REPUBLIC OF INDIA
DIRECTORATE OF URBAN LAND TRANSPORT
URBAN DEVELOPMENT DEPARTMENT
GOVERNMENT OF KARNATAKA

THE MASTER PLAN STUDY ON THE INTRODUCTION OF INTELLIGENT TRANSPORT SYSTEM (ITS) IN BENGALURU AND MYSORE IN INDIA

FINAL REPORT

June 2015

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)

JICA STUDY TEAM Consisted by
NIPPON KOEI CO., LTD.
EAST NIPPON EXPRESSWAY CO., LTD.
CTI ENGINEERING INTERNATIONAL CO., LTD.

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Abbreviations

Abbreviation	Official Name
AADT	Annual Average Daily Traffic
AFC	Automatic Fare Collection
ALB	Automatic Lane Barrier
ANPR	Automatic Number Plate Recognition
ASB	Amber Siren Beacon
ATC	Although Area Traffic Control
ATCC	Automatic Traffic Counter-Cum-Classifier
ATCS	Area Traffic Control Signal System
AVC	Automatic Vehicle Classifier
BAU	Business As Usual
BBMP	Bruhat Bengaluru Mahanagar Palike
BDA	Bengaluru Development Authority
BEL	Bharat Electronics Ltd.
BEML	Bharat Earth Movers Limited
BETL	Bengaluru Elevated Tollway Limited
BHEL	Bharat Heavy Electricals Limited
BMA	Bengaluru Metropolitan Area
BMIC	Bengaluru-Mysore Infrastructure Corridor
BMRCL	Bengaluru Metro Rail Corporation Limited
BMRDA	Bengaluru Regional Development Authority
BMTC	Bengaluru Metropolitan Transport Corporation
BOT	Built-Operate-Transfer
BRT	Bus Rapid Transit
BRTS	Bus Rapid Transit System
B-TIC	Bengaluru Traffic Information Centre
BTP	Bengaluru Traffic Police
B-TRAC	Bengaluru Traffic Action Committee
CA	Commercial Area
CBD	Central Business District

CCTV	Closed Circuit Television
CDAC	Centre for Development of Advanced Computing
CiSTUP	Centre for infrastructure, Sustainable Transportation and Urban Planning
CMC	City Municipal Councils
CN	Cellular Network
CPCB	Central Pollution Control Board
CRR	Core Ring Road
CTTP	Comprehensive Traffic and Transportation Plan
CTTS	Comprehensive Traffic and Transportation Study
CWR	Carriage Way Road
DoP	Department of Tourism
DOT	Department of Transport
DPR	Detailed Project Report
DRM	Digital Road Map
DSRC	Dedicated Short Range Communication
DULT	Directorate of Urban Land Transport of Karnataka State Government
ECB	Electronic Call Boxes
EIRR	Economic Internal Rate of Return
EMV	Europay, MasterCard and Visa
EPC	Engineering Procurement and Construction
EPS	Electronic Parking System
ERP	Electronic Road Pricing
ETC	Electronic Toll Collection System
ETM	Electronic Ticketing Machine
ETS	Electronic Ticketing System
FDI	Foreign Direct Investment
FSW	Emergency Footswitch
GDP	Gross Domestic Product
GIS	Geographic Information System
GNSS	Global Navigational System
GPS	Global Positioning System

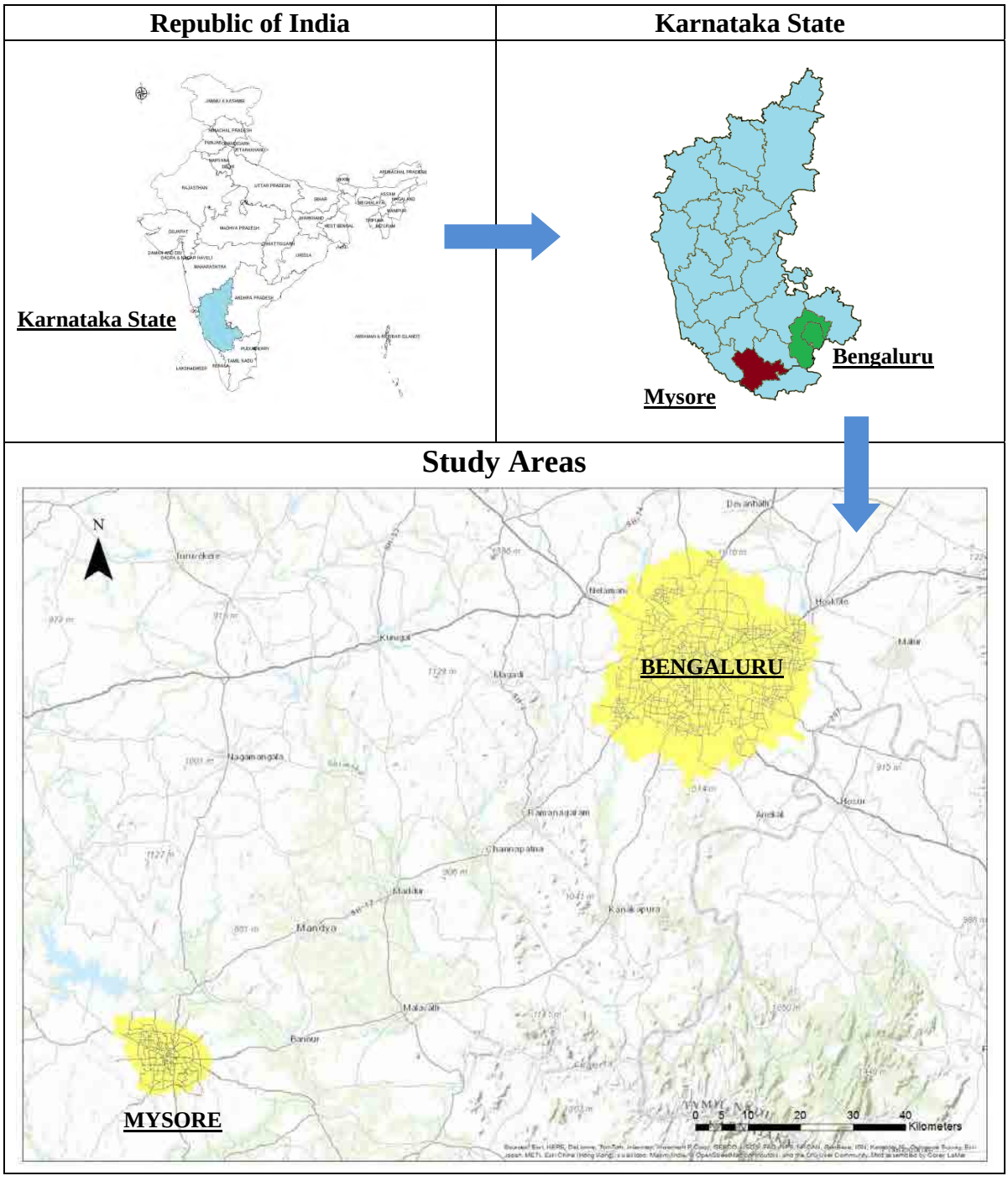
GSMC	Global Service Management Center
HAL	Hindustan Aeronautics Limited
HCV	Heavy Commercial Vehicle
HMT	Hindustan Machine Tools
HOV	High Occupancy Vehicle
HSRP	High Security Registration Plate
HTMS	Highway Traffic Management System
IA	Industrial Area
IC	Integrated Circuit
ICT	Information Communication Technology
ICRA	Investment Information and Credit Rating Agency of India Ltd
IIM-B	Indian Institute of Management Bengaluru
IISc	Indian Institute of Science
IMaCS	Management Consulting Services Ltd
IPT	Intermediate Public Transport
IRC	Indian Road Congress
IRR	Inner Ring Road
ISRO	Indian Space Research Organization
ISU	Intercom Slave Unit
IT	Information Technology
ITES	Information Technology Enabled Services
ITPL	International Technology Park Ltd.
ITS	Intelligent Transport Systems
IVRS	Interactive Voice Response System
JCC	Joint Coordination Committee
JICA	Japan International Cooperation Agency
JICA STRADA	JICA System for Traffic Demand Analysis
JNNURM	Jawaharlal Nehru National Urban Renewal Mission
KRDCL	Karnataka Road Development Corporation Limited
KRS	Krishna Raja Sagar
KSPCB	Karnataka State Pollution Control Board
KSRTC	Karnataka State Road Transport Corporation

KSTDC	Karnataka State Tourism Development Corporation
KTCP	Karnataka Town and Country Planning
KUDA	Karnataka Urban Development Authority
KUIDFC	Karnataka Urban Infrastructure Development and Finance Corporation Limited
LCV	Light Commercial Vehicle
LPA	Local Planning Area
LRT	Light Rail Transit
LTA	Land Transport Authority
LTL	Lane Traffic Light
LUT	Land Use Transport
MCA	Ministry of Corporate Affairs
MCC	Mysore City Corporation
MITRA	Mysore Intelligent TRAsport System
MORTH	Ministry of Road Transport and Highways
MTP	Mysore Traffic Police
M-TRAC	Mysore Traffic Action Committee
MUDA	Mysore Urban Development Authority
NAL	National Aerospace Laboratories
NEKRTC	North East Karnataka State Road Transport Corporation
NFC	Near Field Communication
NH	National Highway
NHAI	National Highway Authority of India
NICE	Nandi Infrastructure Corridor Enterprises
NMT	Non Motorist Transport
NO2	Nitrogen Dioxide
NPCI	National Payment Corporation of India
NPV	Net Present Value
NURM	National Urban Renewal Mission
NUTP	National Urban Transport Policy
OBU	On-Board Unit
OCR	Optical Character Recognition

OD	Origin-Destination
OHTL	Overhead Traffic Light
ORR	Outer Ring Road
PBS	Public Bicycle sharing
PCS	Plaza Computer System
PCU	Passenger Car Unit
PIS	Passenger Information System
POS	Point of Sales
PRR	Peripheral Ring Road
PWD	Public Works Department
RA	Residential Area
RBI	Reserve Bank of India
RFID	Radio Frequency Identification
ROW	Right of Way
SA	Sensitive Area
SRW	Smartcard Reader/Writer
SH	State Highway
SO2	Sulfur Dioxide
SPV	Special Purpose vehicle
STPI	Software Technology Parks of India
TAG	Technical Advisory Group
TCC	Traffic Control Centre
TCCS	Traffic Control Centre System
TDM	Traffic Demand Management
TCT-RPR	Toll Collector Terminal with Receipt Printer
TLC	Toll Lane Controller
TMC	Traffic Management Centre
TMS	Toll Management System
TnG	Touch & Go
TOD	Time-of-Day
TTC	Travel Time Cost
UFD	User Fare Display

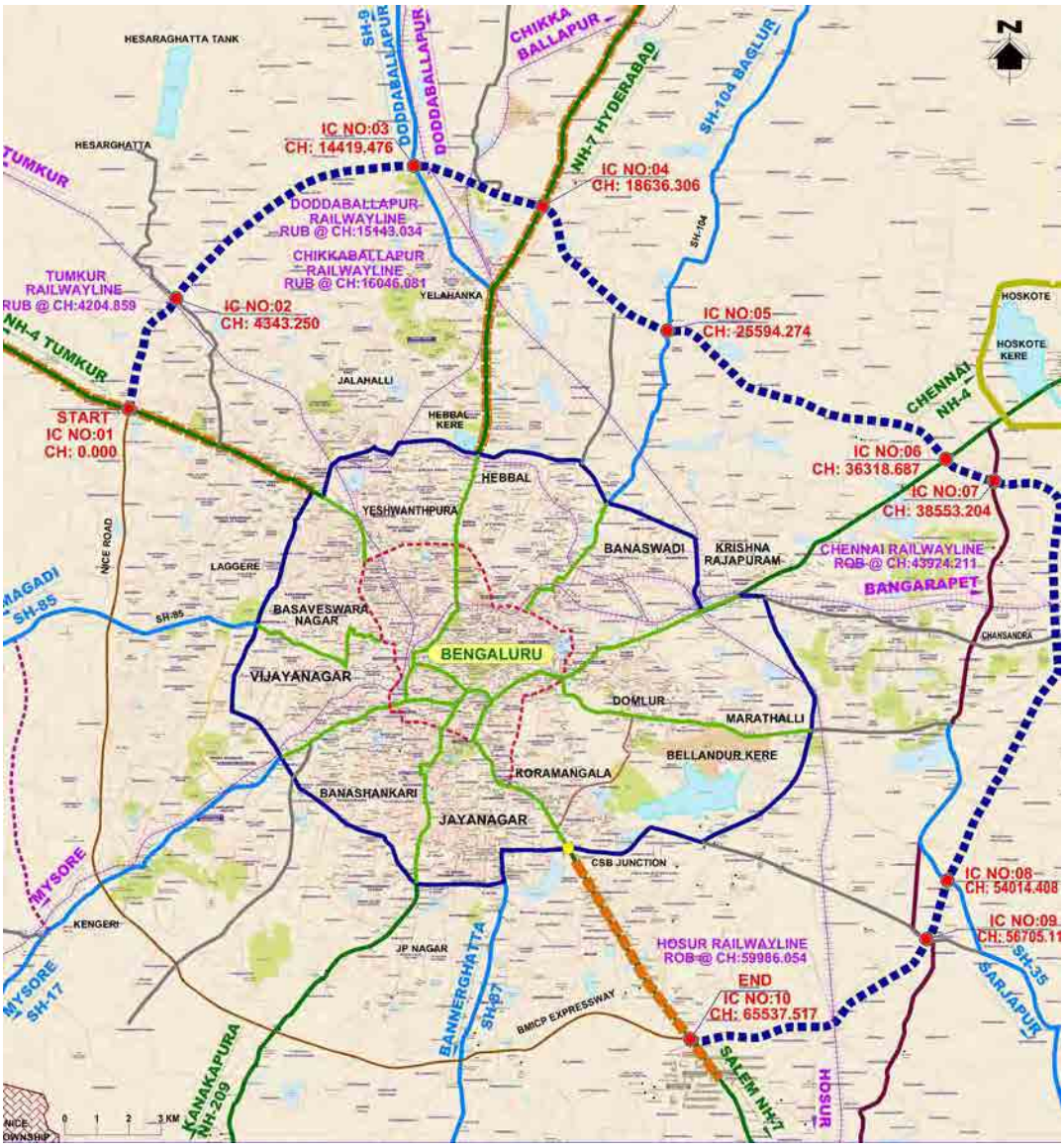
UTP	Urban Transport Planning
V/C	Volume by Capacity
VMS	Variable Message Sign
VOC	Vehicle Operation Cost
VTS	Vehicle Tracking System

Location Map



(Source: Jointly prepared by DULT and JICA Study Team)

Location Map: Bengaluru Metropolitan Area



LEGEND:

- PERIPHERAL RING ROAD (PLANNED)
- ELEVATED ROADS
- NATIONAL HIGHWAY
- STATE HIGHWAY
- OUTER RING ROAD
- NICE ROAD
- INNER RING ROAD
- CORE RING ROAD
- RAILWAYS
- INTERMEDIATE RING ROAD
- TOWN RING ROAD
- RADIAL ROADS
- OTHER ROADS
- WATER BODIES

(Source: Jointly prepared by DULT and JICA Study Team)

Location Map: Mysore

(Source: Jointly prepared by DULT and JICA Study Team)

1 Introduction

1.1 Study Background

Bengaluru is a capital city of Karnataka state and the fifth largest metropolis in India. It is widely known as India's IT capital and an important industry hub in the region of south India with a number of leading Indian and foreign companies such as Microsoft, Toyota, and etc. Due to rapid urbanisation, severe traffic congestion is becoming a serious problem and causing a bottleneck for business activities in the region.

Hard measures of infrastructure development are underway. They include for example improvement of radial road, extension of the existing Metro, and etc. The development of the Peripheral Ring Road under Japanese Yen loan project is under consideration. Hence, it is also important to simultaneously take soft measures, represented by Intelligent Transport Systems (ITS), to contribute to effective use of infrastructure.

Mysore, the second largest city in Karnataka state, is located 140 km southwest of Bengaluru and a major tourist destination in the state with a plenty of historical heritages. Having been a former capital of Kingdom of Mysore for decades, Mysore is still the home of people's heart in the state. Promotion of tourism preserving environment is the most important policy of Mysore. Hence, the population and vehicles are expected to become double within a decade, and so urban transport measures achieving the policy of Mysore is increasingly important.

An ITS seminar co-hosted by India and Japan was held in Bengaluru in March 2012, and attended by a number of Indian stakeholders in the ITS field. The officials of Directorate of Urban Land Transport of Karnataka State Government (DULT) participated in the ITS training programme in Japan in 2013. Taking a cue from these events, ITS and related advanced technologies that Japan possesses have drawn attention to comprehensively address the urban transport growth.

The Government of Karnataka requested the Government of Japan to carry out a study to prepare a comprehensive ITS Master Plan for this region. As a result, Urban Development Department, the Government of Karnataka State, and Japan International Cooperation Agency (JICA) agreed that both parties would cooperate sincerely with each other to formulate an ITS Master Plan for Bengaluru metropolitan area and Mysore.

1.2 Study Outline

1.2.1 Study Overview

The overview of the Study is shown in Table 1.1.

Table 1.1 Study Overview

Item	Content
Project Name	The Master Plan Study on the Introduction of Intelligent Transport System (ITS) in Bengaluru and Mysore in India
Study Period	January 2014 - June 2015 (18 months)
Target Region	Bangalore Metropolitan Area and Mysore in Karnataka State of India
Study Scope	● Formulation of ITS Master Plan for Bangalore Metropolitan Area ● Formulation of ITS Master Plan for Mysore ● Preparation of Draft Specification for Prioritised ITS for Bengaluru Metropolitan Area
Capacity Building	● ITS Technical Tour to Singapore and Japan
Major ITS Components for Consideration	● ITS in the City for traffic management ● ITS for Peripheral Ring Road (Highway Traffic Management System and Toll Management System) in Bengaluru ● Electronic Road Pricing System in Bengaluru ● Clearinghouse for Common Smartcard
Milestones	● May 2015: ITS Master Plan for Bangalore Metropolitan Area ● May 2015: ITS Master Plan for Mysore ● May 2015: Draft Specification for Prioritised ITS for Bengaluru Metropolitan Area ● May 2015: Draft Final Report ● June 2015: Final Report
Counterpart and Organisation Arrangement for the Study	● Counterpart: Directorate of Urban Land Transport (DULT), Government of Karnataka ● Other Relevant Organisations: Urban Transport Related Organisations in Bengaluru and Mysore ● Joint Coordinating Committee (JCC): formulated by DULT, BDA, BBMP, JICA and JICA Study Team as Core Members for the Study ● Technical Advisory Group (TAG): formulated by relevant organization in Bengaluru and Mysore

(Source: JICA Study Team)

1.2.2 Expected Goals

ITS is a soft measure for assisting the measures on urban transport. It supports to enable;

- Reduced traffic congestion and traffic flow on the road network including PRR
- Enhanced and improved usage of public transport
- Proper planning and implementation of road infrastructure development and traffic management by the utilisation of quantitative data on traffic made available by ITS

1.2.3 Project Site and Beneficiaries

The project sites are Bengaluru metropolitan area, and Mysore as supplementary study area. The beneficiaries of the project are road users, public transport users and related government authorities.

1.2.4 Stakeholders and Study Implementation Structure

Joint Coordinating Committee (JCC) and Technical Advisory Group (TAG) were organised for smooth execution of the Study.

- Joint Coordinating Committee (JCC)

JCC was organised to facilitate execution of the Study. It functioned as a decision making body, assuring the study objectives and inter-organisational coordination. JCC was chaired by the commissioner of DULT and held whenever deemed necessary.

- Technical Advisory Group (TAG)

TAG was organised to achieve consensus for the issues across related agencies. TAG meetings were convened as required. As per the issues to be discussed, the relevant members were invited for the meetings. TAGs for Bengaluru and Mysore were respectively organised and consisted by the relevant organisations in these regions.

The structure and member organisations of JCC and TAGs are shown in Figure 1.1 and Figure 1.2.

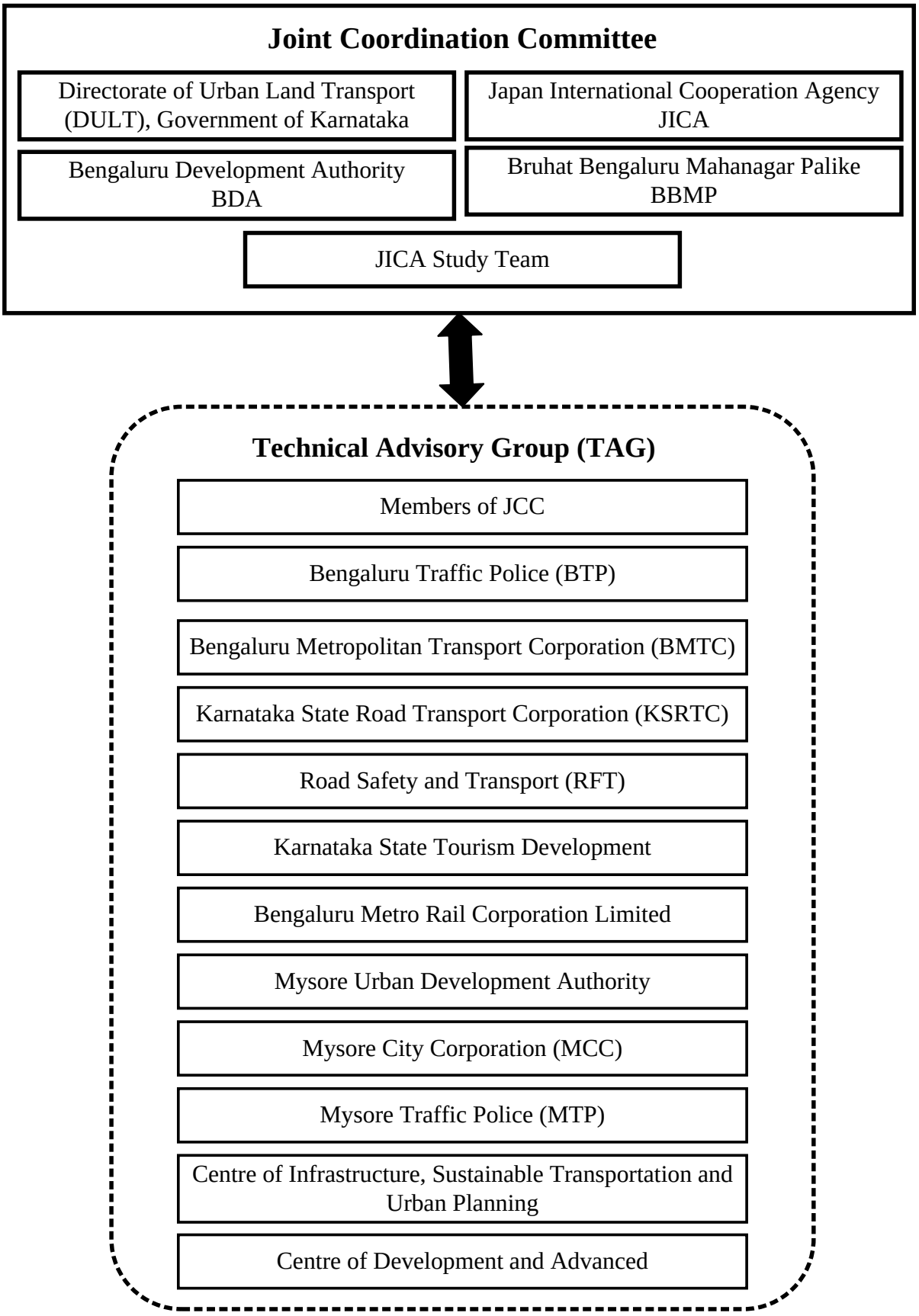


Figure 1.1 Members of JCC and TAG for Bengaluru

(Source: JICA Study Team)

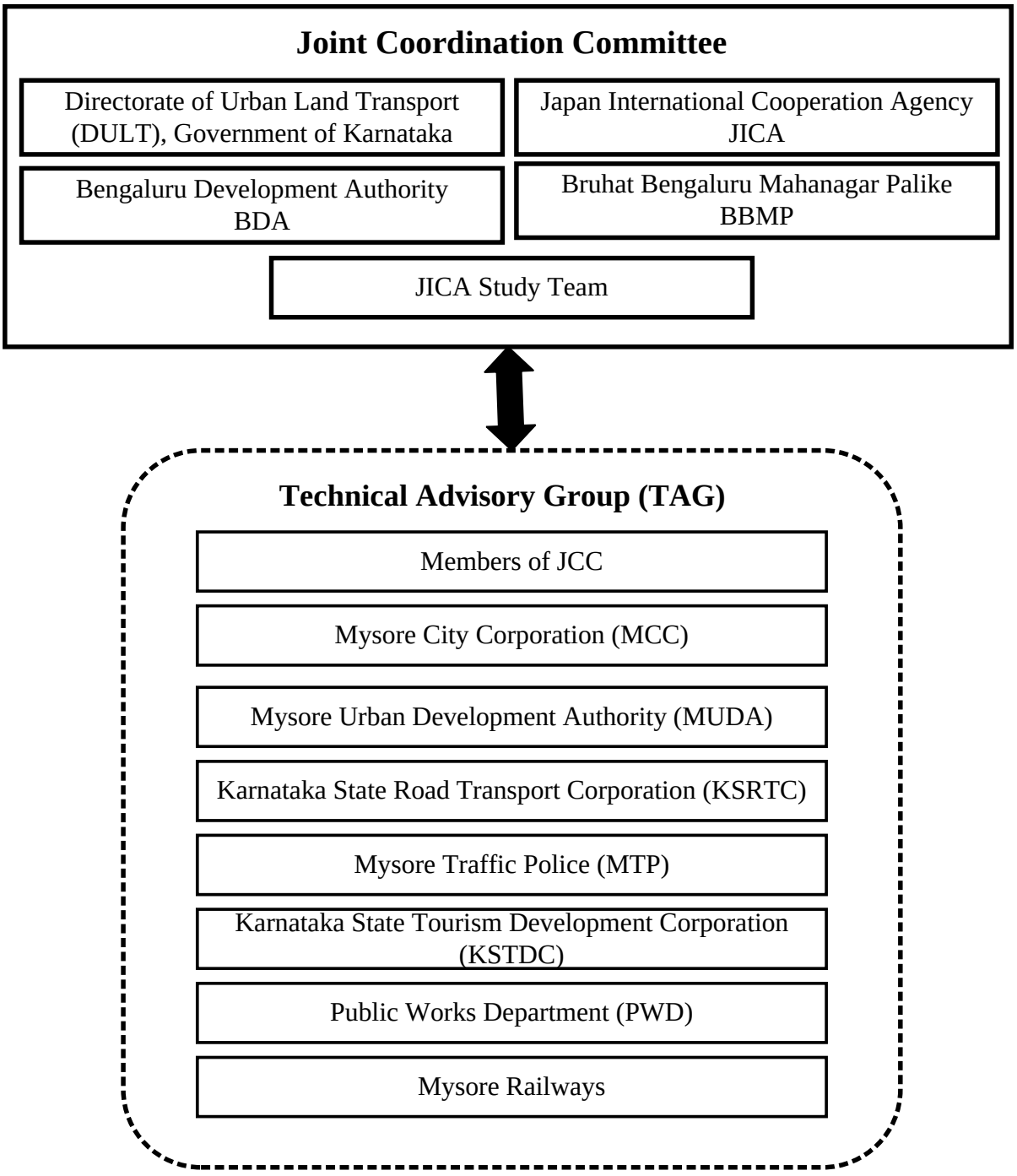


Figure 1.2 Members of JCC and TAG for Mysore

(Source: JICA Study Team)

1.2.5 Study Members and Study Team Structure

The study members and structure of JICA Study Team are shown in Figure 1.3.

