would decrease from 866329 to 741750 (-14.38%); other vehicle trips would decrease from 404270 to 346095 (-14.39%); bus trips would increase from 6606608 to 6656803 (0.76%) and the total trips would decrease from 15111816 to 13576070 (-10.16%). Bicycle travel demand would increase from 1.36 to 1.54 Million Persons Kilometres /year (13.23%); two-wheeler travel demand would decrease from 78.35 to 60.84 MPK/year (-22.34%); three-wheeler travel demand would decrease from 135.40 to 117.98 MPK/year (-12.86%); car travel demand would decrease from 23.39 to 20.00 MPK/year (-14.49%); bus travel demand would increase from 1308.11 to 1318.05 MPK/year (0.75%) and the total travel demand would decrease from 1546.62 to 1518.48 MPK/year (-1.82%). Vehicle density would decrease from 33873 to 29357 vehicles per transportation area (vehicles per sq. km) (-13.33%) and the vehicle congestion level would decrease from 5.37 to 4.89 (-8.94%). Fuel consumption in two-wheeler would decrease from 713.18 to 249.62 Million Litres/year (-64.99%); fuel consumption in three-wheeler would decrease from 247.36 to 86.58 ML/year (-64.99%); fuel consumption in cars would decrease from 472.24 to 158.71 ML/year (-66.39%); fuel consumption in other vehicles would decrease from 1345.63 to 468.41 ML/year (-65.19%); fuel consumption in buses would increase from 315.03 to 355.98 ML/year (12.99%) and the total fuel consumption would decrease from 3093.44 to 1319.30 ML/year (-57.36%). Two-wheeler emission load would decrease from 240577 to 84202 t/year (-64.99%); three-wheeler emission load would decrease from 219055 to 76669 t/year (-65.00%); car emission load would decrease from 58289 to 19589 t/year (-66.36%); other emission load would decrease from 97983 to 34196t/year (-65.10%); bus emission load would increase from 3617 to 4087 t/year (12.99%) and the total emission load would decrease from 619521 to 218743 t/year (-64.69%).

7.2.14. Policy-14

A policy has been developed by decrease in two-wheelers by 70.00 per cent, decrease in three-wheelers by 70.00 per cent, decrease in cars by 70.00 per cent, decrease in other vehicles by 70.00 per cent, increase in buses by 14.00 per cent, increase in transportation area by 14.00 per cent and increase in bicycle trips by 14.00 per cent in the projected year model 2031 A. D. It results that the two-wheeler trips would decrease from 5804028 in the projected year model 2031 AD to 4406933 (-24.07%); three-wheeler trips would decrease from 1128345 to 980451 (-13.11%); car trips would decrease from 866329 to 740798 (-14.49%); other vehicle trips would decrease from 404270 to 345610 (-14.51%); bus trips would increase from 6606608 to 6660648 (0.82%) and the total trips would decrease from 15111816 to 13478989 (-10.80%). Bicycle travel demand would increase from 1.36 to 1.55 Million Persons Kilometres /year (13.97%); two-wheeler travel demand would decrease from 78.35 to 59.49 MPK/year (-24.07%); three-wheeler travel demand would decrease from 135.40 to 117.65 MPK/year (-13.11%); car travel demand would decrease from 23.39 to 19.97 MPK/year (-14.59%); bus travel demand would increase from 1308.11 to 1318.81 MPK/year (0.82%) and the total travel demand would decrease from 1546.62 to 1517.48 MPK/year (-1.88%). Vehicle density would decrease from 33873 to 29105 vehicles per transportation area (vehicles per sq. km) (-14.07%) and the vehicle congestion level would decrease from 5.37 to 4.85 (-9.68%). Fuel consumption in two-wheeler would decrease from 713.18 to 213.95 Million Litres/year (-70.00%); fuel consumption in three-wheeler would decrease from 247.36 to 74.21 ML/year (-69.99%); fuel consumption in cars would decrease from 472.24 to 134.59 ML/year (-71.49%); fuel consumption in other vehicles would decrease from 1345.63 to 388.88 ML/year (-71.10%); fuel consumption in buses would increase from 315.03 to 359.14 ML/year (14.00%) and the total fuel consumption would decrease from 3093.44 to 1170.77 ML/year (-62.15%). Two-wheeler emission load would decrease from 240577 to 72173 t/year (-70.00%); three-wheeler emission load would decrease from 219055 to 65717 t/year (-69.99%); car emission load would decrease from 58289 to 16612 t/year (-71.50%); other emission load would decrease from 97983 to 29169 t/year (-70.23%); bus emission load would increase from 3617 to 4123 t/year (13.98%) and the total emission load would decrease from 619521 to 187794 t/year (-69.68%).

7.2.15. Policy-15

A policy has been developed by decrease in two-wheelers by 75.00 per cent, decrease in three-wheelers by 75.00 per cent, decrease in cars by 75.00 per cent, decrease in other vehicles by 75.00 per cent, increase in buses by 15.00 per cent, increase in transportation area by 15.00 per cent and increase in bicycle trips by 15.00

per cent in the projected year model 2031 A. D. It results that the two-wheeler trips would decrease from 5804028 in the projected year model 2031 AD to 4307140 (-25.79%); three-wheeler trips would decrease from 1128345 to 979246 (-13.21%); car trips would decrease from 866329 to 849045 (-14.18%); other vehicle trips would decrease from 404270 to 346904 (-14.19%); bus trips would increase from 6606608 to 6664494 (0.87%) and the total trips would decrease from 15111816 to 13388857 (-11.40%). Bicycle travel demand would increase from 1.36 to 1.56 Million Persons Kilometres /year (14.70%); two-wheeler travel demand would decrease from 78.35 to 58.15 MPK/year (-25.78%); three-wheeler travel demand would decrease from 135.40 to 117.51 MPK/year (-13.21%); car travel demand would decrease from 23.39 to 19.95 MPK/year (-14.19%); bus travel demand would increase from 1308.11 to 1319.57 MPK/year (0.87%) and the total travel demand would decrease from 1546.62 to 1516.75 MPK/year (-1.93%). Vehicle density would decrease from 33873 to 28857 vehicles per transportation area (vehicles per sq. km) (-14.81%) and the vehicle congestion level would decrease from 5.37 to 4.82 (-2.60%). Fuel consumption in two-wheeler would decrease from 713.18 to 178.29 Million Litres/year (-75.00%); fuel consumption in three-wheeler would decrease from 247.36 to 61.84 ML/year (-75.00%); fuel consumption in cars would decrease from 472.24 to 110.47 ML/year (-76.60%); fuel consumption in other vehicles would decrease from 1345.63 to 333.31 ML/year (-75.23%); fuel consumption in buses would increase from 315.03 to 362.29 ML/year (15.00%) and the total fuel consumption would decrease from 3093.44 to 1046.20 ML/year (-66.18%). Two-wheeler emission load would decrease from 240577 to 60144 t/year (-75.00%); three-wheeler emission load would decrease from 219055 to 54764 t/year (-74.99%); car emission load would decrease from 58289 to 13635 t/year (-76.60%); other emission load would decrease from 97983 to 24182 t/year (-75.32%); bus emission load would increase from 3617 to 4159 t/year (14.98%) and the total emission load would decrease from 619521 to 156884 t/year (-74.67%).