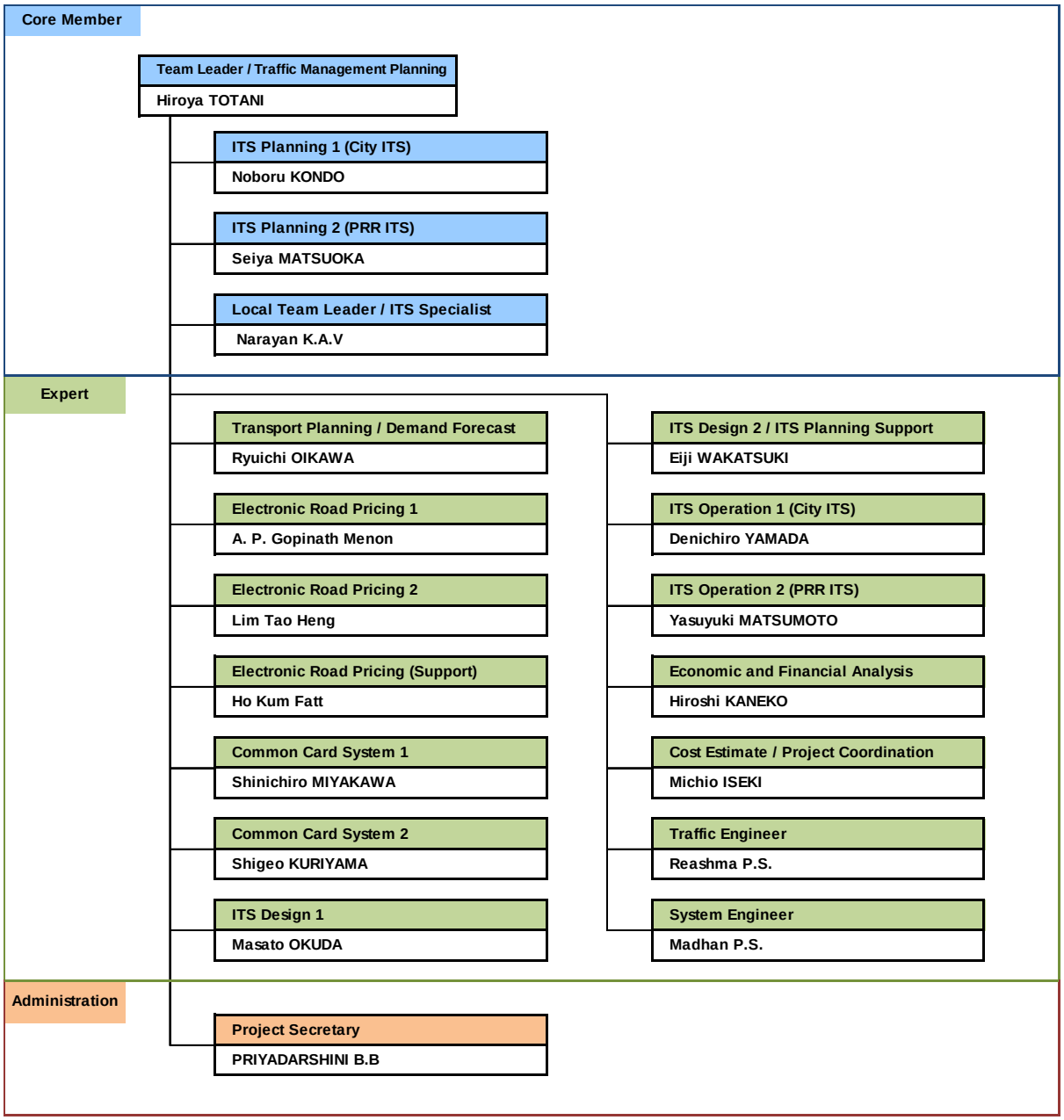


Figure 1.3 Members and Structure of JICA Study Team

(Source: JICA Study Team)

1.2.6 Report Submission and Study Schedule

The reports which have been prepared and the study schedule are shown in Table 1.2 and Figure 1.4.

Table 1.2 Submitted Report

Report Name	Submission Date	Number of Copies
Inception Report	January 2014	30 Copies in English (10 for JICA)
ITS Master Plan for Bengaluru Metropolitan Area	May 2015	30 Copies in English (5 for JICA)
ITS Master Plan for Mysore	May 2015	30 Copies in English (5 for JICA)
Draft Specifications	May 2015	30 Copies in English (5 for JICA)
Draft Final Report	May 2015	30 Copies in English (5 for JICA) 30 Summaries in English (5 for JICA)
Final Report	June 2015	40 Copies in English (10 for JICA) 40 Summaries in English (10 for JICA) 10 Summaries in Japanese

(Source: JICA Study Team)

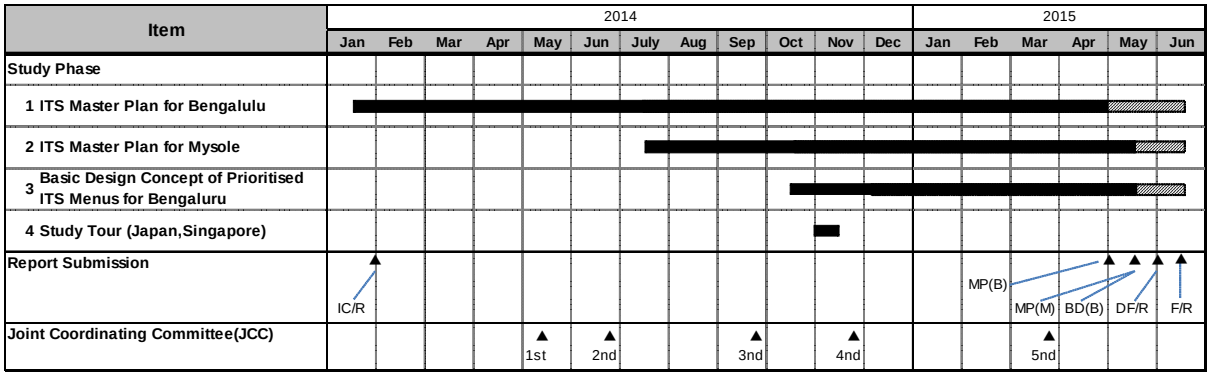


Figure 1.4 Study Schedule

(Source: JICA Study Team)

1.3 Basic Study Approach

1.3.1 Major Issues

(1) Increase in Traffic and Inadequate Road Transportation Infrastructure

Inadequate roads and transportation infrastructure are major challenges in urban transportation. Particularly in Bangalore metropolitan area, road and transportation infrastructures have not caught up with the increase in traffic due to rapid metropolitan development. Recently the development of Metro is underway, and city buses are in use as urban mass transportation system. However, transfer facilities between different modes are not sufficiently in place, and diversion of transport demand to public transportation has not been achieved. It cannot be said that the sidewalks are developed enough since a lot of pedestrians and street stalls exist in drivers way, and the urban traffic condition results in a chaotic condition. Since ITS is a soft measure which exhibits maximum effects under the traffic conditions of certain degree of regular order with appropriate road and transportation infrastructure, it is important that the ITS be planned in a phased manner in accordance with the development of road and transportation infrastructure.

Figure 1.5 Road and Traffic Condition in the City

(Source: JICA Study Team)

(2) Ineffective Use of Data Necessary for Proper Road and Traffic Management

In Bangalore and Mysore, basic road and traffic data/information necessary for proper road and traffic management has not been effectively utilised. For example, a traffic control centres are operated by Bengaluru Traffic Police in Bengaluru and Mysore Traffic Police in Mysore. However traffic monitoring by CCTV camera is a major monitoring method in both regions, and traffic conditions are not objectively comprehended based on the quantitatively measured traffic data. Therefore, dynamic traffic information cannot be provided to the users and appropriate traffic guidance has not been realised. In addition, such data is not utilised for traffic management measures and road and transportation infrastructure improvement. It is important to prepare a mechanism whereby basic data/information required for proper road and traffic management is equipped with the road and

traffic administrators, and quantitatively measured data is effectively utilised for road and traffic management.

(3) Absence of Comprehensive ITS Planning

Some ITS systems are planned and being implemented in Bengaluru and Mysore. For example, the traffic control centre of Bengaluru Traffic Police is under renovation and upgrade in Bengaluru. A bus operation management and information provision system called "MITRA" is under operation in Mysore. Apart from these, a road pricing system is under consideration by DULT. Bus operation management and information provision system by the bus operator in Bangalore, card systems by public transport operators etc. are planned. However, there is not sufficient mutual coordination amongst these, and there is no comprehensive planning and execution. For this reason for example, provision of collected information to road users and effective utilisation by the road and traffic administrators remain limited. Moreover, such situation results in lack of convenience of public transportation for users. Therefore, preparing a comprehensive ITS plan that encompasses these aspects is an important need.

(4) Sense of Urgency of Implementation of ITS

Directorate of Urban Land Transport of Government of Karnataka (DULT), which is the competent authority of this study, has a keen sense of urgency about the fact that development of individual ITS is separately progressing because of inadequate coordination amongst various institutions. For this reason, it is important that the overall picture of ITS will be shown and ITS will be implemented as early as possible and yet in a comprehensive manner.

(5) Many Stakeholders

The scope of this study covers Bangalore and Mysore. Also, there is a wide range of ITS components to be considered, such as ITS in the city, ITS for Peripheral Ring Road in Bengaluru, a common smartcard and road pricing system. For this reason, there are inevitably many stakeholders such as road administrators, traffic administrators, public transport operators, private operators (taxi operators, SI operators, etc.), and financial institutions.

1.3.2 Technical Policy

In light of the aforementioned issues, the Study was carried out on the basis of the following technical policies.

Policy1: *Effective Use of Road and Traffic Data for Appropriate Road Traffic Management*

Policy2: *Traffic Control Utilising ITS*

Policy3: *Integration of ITS*

Policy4: *Phased Implementation of ITS*

[Technical Policy 1] Effective Use of Road and Traffic Data for Appropriate Road Traffic Management

The Study was conducted based on the following policies for effective use of road and traffic data for appropriate road traffic management.

- Quantitative Comprehension of Traffic Conditions
- Aggregation of Data and Information Necessary for Road Traffic Management
- Utilisation of Aggregated Data and Information for Road Traffic Management and Users

The following considerations were taken:

- Preparation of mechanism of quantitative comprehension of traffic conditions utilising ITS
- Aggregation of data/information, such as construction work information and etc. that should be equipped with the road and traffic administrators and making the best use of the information obtained from existing institutions
- Utilising such data/information for effective road traffic infrastructure plan and traffic measures and realising the provision of dynamic traffic information to the uses

[Technical Policy 2] Traffic Control Utilising ITS

For easing traffic congestion, it is necessary that traffic is properly controlled. Major examples of ITS and related technologies for controlling traffic include providing dynamic information to guide traffic, signal control, electronic road pricing system, and etc.

The focus was paid to realising proper traffic control assisted by ITS to alleviate traffic congestion in the city.

[Technical Policy 3] Integration of ITS

It is important to draw a comprehensive plan of ITS in Bengaluru and Mysore where a variety of ITS services will be in place in the future. The Study took into account the effective integration of ITS in both technical and organisational aspects. The considerations were made to centralisation of information obtained from ITS, organisation for continuous promotion of ITS and realisation of wide metropolitan comprehensive traffic information.

[Technical Policy 4] Phased Implementation of ITS

In light of technical policies 1, 2, and 3, the Study considers phased implementation of ITS on the basis of the following policies.

- **Short Term**

Development of essential ITS functions in the most important area, establishment of new centres and formulation of required organisations

- **Mid Term**

Expansion of target area and upgrade of functions of ITS which are developed in the short term in accordance with progress of infrastructure improvement/development and change in traffic characteristics

- **Long Term**

Further upgrade of ITS in the advent of new technologies

1.3.3 Study Implementation Policy

The Study was carried out on the basis of the following study implementation policies.

Policy1: Close *Collaboration with Joint Coordination Committee and Technical Advisory Group*

Policy2: *Working together with Counterpart Personnel, Aiming at Capacity Building*

Policy3: *Efficient Study Implementation, Utilising Knowledge of Similar Past Works*

[Study Implementation Policy 1] Close Collaboration with Joint Coordination Committee and Technical Assistance Group

The Study covers Bangalore and Mysore. There is also a wide range of ITS components for consideration, such as ITS in the city, ITS for Bangalore Peripheral Ring Road, clearinghouse for common smartcard and electronic road pricing. For this reason, the Study was carried out maintaining close communication throughout the study activities to achieve mutual understanding with the stakeholders including the relevant organisations in Indian side, JICA and JICA Study Team.

The Study was carried out in collaboration with Joint Coordination Committee (JCC) having a sense of unity with the comprising members of JCC. Information, opinions and ideas in terms of technical, organisational and operational aspects were exchanged on a series of meetings of Technical Advisory Group (TAG) which consists of several different related organisations.

The cooperation structure with the stakeholders for this study is shown below.

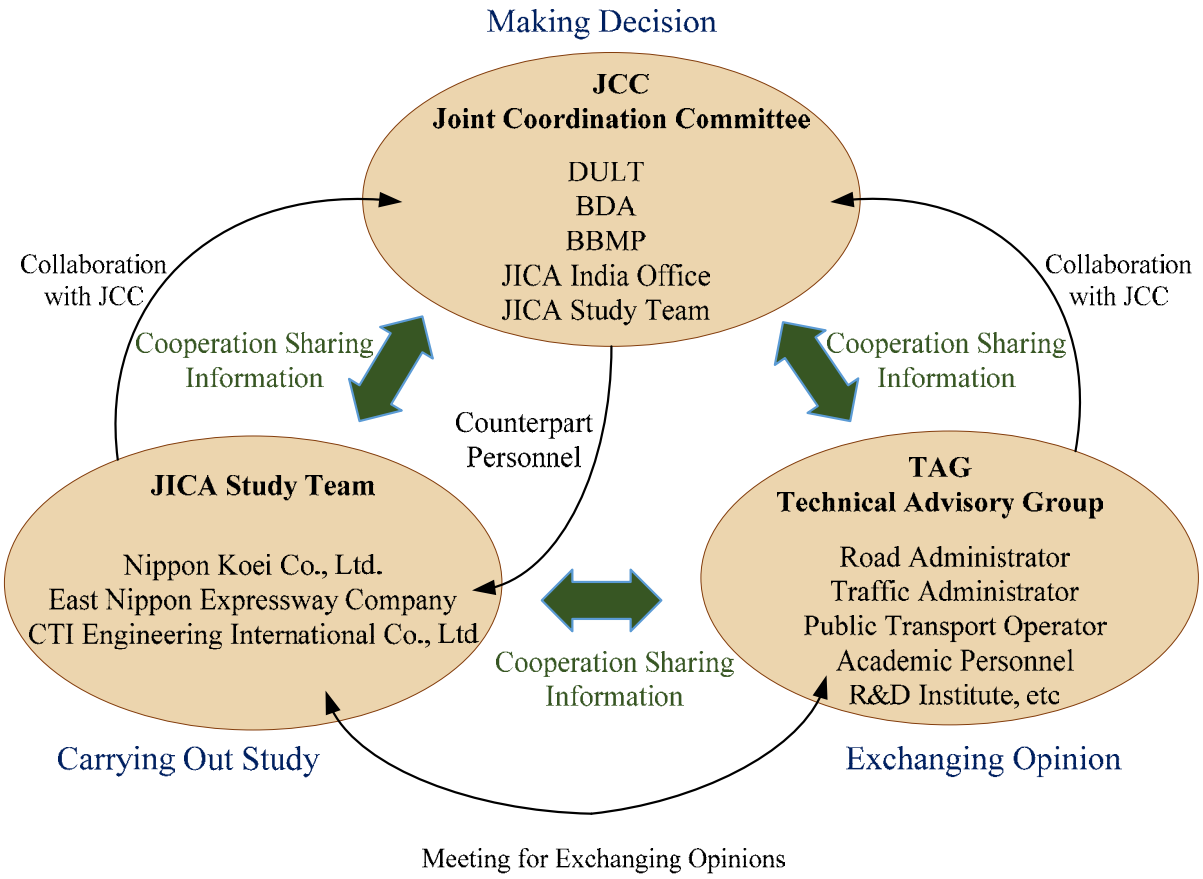


Figure 1.6 Cooperation Structure for the Study

(Source: JICA Study Team)

[Study Implementation Policy 2] Working Together with Counterpart Personnel, Aiming at Capacity Building

The capability of personnel especially on government side is extremely important for sustainable implementation of ITS. Building a capacity with sufficient and proper knowledge of ITS is a key factor for successful management, planning, implementation and promotion of ITS for the long-term.

The Study period is regarded as the best opportunity for capacity building of counterparts. Thus, the following staffing arrangement was made for the purpose of both counterpart capacity strengthening and efficient implementation of the Study.

- Counterparts to continuously reside in the study team office as a member of the study team throughout the study period.
- They will work together with the study team consulting with relevant organisations, and involving in various other works.

- They will function as the contact point of relevant organisations and coordinates amongst counterpart organisations and involved organisations.

[Study Implementation Policy 4] Efficient Study Implementation, Utilising Knowledge of Similar Works, and with Assistance of Local Offices and Headquarters

The Study was carried out by utilising knowledge of similar past works engaged by the members of JICA Study Team and with a great deal of assistance of local offices and headquarters for assurance of quality and efficiency of the Study.

Table 1.3 shows examples of the similar past works of JICA Study Team.

Table 1.3 Examples of Similar Past Works and Relevant Projects

Project Name	Similarities and Advantages
JICA Special Assistance for Project Implementation (SAPI) for the Assistance for the Introduction of ITS on Road Network in Hyderabad Metropolitan Area	● Carried Out by Nippon Koei Co., Ltd. Joint Venture ● ITS Master Plan in Hyderabad and Design for the Pilot Project
ITS Introduction for Hyderabad Outer Ring Road Construction Support Project (Supplementary Loan Project) in India	● Carried Out by Members of This Study ● Design of ITS for Outer Ring Road in Hyderabad
Data Collection Survey on the Introduction of ITS to the Urban Transportation of Major Cities in India	● Carried Out by Nippon Koei-Joint Venture. ● Included Bangalore and Mysore in the Study Area.
ITS Counterpart Training in Japan	● Carried out by Nippon Koei-Joint Venture. ● Knowledge / findings can be utilized in planning and implementing ITS Study Tour for this study
Detailed Planning Survey for the Master Plan Study on the Introduction of Intelligent Transport Systems (ITS) in Bengaluru and Mysore	● A preliminary survey for this study ● Participated by the members of this study ● Prior understanding of issues and requirements, etc. in Bangalore and Mysore.

(Source: JICA Study Team)

2 Study Contents for Bengaluru

The study described in this chapter was carried out for ITS Master Plan preparation. ITS Master Plan for Bengaluru Metropolitan Area was formulated based on the study made in this chapter.

2.1 Current Conditions and Issues in Bengaluru

2.1.1 Socio-Economic Conditions

(1) General Overview

Bengaluru is the capital and largest city in Karnataka state. With a population of over 9 million, it is the fifth largest metropolitan city in India and 27th largest city in the world. Bengaluru is one of the most ethnically diverse cities in India. More than 60% of the population isare immigrants from other places in India.

Bengaluru is located in southern India on the Deccan Plateau at 900 m above mean sea level. The city has a tropical monsoon climate which is moderate and pleasant throughout year.

Socio-economic conditions in Bengaluru such as population, economy, industry, tourism, trade, etc. were reviewed and utilised as basic information for the study. The following sections provide an overview.

(2) Demographic Outlook

The population of Bengaluru has been growing at more than 3% per annum on average since independence in 1947. The population stands at 9.62 million as per 2011 census. It constitutes approximately 16% of total population in Karnataka state. The literacy rate in Bengaluru is 89%. It is the 2nd highest literacy rate amongst all metropolitan cities in India.

Table 2.1 shows an overview of demographic features of Bengaluru and Karnataka State in 2011**.**

Table 2.1 Demographic Features of Bengaluru in 2011

No.	Item	Bengaluru	Karnataka State
1	Geographical Area	741 km2	1,91,791 km2
2	Population	9.62 million	61.13 million
3	Decade Growth Rate of Population	65.2 %	15.67 %
4	Population Density	11,371 people /sq.km	319 people /sq.km
5	Literacy Rate	89.59 %	75.60%

(Source: Edited by JICA Study Team based on census of Karnataka)

The work force structure in Bengaluru is predominantly non-agrarian. Only 6% of the workforce engage in agriculture-related activities. Roughly 10% of population live in slums. This proportion is relatively low compared to other cities in the developing countries.

Hinduism is a dominant religion in the city and it constitutes 79.4% of population. Islam with 13.4% of population and Christianity with 5.8% are other major religions. Kannada is the most widely spoken language in Bengaluru. Other languages are English, Tamil, Hindi and Telugu.

(3) Major Industries

The major industries in Bengaluru are Information Technology (IT), IT related services, manufacturing, aerospace, automobile, and biotechnology. Bengaluru is nationally and internationally famous for high-technology industries, particularly in the IT and biotechnology sectors.

Bengaluru is also known as 'Silicon Valley of India'. There are a large number of IT companies, accounting for 38% of IT and software export of India. There are mainly three IT parks: Software Technology Parks of India, Bengaluru (STPI), International Technology Park Ltd. (ITPL), and Electronics city. A number of leading IT companies such as Google, Microsoft, Infosys, Wipro, etc. are located there.

The headquarters of India's major manufacturers are located in Bengaluru. They include for example Hindustan Aeronautics Limited (HAL), National Aerospace Laboratories (NAL), Bharat Heavy Electricals Limited (BHEL), Bharat Electronics Ltd. (BEL), Bharat Earth Movers Limited (BEML), and Hindustan Machine Tools (HMT). In 1972, the Indian Space Research Organization (ISRO) was established under the Department of Space. It engages in leading research on space technologies in India.

Biotechnology is a rapidly growing field in Bengaluru. There are approximately 47% of Indian biotechnology companies in Bengaluru. Bengaluru is also known for education and research. Indian Institute of Science, National Law School of India, Indian Institute of Management (IIM-B), and Tata Institute of Fundamental Research are major examples of leading education and research institutes in Bengaluru.

(4) Tourism

Karnataka state is one of the top ten domestic tourism destinations in India; it was ranked at 4th in 2011. Given the variety of its tourism assets, the state promotes under the policy of "One state, many worlds". According to the statistics of Department of Tourism, 8.46 crore travellers visited Karnataka in 2011. It rose to 9.14 crore, including 5.83 lakh foreign tourists, in 2012.

Figure 2.1 shows overall percentage contribution of Karnataka to the India tourism.

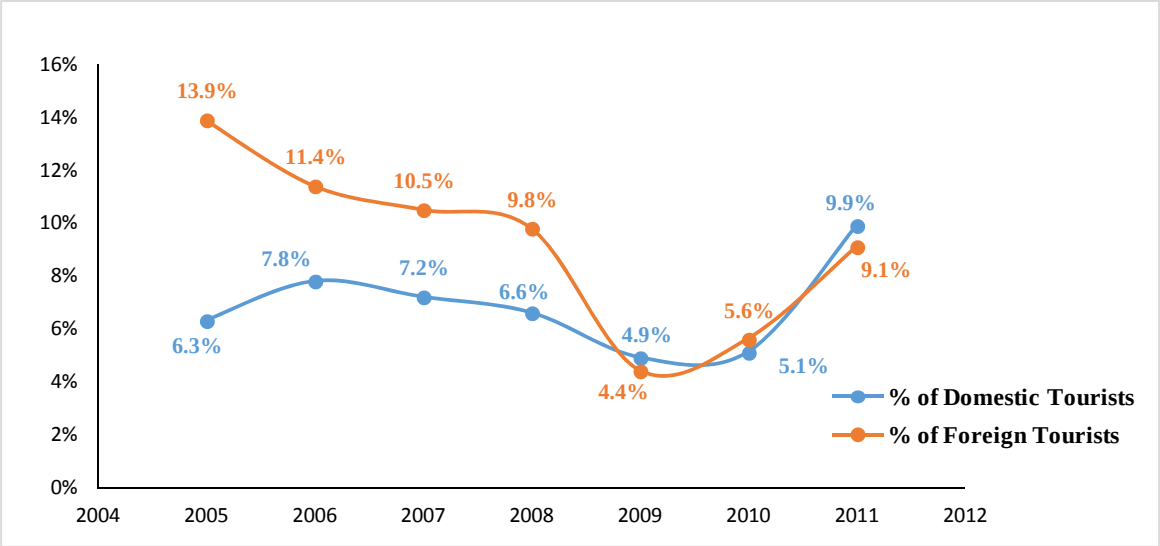


Figure 2.1 Percentage Share of Tourists Visiting Karnataka Against Total Tourists Visiting India

(Source: Department of Tourism: http://www.goatourism.gov.in/)

The figure shows that nearly 10 percent of tourist visited Karnataka state in 2011. Considering that there are 29 states and five union territories in India, this indicates that Karnataka state is one of the major destinations of the tourists in India. As shown in the Figure 2.1, the number of the tourists declined in 2009 due to the global economic downturn. Nevertheless a steady increase after this is observed.

(5) Economy

"Bangalore is not only the administrative capital but also the economic and financial capital of the state. It is the largest contributor to the State's GDP. Over past two decades, Bangalore's economy has undergone a significant transformation in with service industry playing a major role in the economic development. The share of tertiary or services sector has increased over the recent years with a significant proportion of new jobs occurring across a whole range of activities. Of late, this sector has emerged as the single largest employer and will continue to grow as the dominant sector in the future, considering the developmental initiatives planned in the city.

Bengaluru has relatively high per capita incomes. The average per capita GDP of urban India is about 10 times higher than in rural areas.

Between 2001 and 2011, total employment in Bangalore rose by 6.12%. This is because in Bangalore the share of tourism, ICT, and cultural activities is high, which have high employment potential. These are the characteristics for advanced knowledge-based urban economies in which the "creative" element, added value and employment growth are expected to be relatively high. Consequently, in Bangalore the share of rapidly growing service sectors is larger. It is important to note that nearly 67% of the households in Bangalore hold Bank accounts."

(Source: Benchmarking Bangalore City for sustainability― An indicator-based approach, Final Report (Draft), IISC, Bengaluru)

Table 2.2 lists the economic indicators of Bengaluru in 2011.

Table 2.2 Economic Indicators of Bengaluru in 2011

Item	Figure
GDP	US$ 83 billion
Per capita income	US$ 10,247
Percentage share of exports in GDP	2.2%
Percentage share of IT exports in GDP	6.2%
Unemployment rate	14%
Employment growth rate % (2001 to 2011)	6.12%

(Source: Benchmarking Bangalore City for sustainability― An indicator-based approach, Final Report (Draft), IISC, Bengaluru)

2.1.2 Environment

Central Pollution Control Board of Government of India (CPCB) and Karnataka State Pollution Control Board (KSPCB) are collaborating to execute National Air Quality Monitoring Programme (NAMP). Under this programme, 24 stations have been installed and monitoring ambient air quality in Karnataka State. The noise level is also monitored at five locations in Bengaluru.

(1) Ambient Air Quality

Three pollutants: sulphur dioxide (SO_2), nitrogen dioxide (NO_2), and respirable particulate matter (RSPM/PM10) are monitored at 15 locations in Bengaluru under NAMP programme. These 15 locations are located in the categorised areas which are industrial, urban and sensitive areas and monitor for 24 hours.

Table 2.3 shows the national standard of three pollutants and the annual average of the measured values at 15 stations from April 2013 to March 2014. It shows that the level of RSPM exceeds the national standard, 60.0 μg/m^3, at 12 locations whereas SO2 and NO2 are within the national standard.

Table 2.3 National Standard and Annual Average of Measured Air Pollutants at 15 locations (April 2013 – March 2014)

Categorised Area	No.	Name of Monitoring Station	SO2 (ug/m3)	NO2 (ug/m3)	RSPM (ug/m3)
Industrial Area Urban Area	**National Standard**		**50.0**	**40.0**	**60.0**
	1	Graphite India	15.2	30.0	133.0
	2	K.H.B. Industrial Area (Yelahanka)	14.0	25.0	128.0
	3	Peenya Industrial Area (Gymkhana)	15.0	30.0	123.0
	4	Peenya Industrial Area	12.4	28.3	125.0
	5	Yeshwanthpura Police Station	14.0	31.0	110.0
	6	AMCO Batteries on Mysore Road	15.0	29.0	170.0
	7	Central Silk Board on Hosur Road	15.0	30.0	175.0
	8	DTDC House on Victoria Road	14.0	30.0	114.0
	9	TERI Office in Domlur	6.7	9.8	58.0
	10	Benswadi Police Station	11.0	24.3	85.0
	11	Kajisonnenahalli	12.0	29.0	67.0
	12	CAAQM City Railway Station	9.0	23.0	64.0
	13	CAAQM S.G. Halli	7.0	18.0	22.0
Sensitive Area	**National Standard**		**20.0**	**30.0**	**60.0**
	14	Victoria Hospital	13.0	29.0	88.0
	15	Indira Gandhi Children Care Institute (NIMANHS)	13.0	29.0	79.0

indicates the value which exceeds National Standard

(Source: Summarised by JICA Study Team based on Statistics of KSPCB)

(2) Noise Level

The noise level is measured at five monitoring stations in Bengaluru. The measured areas are categorised as residential, commercial, industrial and sensitive area. The noise revel limits by the categorised area are defined by national standard as shown in Table 2.4.

Table 2.4 Noise Level Standards in India

Unit=dB in Leq (*)

Categorised Area	**Noise Level Limit**	
	Day Time	Night Time
Residential Area	55	45
Commercial Area	65	55
Industrial Area	75	70
Sensitive Area	50	40

*Leq: Sound value which takes into account total sound energy over the period of time of interest.

(Source: KSPCB)

Table 2.5 shows the monthly average noise level measured from January to March 2014. Most of the measured values exceed the noise level limit of National Standard especially night time

Table 2.5 Monthly Average Noise Level in Bengaluru

Unit=dB in Leq

Location	Categorised Area	Month (2014)	Day Time		Night Time	
			Noise Level Limit	Measured Value	Noise Level Limit	Measured Value
BTM Layout	Residential Area	January	55	66.2	45	58.9
		February		63.2		57.2
		March		65.4		59.8
Marathahalli	Commercial Area	January	65	61.1	55	66.6
		February		63.6		57.8
		March		63.5		58.6
Nisarga Bhavan, SG Halli	Residential Area	January	55	52.6	45	51.2
		February		59.7		52.6
		March		55.2		52.0
Parisara Bhavan, Church Street	Commercial Area	January	65	67.9	55	66.2
		February		66.0		60.8
		March		66.9		59.0
Peenya	Industrial Area	January	75	66.9	70	68.2
		February		78.4		64.1
		March		68.8		63.9

indicates the value which exceeds the noise level limit of National Standard

(Source: Summarised by JICA Study Team based on Statistics of KSPCB)

2.1.3 Road and Transport Network

(1) Road Network

The road network in Bengaluru is formed in radial pattern and consisted of three existing ring roads connecting the radial roads. The major radial roads are consisted of parts of NH4 lying through the city in east-west direction, NH7 in north-south direction, NH209 to the south and other state highways.

The existing ring roads include Core Ring Road (CRR) , Inner Ring Road (IRR) and Outer Ring Road (ORR). A semi-circle peripheral ring road, called NICE Road, 45 km in length, lies south-west of the city. The construction of Peripheral Ring Road (PRR), 65 km in length, is planned to connect with NICE Road forming a full circle ring road around Bengaluru in the future. The total length of the existing road network in Bengaluru is approximately 4,000 km. The major radial roads and ring roads are summarised in Table 2.6.

Table 2.6 Major Radial Road and Ring Road in Bengaluru

Type	Road	Connected Cities/Areas/Roads	Name of Radial/Ring Road as in Figure 2.2	Remarks
Radial Road	NH-4	Mumbai, Pune, Bengaluru, Chennai	Tumkur Road Old Madras Road	
	NH-7	Varanasi, Hyderabad, Bengaluru, Kanyakumari	Bellary Road Hosur Road	
	NH-209	Bengaluru, Coimbatore, Dindigul	Kanakapura Road	
	SH-17	Bengaluru, Mysore	Mysore Road	
	SH-85	Bengaluru, Jalsoor	Magadi Road	
	SH-87	Bengaluru, Anekal	Bannerghatta Road	
Ring Road	Core Ring Road	Richmond Circle, Bangalore Palace, Majestic	CRR	
	Inner Ring Road	Indiranagar, Koramangara, Rajaj Nagar	IRR	
	Outer Ring Road	Hebbal(NH7), Krishnarajapuram(NH4), Marathahalli, Madiwala(NH7), JP Nagar, Banashankari, Kengeri, Nagarbhavi, Gokula.	ORR	Most intersections are grade separated structure
	NICE Road	Hosur Road(NH-4), Bannerghatta Road(SH-87), Kanakapura Road(NH-209), Mysore Road(SH-17), Magadi Road(SH-85), Tumkur Road(NH-4)	Nice Road	It will be south east part of the ring road by connecting with PRR in future.
	Peripheral Ring Road (Planned)	Tumkur Road(NH-4), Hesarghatta Road, Doddaballapur, Bellary Road(NH-7), Hennur Road, Old Madras Road(NH-4), White Field-Hoskote Road, Hosekote-Anekal Road, Sarjapur Road, Hosur Road(NH-7)	PRR	It is in planning stage and it will be north west part of the ring road with Nice road.

(Source: JICA Study Team)

The road network in Bengaluru is shown in Figure 2.2.

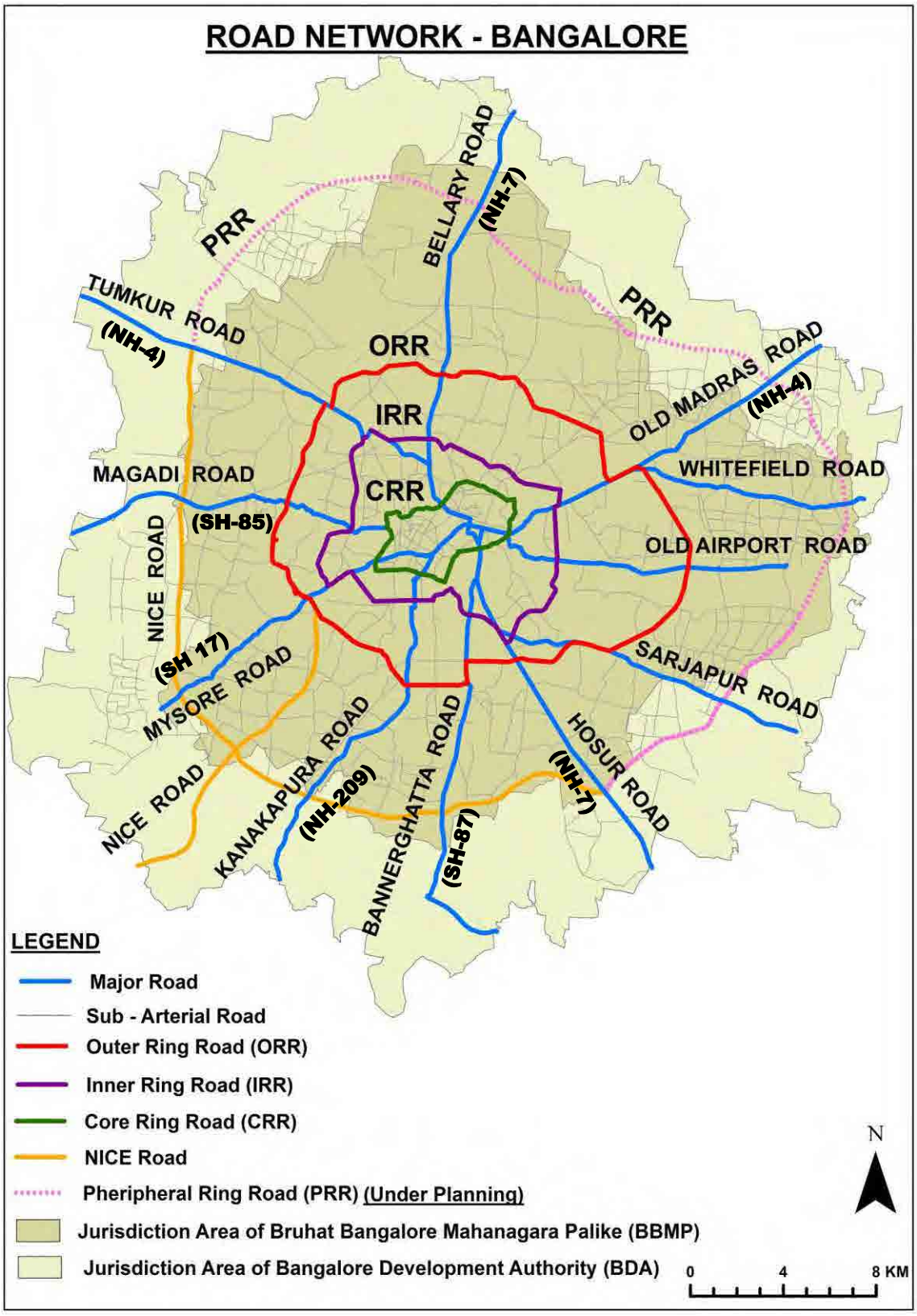


Figure 2.2 Road Network in Bengaluru

(Source: Jointly prepared by DULT and JICA Study Team)

According to Comprehensive Traffic and Transportation Plan (CTTP), the road network in Bengaluru is mostly underdeveloped in terms of width, structure, continuity and connectivity. Table 2.7 shows the length and its share of the existing roads of two-lane and more in Bengaluru. Nearly 82% of the the 1,763 km roads are two-lane undivided roads. The length of the road of four-lane and more is limited to 290 km. The road network in Bengaluru is characterized by many one-way roads, especially in the core area of the city.

Table 2.7 Road Length by Carriageway Width

Classification	Length (Km)	Share (%)
Two lane undivided one-way	62.3 km	3.53%
Two lane undivided two-way	1379.2 km	78.21%
Three lane	31.6 km	1.79%
Four lane undivided one[way	10.3 km	0.59%
Four lane undivided two-way	49.7 km	2.82%
Four lane divided two-way	198.5 km	11.25%
Six lane divided	31.4 km	1.78%
Six lane undivided one-way	0.5 km	0.03%
Total	1763.5 km	100%

(Source: CTTP, DULT)

There are road development plans to accommodate the traffic demand in Bengaluru. Amongst then, one of the major road development plans is the construction of Peripheral Ring Road (PRR) as described earlier. It is planned to develop by Bengaluru Development Authority (BDA) under the financial assistance of Yen Loan of Japan International Cooperation (JICA). Some elevated roads and flyovers are also planned or proposed to improve the capacity at bottleneck points. These are targeted to implement by 2020 and are shown in Figure 2.3.

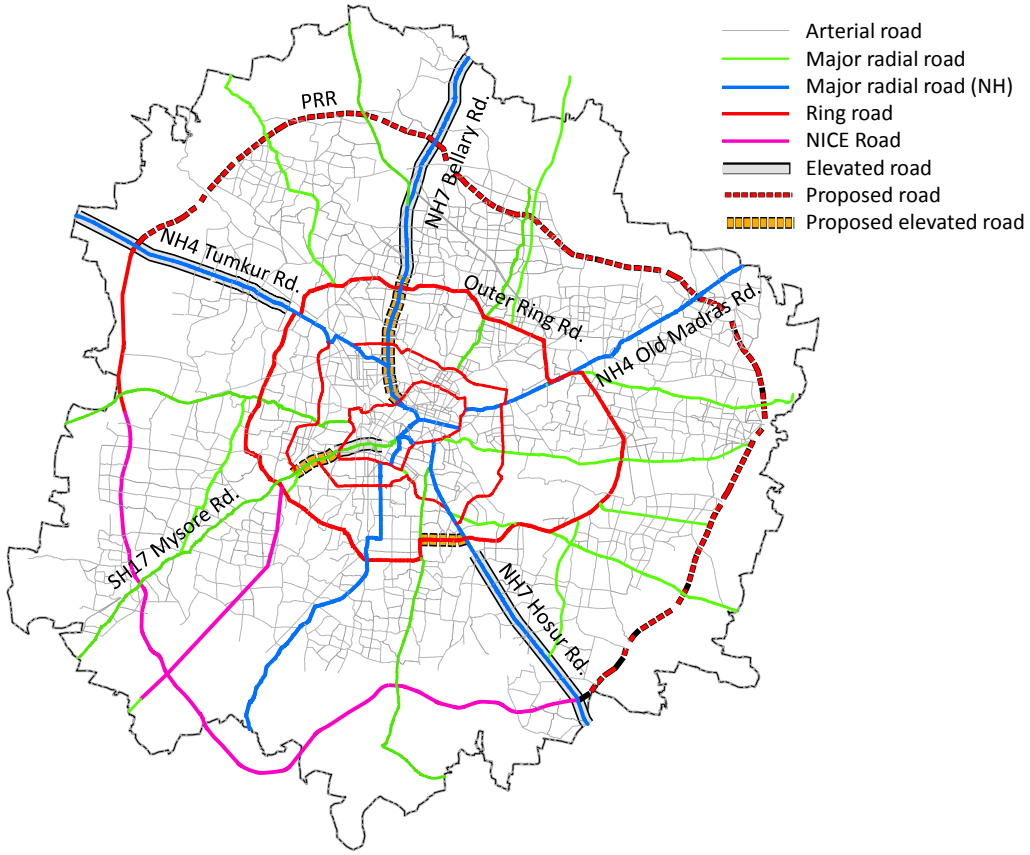


Figure 2.3 Proposed Major Roads by 2020

(Source: JICA Study Team based on interview to BDA, BBMP)

(2) Metro Network

(a) Overview of Bengaluru Metro

Bengaluru Metro, called "Namma Metro", is currently under development by Bengaluru Metro Rail Corporation Limited (BMRCL). BMRCL is a special purpose vehicle entrusted with implementation and operation of Bengaluru Metro. It is a joint venture of the Government of India and the Government of Karnataka. A total in length of 127.3km metro network is planned in three phases; 42.3km in Phase-I, 72km in Phase-II and 13km in Phase-III respectively.

The construction of the metro corridor in Phase-I is underway and it is expected to complete in December 2015. The sections of 6.7km have been in operation since October 2011.

The project of Phase-II estimated at INR 2,64,050 million was approved by the Government of India in 2014 and it is targeted to complete in 2020.

The completion of the metro network is expected to considerably improve the public transport network in Bengaluru.

The planned metro network of Phase-I, Phase-II and Phase-III is shown in Figure 2.4.

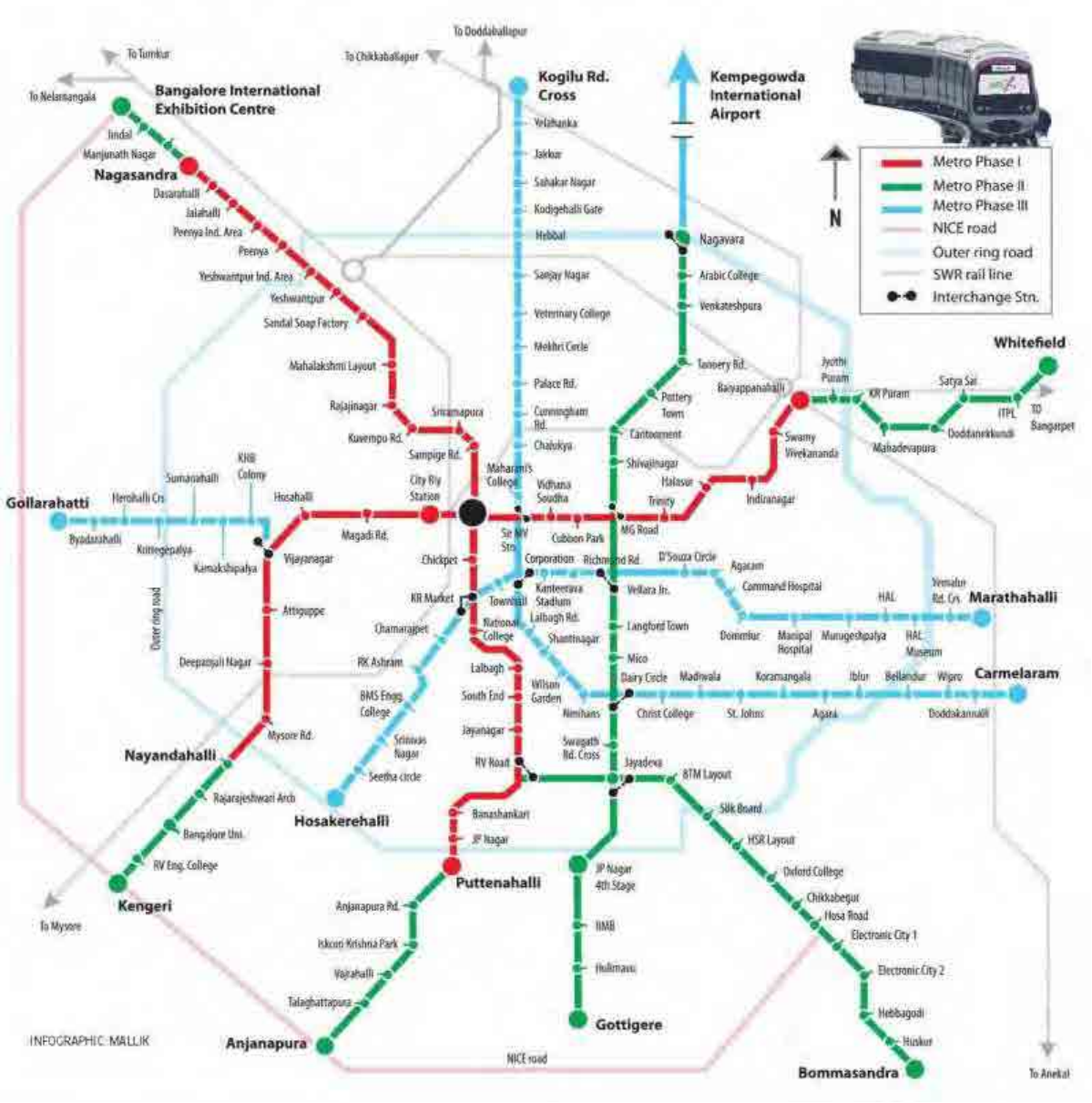


Figure 2.4 Planned Bangalore Metro Network

(Source: BMRCL)

(b) Outline of Phase-I of Bangalore Metro

The metro lines of Phase-I comprises 42.3 km corridors in total and it consists of East-West corridor which is called 'Purple Line' and North-South corridor which is called 'Green Line' as follows:

- East-West corridor (Purple Line): 18.1 km in length, starting from Baiyappanahalli station in the east and terminating at Mysore road station in the west, and
- North-South corridor (Green Line): 24.2 km in length, starting from Nagasandra station in the north and terminating at Puttenahalli station in the south

These are further divided into Reach-1, Reach-2, Reach-3 and Reach-4 with sub-divisions of extension.

Out of 42.3 km, the sections of 8.82 km will be constructed underground and the remaining sections will be elevated structure. A total of 40 stations will be constructed. Bangalore Metro is the first metro project in India which is designed with 750 V DC and the third project which is designed by standard gauge.