7.2.16. Policy-16

A policy has been developed by decrease in two-wheelers by 80.00 per cent, decrease in three-wheelers by 80.00 per cent, decrease in cars by 80.00 per cent, decrease in other vehicles by 80.00 per cent, increase in buses by 16.00 per cent, increase in transportation area by 16.00 per cent and increase in bicycle trips by 16.00 per cent in the projected year model 2031 A. D. It results that the two-wheeler trips would decrease from 5804028 in the projected year model 2031 AD to 4207348 (-27.51%); three-wheeler trips would decrease from 1128345 to 977824 (-13.34%); car trips would decrease from 866329 to 745043 (-14.00%); other vehicle trips would decrease from 404270 to 347672 (-14.00%); bus trips would increase from 6606608 to 6668339 (0.94%) and the total trips would decrease from 15111816 to 13296820 (-12.01%). Bicycle travel demand would increase from 1.36 to 1.58 Million Persons Kilometres /year (16.17%); two-wheeler travel demand would decrease from 78.35 to 56.80 MPK/year (-27.50%); three-wheeler travel demand would decrease from 135.40 to 117.37 MPK/year (-13.31%); car travel demand would decrease from 23.39 to 20.07 MPK/year (-14.19%); bus travel demand would increase from 1308.11 to 1320.33 MPK/year (0.93%) and the total travel demand would decrease from 1546.62 to 1516.16 MPK/year (-1.96%). Vehicle density would decrease from 33873 to 28613 vehicles per transportation area (vehicles per sq. km) (-15.52%) and the vehicle congestion level would decrease from 5.37 to 4.79 (-10.80%). Fuel consumption in two-wheeler would decrease from 713.18 to 14.63 Million Litres/year (-80.00%); fuel consumption in three-wheeler would decrease from 247.36 to 49.47 ML/year (-80.00%); fuel consumption in cars would decrease from 472.24 to 86.35 ML/year (-81.71%); fuel consumption in other vehicles would decrease from 1345.63 to 267.78 ML/year (-80.10%); fuel consumption in buses would increase from 315.03 to 365.44 ML/year (16.00%) and the total fuel consumption would decrease from 3093.44 to 911.67 ML/year (-70.52%). Two-wheeler emission load would decrease from 240577 to 48115 t/year (-80.00%); three-wheeler emission load would decrease from 219055 to 43811 t/year (-80.00%); car emission load would decrease from 58289 to 10659 t/year (-81.71%); other emission load would decrease from 97983 to 19596 t/year (-80.00%); bus emission load would increase from 3617 to 4195 t/year (15.98%) and the total emission load would decrease from 619521 to 126376 t/year (-79.60%).

7.2.17. Policy-17

A policy has been developed by conversion from diesel driven public transport buses into battery-powered operated in the study area i.e., from 10.00 to 90.00 per cent in the projected year model 2031 A. D. It results that the conversion of public transport buses by 10.00 per cent results into fuel consumption in buses would decrease from 315.03 ML/year in the projected year model 2031 A.D. to 283.53 ML/year (1.02% to total); emission load per year would decrease from 3617 to 3255 t/year (0.058% to total); The conversion of public transport buses by 20.00 per cent results into fuel consumption in buses would decrease from 315.03 to 252.02 ML/year (2.04% to total); emission load per year would decrease from 3617 to 2893 t/year (0.117% to total). The conversion of public transport buses by 30.00 per cent results into fuel consumption in buses would decrease from 315.03 to 220.52 ML/year (3.06% to total); emission load per year would decrease from 3617 to 2531 t/year (0.175% to total). The conversion of public transport buses by 40.00 per cent results into fuel consumption in buses would decrease from 315.03 to 189.02 ML/year (4.07% to total); emission load per year would decrease from 3617 to 2170 t/year (0.234% to total). The conversion of public transport buses by 50.00 per cent results into fuel consumption in buses would decrease from 315.03 to 157.51 ML/year (5.09% to total); emission load per year would decrease from 3617 to 1809 t/year (0.292% to total). The conversion of public transport buses by 60.00 per cent results into fuel consumption in buses would decrease from 315.03 to 126.01 ML/year (6.11% to total); emission load per year would decrease from 3617 to 1447 t/year (0.35% to total). The conversion of public transport buses by 70.00 per cent results into fuel consumption in buses would decrease from 315.03 to 94.51 ML/year (7.13% to total); emission load per year would decrease from 3617 to 1085 t/year (0.409% to total). The conversion of public transport buses by 80.00 per cent results into fuel consumption in buses would decrease from 315.03 to 63.00 ML/year (8.15% to total); emission load per year would decrease from 3617 to 723 t/year (0.467% to total). The conversion of public transport buses by 90.00 per cent results into fuel consumption in buses would decrease from 315.03 to 31.50 ML/year (9.17% to total); emission load per year would decrease from 3617 to 362 t/year (0.525% to total).

7.3. RECOMMENDED POLICY

The Investigator observed that the policy number 16 would be more suitable for development of transportation subsystem in the system and overall development of the system based on the detailed analysis of the policies and their results. This policy number 16 is developed based on the composite scenario by decrease in two-wheelers by 80.00 per cent, decrease in three-wheelers by 80.00 per cent, decrease in cars by 80.00 per cent, decrease in other vehicles by 80.00 per cent, increase in buses by 16.00 per cent, increase in transportation area by 16.00 per cent and increase in bicycle trips by 16.00 per cent. The Investigator, therefore, has considered this policy for recommendation, and phase wise development of transportation subsystem parameters are calculated from 2011 to 2031 A.D. Phase wise analysis have been done period wise, i.e., phase no. 1 is between the year 2011 and 2016; the phase no. 2 is between the year 2016-2021; the phase no. 3 is between the year 2021 and 2026 and the phase no. 4 is between the year 2026 and 2031 for clarity in presentation and presented in Table 7.1 and in Fig. 7.1 (A) to Fig. 7.1 (F). These table and the figures reveal that the achievements and thrust areas at different phases vary considerably in the study area. The phase wise transportation parameters in different phases are presented as below. They are:

7.3.1. PHASE NO. 1: (2011-2016)

In this phase, it has been observed that the number of bicycle trips would be 199463, the number of two-wheeler trips would be 2315482, the number of three-wheeler trips would be 557122, the number of car trips would be 423000, the number of bus trips would be 3657167, the number of other vehicle trips would be 174822, and the total number of trips would be 7327055 in the system. In travel demand analysis, it has been observed that the travel demand for bicycles would be 0.90 MPK/year, the two-wheeler travel demand would be 31.26 MPK/year, the three-wheeler travel demand would be 66.85 MPK/year, the car travel demand would be 11.42 MPK/year, the bus travel demand would be 724.12 MPK/year, and the total travel demand would be 834.55 MPK/year. In vehicle density analysis, it is observed that vehicles per transportation area would be 23996, and the congestion level would be 2.97. In fuel demand analysis, the two-wheeler fuel demand would be 93519990 ML/year, the three-wheeler fuel demand would be 32437114 ML/year, the car fuel demand would be 56617507 ML/year, the other vehicles fuel demand would be 163673354 ML/year, the bus fuel demand would be 239599618 ML/year, and the total fuel demand would be 585847582 ML/year. In emission analysis, it has been observed that the two-wheeler emission load would be 31547 t/year, the three-wheeler emission load would be 28725 t/year, the car emission load would be 6988 t/year, the other vehicle emission load would be 11977 t/year, the bus emission load would be 2751 t/year and the total emission load would be 81987 tonne in the year 2031 A.D in the system.

7.3.2. PHASE NO. 2: (2016-2021)

In this phase, it has been observed that the number of bicycle trips would be 240719, the number of two-wheeler trips would be 2825222, the number of three-wheeler trips would be 672353, the number of car trips would be 510490, the number of bus trips would be 4500146, the number of other vehicle trips would be 219571, and the total number of trips would be 8968501 in the system. In travel demand analysis, it has been observed that the travel demand for bicycles would be 1.08 MPK/year, the two-wheeler travel demand would be 38.14 MPK/year, the three-wheeler travel demand would be 80.68 MPK/year, the car travel demand would be 13.78 MPK/year, the bus travel demand would be 891.03 MPK/year, and the total travel demand would be 1024.72 MPK/year. In vehicle density analysis, it is observed that vehicles per transportation area would be 25804, and the congestion level would be 3.67. In fuel demand analysis, the two-wheeler fuel demand would be 109561343 ML/year, the three-wheeler fuel demand would be 38001006 ML/year, the car fuel demand would be 66329029 ML/year, the other vehicles fuel demand would be 197553838 ML/year, the bus fuel demand would be 280697806 ML/year, and the total fuel demand would be 692143024 ML/year. In emission analysis, it has been observed that the two-wheeler emission load would be 36958 t/year, the three-wheeler emission load would be 33652 t/year, the car emission load would be 8187 t/year, the other vehicle emission load would be 14457 t/year, the bus emission load would be 3222 t/year and the total emission load would be 96476 tonne in the year 2031 A.D in the system.