Table 2.8 summarises the Phase-I.

Table 2.8 Summary of Bangalore Metro Phase I

Item	Description
East-West Corridor: Purple Line	18.10 km
North-South Corridor: Green Line	24.20 km
Elevated Section	33.48 km
Underground Section	08.82 km
Design Speed	Maximum 80 km/h, Average 34 km/h
Number of Metro Station	40 stations (33 elevated stations and 7 underground stations)
Travel Time	Approx. 30 to 45 minutes between terminal stations (both corridors)
Gauge	Standard Gauge
Traction	750 Volt DC Third Rail

(Source: BMRCL)

Figure 2.5 shows the metro network of Phase-I and the sections in operation. The sections of Reach-1 on East-West corridor between Baiyappanahalli station and Mahatma Gandhi Road station and Reach-3 and Reach-3A on North-South corridor between Peenya Industry station and Mantri Square Sampige Road station are currently in operation.

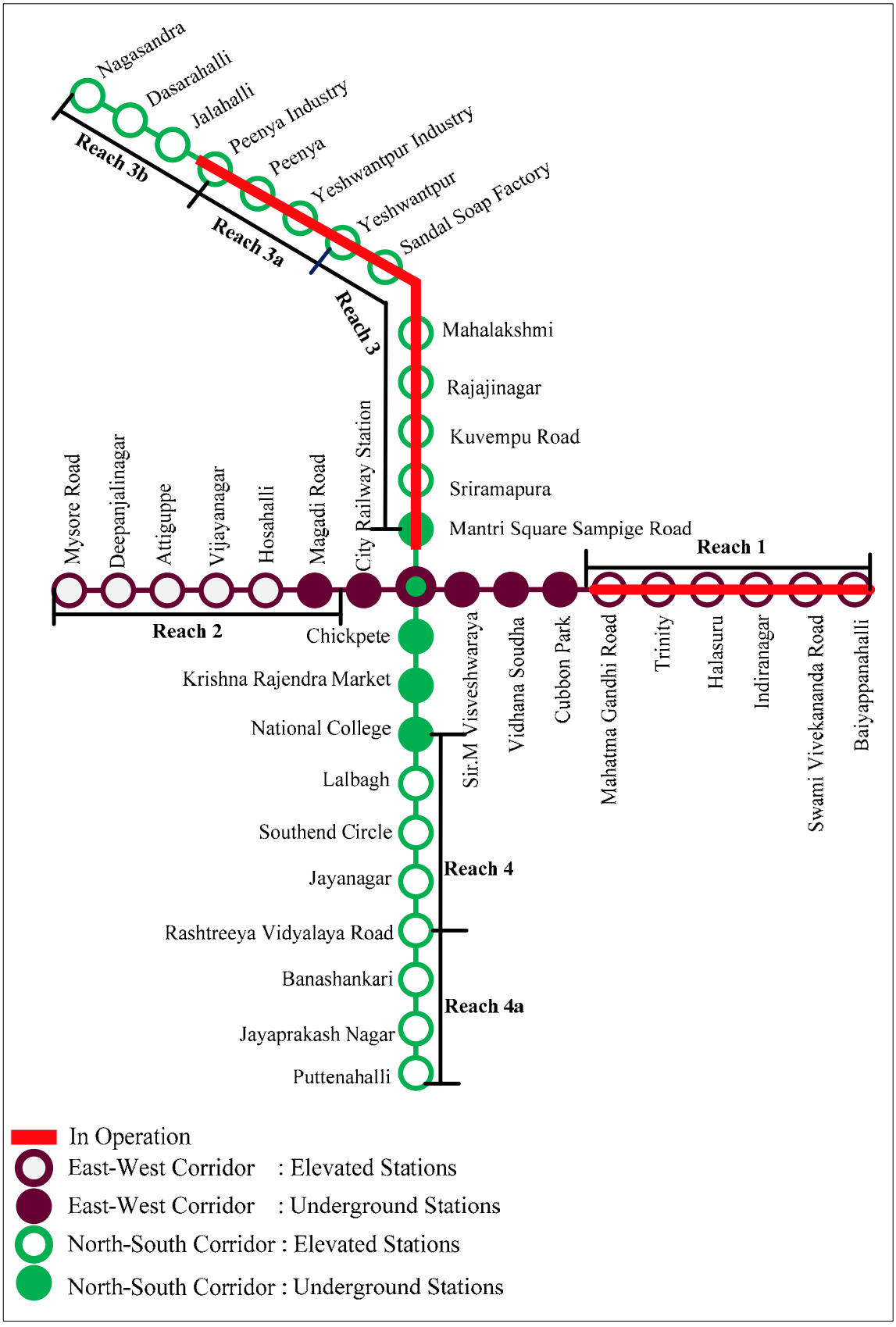


Figure 2.5 Metro Network of Phase I

(Source: Edited by JICA Study Team based on BMRCL Website)

They are operated as follows:

- Reach 1: Between Baiyappanahalli station and Mahatma Gandhi Road station
  - Operation Hours: From 6 am to 10 pm
  - Operating every 10 minutes from 8 am to 8 pm
  - Operating every 15 minutes from 6 am to 8 am and from 8 pm to 10 pm
- Reach 3 and3A: Between Peenya Industry station and Mantri Square Sampige Road station
  - Operation Hours: From 6 am to 10 pm
  - Operating every 10 minutes from 8 am to 10 pm
  - Operating every 15 minutes from 6 am to 8 am

Figure 2.6 shows the metro construction sites of Phase-I.

Figure 2.6 Construction Sites of Metro

(Source: JICA Study Team)

(c) Passenger Ridership of Bangalore Metro

The passenger ridership of Bangalore Metro is shown in Figure 2.7 and Figure 2.8. Figure 2.7 shows the monthly passenger ridership on Reach 1 from October 2011 to December 2014. Figure 2.8 shows the monthly passenger ridership on Reach 3 and 3A from March 2014 to August 2014.

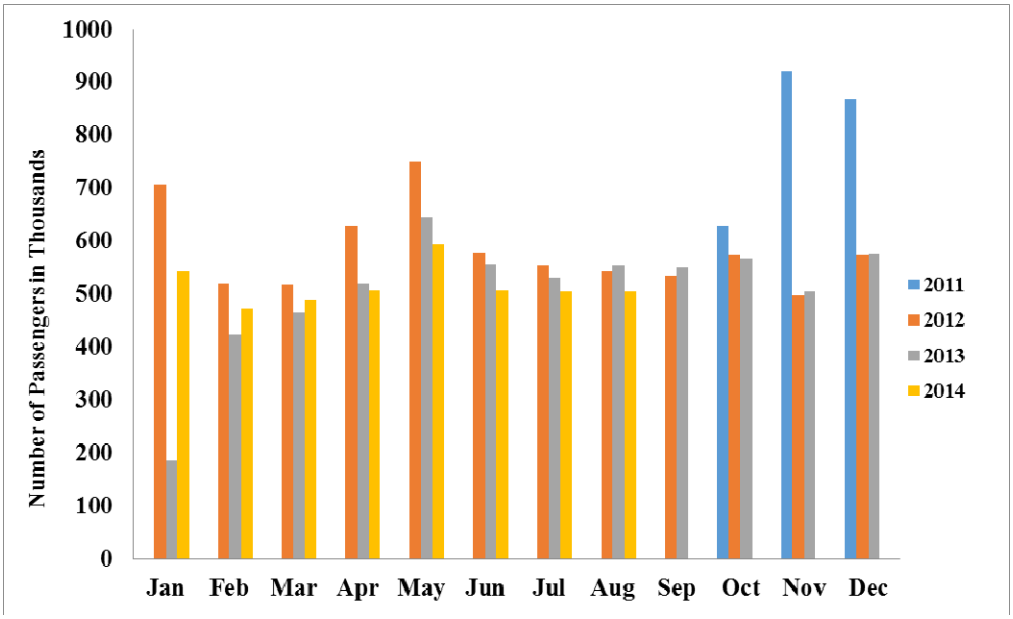


Figure 2.7 Monthly Passenger Ridership on Reach 1 of Bangalore Metro From 2011 to 2014

(Source: Edited by JICA Study Team based on BMRCL Website)

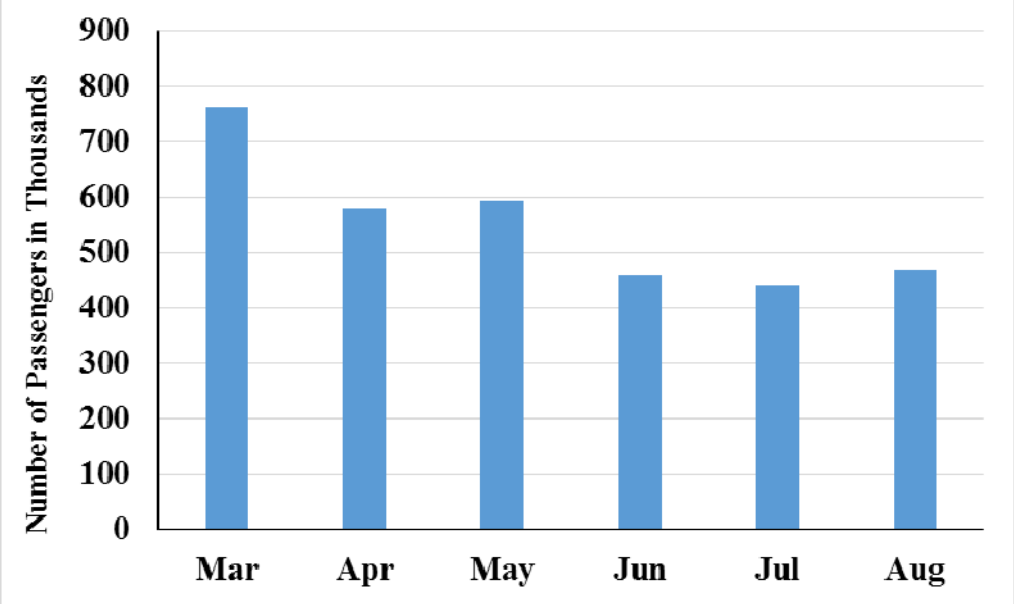


Figure 2.8 Monthly Passenger Ridership on Reach 3 and 3A of Bangalore Metro in 2014

(Source: Edited by JICA Study Team based on BMRCL Website)

(3) Bus Network

The bus transport in Bengaluru is operated by Bangalore Metropolitan Transport Corporation (BMTC) and Karnataka State Road Transport Corporation (KSRTC).

(a) Bangalore Metropolitan Transport Corporation (BMTC)

Bangalore Metropolitan Transport Corporation (BMTC) is a governmental bus transport agency in Bengaluru. It offers the bus services in urban, sub-urban and rural areas. BMTC currently operates approximately 6,700 buses carrying about 4.95 million daily passengers. The number of bus has been increasing to accommodate the demand in the city, as shown in Figure 2.9. The bus transport has become major public transport mode for the people in Bengaluru.

The buses are operated from 5 a.m. to 11 p.m. on major routes. The distance-based fare system is adopted. There are A/C and non-A/C buses. The minimum fare of A/C bus ranges from INR15 to INR65 and non-A/C bus from INR 6 to INR 44. There is also a monthly pass for regular commuters.

The performance indicators are shown in the Table 2.9 and Figure 2.9 below.

Table 2.9 Performance Indicator of BMTC

Indicator	Figure
Number of Depot	39 Depots
Number of Bus Station	50 Bus Stations
Number of Bus	6,700 Buses
Number of Daily Bus Schedule	6,300 Schedules
Number of Daily Bus Trip	79,700 Trips
Approximate Daily Service Kilometre	1.31 million km
Approximate Daily Revenue	60.2 million INR
Approximate Daily Passenger	4.95 million Passengers
Approximate Employee	36,000 Employees

(Source: Summarised by JICA Study Team based on BMTC Website)

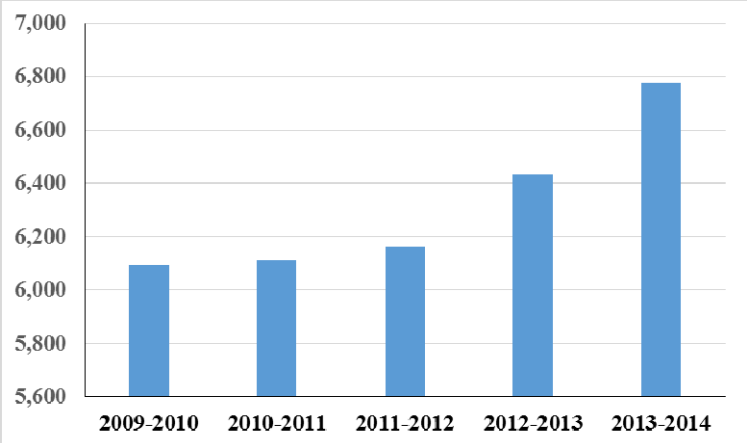


Figure 2.9 Number of Bus of BMTC

(Source: Edited by JICA Study Team based on BMTC Website)

There are 2 major bus stations, 26 minor bus stations and 10 Traffic & Transit Management Centres (TTMCs) in Bengaluru. The passenger facilities are provided in the major bus stations and TTMCs. They are, for example, bus bays/platforms, food court, refreshment rooms, retail stores, ticket booking/pass issuance counters, toilets, drinking water facilities, passenger information boards, bank ATM, and etc.

There are also commercial spaces and government offices in the major bus stations and TTMCs. The commercial spaces are rented on a term basis to the private agencies such as retail shops. They pay monthly license fee to BMTC.

Figure 2.10 shows the major TTMCs in Bengaluru.

TTMC Koramangala

TTMC Shantinagar

Figure 2.10 Traffic Transit Management Centres (TTMC) of BMTC

(Source: BMTC)

(b) Karnataka State Road Transport Corporation (KSRTC)

Karnataka State Road Transport Corporation (KSRTC) is a governmental bus transport agency for inter-city in Karnataka state and inter-state bus services.

KSRTC comprises 15 divisions including 14 operating divisions and Kempegowda Bus Station-KBS with approximately 37,800 permanent employees. There are 77 depots, 145 bus stations, 65 control points and 31 rural way side shelters under its network of the 15 divisions.

KSRTC operates 5,824 routes of 551,164 km in total. There are 8,300 buses and they carry approximately 2.6 million daily passengers as of 2013. Amongst them, approximately 15,000 passengers travel between Bengaluru and Mysore every day. 500 buses are operated on the route between these cities. Table 2.10 shows the performance indicators of KSRTC bus service.

Table 2.10 Performance Indicator of KSRTC

Indicator	Figure
Number of Depot	77 Depots
Number of Bus Station	145 Bus Stations
Number of Bus	8,300 Buses
Number of Daily Bus Schedule	7,700 Schedules
Approximate Daily Service Kilometre	2.7 million km
Approximate Daily Revenue	70.6 million INR
Approximate Daily Passenger	2.60 million Passengers
Approximate Employee	37,800 Employees

(Source: Summarised by JICA Study Team based on KSRTC Website)

(4) Other Transportation System

(a) Plan of Bus Rapid Transit System

Comprehensive Traffic and Transportation Plan 2011 for Bengaluru (CTTP) recommends 279.6 km of Bus Rapid Transit System (BRTS) as a measure to alleviate the congestion in Bengaluru. The Directorate of Urban Land Transport (DULT) carried out a feasibility study on BRTS of 30 km stretch along Outer Ring Road corridor between Silk Board Junction and Hebbal Junction.

BRTS is proposed to operate on the segregated median lane with one lane on each direction dedicated to BRTS. The passing lanes are considered at all stations. 39 stations and terminals at every 500 to 600 meters on average are planned. The project cost is estimated approximately at INR 1,042 crore.

The proposed BRTS of 30 km stretch along ORR is currently under process of funding arrangement for implementation.

(b) Intermediate Public Transport

Auto rickshaws, popularly known as autos, and taxis are categorised as Intermediate Public Transport (IPT) in India. The autos are very popular transport mode in India. They are important and common daily transport mode for the people in Bengaluru as well. The auto has three wheels with seating capacity of three passengers. They are highly manoeuvrable and provide fast and ‘easy-go’ services. Most of the autos are owned by individual owners.

Several taxi operators offer taxi services. They are commonly called city taxis or call taxis. The number of autos and call taxis registered in Bengaluru in 2014 is approximately 37,241 and 66,264 units, respectively. The growth rate of autos compared to the previous year is 6.04% and that of taxi is 16.47%.

(c) Public Bicycle Sharing

The public bicycle sharing is planned in Bengaluru. The plan includes development of bicycle route of 50 km and bicycle sharing system. The electronic prepaid card is planned to apply to the public bicycle sharing system. This public bicycle sharing system could serve as a mode to cover feeder transport in the core area of the city. However, it is important to overcome such issues as a shortage of basic road infrastructures, construction of sufficient number of bicycle dock stations, sustainable maintenance, funding, and etc. for the system to properly function.

Figure 2.11 shows the bicycle station and card reader for payment.

Bicycle Station

Card Reader

Figure 2.11 Public Bicycle Sharing System

(Source: JICA Study Team)

2.1.4 Major Development Plans

(1) National Urban Transport Policy

The current population in urban area in India is approximately 30% of the total population. The urban population is projected to grow to almost 473 million by 2021 and 820 million by 2051 from 285 million in 2001. The Government of India launched National Urban Renewal Mission (NURM) to provide suitable mobility to the growing urban population. NURM is an initiative for balanced urban development. It aims to bring about comprehensive improvements of urban infrastructure, substantial funds, and structural reforms.

The state governments are responsible for managing urban areas and urban transport in India. However a central policy is necessary for the following reasons:

- Several key agencies under the Government of India have important roles for urban transport planning,
- Several acts and regulations which are important for and related with urban transport are administered by the Government of India,
- State level action plans need to be guided under overall framework, and
- A time framework needs to be provided for financial support from the Government of India to invest in urban transport and infrastructures.

(Source: JnNURM, MOUD)

Under the concept of NURM, National Urban Transport Policy (NUTP) was formulated. It is a central policy for urban transport.

(a) Objectives and Visions of NUTP

The objectives of NUTP are to ensure safe, affordable, quick, comfortable, reliable and sustainable access for growing number of city residents to jobs, education, recreation and other needs in the cities.

The visions of NUTP are set out by the Government of India as stated below:

- To focus on people and all plans needed to bring about their common benefit and well-being,
- To make cities the most liveable in the world and enable them to become ‘engines of economic growth’ that empowers India’s development in the 21st century, and
- To allow cities to evolve into an urban form that is best suited for the unique geography of their locations and is best placed to support the social and economic activities that take place in the city.

(Source: NUTP published by MOUD)

(b) Target Areas of NUTP

The following major targets are identified by NUTP to achieve the objectives:

Table 2.11 Targets Identified by NUTP

Focus Area	Target
Planning Integration	▪ To incorporate urban transport as an important parameter into urban planning ▪ To encourage integrated land use and transport planning in all cities to minimise travel distances and enable to access to livelihood, education, and other social needs especially for marginal segments of urban population
Accessibility	▪ To improve access of business to markets and various factors of production ▪ To bring about equitable allocation of road space to people as main focus
Public Transport	▪ To encourage use of public transport and non-motorized transport by central financial assistance ▪ To establish quality-focused and well-integrated multi-modal public transport systems to realise seamless travel across modes
Enforcement	▪ To establish effective regulatory and enforcement mechanism to enhance safety
Institution	▪ To establish institutional mechanism for enhancing coordination for planning and management of transport
ITS	▪ To introduce and utilise Intelligent Transport Systems for traffic management and urban transport
Safety	▪ To improve road safety
Pollution	▪ To reduce pollution through changes in travel patterns, efficient enforcement, technology improvement, etc
Capacity	▪ To build institutional and human capacity for planning of suitable urban transport
Financing	▪ To finance through a mechanism which efficiently utilises land for investment in urban transport infrastructure
Private Sector	▪ To collaborate with private sector in the areas where their strengths can be maximised and bring about benefit
Proof of Concept	▪ To take up pilot projects and demonstrate the potentials of best practices in the areas of urban transport

(Source: Summarized by JICA Study Team based on NUTP, 2006)

(2) Master Plan Bengaluru 2015

Master Plan Bengaluru 2015 was prepared by Bangalore Development Authority (BDA) under Karnataka Town and Country Planning Act. It covers a planning area of 1306 km^2 including 387 villages, seven City Municipal Councils and one Town Municipal Council. It serves as a foundation for developing strategic plans and local area plans.

(a) Visions of Master Plan Bengaluru 2015

The vision of Master Plan Bengaluru 2015 sets out framework and general direction of urban development. The principles of the vision of Master Plan Bengaluru 2015 are as follows:

- Respect the natural environment,
- Promote economic efficiency,
- Ensure social equality,
- Preserve historical heritage,
- Ensure efficient and affordable transport systems, and
- Strategically develop efficient transport network.

(Source: Master Plan Bengaluru 2015)

(3) Comprehensive Traffic and Transportation Plan for Bengaluru

Comprehensive Traffic and Transportation Plan for Bengaluru (CTTP) was prepared in 2011 to develop transport network. It was formulated under the framework envisaged by NUTP.

(a) Objectives of CTTP

The objectives of CTTP are:

- Realise convenient and cost effective accessibility to the places of employment and education for the next 20 years,
- Assess the existing infrastructure and identify the short term and long term requirements,
- Assess relevance of the existing strategies, identify alternatives and recommend/update a long term comprehensive transport strategy up to 2025,
- Integrate the transport strategy into urban planning,
- Identify phased programs of appropriate and affordable investments, policy proposals and integration of various modes of mass transit,
- Recommend institutional mechanism for proper coordination across agencies, and

- Assist to strengthen the skills in transport planning and transfer the knowledge gained through the studies and activities by the concerned agencies.

(Source: Comprehensive Traffic and Transportation Plan (CTTP) for Bengaluru)

(b) Visions and Actions Set Out by CTTP

CTTP sets out its vision for Bengaluru Metropolitan Area as stated below:

- To establish efficient, people-friendly transport system with minimum travel time and maximum safety and comfort and optimally use the facilities.

The actions identified by CTTP to realise the vision are as follows:

- Promote affordable public transport and discourage private vehicle usage,
- Integrate ticketing system for all public transport modes,
- Enhance efficient transfer amongst different transport modes,
- Design and construct spaces for pedestrians and bicycle in the city,
- Establish proper management mechanism for structured road network at secondary and tertiary level,
- Establish hierarchical structure of road network,
- Focus on highly concentrated zones along transport corridors,
- Focus on highly concentrated CBD areas for mass transit,
- Focus on pedestrian zones in CBD areas, and
- Develop special facilities for physically disabled people, elderly people and children in public transport and pedestrian spaces.

(Source: Comprehensive Traffic and Transportation Plan for Bengaluru (CTTP), 2011)

(4) Comprehensive Traffic and Transportation Study for Bengaluru

Comprehensive Traffic and Transportation Study for Bengaluru (CTTS) is currently under preparation by Bangalore Regional Development Authority (BMRDA). It sets out the policies and strategies and formulates a roadmap for improvement of transport in Bengaluru for the future under the framework of National Urban Transport Policy (NUTP).

CTTS aims to integrate land use and transport plan that encourages investments in transport in an efficient manner to achieve an overall transport vision for Bengaluru. The study develops a long-term transport plan and identifies investment programmes up to 2031.

The following mass transit systems are recommended in CTTS:

- Metro System
- LRT System
- Bus Rapid System (BRT)
- Intermodal Stations

(Source: Comprehensive Traffic and Transportation Study (CTTS) for Bengaluru)

2.1.5 Study on Traffic and Future Traffic Demand Forecast

(1) Objective and Procedure

The analyses of current traffic situation and future traffic demand forecast were carried out for ITS Master Plan.

The overall traffic situation of Bengaluru metropolitan area was reviewed using the existing traffic survey results provided from the past studies. The traffic surveys were conducted by several studies such as Comprehensive Traffic and Transportation Plan for Bengaluru (CTTP), Comprehensive Traffic and Transportation Study for Bengaluru (CTTS), and Detail Project Report for Peripheral Ring Road (PRR), etc. in Bengaluru.

A supplementary traffic survey was then conducted to collect the latest and primary data and the current traffic situation on the major arterial roads was analysed.

Based on the results of these analyses, future traffic demand was forecasted to understand the future traffic situation. Based on the result of the future traffic demand forecast, issues on traffic were identified. The result of the future traffic demand forecast was also used to calculate the impact of ITS measures proposed by ITS Master Plan.

The procedure of the study on traffic and future traffic demand forecast is shown in Figure 2.12 below.

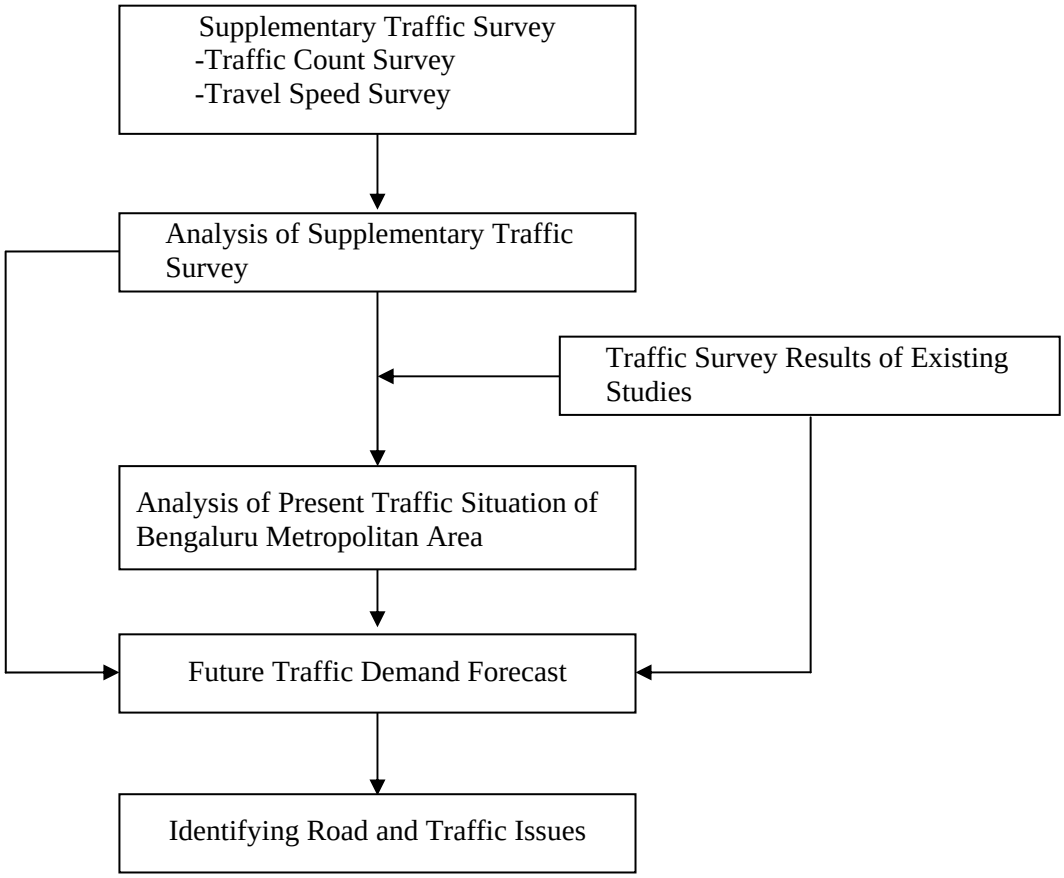


Figure 2.12 Procedure of Study on Traffic and Future Traffic Demand Forecast

(Source: JICA Study Team)

(2) Present Traffic Situation

(a) Outline of Supplementary Traffic Survey

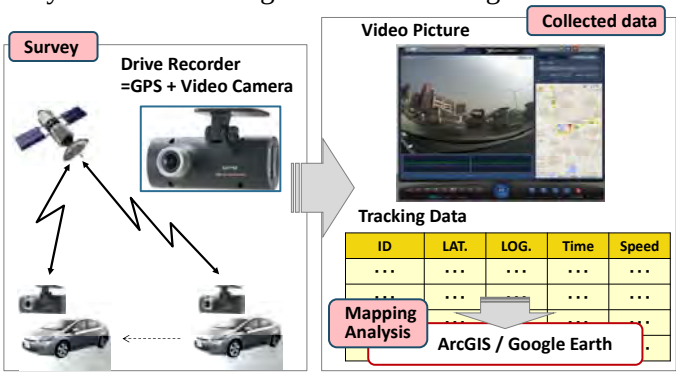
A supplementary traffic survey was conducted for the purpose of understanding the present traffic condition and using as basic data for future traffic demand forecast. The survey consists of (i) traffic count survey and (ii) travel speed survey.

The traffic count survey was conducted to collect data on traffic volume and to understand traffic characteristics on the major arterial roads in Bengaluru. It was carried out to count the traffic volume of cross section at nine survey stations on one week day for 24 hours. The survey stations were selected on cordon line along Outer Ring Road (ORR) and on the major arterial roads, such as MG Road and NICE road.

The travel speed survey was conducted to grasp the characteristics of traffic flow and to find the major bottleneck points on the major arterial roads in Bengaluru. It was carried out during morning peak hours as the traffic volume is the highest in a day. The major arterial roads and ORR were covered. A floating car method using GPS devices was adopted.

Outline of the supplementary traffic survey is summarised in Table 2.12.

Table 2.12 Outline of Supplementary Traffic Survey

Survey	Description
Traffic Count Survey	• Survey Date: One Weekday (Tuesday, 25th March 2014) • Survey Time: 24 Hours • Survey Station: Nine Stations on Major Arterial Road • Classification: Six Types of Vehicles, which are Two-wheeler, Auto-rickshaw, Car, Bus, Light Commercial Vehicle and Truck
Travel Speed Survey	• Survey Date: Weekday (From 25th (Tuesday) to 27th (Thursday) in March 2014 and From 4rd (Tuesday) to 6th (Thursday) in April 2014) • Survey Time: Morning Peak Hours • Survey Road: Major Arterial Roads and Outer Ring Road • Survey Method: Floating Car Method Using GPS Devices 

(Source: JICA Study Team)

(b) Traffic Count Survey

1) Location of Survey Station

The locations of the survey stations for the traffic count survey are shown in Table 2.13

Table 2.13 Location of Survey Station for Traffic Count Survey

No.	Survey Station Name	Remarks
1	SH17 Maysore Road	Outside of NICE Road
2	NH7 Hosur Road	Ground Level Road in front of Oxford Engineering Institute
3	NH4 Old Madras Road	Section under Skywalk between ORR and KR Puram Bridge
4	NH7 Bellary Road	Section between ORR junction and Elevated Road
5	NH4 Tumkur Road	Section between ORR junction and Elevated Road
6	Outer Ring Road (West)	Section between SH85 Mgadagi Road and Pipeline Road
7	White Field Road	East side of ORR in front of Brilliant School
8	Outer Ring Road (East)	350 meters south from Hotel Dolphin
9	MG Road	Under Trinity Metro Station

(Source: JICA Study Team)

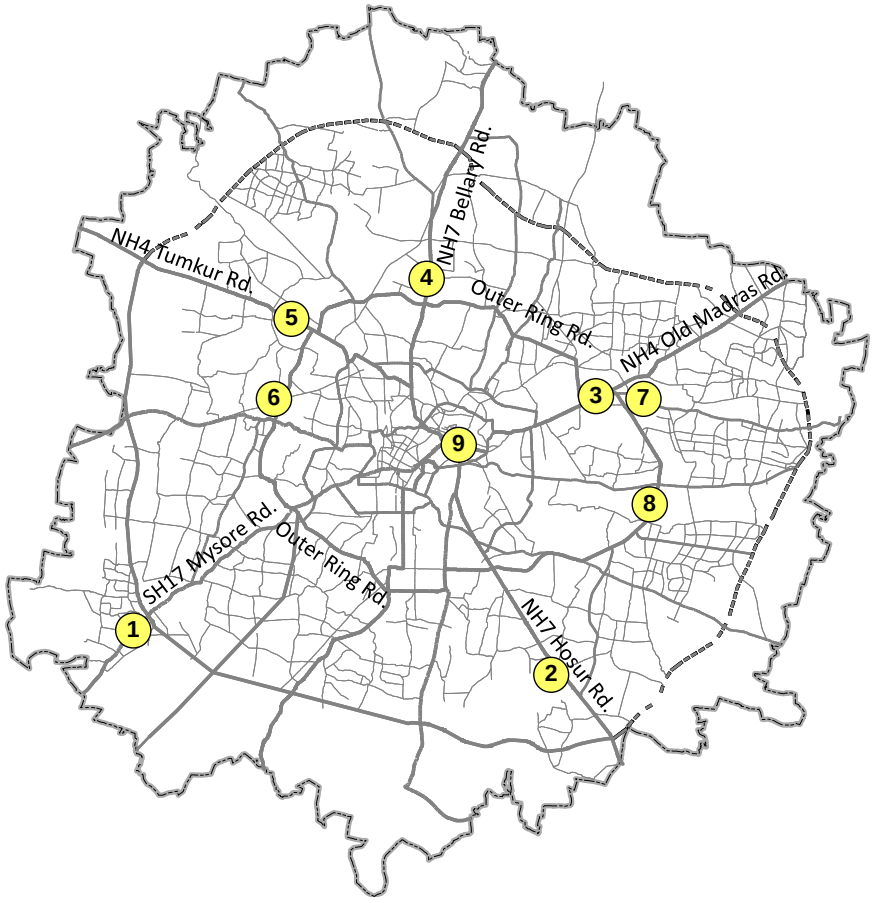


Figure 2.13 Location of Survey Station for Traffic Count Survey

(Source: JICA Study Team)

2) Daily Traffic Volume

The results of the traffic count in number of vehicle are summarised in Table 2.15. The traffic volume converted into Passenger Car Unit (PCU) is shown in Table 2.16. The conversion factors defined by Indian Road Congress (IRC) were adopted to convert from vehicles in number into PCU. The conversion factors defined by IRC are shown in Table 2.14.

Table 2.14 Conversion Factor to PCU Defined by IRC

	Two-wheeler	Auto-rickshaw	Car/Jeep	Bus	LCV	Truck
Below 10%*	0.50	1.20	1.00	2.20	1.40	2.20
Above 10%*	0.75	2.00	1.00	3.70	2.00	3.70

* Different conversion factors for each type of vehicle except car/jeep are defined by IRC. They are defied either below or above 10% of traffic volume of each type of vehicle in total traffic volume. The conversion factors for this study were adopted accordingly.

(Source: IRC)

Table 2.15 Summary of Traffic Count Survey Result (in Number of Vehicles per Day)

Survey Station		Direction	Two-W*	Auto*	Car/Jeep	Bus	LCV*	Truck	Total
No	Name								
1	SH 17 Mysore Rd.	In**	7,688	2,487	6,779	3,690	3,074	4,294	28,012
		Out**	7,186	1,994	10,403	3,759	2,871	3,593	29,806
		Total	14,874	4,481	17,182	7,449	5,945	7,887	57,818
2	NH7 Hosur Rd.	In	16,505	1,123	7,057	4,022	1,835	1,790	32,332
		Out	14,530	1,676	7,894	3,501	1,642	1,068	30,311
		Total	31,035	2,799	14,951	7,523	3,477	2,858	62,643
3	NH4 Old Madras Rd.	In	39,002	3,559	34,969	9,141	5,549	4,951	97,171
		Out	43,405	4,598	38,955	4,410	3,308	6,456	101,132
		Total	82,407	8,157	73,924	13,551	8,857	11,407	198,303
4	NH7 Bellary Rd.	In	29,375	3,350	36,106	4,436	1,723	2,178	77,168
		Out	33,824	1,868	33,912	2,827	1,563	2,129	76,123
		Total	63,199	5,218	70,018	7,263	3,286	4,307	153,291
5	NH4 Tumkur Rd.	In	20,036	3,291	14,848	4,106	2,970	7,026	52,277
		Out	22,255	3,243	14,291	5,173	2,720	5,273	52,955
		Total	42,291	6,534	29,139	9,279	5,690	12,299	105,232
6	Outer Ring Rd. (West)	N-S***	19,946	2,946	11,481	2,104	3,443	2,152	42,072
		S-N***	18,985	2,915	9,623	1,910	3,509	2,075	39,017
		Total	38,931	5,861	21,104	4,014	6,952	4,227	81,089
7	White Field Rd.	In	16,896	990	16,667	1,388	844	1,287	38,072
		Out	17,208	1,748	16,330	1,815	1,091	2,378	40,570
		Total	34,104	2,738	32,997	3,203	1,935	3,665	78,642
8	Outer Ring Rd.(East)	N-S	32,205	2,112	34,192	4,505	1,492	1,396	75,902
		S-N	35,668	1,717	33,146	4,416	1,558	1,751	78,256
		Total	67,873	3,829	67,338	8,921	3,050	3,147	154,158
9	MG.Rd.	In	20,754	6,397	18,039	492	268	164	46,115
		Out	30,771	7,235	24,504	2,451	497	296	65,754
		Total	51,525	13,632	42,543	2,943	765	460	111,869

*Two-W: Two-wheeler, Auto: Auto-rickshaw, LCV: Light Commercial Vehicle
**In: Inbound toward city centre, Out: Outbound from city centre
***N-S: from North to South, S-N: from South to North
(Source: JICA Study Team)

Table 2.16 Summary of Traffic Count Survey Result (in PCU per Day)

Survey Station		Direction	Two-W*	Auto*	Car/Jeep	Bus	LCV*	Truck	Total
No	Name								
1	SH 17 Mysore Rd.	In**	5,736	4,376	6,779	12,882	5,322	15,567	50,662
		Out**	5,363	2,734	10,403	13,031	4,827	12,226	48,584
		Total	11,099	7,111	17,182	25,913	10,149	27,793	99,246
2	NH7 Hosur Rd.	In	12,342	1,348	7,057	13,651	2,774	5,102	42,274
		Out	10,888	2,124	7,894	11,376	2,589	2,930	37,800
		Total	23,230	3,472	14,951	25,027	5,363	8,032	80,075
3	NH4 Old Madras Rd.	In	29,252	4,271	34,969	29,022	9,544	12,617	119,674
		Out	32,523	5,518	38,955	9,702	4,631	17,004	108,333
		Total	61,775	9,788	73,924	38,724	14,175	29,621	228,007
4	NH7 Bellary Rd.	In	21,991	4,020	36,106	10,545	2,505	5,864	81,031
		Out	25,311	2,242	33,912	6,219	2,188	5,393	75,266
		Total	47,302	6,262	70,018	16,765	4,693	11,257	156,297
5	NH4 Tumkur Rd.	In	14,975	4,168	14,848	11,385	4,438	22,894	72,708
		Out	16,628	4,105	14,291	16,062	3,982	15,972	71,039
		Total	31,603	8,273	29,139	27,447	8,420	38,866	143,747
6	Outer Ring Rd. (WEST)	N-S***	14,937	3,960	11,481	4,888	5,409	6,062	46,738
		S-N***	14,219	4,012	9,623	4,798	6,090	5,108	43,850
		Total	29,156	7,972	21,104	9,686	11,500	11,170	90,587
7	White Field Rd.	In	12,672	1,188	16,667	3,054	1,182	2,936	37,699
		Out	12,901	2,098	16,330	5,612	1,527	6,018	44,485
		Total	25,573	3,286	32,997	8,665	2,709	8,954	82,184
8	Outer Ring Rd.(East)	N-S	24,133	2,534	34,192	10,775	2,089	3,793	77,516
		S-N	26,731	2,060	33,146	10,447	2,181	4,124	78,690
		Total	50,865	4,595	67,338	21,222	4,270	7,916	156,206
9	MG.Rd.	In	15,566	11,986	18,039	1,083	376	362	47,411
		Out	23,078	13,008	24,504	6,597	696	651	68,534
		Total	38,644	24,994	42,543	7,680	1,072	1,013	115,946

*Two-W: Two-wheeler, Auto: Auto-rickshaw, LCV: Light Commercial Vehicle
**In: Inbound toward city centre, Out: Outbound from city centre
***N-S: from North to South, S-N: from South to North
(Source: JICA Study Team)

3) Hourly Traffic Variation

Figure 2.14 shows the hourly traffic variation in number of vehicle at each survey station. The vertical axis of the figure indicates the ratio of hourly traffic volume against total daily traffic volume. The horizontal axis of the figure shows time. The result shows that the peak hour in the morning is from 9:00 to 10:00 and the peak hour in the evening is from 17:00 to19:00. The peak time during a mid-day was not confirmed.

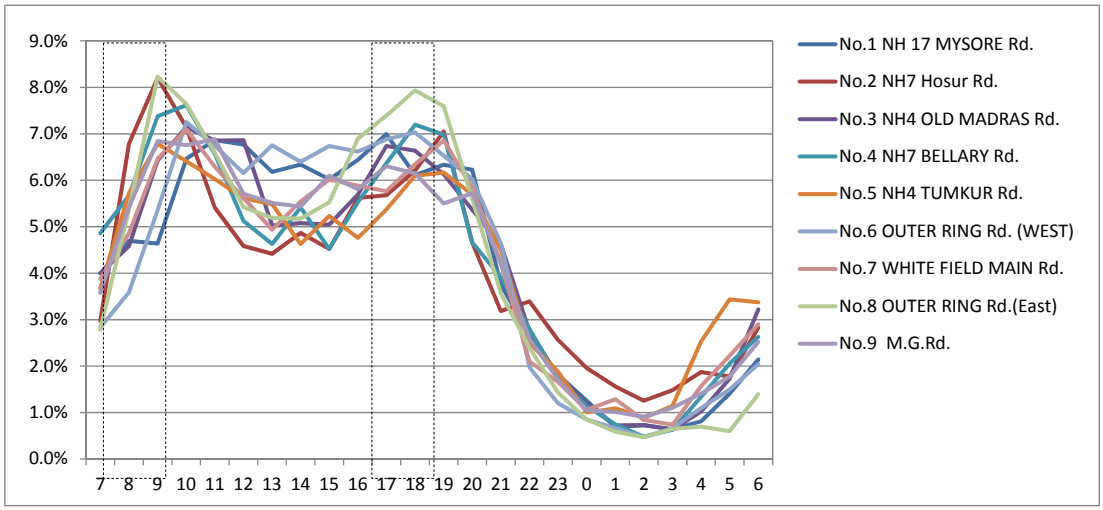


Figure 2.14 Hourly Traffic Variation by Survey Station (in Number of Vehicle)

(Source: JICA Study Team)

4) Share of Traffic Volume During Day-time and Night-time

Figure 2.15 shows the share of traffic volume in number of vehicle during day-time and night-time at each survey station. The percentage of day-time traffic volume against total daily traffic volume is approximately 70% at almost all survey stations. The share of night-time traffic volume at survey stations No.2 NH7 Hosur Road and No.5 NH4 Tumkur Road is slightly higher than others.

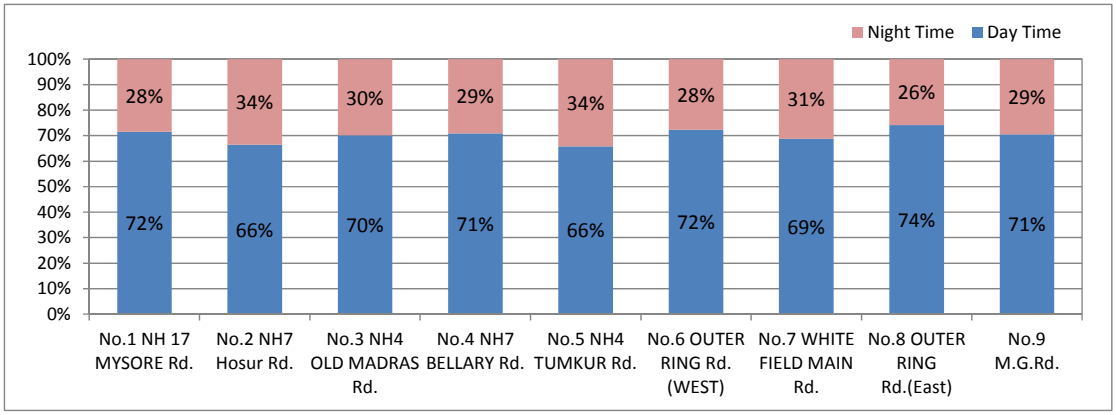


Figure 2.15 Share of Traffic Volume During Day-time and Night-time (in Number of Vehicle)

(Source: JICA Study Team)

5) Peak Hour Traffic Volume by Direction: Inbound and Outbound

Figure 2.16 and Figure 2.17 show the share of peak hour traffic volume in number of vehicle by direction; inbound and outbound. Inbound means the direction towards city centre. Outbound means the direction from city centre. In the morning peak hour, the outbound traffic volume is larger than inbound traffic volume at survey stations No.1 SH 17 Mysore Road, No.2 NH7 Hosur Road, No.7 White Field Road and No. 9 MG Road. The trend reverses in the evening peak hour except No.9 MG Road. It is considered that these roads are used to commute to work places outside the city centre.

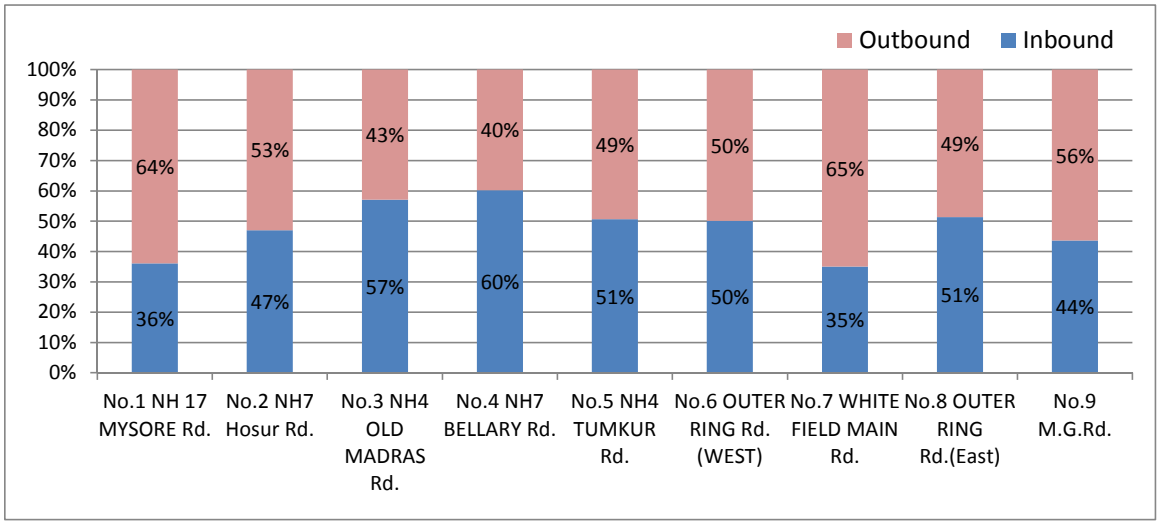


Figure 2.16 Share of Traffic Volume by Direction in Morning Peak Hour (in Number of Vehicles)

(Source: JICA Study Team)

Note: Inbound and Outbound of No.6 Outer Ring Road (West) and No. 8 Outer Ring Road (East) mean clockwise direction and counter clockwise direction respectively.

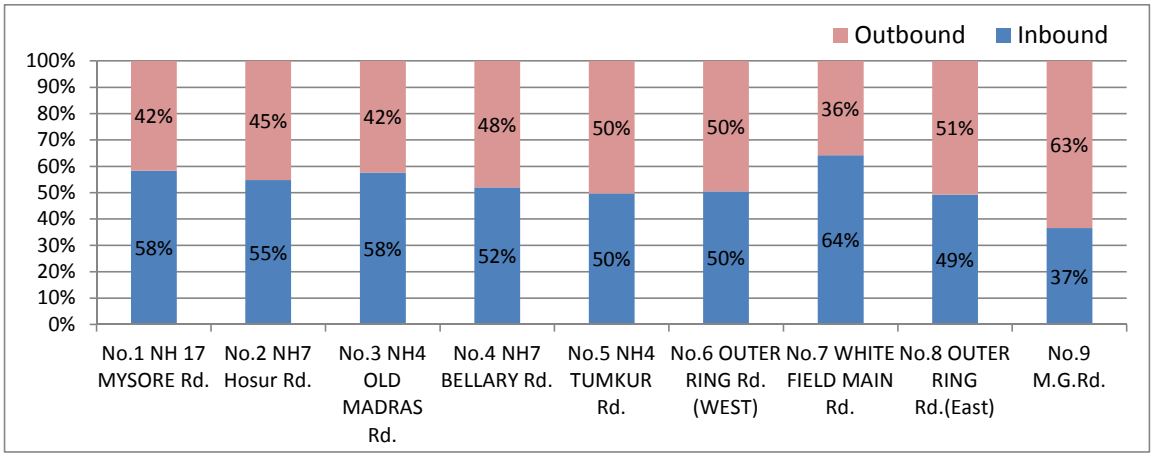


Figure 2.17 Share of Traffic Volume by Direction in Evening Peak Hour (in Number of Vehicles)

(Source: JICA Study Team)

Note: Inbound and Outbound of No.6 Outer Ring Road (West) and No. 8 Outer Ring Road (East) mean clockwise direction and counter clockwise direction respectively.

6) Traffic Composition

Figure 2.18 and Figure 2.19 show the share of traffic composition of daily traffic in number of vehicle at each survey station. The two-wheeler, auto-rickshaw and car constitute more than 80% of the daily traffic volume at almost all survey stations except No1. SH17 Mysore Road and No.5 NH4 Tumkur Road.

Figure 2.20 shows the share of traffic volume of truck in total traffic volume in number of vehicle. The share is more than 10% at survey stations No1. SH17 Mysore Road and No.5 NH4 Tumkur Road. This indicates that these roads are major routes for commercial distribution.