7.3.3. PHASE NO. 3: (2021-2026)

In this phase, it has been observed that the number of bicycle trips would be 290508, the number of two-wheeler trips would be 3447171, the number of three-wheeler trips would be 811418, the number of car trips would be 616076, the number of bus trips would be 5481793, the number of other vehicle trips would be 275774, and the total number of trips would be 10922739 in the system. The travel demand analysis, it has been observed that the travel demand for bicycles would be 1.31 MPK/year, the two-wheeler travel demand would be 46.54 MPK/year, the three-wheeler travel demand would be 97.37 MPK/year, the car travel demand would be 16.63 MPK/year, the bus travel demand would be 1085.39 MPK/year, and the total travel demand would be 1247.24 MPK/year. In vehicle density analysis, it is observed that vehicles per transportation area would be 27333, and the congestion level would be 4.26. In fuel demand analysis, the two-wheeler fuel demand would be 125775820 ML/year, the three-wheeler fuel demand would be 43624947 ML/year, the car fuel demand would be 76145362 ML/year, the other vehicles fuel demand would be 231870702 ML/year, the bus fuel demand would be 322239540 ML/year, and the total fuel demand would be 799656371 ML/year. In emission analysis, it has been observed that the two-wheeler emission load would be 42427 t/year, the three-wheeler emission load would be 38632 t/year, the car emission load would be 9399 t/year, the other vehicle emission load would be 16968 t/year, the bus emission load would be 3699 t/year and the total emission load would be 111125 tonne in the year 2031 A.D in the system.

7.3.4. PHASE NO. 4: (2026-2031)

In this phase, it has been observed from this scenario that the number of bicycle trips would be 350594, the number of two-wheeler trips would be 4207348, the number of three-wheeler trips would be 979246, the number of car trips would be 743501, the number of bus trips would be 6668339, the number of other vehicle trips would be 347672, and the total number of trips would be 13296700 in 2031 A.D. In travel demand analysis, it has been observed that the travel demand for bicycles would be 1.58 MPK/year, the two-wheeler travel demand would be 56.80 MPK/year, the three-wheeler travel demand would be 117.51 MPK/year, the car travel demand would be 20.07 MPK/year, the bus travel demand would be 1320.33 MPK/year, and the total travel demand would be 1516.29 MPK/year. In vehicle density analysis, it is observed that vehicles per transportation area would be 28613, and the congestion level would be 4.79.

In fuel demand analysis, the two-wheeler fuel demand would be 142637983 ML/year, the three-wheeler fuel demand would be 49473535 ML/year, the car fuel demand would be 86353806 ML/year, the other vehicles fuel demand would be 267780000 ML/year, the bus fuel demand would be 365440655 ML/year, and the total fuel demand would be 911685980 ML/year. In emission analysis, it has been observed that the two-wheeler emission load would be 48115 t/year, the three-wheeler emission load would be 43811 t/year, the car emission load would be 10659 t/year, the other vehicle emission load would be 19596 t/year, the bus emission load would be 4195 t/year and the total emission load would be 911685980 tonne in 2031 A.D.

7.4. RECOMMENDATIONS

The Investigator has made specific recommendations based on the policy run (Scenario No. 16) and general recommendations are made based on the findings of the investigation and are presented in the sequel.

7.4.1. SPECIFIC RECOMMENDATIONS

The Administrators of the study area should increase the public transportation infrastructure by 16.00 per cent by 2031 A.D., which would be staggered into 4.00 per cent in each phase, which is mentioned above; in turn it will decrease the usage of two-wheelers, three-wheelers, cars and other vehicles by 80.00 per cent respectively in the system. to increase the public transportation infrastructure and also to make use of the infrastructure by the people with comfort the following policies are recommended.

1. A Development Plan comprising of all subsystems of the system, which include physical subsystem, social subsystem, economic subsystem, ecology subsystem, environment subsystem, infrastructure subsystem and institution subsystem and shall be implemented in the system.
2. Transportation network plans shall be evolved at micro level based on the requirement in different parts of the city by considering land use, trip generation, trip distribution, modal split and traffic assignment and implemented the same in the study area, which should be economically viable, technically feasible, socially acceptable, and practically executable.

3. High-tech buses like Pushpak, Volvo, etc., should be introduced in the system to attract the general public in all important routes with required amount of frequency.
4. Evolve integrated land use plan with transportation system to minimize the traveling distance, travel time, travel cost, etc., and shall be implemented in the system.
5. Adequate transportation infrastructure shall be provided in the system, which includes subways, bus-shelters, etc., based on the requirement in the system.
6. Economically weaker section, disabled and elderly person's interest must be taken care off by providing subsidized fares, convenient low floor buses, etc.
7. Bus Rapid Transit System across the city shall be introduced based on the requirement. As a consequence, it reduce the congestion and would protect the environment.
8. Required amount of transportation infrastructure facilities shall be developed and implemented in the system after conducting thorough investigation to provide bicycle lanes, two-wheeler lanes, three-wheeler and car lanes and bus lanes to avoid intermingling, accidents, traffic jams, etc., and increase their efficiency.
9. Efficient traffic management system shall be introduced in the system to avoid chaos.
10. Obsolete and old vehicles (more than 10 years old) shall not be allowed to use in the system to protect the environment in the system.
11. Optimal road network system shall be developed by widening the roads, connecting the arterial roads, sub-arterial roads, creating ring roads, based on the requirement and efficient traffic management system shall be imparted.
12. Adequate parking facilities shall be provided in different parts of the city based on the requirement.
13. Battery-powered vehicles shall be introduced in the system in all kinds of transportation modes to reduce the fuel consumption on one hand and to protect the environment in the system on the other.
14. Pedestrian lanes shall be developed besides all kinds of roads and encourage pedestrian movements. As a consequence, healthy atmosphere of the system would be anticipated. To develop pedestrian lanes appropriate studies shall be conducted, proper plans shall be evolved and implemented in the system.

7.4.2. GENERAL RECOMMENDATIONS

1. The land area under the city is increasing considerably; the city is growing with high rate. When the city grows it encroach the periphery (the fringe areas of the city). Proper transportation network plan shall be evolved after conducting thorough investigation to develop these areas, otherwise there would be a chaotic situation in the system. Therefore, it is recommended to evolve micro level development plan by considering transportation as one of the subsystems and implemented in these areas.
2. To reduce the congestion in the core areas of the city certain important activities such as wholesale marketing may be shifted from the core area to fringe areas.
3. Ring roads may be developed, and the trucks, tractors, trailers and heavy vehicles and other long route vehicles shall be diverted to avoid vehicle congestion in the core areas of the city.
4. Employment opportunities and income earning opportunities shall be developed in the fringe areas of the city which would pave the way for population movement from the core areas to the fringe areas automatically.
5. The city is blessed with good number of tanks and lakes. It has been observed that considerable amount of tanks and lakes were vanished from the system. To safe guard the ecology and environment in the system, the available tanks and lakes shall be protected.
6. Air Quality Index shows that most part of the areas of the city has higher level of air pollution. To bring down the air pollution level, optimal measures shall be evolved and implemented in the system.

Table No. 7.1: Perceived Phase Wise Policy Results

Phase No.	Year	No. of Bicycle Trips	No. of Two-wheeler Trips	No. of Three-wheeler Trips	No. of Car Trips	No. o Bus Trips	No. of Other Trips	Total No. of Trips
1	2	3	4	5	6	7	8	9
	2011	165278	1896931	461640	350504	2933182	139193	5946728
1	2011-2016	199463	2315482	557122	423000	3657167	174822	7327055
2	2016-2021	240719	2825222	672353	510490	4500146	219571	8968501
3	2021-2026	290508	3447171	811418	616076	5481793	275774	10922739
4	2026-2031	350594	4207348	979246	743501	6668339	347672	13296700

Table No. 7.1: Perceived Phase Wise Policy Results

Phase No.	Year	Bicycle Travel Demand in MPK/year	Two-wheeler Travel Demand in MPK/year	Three-wheeler Travel Demand in MPK/year	Car Travel Demand in MPK/year	Bus Travel Demand in MPK/year	Total Travel Demand in MPK/year	Vehicle Density in Vehicles per Transportation Area	Congestion
1	2	10	11	12	13	14	15	16	17
	2011	0.74	25.61	55.40	9.46	580.77	671.98	23160	2.50
1	2011-2016	0.90	31.26	66.85	11.42	724.12	834.55	23996	2.97
2	2016-2021	1.08	38.14	80.68	13.78	891.03	1024.72	25804	3.67
3	2021-2026	1.31	46.54	97.37	16.63	1085.39	1247.24	27333	4.26
4	2026-2031	1.58	56.80	117.51	20.07	1320.33	1516.29	28613	4.79

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Table No. 7.1: Perceived Phase Wise Policy Results

Phase No.	Year	Two-wheeler Fuel in ML per year	Three-wheeler Fuel in ML per year	Car Fuel in ML per year	Other Vehicles Fuel in ML per year	Bus Fuel in ML per year	Total Fuel in ML per year
1	2	18	19	20	21	22	23
3	2011	77062429	26728861	46654011	128712725	197435101	476593126
4	2011-2016	93519990	32437114	56617507	163673354	239599618	585847582
5	2016-2021	109561343	38001006	66329029	197553838	280697806	692143024
6	2021-2026	125775820	43624947	76145362	231870702	322239540	799656371
7	2026-2031	142637983	49473535	86353806	267780000	365440655	911685980

Table No. 7.1: Perceived Phase Wise Policy Results

Phase No.	Year	Two-wheeler Emission Load in t/year	Three-wheeler Emission Load in t/year	Car Emission Load in t/year	Other Vehicle Emission Load in t/year	Bus Emission Load in t/year	Total Emission Load in t/year
1	2	24	25	26	27	28	29
	2011	25995	23670	5758	9419	2267	67109
1	2011-2016	31547	28725	6988	11977	2751	81987
2	2016-2021	36958	33652	8187	14457	3222	96476
3	2021-2026	42427	38632	9399	16968	3699	111125
4	2026-2031	48115	43811	10659	19596	4195	126376

7.5. CONCLUSION

Micro level planning for transportation system is highly essential for the development of transportation system in an urban system. Secondary sources of data may not give more insight about the particular system, and moreover the available secondary sources of data are old and published some years back for e.g., the census data which is available right now is published in the year 2001 which may not give real characteristics of the system since the system is dynamic one. In order to overcome the inherent shortcomings, the Investigator developed a schedule, pretested and employed to conduct survey at the grassroots level to collect the required information for the present investigation. A detailed survey on a carefully chosen segment of the population was carried out for supplementing the data available from different sources of the secondary data. The collected data were processed carefully by employing the statistical tools and techniques to identify the control parameters those decide the function of the system. A system dynamics model was developed, by considering the parameters which decide the functions of the transportation subsystem of the system which include population, population density, vehicle ownership, vehicular population, modal split, travel demand, vehicle density, congestion, fuel consumption and vehicular emission load. The developed system dynamics model was validated and further used for developing the projected year model (2031 A.D). Relevant alternative scenarios were developed based on the results of the investigation, expert's opinion, assumption, etc., and tested in the model to understand the functions of the transportation subsystem in different alternative conditions. An optimal scenario was selected among the tested scenarios (policy runs) in the projected year model and used for evolving a set of policy guidelines. The study concludes with plausible recommendations.

7.6. SUGGESTIONS FOR FURTHER RESEARCH

The present investigation has got a lot of scope for further research and extension. It has a few limitations, such as, limited samples are considered for conducting the present investigation at the grassroots level due to limited time and resources availability. Further, the investigation is made at the micro level of the system. Therefore, the

Investigator observes that the present investigation has ample scope to extend, and are presented as below:

1. Survey at large scale shall be considered to have exact picture of the socio-economic conditions, industrial scenario and transportation status of the system (study area).
2. The gender based mobility for different purposes and by different mode of transportations used shall be studied in detailed.
3. Micro level studies shall be conducted to evolve Integrated Development Plans spanning the period of five years by employing location analysis, optimization techniques, Discounted Cash Flow (DCF) techniques, input and output models, etc. Further, annual plans shall be prepared based on the Integrated Development Plan. Subsequently, projects/ schemes shall be prepared to implement programmes to achieve realistic development in the system.
4. Detailed study shall be conducted for the weekdays, weekend days and the occasional days travel characteristics of the households at the larger extent to establish the relationship between them and to achieve greater mobility of the people.
5. Detailed study shall be conducted for assessing the requirement of the motorized and non-motorized infrastructures at the micro level and macro level.

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APPENDIX – I: SURVEY SCHEDULE – 1

Department of Architecture & Planning
Indian Institute of Technology Roorkee

Planning for Optimal Transportation System in a Mega city-Bangalore, India

1. **Demographic and Socio-economic Characteristics:**

Personal Particulars:
Name of the Head of Household :
Number of Earning Members :
Ward No. Extension, Locality :

Car ownership:
Vehicle ownership: 0 car/ 1car/ More than 1 car/ two/three wheeler/
Total no. members of Household:
Address: House. No /Division/Village No:
Detailed address other than above:

Household Particulars:

Physical Characteristics: Housing:

Sl No.	Name of the Household and his family members	Gender M/F	Age	Marital status	Academic qualification	Whether Employed or not Occupation	Working status/ Place of work	Family income Rs.	Type of Dwelling unit	Age of the House	Physical condition	Ownership
1									Detached		Good	Rented
2									Semi Detached		Livable	Owned
3									Apartment		Dilapidated	Other
4									Row			

Gender: 1 for Male, 2 for Female
Marital Status: 1 for Married
2 for Unmarried

Age group: 1 for <5
2 for 6-18
3 for 19-25
4 for 26-40
5 for 41-58
6 for 59-65
7 for >65

Vehicle Ownership: 1 for two-wheeler
2 for three-wheeler
3 for light vehicles
4 Car owner

Working status:
1 for full time (30+hrs per week)
2 for Part-time employee (1-29 hrs./week)
3 for Self-employed
4 for Unemployed
5 for Retired
6 for Student
7 for Housewife
8 for Others

Academic Qualification
1 for < HSC
2 for HSC
3 for UG
4 for PG
5 for Technical
6 for Medical
7 for Diploma
8 for illiterate
9 PUC
10 for others

Family income from different **sources**
1 for Govt.
2 for Pvt. Services
3 for Agriculture
4 for Horticulture
5 for Animal Husbandry
6 for Trade & commerce
7 for Industry (specify)
8 for Sericulture
9 for Self-employed
10 for others

Sl No.	Finance	Monthly expenditure on	In Rs. /month	Household Appliances:	Physical Infrastructure: (1) Water supply		
1	Bank	Food		Refrigerator	Supply system	Time of supply (in hrs)	Use of equipment
2	Self	Recreation		Television	Public supply system		Filter
3	Ancestral	Transportation Private travel costs Cost of petrol		A.C	Own source		Aqua guard
4	Any other	Cost of diesel			Both		
5		Cost of lubricants, spare parts, tyres					
6		Interest on loan for purchase of vehicles					
7		Public travel costs					
8		Car parking costs					
9		Clothes		Stove			
10		Saving		Mixer/Grinder			
11		Education		Computer			
12		Drinking		Washing machine			
13		Loan Repayment		Pressure cooker			
14		Health		Cooler			
15		Telephone		Geyser			
16		Water supply		Microwave			
17		ENERGY		Solar cooker			
18		LPG		Tape recorder			
19		Kerosene		Any other specify			
20		Charcoal					
21		Electricity					
22		Fuel wood					
23		Entertainment					
24		Any other					
25		Total					