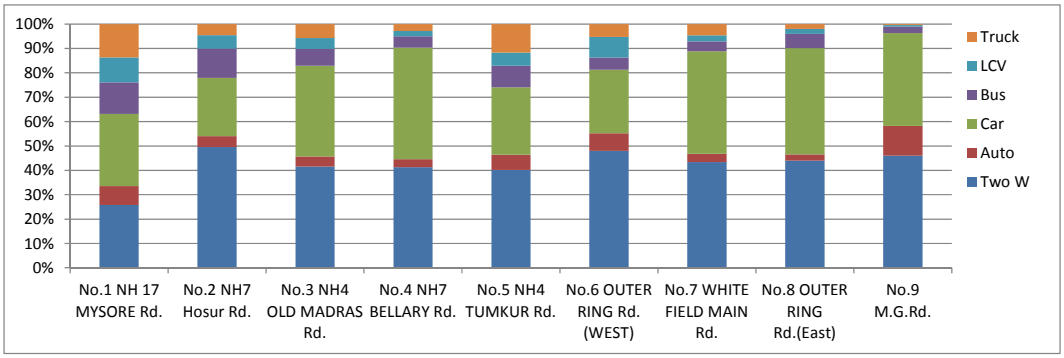


Figure 2.18 Traffic Composition: All Types of Vehicle (in Number of Vehicles)

(Source: JICA Study Team)

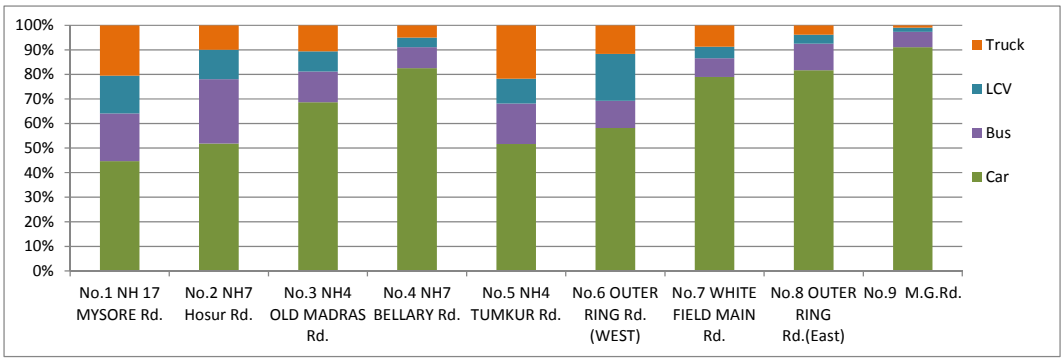


Figure 2.19 Traffic Composition: Without Two-wheeler and Auto-rickshaw (in Number of Vehicles)

(Source: JICA Study Team)

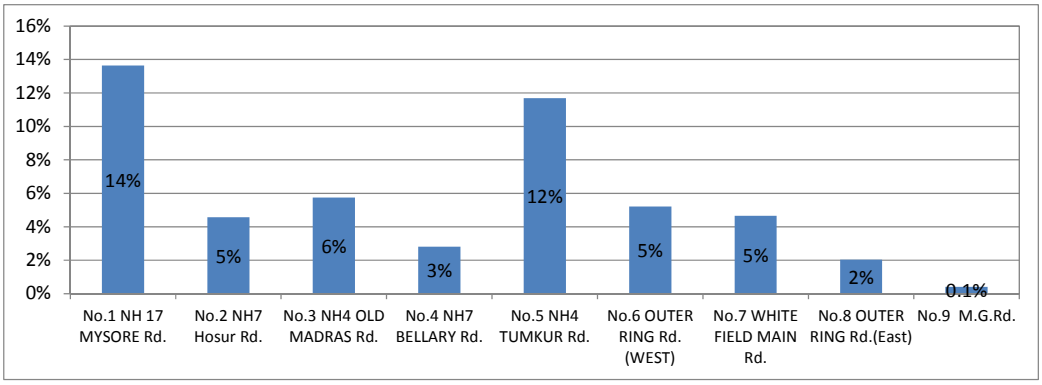


Figure 2.20 Share of Traffic Volume of Truck in Total Traffic Volume (in Number of Vehicles)

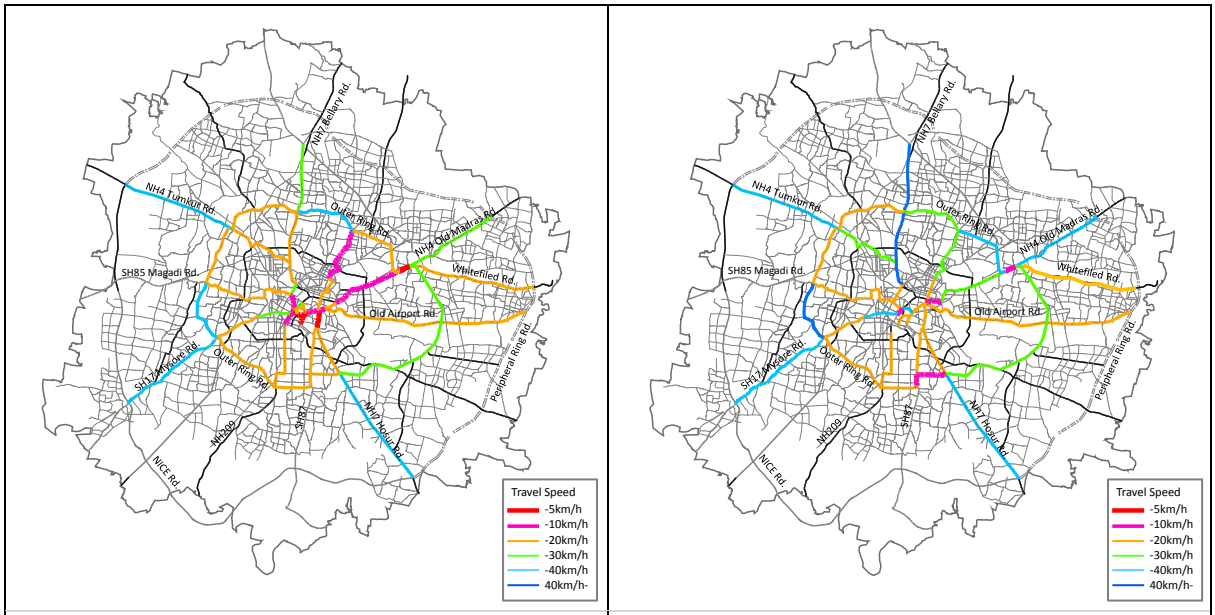
(Source: JICA Study Team)

(c) Travel Speed Survey

1) Travel Speed

The results of travel speed survey during morning peak hour are shown in the figures and tables below. The figure on the left of Figure 2.21 shows the travel speed of inbound direction on the major arterial roads and clockwise direction on ORR. The figure on the right in Figure 2.21 shows the travel speed of opposite direction.

It became evident that the travel speed inside ORR is low, especially in the core area of the city and on Old Madras Road, Hennur Road and section of ORR in the south.



Inbound Direction on Major Arterial Roads and Clockwise Direction on ORR

Outbound Direction on Major Artterial Roads and Counter Clockwise Direction on ORR

Figure 2.21 Travel Speed During Morning Peak Hour

(Source: JICA Study Team)

Table 2.17 and Table 2.18 show the travel speed on each road by direction.

Table 2.17 Travel Speed on Major Radial Road During Morning Peak Hour

Unit: km/hr

Road	Inbound		Outbound	
	Outside ORR	Inside ORR	Outside ORR	Inside ORR
NH4 Old Madras Road	8.1	6.5	24.4	12.2
Old Airport Road	17.4	5.1	19.4	15.6
NH7 Hosur Road	8.8	4.3	11.2	12.9
Bannerghatta Road	16.8	4.2	15.0	12.9
Rastriya Vidyalaya Road	10.3	5.2	13.2	14.3
SH17 Mysore Road	15.2	9.2	14.4	21.3
SH85 Magadi Road	15.0	7.2	19.8	17.3
NH4 Tumkur Road	12.1	6.2	42.3	19.4
NH7 Bellary Road	13.3	5.2	52.3	17.2
Hennur Road	8.6	7.8	20.3	14.1
White Field Road	16.1	-	10.1	-

(Source: JICA Study Team)

Table 2.18 Travel Speed on Outer Ring Road by Section During Morning Peak Hour

Unit: km/hr

Section of ORR		Direction	
From	To	Clockwise	Counter Clockwise
NH4 Old Madras Road	Old Airport Road	28.1	27.5
Old Airport Road	NH7 Hosur Road	24.2	27.8
NH7 Hosur Road	Bannerghatta Road	10.6	8.2
Bannerghatta Road	Rastriya Vidyalaya Road	17.0	18.8
Rastriya Vidyalaya Road	SH17 Mysore Road	15.1	14.2
SH17 Mysore Road	SH85 Magadi Road	37.4	52.6
SH85 Magadi Road	NH4 Tumkur Road	14.0	18.7
NH4 Tumkur Road	NH7 Bellary Road	10.8	19.8
NH7 Bellary Road	Hennur Road	37.2	25.1
Hennur Road	Old Madras Road	16.5	30.8
KR Puram (From Benniganahali Lake to KR Puram Bridge)		4.8	5.8

(Source: JICA Study Team)

2) Major Bottleneck Points

The major bottleneck points were identified. They were identified using the travel speed survey data by the following criteria:

- The intersections where the survey vehicle stops twice or more to pass, and
- The locations where the congestion with 500 m or more in length is observed.

Many bottleneck points in the core area of the city are identified. The bottleneck points exist on all major arterial roads and ORR.

Figure 2.22 Bottleneck Points on Major Arterial Roads and ORR

(Source: JICA Study Team)

(d) Annual Average Daily Traffic Volume (AADT)

Annual Average Daily Traffic Volume (AADT) on the major arterial roads and ORR was estimated to grasp the traffic condition on the road network in Bengaluru. AADT at the survey stations was estimated at first, and AADT on the road network was then estimated as described below.

1) Estimation of Annual Average Daily Traffic Volume at Survey Stations

AADT in number of vehicle and in PCU at each survey station was estimated based on the result of the traffic count survey, applying AADT coefficient. The applied AADT coefficient was created based on the data on annual daily traffic volume on NH4 Tumkur Road which was provided by the concessionaire of NH4. The estimated AADT in number of vehicle and in PCU at survey stations in 2014 are shown in Table 2.19. The figures in the table contain all types of vehicle.

Table 2.19 Estimated Annual Average Daily Traffic Volume at Survey Stations in 2014

No.	Survey Station Name	AADT (Number of Vehicle)	AADT (PCU)
1	SH 17 Mysore Road	62,339	103,772
2	NH7 Hosur Road	68,380	84,501
3	NH4 Old Madras Road	218,133	245,386
4	NH7 Bellary Road	169,850	170,999
5	NH4 Tumkur Road	114,823	152,655
6	Outer Ring Road (West)	89,143	97,866
7	White Field Road	87,081	89,672
8	Outer Ring Road (East)	170,672	170,495
9	MG. Road	124,709	128,442

(Source: JICA Study Team)

2) Estimation of Annual Average Daily Traffic Volume on Other Sections of Major Arterial Roads in 2014

AADT on other sections of the major arterial roads was also estimated using the existing data on traffic volume which was obtained from Comprehensive Traffic and Transportation Plan for Bengaluru (CTTP) and Comprehensive Traffic and Transportation Study for Bengaluru (CTTS). However the survey years of CTTP and CTTS are 2009 and 2011, respectively. Thus, it was adjusted to 2014 by applying growth rate of traffic volume. The growth rate of traffic volume was calculated based on the data of annual traffic volume on NH4 Tumkur Road which was provided by the concessionaire of NH4.

3) Annual Average Daily Traffic Volume and Annual Average Peak Hour Traffic Volume on Major Arterial Roads in 2014

The estimated AADT on the major arterial roads in 2014 is shown in Figure 2.23. The annual average peak hour traffic volume was also estimated as shown in Figure 2.24. The peak hour ratio which was calculated based on the result of the traffic count survey was applied.

Traffic concentration in the core area of the city and major arterial roads is observed. AADT is more than 150,000 PCU per day on NH-7 Bellary Road which connects to Airport, NH4 Old Madras Road and east section of ORR. The annual average peak hour traffic volume is more than 10,000 PCU per hour on the roads in the core area of the city and major arterial roads such as NH-7 Bellary Road and east section of ORR.

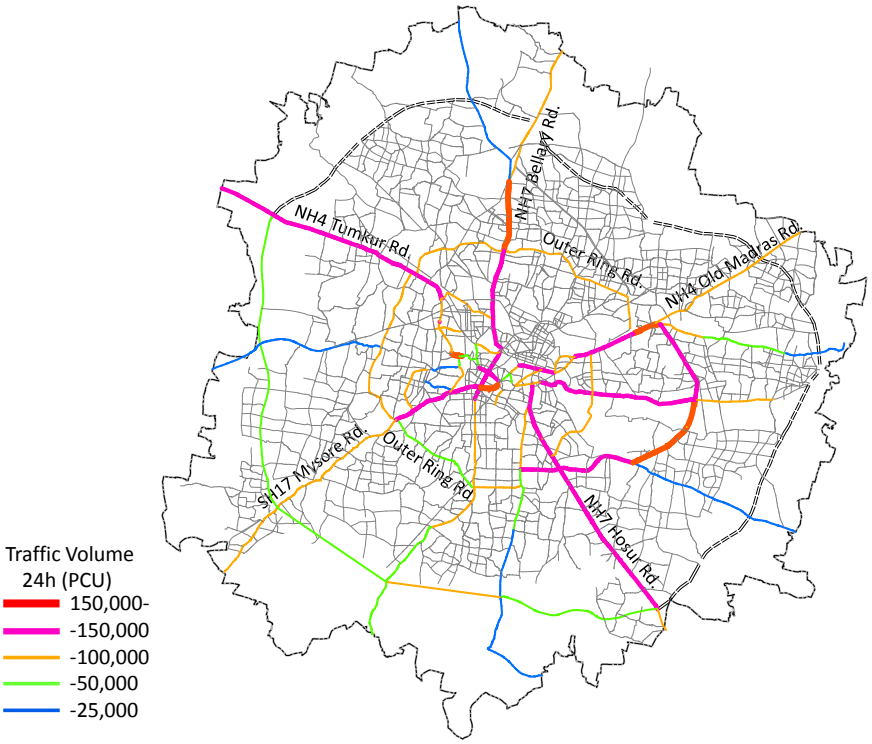


Figure 2.23 Annual Average Daily Traffic Volume on Major Arterial Road in 2014 (in PCU)

(Source: JICA Study Team)

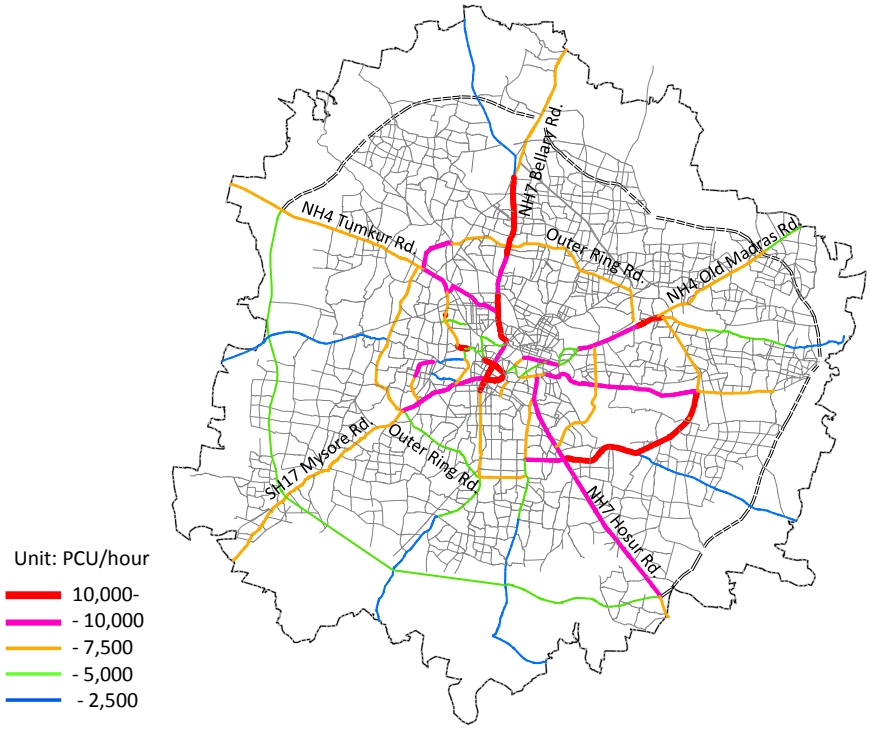


Figure 2.24 Annual Average Peak Hour Traffic Volume on Major Arterial Road in 2014 (in PCU)

(Source: JICA Study Team)

4) Traffic Volume per Road Capacity Ratio (V/C) During Peak Hour

Figure 2.25 shows the ratio of traffic volume per road capacity (V/C) of major arterial roads. V/C was calculated based on annual average peak hour traffic volume in PCU on the major arterial roads. The road capacity defined by Indian Road Congress: IRC 106-1990, Guidelines for Capacity of Urban Roads in Plain Areas, was applied as shown in Table 2.9.

From the results of V/C during peak hour, traffic congestion in core area of the city and on the major arterial roads is severe. They are over capacity as indicated by orange and red lines in the figure below.

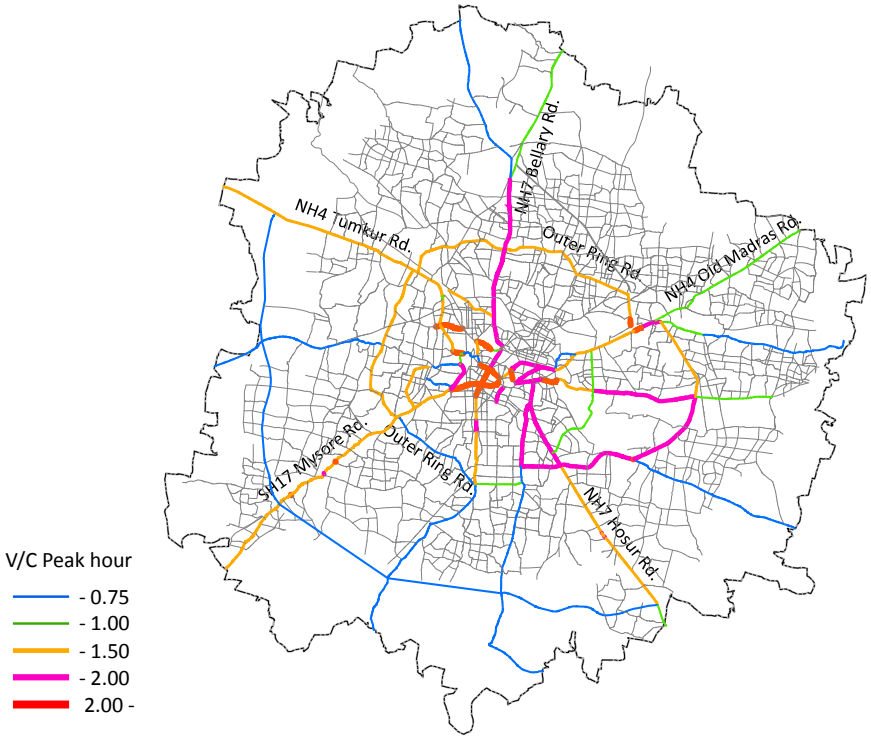


Figure 2.25 V/C of Major Arterial Roads During Peak Hour

(Source: JICA Study Team)

Table 2.20 Road Capacity Defined by IRC

No.	Type of Carriageway	Capacity (PCU/Hour)
1	2 Lane (One-Way)	2400
2	2 Lane (Two-Way)	1500
3	3 Lane (One-Way)	3600
4	4 Lane Undivided (Two-Way)	3000
5	4 Lane Divided (Two-Way)	3600
6	6 Lane Undivided (Two-Way)	4800
7	6 Lane Divided (Two-Way)	5400
8	8 Lane Divided (Two-Way)	7200

(Source: IRC 106-1990, Guidelines for Capacity of Urban Roads in Plain Areas)

(3) Future Traffic Demand Forecast

(a) Objective and Methodology

The future traffic demand is forecasted to grasp the future traffic situation and to analyse impacts of ITS measures. The future traffic demand in Bengaluru metropolitan area was forecasted by the existing traffic studies such as CTTP, CTTS, and so on. However, it was necessary to update these models because they had been made based on the old parameters such as population, employment and road network. In this study, the future traffic demand forecast was generated by the new modelling based on the latest data such as population, employment, road network, and etc.

The urban transportation modelling system was adopted and it consists of four major stages which is often referred to as the four-stage or four-step model, as shown in the Figure 2.26. The trip model usually used in India was applied in this study. The model was calibrated for the morning peak hour and focuses on peak period conditions because these conditions include the most important recurrent congestion period. The peak hour models provide more accurate indications of directional travel patterns than daily models do. The modes that were modelled under this study include two-wheelers, private cars, auto rickshaws, public transport and commercial vehicle such as light commercial vehicle and truck. As the basic trip data by trip purpose was not available, the trip data by vehicle type was updated. The zoning for modelling includes 239 traffic zones inside the study area and 10 external zones outside the study area. The external zones were decided based on the connectivity to the study area. The road network for modelling includes all the major arterial roads, sub arterial roads and major collector roads. The year of 2014 was considered as the base year and the year of 2021 was set as the horizon year for the ITS planning in mid-term. JICA STRADA developed by JICA for the urban transportation modelling was used. This software has good track records of applying to urban transportation modelling worldwide.

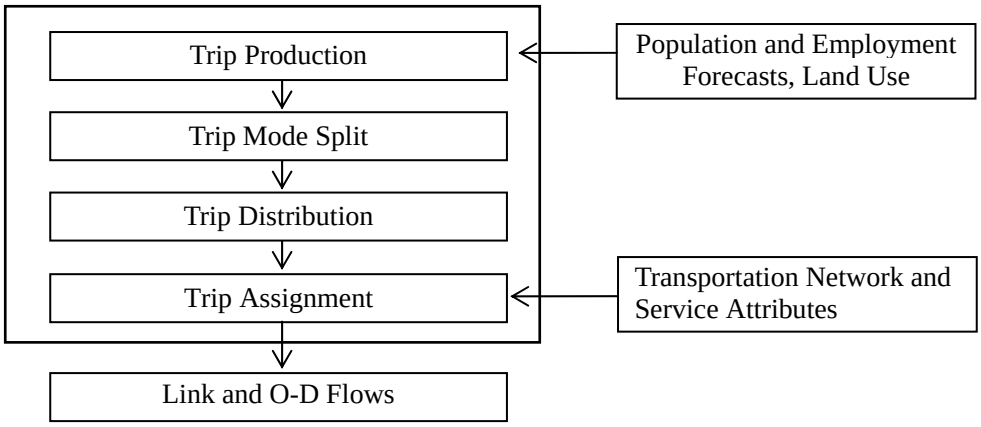


Figure 2.26 Urban Transportation Modeling Method

(Source: JICA Study Team)

(b) Preparation of OD Matrix

1) Zoning

Based on the administrative boundaries and on unit of ward in Bengaluru metropolitan area, the traffic zone for modelling was divided into 239 internal zones and ten external zones, totalling 249 zones. The map showing the traffic zone for the model area is presented in Figure 2.27.

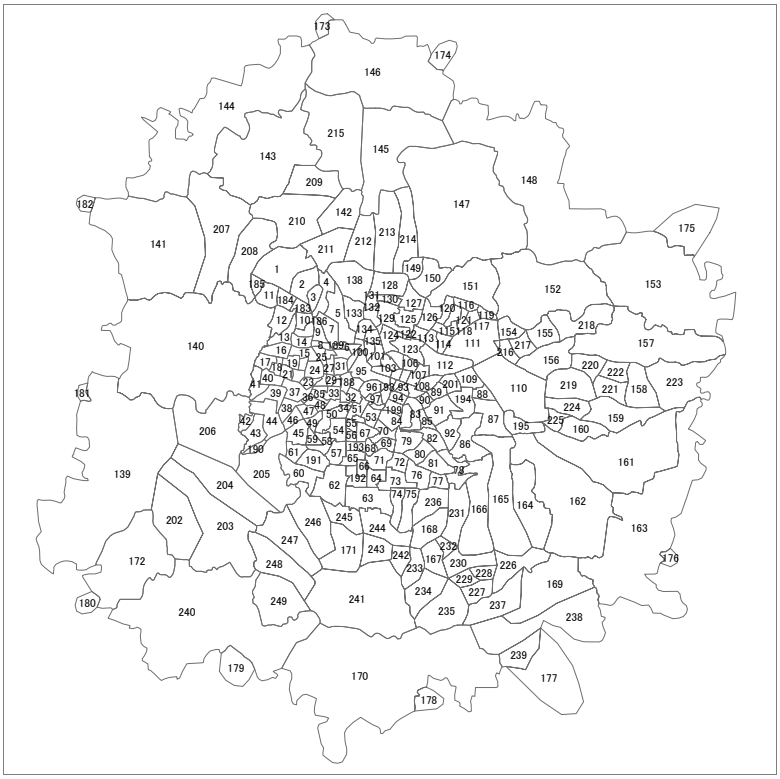


Figure 2.27 Traffic Zone

(Source: JICA Study Team)

2) Socio Economic Frame

Prior to the traffic demand forecast, the framework of total population and the total employment was set. The total number of population was based on the projection of population by Directorate of Economics and Statistics of the Government of Karnataka. The employment was estimated by using the ratio of the employment number against the total population. The ratio of employment against the total population was 42% in the population census in 2011. It was assumed that the ratio of employment would increase to 50% of the total population in 2021 based on the trend of the past years and on the result of interviews to the Indian authorities.