1. Total time required 2. Total km of traveling 3. Mode of travel 4. Expenditures 5. Vehicle Ownership

6. Energy requirement: Quantity of Petrol/Diesel

Sl No.	(2) Electricity								Overflow of drains during rainy seasons
1	Available	Overhead Poles	Tariff	Metered	Voltage Fluctuations	(3) Drainage/ Sewerage			
2	Unavailable	Underground Cables	Monthly	Non-metered		Availability of	Drains	Problems	
3			Flat rate			Septic tank	Open	Overflow	Yes
4						Soak pit	Covered	Clogging	No
5						Sewer	No Drains	Bad Odour	
6						No facility		No Problem	

Sl No.	(4) Waste Disposal									
1	**Method of collection at house**	**Frequency of collection from the area**	**Mode of vehicle using for disposal/authority / Money spending for this**	**Distance in kms**	**Agency for collection**	**(5) Environmental Characteristics:**				
2	Storage container	Everyday			Corporation	Water Quality	Air Quality	Land Quality	Noise Quality	Quality of living
3	Dustbin/ PVC bag	Alternate days			Private Agency	Very Good	Very Good	Very Good	Very High	Excellent
4	Burning	Once in 3 days			NGO	Good	Good	Good	High	Good
5	Throwing out	Once in 4 days				Moderate	Moderate	Moderate	Moderate	Moderate
6		Weekly				Poor	Poor	Poor	Low	Bad

Household Structure-6 classes:

1. No employed residents and one non-employed adult
2. No employed residents and 2 or more non-employed adults
3. One employed resident and one or less non-employed adult
4. One employed resident and 2 or more non-employed adults
5. Two or more employed residents and one or less non-employed adult
6. Two or more employed residents and two or more non-employed adults

2. <u>Journey data:</u> Daily travel/Weekend travel/Seasonal travel/Inter trip travel/Intra trip travel

Sl No.	Purpose of journey	Mode of travel from home to bus/rail station	Distance and time taken from home to bus/rail station	Wait time at bus station	Place of origin	Place of Destination	Mode of travel	Trip distance and time taken	Condition of the road	Maintenance of the road	No. of telephones/ Mobile in your family/ Internet connection	Is it no of trips curtailed/ reduced using this facility?
1									Good	Good		
2									Moderate	Moderate		
3									Poor	Poor		

Purpose of journey
1 to work place
2 work to home
3 home to shop
4 home to shopping
5 workplace to market
6 market to home
7 home to health
8 home to entertainment
9 bank/post office
10 social gathering
11 recreation
12 parks & playgrounds
13 education trips (school/college)
14 for market to workplace

Mode of travel
1 for two wheeler
2 shared two-wheeler (pillion rider)
3 for car
4 shared car
5 for three-wheeler (specify. Eg. Auto rickshaw)
6 by bicycle
7 for light vehicles
8 by Bus
9 by Private Bus
10 by train
11 by foot
12 any other, specify

Possibility of trips
1 for home to workplace
2 for home to shop
3 for home to recreation
4 for school/college
5 for entertainment
6 for hospital/nursing home
7 for parks and playgrounds
8 for bank/post office
9 for market
10 for workplace to market

The range of distances from home to nearest Bus Station/Railway station
1 for < 250m
2 for 251-500 m
3 for 501-750 m
4 for 751-1000 m
5 for 1001-1500 m
6 for 1501-2000 m
7 for 2001-2500 m
8 for 2501-3000 m
9 for > 3000m

Existing transportation infrastructure facilities in the study area

Sl No.	Existing transportation infrastructure	Location and Distance From your locality	Adequate/inadequate
1	Bus station/terminals/transport		
2	Bus depots		
3	Flyovers		
4	Subways		
5	Under bridges		
6	Over bridges		
7	Railway station		
8	Sub station		
9	Airport		

Air traffic/travel/transport

Sl No.	Particulars	Responses	Suggestions
1	Do you travel by air?		
2	How often do you travel by air?		
3	What mode of transportation are you using from home to airport and vice-versa?		
4	What is the trip distance and time will take to reach airport?		
5	What is your suggestions about the existing transportation system		

Parking:

Sl No.	Parameters	Workplace	Shopping	Entertainment	Within premises	On road	Common parking
1	Duration of parking						
2	Distance from home place						
3	Parking charges Hourly Monthly Annual						
4	Parking availability Readily available Available with difficulty Never available						
5	Parking capacity Adequate/ inadequate						

Do you have any idea about how traffic predominant in different situations/periods: Festivals fall on different months

Sl No.	Traffic in different period	Duration	Observations/ Suggestions/	Months	Special festival	Traffic on these days	Suggestions/ Observations
1	Peak hour traffic	Morning/ Evening hours		January February	Makara sankranthi Mahashivaratri		
2	Weekend traffic	Saturday/Sunday		March	Chandramana Ugadi		
3	Festival season traffic	J/F/M/A/S/O/N/D		April	Basava Jayanthi		
4	Rainy season traffic	July/August		August	Tiru Onam		
5	Any other special occasion			September	Ganesha Chaturthi		
				October	Vijayadasami		
				November	Deepavali		
				December	Christmas		

Do you think that these can be the solution to the transportation problems? Can you suggest anything other than this?

Sl No.	Descriptions	Suggestions/Observations/Responses
1	Widening of roads	
2	One way system	
3	Staggering of activities	
4	Traffic management	
5	Co-ordination and co-operation between public And concerned authority	
6	Adding buses	
7	Construction of Flyovers, subways, over bridges, under bridges	

Note: The survey is being conducted by Mohan Kumar Chavan, Research Scholar, Department of Architecture and Planning, Indian Institute of Technology Roorkee, and will be exclusively used for academic purposes.

APPENDIX – 2

MULTIPLE LINEAR REGRESSION ANALYSIS

In this present Investigation, multiple regressions is attempted to find out the tangible relationships of dependent variable, i.e., monthly household income with multiple independent variables, such as demographic parameters, economic parameters, expenditure parameters, .journey characteristics, etc, based on the above control parameters. Multiple regression equations are attempted separately for the parameters, and it is observed that except expenditure parameters, other parameters do not provide tangible relationships in the system, thus a multiple regression analysis is done for expenditure parameters and is presented as below.

$y = f(x_1, x_2, x_3, \ldots\ldots x_n)$

Whereas, y = Monthly Household Income in Rupees

x_1 = Expenditure on Food in Rupees

x_2 = Expenditure on Clothes in Rupees

x_3 = Expenditure on Education in Rupees

x_4 = Expenditure on Health in Rupees

x_5 = Expenditure on Water in Rupees

APPENDIX - 3

(SYSTEM DYNAMICS MODEL EQUATION)

AREA(t) = AREA(t - dt) + (ADDITIONAL_AREA) * dt
INIT AREA = 534.08
INFLOWS:
ADDITIONAL_AREA = AREA*ADDITIONAL_FRACTION
AREA_2(t) = AREA_2(t - dt) + (AREA_IN_RATE) * dt
INIT AREA_2 = 534.08
INFLOWS:
AREA_IN_RATE = AREA_2*AR_IN_FR
PARK_AREA(t) = PARK_AREA(t - dt) + (PACR) * dt
INIT PARK_AREA = 21.32
INFLOWS:
PACR = (DES_PARK_AREA-PARK_AREA)/TTCPA
POPULATION(t) = POPULATION(t - dt) + (BIRTH_RATE + INMIGRATION - DEATH_RATE - OUT_MIGRATION) * dt
INIT POPULATION = 5757020
INFLOWS:
BIRTH_RATE = POPULATION*BIRTH_RATE_FRACTION
INMIGRATION = POPULATION*INMIGRATION_FRACTION
OUTFLOWS:
DEATH_RATE = POPULATION*DEATH_RATE_FRACTION
OUT_MIGRATION = POPULATION*OUT_MIGRATION_FRACTION
RESIDENTIAL_AREA(t) = RESIDENTIAL_AREA(t - dt) + (RACR) * dt
INIT RESIDENTIAL_AREA = 159.76
INFLOWS:
RACR = (DES_RES_AREA-RESIDENTIAL_AREA)/TTCRA
TOTAL_NUMBER_OF_VEHICLES(t) = TOTAL_NUMBER_OF_VEHICLES(t - dt) + (PURCHASES - OBSOLETION) * dt
INIT TOTAL_NUMBER_OF_VEHICLES = 1652956