The total population and the total employment in the model area from 2011 until 2021 are shown in Table 2.21.

Table 2.21 Total Population and Total Employment in Model Area

Year	Population ('000)	Growth Rate	Employment ('000)	Growth Rate	Emp. /Pop.	Remarks
2011	8,446	-	3,506	-	42%	Census 2011
2014	9,252	3.09%	3,980	5.02%	43%	Projection
2021	11,447	3.09%	5,724	5.02%	50%	Projection

(Source: Projection by JICA Study Team based on the Directorate of Economics and Statistics)

In this step, the number of population per traffic zone and the employment per traffic zone were estimated by allocating the total population and the total employment to each traffic zone.

This allocation was processed using the past growth trend of zonal population and the land use plan proposed by Bengaluru Master Plan 2015 as shown in Figure 2.28. The estimated population per zone and the estimated employment per zone are shown in Figure 2.29 and Figure 2.30.

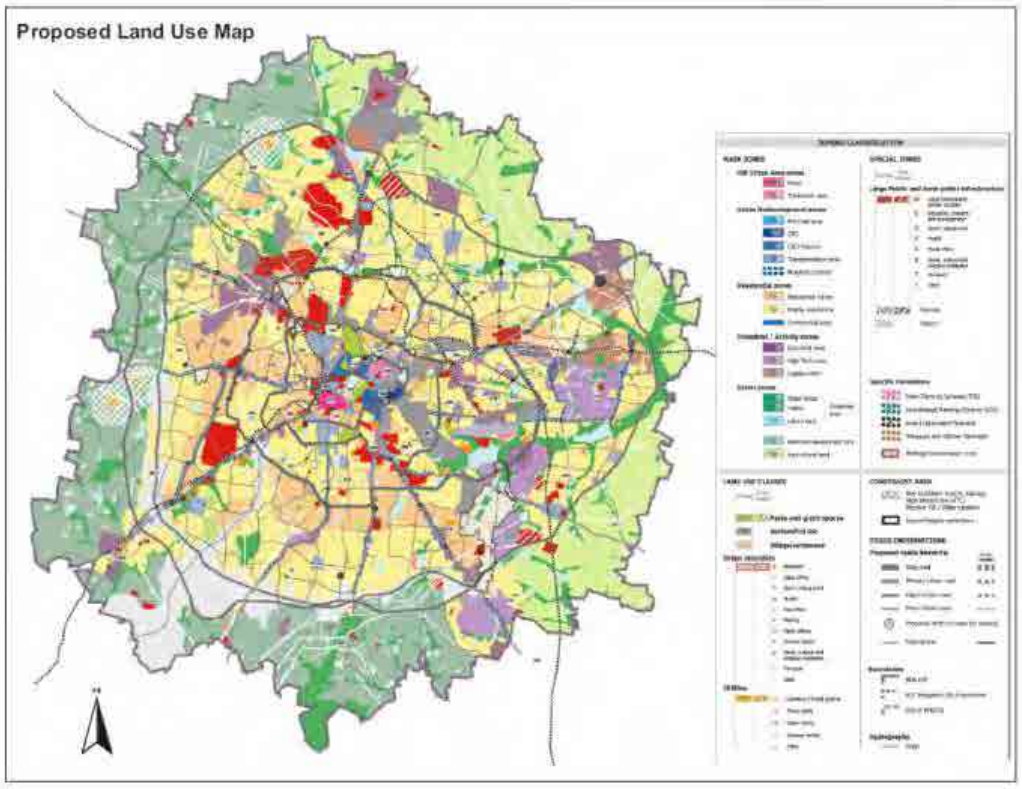


Figure 2.28 Proposed Land Use Plan in 2031

(Source: Bengaluru Master Plan 2015, BDA)

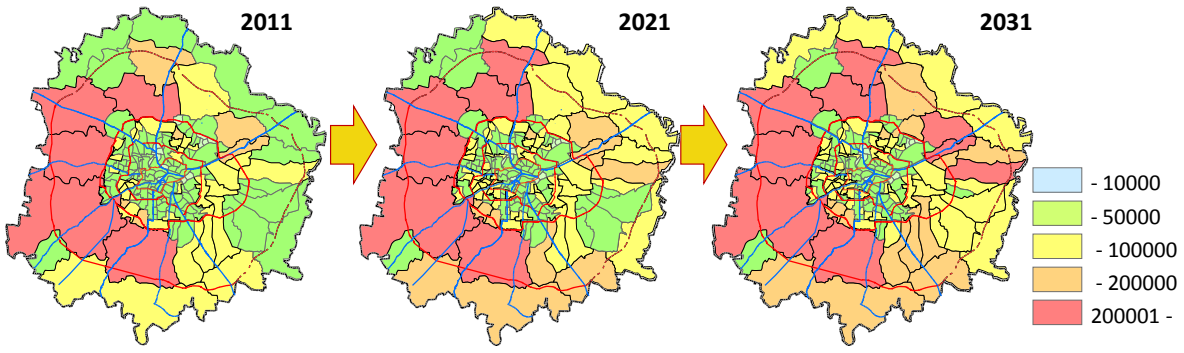


Figure 2.29 Distribution of Population by Traffic Zone

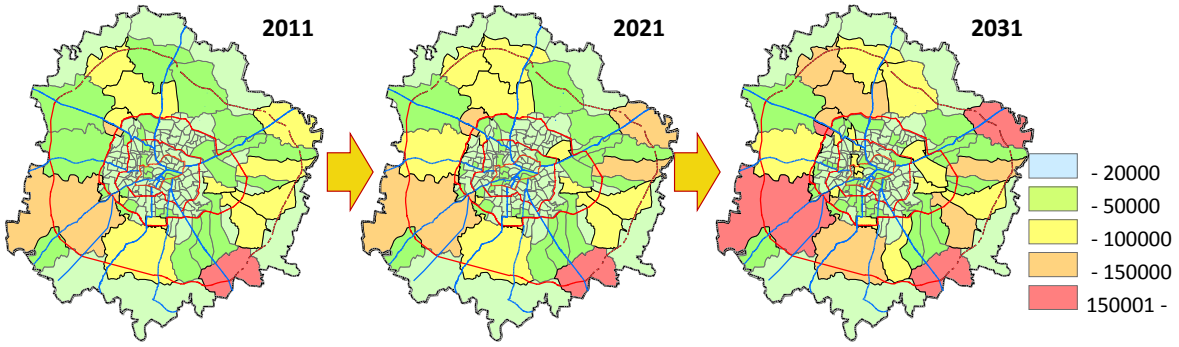


Figure 2.30 Distribution of Employment by Traffic Zone

(Source: Estimation by JICA Study Team)

3) Forecast of Generated and Attracted Trips

In this step, the trip production, the generated and attracted trips were estimated. The trip production is total trips generated in the model area. The generated and attracted trips are total trips per traffic zone. The trips were estimated for the morning peak hour.

The existing trip production data provided by DULT was used as basic data for the trip production. However this data was required to be updated by the latest population census data because it was estimated based on the old population census data in 2001. Concretely, the existing trip data was estimated by the population data which was smaller than the measured number of population. Therefore, the trip production was revised up based on the latest population census in 2011.

The trip production was calculated by multiplying the existing trip production to the ratio of the latest population against the previous population. The same traffic growth rate used by the past traffic studies was applied. The estimated result of the trip production is shown in Table 2.22.

Table 2.22 Passenger Trip Production (Persons)

Year	Trip Production (million trips/peak hour)	Annual Growth Rate
2011	1.42	-
2014	1.52	2.3%
2018	1.66	2.3%
2021	1.78	2.3%

(Source: Estimation by JICA Study Team)

In the next step, the generated and attracted trips per traffic zone were estimated. The estimation of the trip generation and attraction was calculated based on the generated and attracted trip model. The linear model equation was developed for the trip model equation. The explained variables are trip generation and attraction, and the explanatory variables consist of population and employee per zone. Based on this model shown below, the generated and attracted trips were projected. The result of projection is shown in Figure 2.31.

Generation model;

$$G = 0.052P + 0.025E + 598.9 \quad R^2 = 0.83$$

Attraction model;

$$A = 0.013P + 0.158E + 745.3 \quad R^2 = 0.93$$

where

G= Peak hour trip generation per zone

A= Peak hour trip attraction per zone

P= Population per zone

E= Employment per zone

R^2= Coefficient of determination

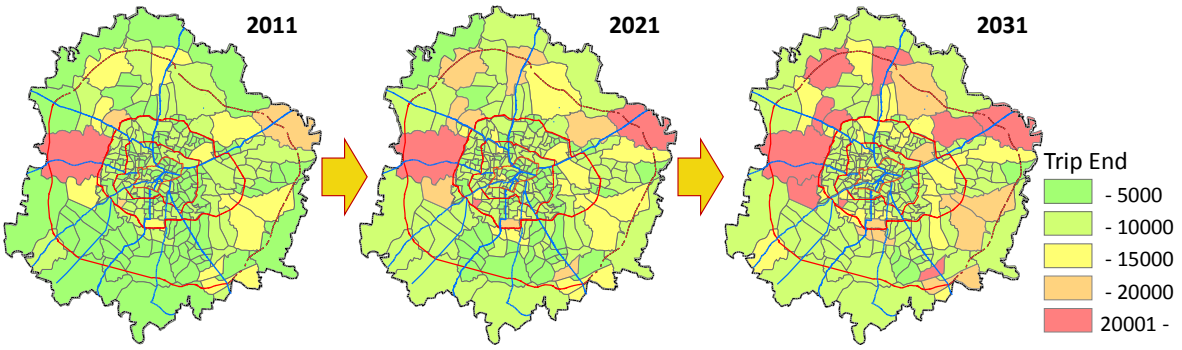


Figure 2.31 Trip Production by Traffic Zone

(Source: Estimation by JICA Study Team)

Regarding the commercial vehicles such as LCV and truck, the trip production in 2014 was estimated by updating the data of year of 2010 by CTTS. The distribution pattern of the trip generation and attraction and the annual growth rate of traffic volume were applied with the same pattern of CTTS.

Table 2.23 Commercial Vehicle Trip Production in Peak Hour (in PCU)

	LCV	Truck
2014	7,586	13,713
2021	9,651	15,770
Annual Growth Rate	3.5%	2.0%

(Source: Estimation by JICA Study Team based on CTTS)

4) Modal Split Forecast

The trip generation and attraction per zone was split to each transportation mode trip as the work step of the modal split forecast. For the first work step, the modal split of metro user was determined. It was set at 90% of the passenger trip within the service area of the metro as the metro users referring to the study carried out by the metro company, Bengaluru Metro Rail Corporation Limited (BMRCL). The number of the metro user was adjusted to the total number of the demand forecast estimated by BMRCL.

For the next work step, the modal split of transport modes except the metro passenger was examined. Based on the estimated mode share shown in Table 2.24, the trip generation and attraction was split to the trip by mode. The mode share in Table 2.24 was estimated based on CTTS with some corrections as necessary.

The unit of trip was converted into the unit in PCU using the average occupancy per vehicle type and the PCU factor defined by IRC as shown in Table 2.25.

Table 2.24 Estimated Mode Share by Year

Year	Two-Wheeler	Auto-Rickshaw	Car	Bus	Total
2011	25.0%	12.0%	14.0%	49.0%	100%
2014	25.8%	12.0%	14.9%	47.4%	100%
2021	27.5%	12.0%	17.0%	43.5%	100%
2031	30.0%	12.0%	20.0%	38.0%	100%

(Source: Estimation by JICA Study Team based on CTTS)

Table 2.25 Number of Passengers (Average Occupancy) Per Vehicle and PCU Factor by IRC

	Two-Wheeler	Auto-Rickshaw	Car	Bus
Number of passengers per vehicle	1.5	2.5	2.5	65
PCU factor	0.75	2.00	1.00	2.20

(Source: CTTS, IRC)

5) Forecast of Trip Distribution

In this step, the trip distribution per transport mode was estimated. The trip distribution means the origin-destination (OD) distribution between zones. The unit applied to the OD distribution is in PCU.

In this study, the basic gravity model was applied as OD trip distribution model by transport mode. The impedance between zones was the travel time by passenger vehicle in this model. The result of parameter estimation is shown in the Table 2.26. The future OD matrix was forecasted based on this model parameters, the future generated trips and attracted trips.

$$T_{ij} = k \cdot \frac{G_i^{\alpha} A_j^{\beta}}{d_{ij}^{\gamma}}$$

Where

Tij=Trip between zone *i* and zone *j*

Gi= Peak hour trip generation per zone *i*

Aj= Peak hour trip attraction per zone *j*

dij= Impedance between *i* and *j* (travel time)

k α, β, γ= parameters

i ,*j* = zone

Table 2.26 Parameters of Distribution Model by Transport Mode

	Two-wheelers	Auto-rickshaw	Car	LCV	Truck	Bus
k	0.0001	0.0001	0.0003	0.365	0.151	0.209
α	0.966	0.738	0.717	0.323	0.367	0.204
β	1.037	0.832	0.729	0.309	0.397	0.173
γ	-0.298	-0.476	-0.163	-0.319	-0.196	-0.077

(Source: Estimation by JICA Study Team)

(c) Road Network for Traffic Assignment

Figure 2.32 shows the road network used for the traffic assignment. It consists of links, nodes, and centroids. The roads targeted for road assignment are the main roads of the city, including NH, SH, the ring road and etc. Each link has the attribute information such as length, capacity, speed, traffic regulation. The toll fee by vehicle type was also set on the existing toll roads, i.e. Hosur road, Tumkur road and NICE road. The traffic assignment in this study was carried out for the morning peak time considering the regulation of heavy vehicles into the inner city. It was set up that the trucks did not pass through the inside of the ORR. PRR was added as a major future road to be in service by 2021. The same toll fees as NICE road were applied to PRR.

Table 2.27 shows the road capacity and the free flow speed by road classification determined in CTTS of Bengaluru. These figures, i.e. road capacity and free flow speed, are larger than the ones defined by IRC. However, almost same figures shown in Table 2.27 were applied to the traffic demand forecast modelling of other past studies. Therefore these figures were applied to this study as well in terms of assuring consistency with the existing studies in Bengaluru.

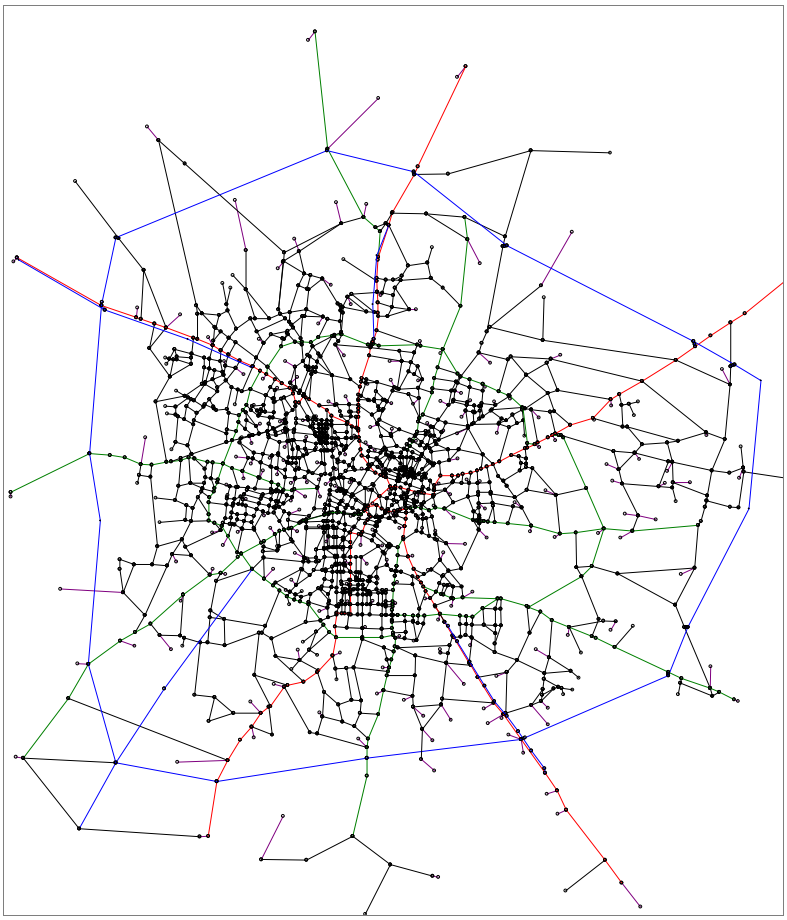


Figure 2.32 Future Road Network for Modeling in 2021

(Source: JICA Study Team)

Table 2.27 Road Capacity and Free Flow Speed by Road Type

No.	Road type	Road Capacity (Q_{max}: PCU/hour)	Free flow Speed (V_{max}: km/hour)	No. of Lanes
1	1L-2W-UD	900	22	1
2	1.5L-1W-UD	4,500	36	1.5
3	1.5L-2W-UD	2,800	27	1.5
4	2L-1W-UD	6,000	36	2
5	2L-2W-UD	3,800	35	2
6	3L-1W-UD	9,000	45	3
7	3L-2W-UD	5,600	38	3
8	3L-2W-D	6,800	31	3
9	4L-1W-UD	12,000	45	4
10	4L-2W-UD	7,600	40	4
11	4L-2W-D	9,000	43	4
12	6L-1W-UD	18,000	58	6
13	6L-2W-D	13,400	50	6

L: Lane, W: Way, D: Divided, UD: Undivided
(Source: CTTS)

(d) Traffic Assignment and Result

1) Methodology of Traffic Assignment

The incremental assignment method was adopted for the traffic assignment using JICA STRADA in this study. The incremental assignment divides the input OD traffic data into the specified increments and assigns each increment to the minimum route wherein the generalised cost, i.e. the impedance calculated from travel time, distance and so on, is the least. The steps of the assignment per increment are as follows:

Step0 Initialise:

- Set the increment $n=0$ and the link traffic pattern $X^{(0)}=0$.

Step1 Link Cost Calculation:

- Calculate the link cost $t^{(n)}$ by the traffic pattern.

Step2 Minimum Route Search:

- Search the minimum route under the link cost of $t^{(n)}$. The minimum route search uses the Dijkstra algorithm.

Step3 Traffic Assignment to Road Network:

- Assignment of the traffic of OD matrix on it to obtain the new traffic pattern $X^{(n)}$. The split rate of OD matrix is 5 times per 20% commonly for all types of vehicle.

Step 4 End Determination:

- If it is the last increment, stop. Otherwise set the increment $n=n+1$ and go to Step 1.

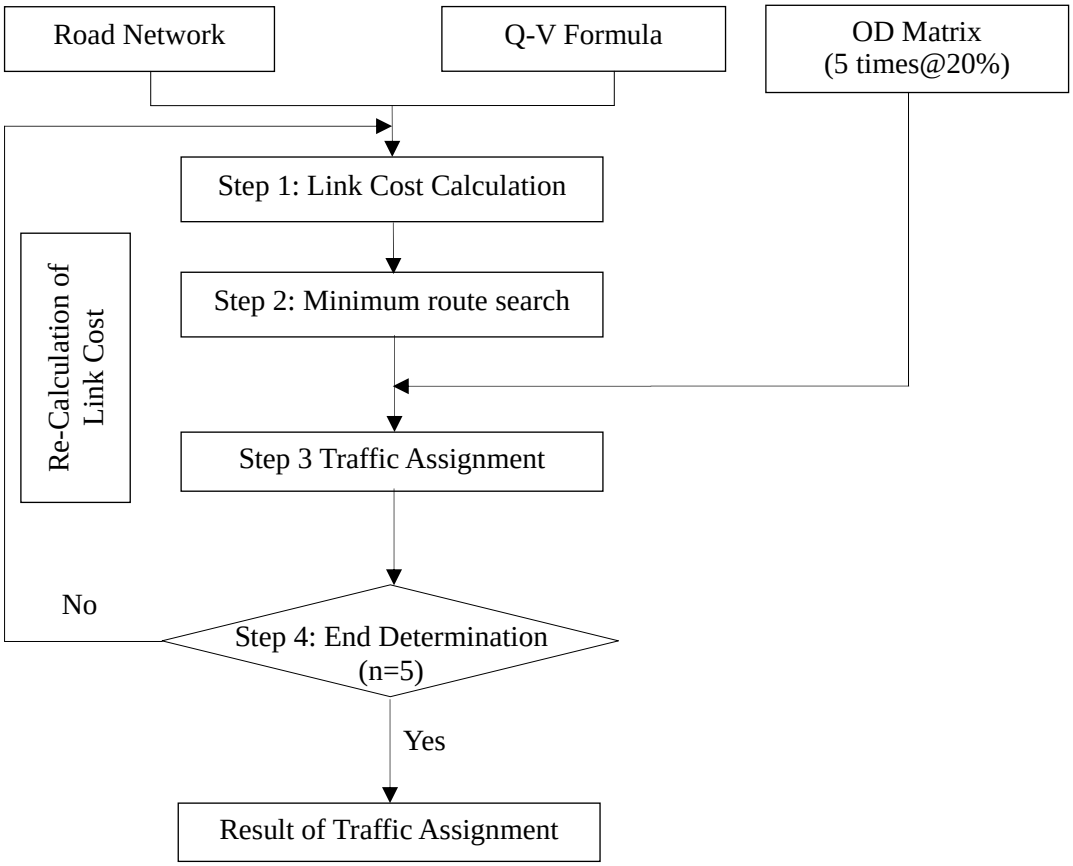


Figure 2.33 Traffic Assignment Procedure

(Source: JICA Study Team)

The Q-V formula as shown in the Figure 2.34 was adopted to this model. It was adopted on the condition that every road shares the same type and each type has two factors: initial speed and capacity. The initial speed is determined by road classification and number of lanes. The capacity includes the number of lanes, width of carriageway and the type of cross section.

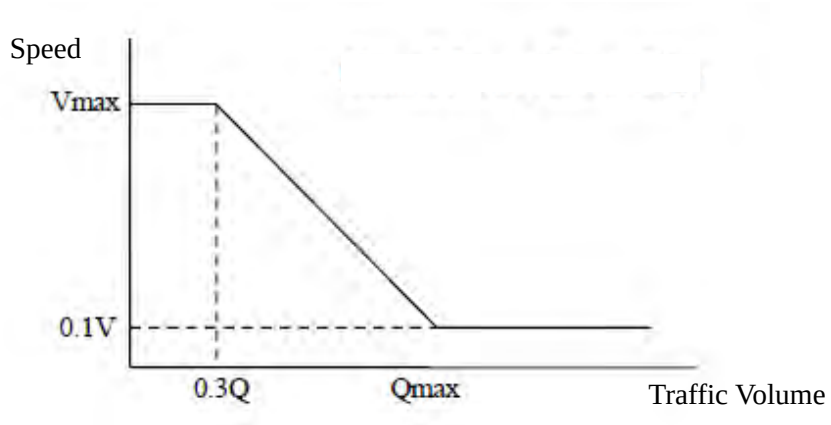


Figure 2.34 Q-V Formula

(Source: JICA Study Team)

The result of comparison between the measured traffic volume which is AADT presented in the previous clause and the estimated traffic volume is shown in Figure 2.35**.** The correlation coefficient based on the result of comparison for 33 road sections is 0.8. As a result, it was judged that the high accuracy of the current state reproducibility was reserved. Based on the above parameter conditions, the future traffic demand forecast was carried out.

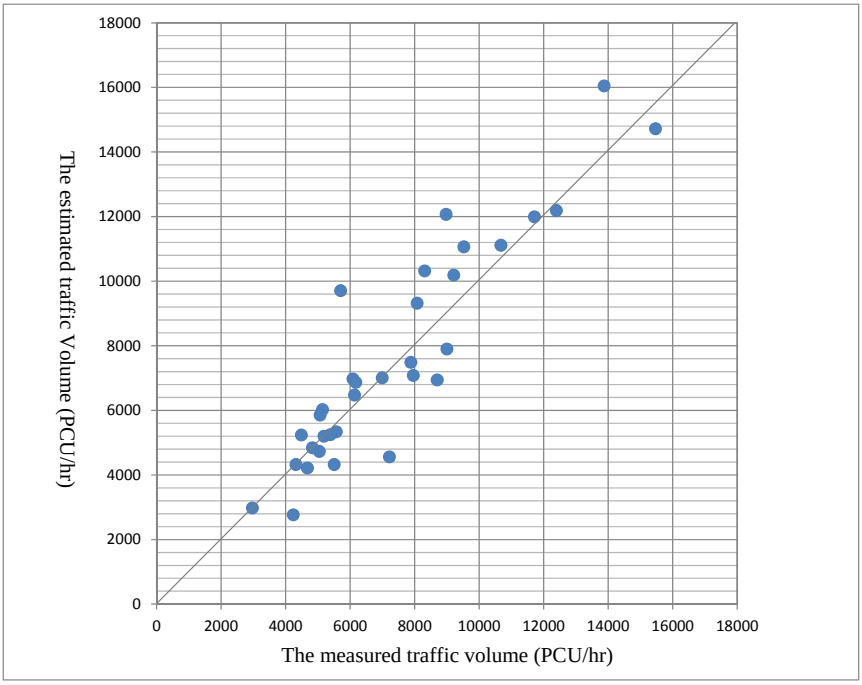


Figure 2.35 Result of Comparison between Measured Traffic Volume and Estimated Traffic Volume

(Source: JICA Study Team)

2) Traffic Assignment Result in 2021

The traffic assignment result of the traffic volume in 2014 and in 2021 are shown in Figure 2.36 and Figure 2.37.