INFLOWS:
PURCHASES =
POPULATION*VEHICLES_PURCHASE_PER_1000*NEW_INDUSTRY
OUTFLOWS:
OBSOLETION = TOTAL_NUMBER_OF_VEHICLES/OBS_TIME
TOTAL_TRIPS_PER_DAY(t) = TOTAL_TRIPS_PER_DAY(t - dt) +
(PER_CAPITA_TRIP_RATE) * dt
INIT TOTAL_TRIPS_PER_DAY = 4891405
INFLOWS:
PER_CAPITA_TRIP_RATE = TOTAL_TRIPS_PER_DAY*PCTRF
TRANSPORTATIONAREA(t) = TRANSPORTATIONAREA(t - dt) + (TR_A_CR) * dt
INIT TRANSPORTATIONAREA = 108.68
INFLOWS:
TR_A_CR = (TRANSPORTATION_AREA-
TRANSPORTATIONAREA)/TIME_TO_CHANGE_TRANSPORTATION_AREA
ACCEPTABLE_TRIPS = 3000000
ACTUAL_VEHICLE_DENSITY =
TOTAL_NUMBER_OF_VEHICLES/TRANSPORTATIONAREA
ADDITIONAL_FRACTION = (0.031)+step(0.09,1975)-step(0.105,1980.5)
AIR_QUALITY = EFFECT_ON_AIR_QUALITY
AR_IN_FR = 0.02
AVERAGE_2WH_TRIP_LENGTH = 13.5*300
AVERAGE_3WH_TRIP_LENGTH = 120
AVERAGE_3__WH_TRIP_LENGTH = 120*300
AVERAGE_BUS_LENGTH = 198
AVERAGE_BUS_TRIP_LENGTH = 186*365
AVERAGE_CARTRIPLENGTH = 27*300
AVERAGE_CAR_TRIP_LENGTH = 27
AVERAGE_HOUSEHOLD_SIZE = 4.46
AVERAGE_TL_OTHERS = 60*300
BICYCLE_AVERAGE_TRIP_LENGTH = 4.5

BICYCLE_FRACTION = MAX(-0.0042*TIME+8.4204,0.02)
BICYCLE_TRIPS = TOTAL_TRIPS_PER_DAY*BICYCLE_FRACTION
BIRTH_RATE_FRACTION = 0.0183
BUS_EFFICIENCY = 0.25
BUS_EMMISSION =
AVERAGE_BUS_TRIP_LENGTH*EMMISSION_PER_KM_BUS*NUMBER_OF_BUSES
BUS_FRACTION = Noname_1
BUS_FUEL =
AVERAGE_BUS_TRIP_LENGTH*BUS_EFFICIENCY*NUMBER_OF_BUSES
BUS_TRIPS = TOTAL_TRIPS_PER_DAY*BUS_FRACTION
CAR_EFFICIENCY = 0.07
CAR_EMMISSION =
AVERAGE_CARTRIPLENGTH*EMMISSION_PER_KM_FOR_CARS*NUMBER_OF_C
ARS
CAR_FRACTION = GRAPH(NUMBER_OF_CARS/INI_NO_OF_CARS)
(1.00, 0.0492), (1.30, 0.0492), (1.60, 0.0492), (1.90, 0.0496), (2.20, 0.0512), (2.50, 0.0524), (2.80, 0.054), (3.10, 0.0556), (3.40, 0.0576), (3.70, 0.0596), (4.00, 0.0604)
CAR_FUEL =
AVERAGE_CARTRIPLENGTH*CAR_EFFICIENCY*NUMBER_OF_CARS
CAR_TRIPS = TOTAL_TRIPS_PER_DAY*CAR_FRACTION
CONG = GRAPH(ACTUAL_VEHICLE_DENSITY)
(1000, 0.762), (5900, 0.92), (10800, 1.17), (15700, 1.48), (20600, 1.94), (25500, 2.55), (30400, 2.94), (35300, 3.23), (40200, 3.35), (45100, 3.46), (50000, 3.50)
CONGESTION = CONG*EFFECT_OF_TRIPS_ON_CONGESTION
DEATH_RATE_FRACTION = 0.0035
DES_PARK_AREA = AREA_2*NORMAL_PARK_FRACTION
DES_RES_AREA = AREA_2*NORMAL_FRACTION*PRESSURE_TO_INC_RA
DIESEL_PER_YEAR = TOTAL_FUEL*0.21
DIFFERENCE_IN_PARK_AREA = (REQUIRED_PARK_AREA-PARK_AREA)/REQUIRED_PARK_AREA

EFFECT_OF_TRIPS_ON_CONGESTION =
GRAPH(TOTAL_TRIPS_PER_DAY/ACCEPTABLE_TRIPS)
(0.5, 0.5), (1.45, 0.808), (2.40, 1.12), (3.35, 1.40), (4.30, 1.60), (5.25, 1.74), (6.20, 1.86), (7.15, 1.91), (8.10, 1.96), (9.05, 1.98), (10.00, 2.00)
EFFECT_ON_AIR_QUALITY = GRAPH(DIFFERENCE_IN_PARK_AREA)
(0.00, 99.5), (0.1, 98.5), (0.2, 97.0), (0.3, 93.0), (0.4, 86.0), (0.5, 72.0), (0.6, 51.5), (0.7, 37.0), (0.8, 29.5), (0.9, 27.5), (1, 27.5)
EMISSIONOTHERS =
AVERAGE_TL_OTHERS*EMISSION_PER_KM_OTHERS*OTHER_VEHICLES
EMISSION_PER_KM_OTHERS = 0.000015
EMMISSION_PER_KM_BUS = 0.00000287
EMMISSION_PER_KM_FOR_2__WH = 0.000013493
EMMISSION_PER_KM_FOR_3_WH = 0.000029223
EMMISSION_PER_KM_FOR_CARS = 0.00000864
FRACTION_2_WHEELERS = (MIN(-14.61+0.0077*TIME,0.74))
FRACTION_3_WHEELERS = ((MAX(-0.1654*TIME+334.25,3.5))/100)
FRACTION_BUSES = 0.014+STEP(0.01,2010)
FRACTION_CARS = MAX(-0.0023*TIME+4.7457,0.14)
FRACTION_OTHERS = (1-
(FRACTION_2_WHEELERS+FRACTION_3_WHEELERS+FRACTION_BUSES+FRACTION_CARS))
FRACTION_TRANSPORTATION_AREA = 0.21
FUEL_OTHERS =
AVERAGE_TL_OTHERS*OTHER_VEHICLES*OTHERS_EFFICIENCY
GRAND_TRAVEL_DEMAND =
TOTAL_TRAVEL_DEMAND_2__WH+TOTAL_TRAVEL_DEMAND_3_WH+TOTAL_TRAVEL_DEMAND_BICYCLE+TOTAL_TRAVEL_DEMAND_BUS+TOTAL_TRAVEL_DEMAND_CAR
INI_NO_OF_CARS = 247943
INMIGRATION_FRACTION = (0.0454*0.60)+step(0.02,1975)-
step(0.02,1980)+step(0.01,1995)-step(0.03,1996)

IN_NO_OF_3_WH = 57853
IN_NO_OF_BUSSES = 5471
NEW_INDUSTRY = GRAPH(STEP(1.2,1995)+STEP(1,2001))
(0.00, 1.00), (0.2, 1.00), (0.4, 1.00), (0.6, 1.00), (0.8, 1.00), (1.00, 3.56), (1.20, 3.85), (1.40, 3.96), (1.60, 3.98), (1.80, 3.98), (2.00, 4.00)
Noname_1 = GRAPH(NUMBER_OF_BUSES/IN_NO_OF_BUSSES)
(1.00, 0.394), (1.40, 0.396), (1.80, 0.405), (2.20, 0.413), (2.60, 0.426), (3.00, 0.434), (3.40, 0.437), (3.80, 0.44), (4.20, 0.443), (4.60, 0.446), (5.00, 0.446)
Noname_2 = GRAPH(NUMBER_OF_3_WHEELERS/IN_NO_OF_3_WH)
(1.00, 0.0648), (1.30, 0.0651), (1.60, 0.0658), (1.90, 0.067), (2.20, 0.0685), (2.50, 0.0712), (2.80, 0.0728), (3.10, 0.0741), (3.40, 0.0746), (3.70, 0.0747), (4.00, 0.0747)
NORMAL_FRACTION = 0.29
NORMAL_PARK_FRACTION = 0.039
NO_OF_BUSS_CORRECTION = SMTH3(NUMBER_OF_BUSES,3)
NUMBER_OF_3_WHEELERS =
TOTAL_NUMBER_OF_VEHICLES*FRACTION_3_WHEELERS
NUMBER_OF_BUSES = (TOTAL_NUMBER_OF_VEHICLES*FRACTION_BUSES)*.23
NUMBER_OF_CARS = TOTAL_NUMBER_OF_VEHICLES*FRACTION_CARS
NUMBER_OF_HOUSEHOLDS = POPULATION/AVERAGE_HOUSEHOLD_SIZE
NUMEBER_OF_2_WHEELERS =
TOTAL_NUMBER_OF_VEHICLES*FRACTION_2_WHEELERS
OBS_TIME = 15
OTHERS_EFFICIENCY = 0.206
OTHERS_FRACTION = (max(1-
(BICYCLE_FRACTION+BUS_FRACTION+CAR_FRACTION+THREE_WH_FRACTION
+TWO__WH_FRACTION),0))*.2
OTHERS_TRIPS = TOTAL_TRIPS_PER_DAY*OTHERS_FRACTION
OTHER_VEHICLES = TOTAL_NUMBER_OF_VEHICLES*FRACTION_OTHERS
OUT_MIGRATION_FRACTION = 0.001
PCTRF = 0.0376
PETROL_PER_YEAR = 0.79*TOTAL_FUEL

POPULATION_DENSITY = POPULATION/AREA
POPULATION_DENSITY_2 = POPULATION/RESIDENTIAL_AREA
POPULATION_NORMAL_DENSITY = 600
PRESSURE_TO_INC_RA = GRAPH(RATIO_OF_DENSITY)
(1.00, 1.00), (2.00, 1.03), (3.00, 1.08), (4.00, 1.14), (5.00, 1.24), (6.00, 1.45), (7.00, 1.73), (8.00, 1.90), (9.00, 1.98), (10.0, 2.00)
RATIO_OF_DENSITY =
POPULATION_DENSITY_2/POPULATION_NORMAL_DENSITY
REQUIRED_PARK_AREA = REUIRED_PARK_FRACTION*AREA_2
REUIRED_PARK_FRACTION = 0.1
THREE_WH_EFFICIENCY = 0.033
THREE_WH_EMMISSION =
AVERAGE_3__WH_TRIP_LENGTH*EMMISSION_PER_KM_FOR_3_WH*NUMBER_OF_3_WHEELERS
THREE_WH_FRACTION = Noname_2
THREE_WH_FUEL =
AVERAGE_3__WH_TRIP_LENGTH*NUMBER_OF_3_WHEELERS*THREE_WH_EFFICIENCY
THREE_WH_TRIPS = TOTAL_TRIPS_PER_DAY*THREE_WH_FRACTION
TIME_TO_CHANGE_TRANSPORTATION_AREA = 2
TOTAL_EMISSION =
BUS_EMMISSION+CAR_EMMISSION+EMISSIONOTHERS+THREE_WH_EMMISSION+TWO_WHEELER_EMMISSION
TOTAL_FUEL =
BUS_FUEL+CAR_FUEL+FUEL_OTHERS+THREE_WH_FUEL+TWO_WH_FUEL
TOTAL_TRAVEL_DEMAND_2__WH =
TOTAL_TRIPS_PER_DAY*TWO_WH_AVERAGE_TRIP_LENGTH*TWO__WH_FRACTION/1000000
TOTAL_TRAVEL_DEMAND_3_WH =
TOTAL_TRIPS_PER_DAY*AVERAGE_3WH_TRIP_LENGTH*THREE_WH_FRACTION/1000000

TOTAL_TRAVEL_DEMAND_BICYCLE =
((TOTAL_TRIPS_PER_DAY*BICYCLE_FRACTION*BICYCLE_AVERAGE_TRIP_LENGTH)/1000000)
TOTAL_TRAVEL_DEMAND_BUS =
TOTAL_TRIPS_PER_DAY*AVERAGE_BUS_LENGTH*BUS_FRACTION/1000000
TOTAL_TRAVEL_DEMAND_CAR =
TOTAL_TRIPS_PER_DAY*AVERAGE_CAR_TRIP_LENGTH*CAR_FRACTION/1000000
TRANSPORTATION_AREA = AREA*FRACTION_TRANSPORTATION_AREA
TTCPA = 5
TTCRA = 5
TWO_WHEELER_EMMISSION =
AVERAGE_2WH_TRIP_LENGTH*EMMISSION_PER_KM_FOR_2__WH*NUMEBER_OF_2_WHEELERS
TWO_WHEELER_TRIPS = TOTAL_TRIPS_PER_DAY*TWO__WH_FRACTION
TWO_WH_AVERAGE_TRIP_LENGTH = 13.5
TWO_WH_EFFICIENCY = 0.04
TWO_WH_FUEL =
AVERAGE_2WH_TRIP_LENGTH*NUMEBER_OF_2_WHEELERS*TWO_WH_EFFICIENCY
TWO__WH_FRACTION = (3/100000000)*NUMEBER_OF_2_WHEELERS+.252
VEHICLES_PURCHASE_PER_1000 = 0.0125
VEHICLE_OGR_FRACTION = min(1,(1.74*(1.0855^(TIME-1971)))/100)
VEHICLE_OWNERSHIP =
NUMBER_OF_HOUSEHOLDS*VEHICLE_OGR_FRACTION

APPENDIX-4

(VARIABLES CONSIDERED FOR SYSTEM DYNAMICS MODELING)

Sl. No.	Variables Considered for System Dynamics Modeling
1.	Population
1.1	Birth Rate
1.2	Death Rate
1.3	In-migration Rate
1.4	Out-migration Rate
2.	Area in Sq. km
3.	Residential Area in Sq. Km
4	Parks and Playground Area in Sq. km
5	Transportation Area in Sq. km
6	Household Vehicle Ownership
6.1	Vehicle Ownership Growth Rate
6.2	Average Household Size
7	Vehicular Population: Total Number of Vehicles
7.1	Number of Two-wheelers
7.2	Number of Three-wheelers
7.3	Number of Cars
7.4	Number of Buses
7.5	Number of Other Vehicles
8	Modal Split: Total Number of Vehicular Trips
8.1	Number of Bicycle Trips
8.2	Number of Two-wheeler Trips
8.3	Number of Three-wheeler Trips
8.4	Number of Car Trips
8.5	Number of Bus Trips
8.6	Number of Other Vehicle Trips
9.	Total Travel Demand
10.	Bicycle Travel Demand
10.1	Total Trips per day
10.2	Bicycle Average Trip Length
10.3	Bicycle Trips Growth Rate Fraction
11.	Two-wheeler Travel Demand
11.1	Two-wheeler Average Trip Length
11.2	Two-wheeler Trips Growth Rate Fraction
12.	Three-wheeler Travel Demand
12.1	Three-wheeler Average Trip Length
12.2	Three-wheeler Average Trips Growth Rate Fraction
13.	Car Travel Demand
13.1	Car Average Trip Length
13.2	Car Average Trips Growth Rate Fraction

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Sl. No.	Variables Considered for System Dynamics Modeling
14.	Bus Travel Demand
14.1	Bus Average Trip Length
14.2	Bus Average Trips Growth Rate Fraction
15.	Road Congestion
15.1	Number of Acceptable trips
15.2	Actual Vehicle Density
16.	Two-wheeler Fuel Consumption
16.1	Efficiency per km trip length of two-wheelers in km per litre
17.	Three-wheeler Fuel Consumption
17.1	Efficiency per km trip length of three-wheelers in km per litre
18.	Car Fuel Consumption
18.1	Efficiency per km trip length of cars in km per litre
19	Bus Fuel Consumption
19.1	Efficiency per km trip length of buses in km per litre
20.	Other Vehicles Fuel Consumption
20.1	Efficiency of Other Vehicles per km trip length in km per litre
21.	Two-wheeler Emission Load
21.1	Emission rate per km trip length of two-wheelers in gms/km
22.	Three-wheeler Emission Load
22.1	Emission rate per km trip length of three-wheelers in gms/km
23.	Car Emission Load
23.1	Emission rate per km trip length of cars in gms/km
24.	Bus Emission Load
24.1	Emission rate per km trip length of buses in gms/km
25.	Other Vehicles Emission Load
25.1	Emission rate per km trip length of Other Vehicles (average)

APPENDIX – 5
(BIODATA)

Name:	**Mohan Kumar Chavan** S/o Mahadeva Rao Chavan Gandhanahally, Krishnaraja Nagara Taluk Mysore District, Karnataka State
Academic Qualification:	Masters Degree in Urban and Regional Planning (M.U.R.P) Post-Graduate Diploma in Business Computing (P.G.D.B.C.) Bachelor of Engineering (Civil Engineering)
Scholarships and Fellowships:	MHRD Fellowship for Ph.D. Research Work 2006-2009.
Research Work:	Planning for Optimal Transportation System in Bangalore City, India Pattern of Utilization of Open spaces in Mysore City (Masters Thesis) Study of Performance of K.S.R.T.C. Hassan Depot. (U.G. Project Report)
Professional Memberships:	Institution of Engineers, India Institute of Town Planners, India Indian Society for Technical Education (ISTE), New Delhi Systems Dynamics Society of India (SDSI) Associate Transport Development of India (ATDI) Institute of Urban Transport (India)

Academics:

2011: Presently a candidate for the Degree of Doctor of Philosophy at Indian Institute of Technology Roorkee, Roorkee, Uttarakhand State, India.

1996: Post-Graduate Diploma in Business Computing (PGDBC) from University of Mysore.

1993: Post-Graduated from Institute of Development Studies, Manasa

Gangothri, Mysore with a Masters in Urban and Regional Planning with First Class.

1989: Graduated from University of Mysore with Bachelors Degree in Civil Engineering with First Class with Distinction.

Experience:

- Working as a Selection Grade Lecturer at Malnad College of Engineering, Hassan from October 2008 to till date.
- Worked as a Senior Lecturer at Malnad College of Engineering, Hassan from October 2003 to October 2008.
- Worked as a Lecturer at Malnad College of Engineering, Hassan from October 1998 to October 2003.
- Worked for more than three-and-years as a Traffic Inspector in Karnataka State Road Transport Corporation (KSRTC), Karnataka.
- Worked for about two years Guest Faculty at Malnad College of Engineering, Hassan, Karnataka State.
- Worked for Seven months part-time Lecturer at Govt. (Smt. L.V. .Polytechnic) Polytechnic, Hassan, Karnataka State.
- Worked for six months part-time Lecturer at Govt. Polytechnic, K.R. Pet, Mandya District, Karnataka State.
- Worked for a yeas as a Graduate Apprentice Engineer, Irrigation Department, Halekote, Holenarasipur Taluk, Hassan District, Karnataka State.
- Worked for four months as a Engineer in Mandya Urban Development Authority, Mandya, Karnataka State.

Awards and Academics:

- MHRD scholarship during Ph. D (July 2006 to July 2009)
- Financial Support (Salary component) from Director of Technical Education, Bangalore, Government of Karnataka and Malnad Technical Education Society, Hassan, Karnataka State.
- Selected for National level workshop, Karnataka State Council for Science and Technology (KSCST) guided VIII Semester Civil Engineering Student Project.

- Awarded Kanchugarakoppal Some Gowda Endowment Gold Medal for Masters Degree in Urban and Regional Planning Thesis from University of Mysore.

Professional Memberships:

- Life member of Institution of Engineers, India (IEI)
- Life member of Institute of Town Planners, India (ITPI)
- Life member for Indian Society for Technical Education (ISTE) New Delhi
- Life member of Systems Dynamics Society of India (SDSI)
- Life member of Associate Transport Development of India (ATDI)
- Life member of American Society of Civil Engineers, India Chapter
- Life member of Institute of Urban Transport (India) (IUTI)

Permanent Address:

Mohan Kumar Chavan
S/o Mahadeva Rao Chavan (late)
Gandhanahally
Krishna Raja Nagar Taluk
Mysore District
Karnataka State.

Address for Communication:

Mr. Mohan Kumar Chavan
B/o Bhyroji Rao Chavan
2151, Bhavani Nilaya
Northern Extension
Hassan – 573 201
Karnataka State.
E-mail: mohankumarchavan@gmail.com
mohankumar_chavan@rediffmail.com

APPENDIX - 6

LIST OF PUBLICATIONS

The following papers have been published/ presented during Ph.D thesis work

1. **Devadas, V., & Chavan, M. K., 2008.** Planning for Optimal Road Transportation in Hassan City, Karnataka State, proceeding of National Conference on 'Emerging Technologies in Civil Engineering NCETCE-2008)' organized by Department of Civil Engineeering, P.D.V.V.P College of Engineering, Ahmednagar held from February 28-29, 2008.
2. **Devadas, V., & Chavan, M. K., 2008.** Transportation Planning for Integrated Development of Bangalore Metropolitan Region, Karnataka State, India, proceeding of National Conference on 'Systems Thinking & System Dynamics (NCSD-2008)' jointly organized by Department of Mechanical Engineering, Institute of Technology, Banaras Hindu University, Varanasi, Uttara Pradesh, India and System Dynamics Society of India (SDSS) held from February 29 to March 1, 2008.
3. **Chavan, M. K., 2008. Devadas, V., & Sreehari, M. N. 2008.** Transportation System at a Glance in Bangalore City, India, Proceeding of "International Conference on Transportation System Studies (ICOTSS 2008)" under the auspices of The Association for Transport Development in India (ATDI) and organized by The Walchand Hirachand Unit in Transport Economics, The Department of Economics, University of Mumbai, Mumbai. (10-12 January, 2008)
4. **Chavan, M. K., Devadas, V., & Sreehari, M. N. 2008.** Traffic and Transportation Problems and their Mitigation Measures in Bangalore City, India, Proceeding of "International Conference on Transportation System Studies (ICOTSS 2008)"under the auspices of The Association for Transport Development in India (ATDI) and organized by The Walchand Hirachand Unit in Transport Economics, The Department of Economics, University of Mumbai, Mumbai. (10-12 January, 2008)
5. **Devadas, V., & Chavan, M. K., 2007.** Problems and Prospects of Transportation in Bangalore City, India, proceeding of seminar volume of All India

Seminar on 'Urbanization in the present global scenario' organized by American Society of Civil Engineers-India Section in Association with Institution of Civil Engineers, U.K, Eastern Region, India. (7-8 December, 2007).