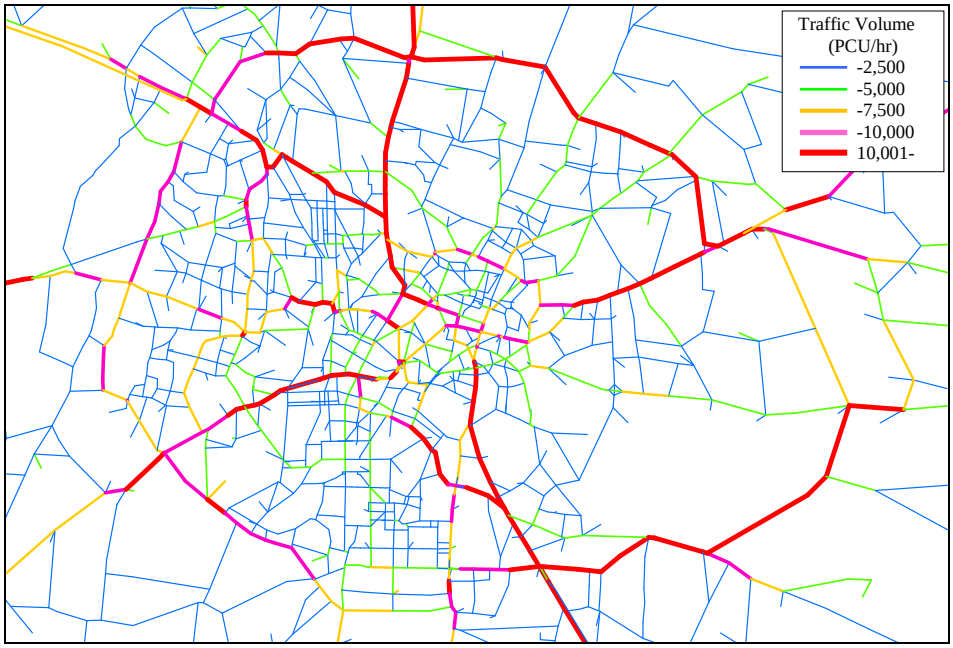


Figure 2.36 Result of Assigned Traffic Volume in 2014

(Source: JICA Study Team)

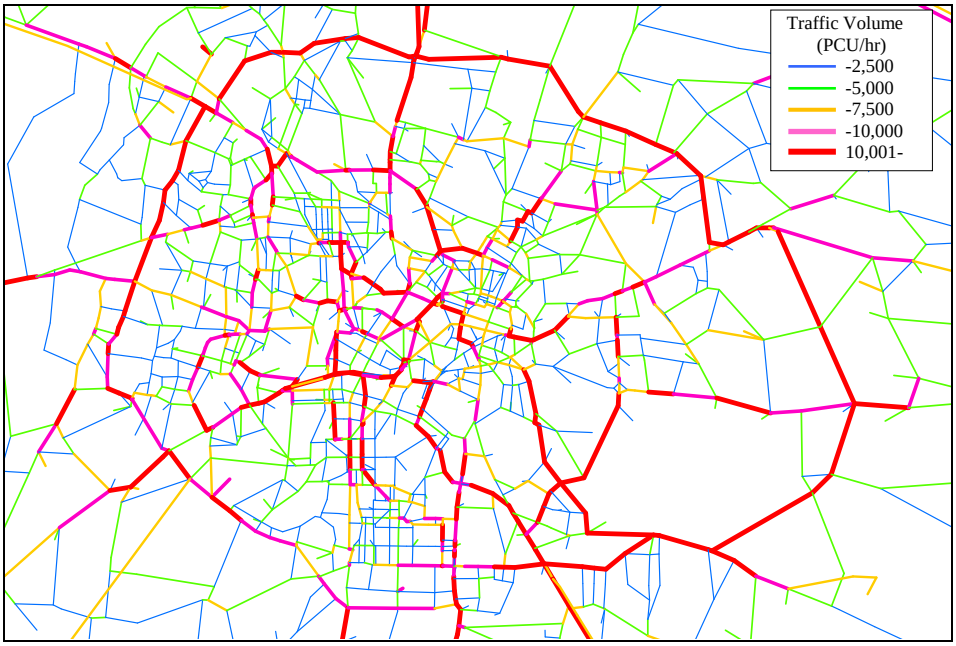


Figure 2.37 Result of Assigned Traffic Volume in 2021

(Source: JICA Study Team)

Table 2.28 Result of Assigned Traffic Volume

No.	Road	Current (2014)		Future (2021)		Increase Ratio: 2021/2014
		Traffic Volume (PCU/hr) *Survey result	V/C	Traffic Volume (PCU/hr) *Estimation	V/C	
1	SH17 Maysore Road	4,900	1.0	7,600	1.5	1.6
2	NH7 Hosur Road	9,400	1.4	12,100	1.8	1.3
3	NH4 Old Madras Road	17,400	2.0	16,400	1.9	0.9
4	NH7 Ballery Road	10,900	1.5	12,300	1.7	1.1
5	NH4 Thumkur Road	7,300	1.1	9,500	1.4	1.3
6	Outer Ring Road (West)	6,100	1.1	10,300	1.9	1.7
7	White Field Road	5,200	1.4	9,000	2.5	1.7
8	Outer Ring Road (East)	11,900	1.7	13,700	1.9	1.2
9	MG Road	8,000	1.5	7,600	1.4	1.0

(Source: JICA Study Team)

(4) Road and Traffic Issues

(a) Traffic Concentration and Rapid Growth of Traffic Demand

The analyses observed that the traffic concentrates on the area of core ring road and specific corridors, especially which connect to major industrial areas such as NH4-Tumkur road to Peenya industrial area, NH4-Old Madras road to White Field and NH7-Hosur road to Electronic City. The volume capacity ratio (V/C) of the road in the cores area around Hudson circle is more than 2.0 during peak hour. The traffic demand forecast reveals the further increase in traffic demand especially on roads within ORR. The measures to prevent/cope with the increasing demand are required.

(b) Slow Travel Speed and Bottlenecks on Major Road

The travel speed survey result shows that the average travel speed during morning hour is around 5 km/h in the core area of the city, 10 km/h on some radial roads, and 20 km/h inside of ORR. Some traffic delays are observed not only in CBD area but also on the arterial roads such as national highway and state highway.

The bottlenecks points are identified at the intersections of the major roads mainly inside ORR. This is considered due to inadequate road capacity, inappropriate road structure and traffic operation issues. Inappropriate road structure and heterogeneous traffic cause the reduction of the capacity of junctions. At the signalized intersections, the signal time should be reviewed to increase the effective road capacity and to reduce delay.

(c) Lack of Road Infrastructure

The road infrastructures are insufficient to accommodate the traffic demand. The existing road infrastructures are not capable to cope with the increasing demand. Such measures as construction of new road are difficult due to limitation of available land especially in the core area of the city. The improvement of design of intersections, construction of flyover and elevated road shall be considered to increase the capacity at bottleneck points. Further, ITS measures are required for increasing road capacity and improving efficiency.

(d) Public Transport

The major public transport in Bengaluru is the city bus operated by BMTC. Although the transport capacity has been improved year by year, the pace of improvement has not caught up with the increasing demand. Also weaknesses of public transportation attraction, such as inflexibility, unpunctuality, no connectivity so on, are issues to be addressed to promote shift from individual vehicles to buses. In such a situation, the development of mass transit transportation and the further service improvement of bus traffic is an urgent issue to handle the rapid growth of traffic demand. Actually, the Namma Metro construction is making progress in the main system to drastically address the traffic issues in Bengaluru. Two sections of Phase-I are now open and all of Phase-I will be opened to traffic in 2 years time. The promotion of utilization from car to metro is a significant key to addressing the current situation of Bengaluru traffic issues. The issues are the following:

- Upgrading quality of service of public transportation system; Punctuality, Connectivity, Info-service
- Seamless public transportation network between the Metro and the feeder transport
- Upgrading the last mile accessibility keeping in step with the Metro development

2.1.6 Conditions of ITS in Bengaluru

Some ITS components have been introduced and in operation in Bengaluru. The following sections describe the current condition and plans of ITS in Bengaluru.

(1) Bangalore Traffic Police - B-TRAC

The traffic control centre and associated equipment were developed by Bangalore Traffic Police. The major purposes of the system are traffic monitoring and enforcement. The system was developed under the project called 'B-TRAC' funded by the state government. B-TRAC was implemented by "Karnataka Road Development Corporation Limited" (KRDCL), a Karnataka state government agency.

Table 2.29 shows major components of the B-TRAC system.

Table 2.29 ITS Components of B-TRAC

Component	Description
Traffic Management Centre (TMC)	• Located in a headquarters of Bangalore Traffic Police • A large-size video wall of 83' x 11' in size • 40 workstations for operators • TMC monitors 20 major corridors in Bengaluru city
CCTV Camera	• CCTV cameras installed at 179 intersections • Cameras equipped with pan, tilt and zoom functions • Cameras connected to TMC by optical fibre cable of service provider, BSNL, a government telecom company
Over-speed Enforcement Camera	• 5 speed cameras installed in the city • It captures over-speeding vehicle and transmit the information to TMC
Variable Message Sign (VMS)	• 20 VMS installed in the city • Static messages e.g. for safety are shown on VMS
Traffic Signal [1]	• 352 signals exist in the city • Signals connected to TMC by optical fibre cable • Signal phase timings are changed by operator from TMC
Traffic Violation Enforcement System	• It is called “E-Challan” system • It takes pictures of vehicle violated traffic regulation • It generates penalty notice by identifying the vehicle number plate based on the captured pictures
Vehicle Database	• Online connection from TCC to vehicle database of Department of Transport

(Source: Summarised by JICA Study Team based on interview to Bangalore Traffic Police)

[1] Bharat Electronics Limited (BEL), an Indian government agency, is the vendor that installed and maintains the traffic signals. One year defect liability period and two year maintenance were included in the initial contract. After expiry of the initial contract, three year maintenance contract until 2015 was made.

(a) Traffic Management Centre (TMC)

TMC building of 5,620 sq.m was constructed at the cost of INR 23.35 crore. It was funded by the Government of Karnataka. TMC is equipped with large-size video wall to view live images captured by CCTV installed in the city. There are 40 workstations for operators. Figure 2.38 shows the image of TMC of Bengaluru Traffic Police

Figure 2.38 Video Wall at Traffic Management Centre of Bangalore Traffic Police

(Source: Bangalore Traffic Police)

(b) Enforcement System

Bangalore Traffic Police adopt two methods for enforcement. They are:

- On-Street Enforcement: To catch the violating vehicle by traffic officers on the street, using handheld devices to record the traffic violation, and
- Surveillance Enforcement: To monitor the violated vehicles at TCC by images captured by surveillance cameras

As to on-street enforcement, the traffic police officer on the street uses the handheld blackberry device. It records the details of violation and prints out the penalty slip, called “challan”, on the spot. Figure 2.39 shows images of the handheld blackberry device and wireless printer.

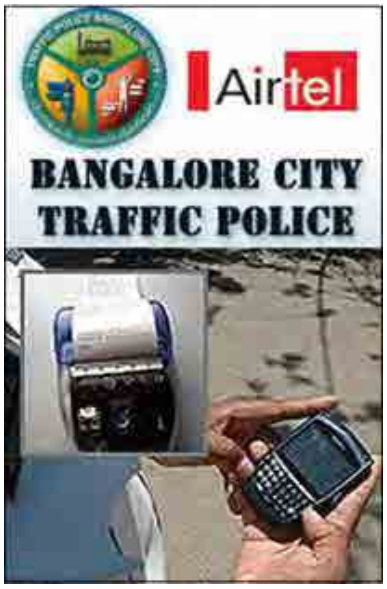


Figure 2.39 Blackberry Device and Wireless Printer

(Source: Bangalore Traffic Police)

As to surveillance enforcement, the cameras installed at intersections take pictures of the number plate of the violating vehicle and the image is sent to the TCC. The operator in the TCC views the captured image and inputs the vehicle number plate into the database. The penalty slip, "challan", is then generated and sent to the address of the vehicle owner.

Figure 2.40 show images of the captured vehicle and the generating "challan".

Installed Camera | Captured Image of Violating Vehicle | Penalty "Challan" with Picture of Vehicle Number Plate

Figure 2.40 Violation Recording and Penalty 'Challan'

(Source Bangalore Traffic Police)

(c) Outline of Status of B-TRAC

It was originally targeted to improve 500 junctions, install 680 surveillance cameras, 95 pelican signals and 26 enforcement cameras under the Phase I of B-TRAC. It was achieved as improvement of 46 junctions, installation of 179 surveillance cameras, 16 pelican signals and 5 enforcement cameras as of September in 2014. A malfunction of equipment is serious issue of B-TRAC. Approximately 40% of the existing cameras and traffic signals are not working due to communication problems and lack of maintenance.

Traffic Police are taking measures to complete the pending works of Phase I. The Government of Karnataka approved the proposed expansion of B-TRAC as part of Phase II work.

(2) Karnataka State Road Transport Corporation (KSRTC)

Karnataka State Road Transport Corporation (KSRTC) is a Karnataka state government owned bus operator. It operates buses to other locations within the state which are called intra-state services and to locations/cities of other states which are called as inter-state services.

KSRTC started a project to develop ITS for KSRTC buses that operate from Bengaluru. A total of 4,000 buses will be covered by the project. It includes 200 buses that ply between Bengaluru to Mysore and 3,800 buses for intra-state and inter-state services. CMC Ltd, a private agency, was selected as a vendor for the project. The ITS components of the project include the following:

- Automatic Vehicle Location System
- Real time Passenger Information System
- In-Vehicle Display System
- Central Control Centre

(3) Bangalore Metropolitan Transport Corporation (BMTC)

Bangalore Metropolitan Transport Corporation (BMTC), a state government owned city bus operator, started a project to introduce ITS components. The ITS components are shown in Table 2.30.

Table 2.30 ITS Components of BMTC System

Component	Description
Vehicle Tracking System (VTS)	• GPS unit to be installed on 6,500 city buses • Vehicle tracking application • Probe data recorded by GPS unit is sent to Command Control Centre
Electronic Ticketing System (ETS)	• Electronic Ticketing Machine (ETM) to issue printed ticket • Smart card for electronic payment
Passenger Information System (PIS)	• Provision of real-time bus information • LED display board at major bus terminals • Information provision through web site, SMS, and automated voice service
Data Centre	• Database Server (GPS Server, ETM Serve , etc.) • Communication Server • Application Server • IVRS Server for automated voice service • LED Display Server • SMS Server
Command Control Centre	• Monitoring bus locations • Handling administrative work for bus operation • Equipped with video wall and workstations

(Source: Summarised by JICA Study Team based on interview to BMTC)

The total period of the project is five years. It includes one year for installation and four years for operation and maintenance. The project has been executed by a private agency, “TRIMAX”. The project started in 2013 and the operation of the pilot commenced in September 2014. Under the pilot project, GPS units were installed on 200 city buses and a command control centre was prepared in the BMTC office in Shanthinagar. The command control centre is equipped with a video wall. The project will be executed in phased manner to cover entire fleet of 6,500 buses of BMTC.

The Figure 2.41 shows the Central Command Centre of BMTC established under the pilot project.

Figure 2.41 Central Command Centre of BMTC

(Source: JICA Study Team)

(4) Electronic Fare Collection of Bangalore Metro

Bangalore metro adopts distance based fare system and electronic fare payment system has been introduced. Two types of tickets are issued by metro. They are:

- Smart Token
- Contactless Smartcards

(a) Smart Token

One token is valid for a single trip. The tokens are touched on the pad at entry gate and dropped in the slots at exit stations after use. The passengers can buy a maximum of six tokens at a time.

(b) Contactless Smartcard

Contactless smartcards are used by frequent passengers. There are two types of the contactless smartcard:

Namma Metro Travel Card:

It is issued by metro rail authority and used exclusively for the payment of metro rail fare. The card costs INR 50. The passengers can recharge the value on the card at metro stations.

Combo Card:

It is a combined card of contactless chip for metro fare payment and magnetic stripe of bank debit card for other use such as shopping. The combo card is issued by banks, State Bank of India (SBI) and Federal Bank. These banks made business agreement with Metro to issue the combo card. The method to use is same as Namma metro travel card. The passengers can recharge the value on the card by charging machine at metro stations and ATM machines in the city.

The electronic fare system was developed by Samsung. Mifare framework is adopted to the smartcard.

Combo Card

Entry and Exit Gates in Metro

Metro Station

Figure 2.42 Metro Rail

(Source: BMRCL)

(5) Taxi System of Karnataka State Tourism Development Corporation (KSTDC)

Karanataka State Tourism Development Corporation (KSTDC), a government agency of Karnataka, was formed in 1971 under Department of Tourism. Its roles and responsibilities include promotion of tourism in the state by improving tourism-related facilities and services for tourists. KSTDC is involved in taxi services in Bengaluru as well. They made agreement with Bangalore airport authority, Kempegowda International Airport Ltd, to offer taxi services between airport and city.

All taxis under KSTDC are equipped with a GPS unit. The taxis are monitored at a call centre. The GPS unit sends data the location of the taxi to the centre every 30 seconds. The call centre identifies the available taxi nearest the customer and dispatches to the requested place to pick up the passengers upon their request.

(6) Bangalore Elevated Tollway

Bangalore Elevated Tollway is a 9.985 km long 4 lane two-way elevated national highway that connects Silk Board Junction with Electronic City Junction. The national highway comes under the jurisdiction of National Highway Authority of India (NHAI). The tollway was built by private consortium “Bangalore Elevated Tollway Limited (BETL)” under Built-Operate-Transfer (BOT). The consortium was awarded the project to operate and maintain for 18 years.

Figure 2.43 Bangalore Elevated Tollway

(Source: JICA Study Team)

The facilities of the tollway include

- Highway Traffic Management System (HTMS)
- Toll Management System (TMS)

HTMS and TMS were supplied and installed by EFKON as system integrator.

(a) Highway Traffic Management System (HTMS)

HTMS is composed of the following major facilities:

- CCTV Surveillance System
- Automatic Vehicle Counting and Classification System
- Meteorological System
- Variable Message Sign Boards (VMS)
- Emergency Call Boxes (ECB) for emergency
- Mobile route patrol system
- HTMS Control Room

(b) Toll Collection System

Three types of toll collection are adopted. They are:

- Electronic Toll Collection System (ETC)
- Touch & Go (TnG) system using smartcard
- Manual Toll Collection

The salient features are as follows:

Electronic Toll Collection System (ETC)

- Passive DSRC with one-piece type On-Board Unit (OBU) is adopted for ETC.
- OBUs are issued to motorised vehicles such as four wheelers and large-sized vehicles.
- OBUs are not provided to 2-wheelers.
- OBU costs INR 1000. BETL is offering the OBU at reduced price of INR 150 to encourage usage.
- The number of vehicles installed with OBU is currently 20,000.

Touch & Go (TnG) System

- TnG system is used only by 2-wheelers.
- There are currently approx. 3,000 smartcard users.
- The smartcards can be recharged by users at charging machine at tollway.
- Manual Toll Collection
- The users who do not have either OBU or smartcard pay the toll fare in cash.

According to the tollway operator, BETL, the current ETC system is facing problems such as slow response of the system resulting in queues at the toll gate, processing errors, difficulties in tracing the violating vehicles due to incomplete vehicle registration information, misused OBU by other types of vehicles, etc.

BETL is planning to replace the current Passive DSRC system with RFID based system. The pilot project was carried out to verify feasibility of the RFID system. It is approximately estimated at INR 1 crore for replacement.

(7) Registration and Standardisation of Number Plate of Motor Vehicles

Department of Transport (DOT), Government of Karnataka, is in charge of registration of motor vehicles, issuance of driving licenses, collection of vehicle related taxes, etc.

(a) Registration of Motor Vehicle

Computerisation of activities of the department has been underway since June 2009. The initiative is called ‘Computerised Service Delivery System’. Under this initiative, the registered motor vehicle information has been computerised in a database. The vehicle owners are required to register their vehicles in the office of the department at the time of purchasing the vehicles. The information such as name of owner, her/his address, vehicle type, date of purchase, etc. is registered.

The registered information is shared with Bangalore Traffic Police online. Bangalore Traffic Police use the shared motor vehicle information for enforcement of traffic violations. For example, the notice of fine against the traffic violation which is identified by the enforcement system at the traffic management centre of Bangalore Traffic Police is sent to the owner of the vehicle.

However, the issue is that second-hand vehicle owners may not be traceable. Another issue is that the information of disposed vehicles may still remain in the database. Thus, the vehicle database may not necessarily represent the correct number of the vehicles in use in the state.

Prime reasons of this situation are that: (i) the owner of private vehicle is required to pay only 'one-time' vehicle tax at the time of purchasing, (ii) a regular inspection of private vehicle is not mandated in India. Therefore, there may be some cases that people do not necessarily follow the rule of registration particularly at the time of disposal or altering ownership.

It is important to develop a scheme that the owner of vehicle can be confirmed and the registration of vehicle is surely carried out specifically in view of enforcement utilising ITS and proper management of motor vehicles.

(b) Number Plate Standardization

Standardisation of motor vehicle number plate is underway in India. The Government of India mandated to introduce the standardised number plate on the 1st June 2005, by amending the rule 50 of Central Motor Vehicle Rules, 1989. The number plate is called a tamper proof High Security Registration Plates (HSRP). According to the amended rule, HSRP number plate is supposed to be equipped with all new motor vehicles that have come into the market since then. The existing motor vehicles were given two years for replacement.

HSRP number plate standardises abbreviated character of state, district code, unique number by district, hologram to prevent unauthorised copying, standardised fonts, character sizes, etc. The location to place HSRP number plate on the vehicle is stipulated.

Figure 2.44 shows an example of HSRP number plate.

Figure 2.44 HSRP Number Plate for Karnataka State

(Source: Department of Transport)

Three Indian states, Meghalaya state, Sikkim state and Goa state, have fully implemented them. Seven states are under process of introducing HSRP number plates.

The standardisation of number plate has not been implemented in Karnataka state yet. The department of transport in Karnataka initiated the process in 2005. However they have been facing a court issue regarding tender process of number plate installation. Therefore, the standardisation of number plate in Karnataka state is still on hold.

The current number plates in Karnataka state use different materials, fonts, character sizes, languages, equipping positions on the vehicles, etc. It is technically difficult to automatically detect and recognise the number plate by automatic number plate system under such conditions. Lack of standard number plate remains a challenging issue for most of ITS application, especially enforcement.

Figure 2.45 shows typical example of number plates currently used on vehicles. The left picture shows the printed number plate on 4-wheeler and right picture shows the handwritten number plate on 2-wheeler.

Figure 2.45 Typical Examples of Number Plates Currently in Use

(Source: Pictures taken by JICA Study Team)

2.1.7 Outcome of ITS Opinion Survey

This section describes the outline and results of ITS Opinion Survey. The details can be found in Appendix-1：ITS Opinion Survey for Bengaluru.

(1) Outline

ITS Opinion Survey in Bengaluru was carried out for the purpose of identifying potential needs. The surveyors randomly distributed the interview sheets and collected the responses on the spot in the vicinity of shopping malls, parking lots of government institutions and other places in Bengaluru. The outline of the ITS Opinion Survey is shown in the table on the next page.

Table 2.31 Outline of ITS Opinion Survey

Target	Samples	Location	Question
Motorcycle User	150	Jayanagar, Banashankari, BTM, Marathahalli, Madiwala, Forum mall, Corporation, Shantinagar, Shivaji nagar, Hebbal, Yelahanka, MG Road, Garuda mall, Mekri	**1. General Information** • User (Driver) Profile (All) • Frequency of Trips (All) • Purpose of the Trip and Travel Time (Motorcycle, Car) • Trip Purpose: Commuters (Bus, Metro) • Mode of Payment (Bus, Metro) • Reason for not Opting Public Transport (Motorcycle, Car) • Parking Facility and Willingness to Pay (Motorcycle, Car) • Transfer to/from Other Modes (Motorcycle, Car) **2. Traffic, Transportation and ITS** • Congestion and Current Traffic Information Facility (Motorcycle, Car, Truck, Ambulance) • Required Information (Motorcycle, Car, Truck, Ambulance) • Choice on Mode of Information (Motorcycle, Car) • Expressway - Problems and the Solutions (Motorcycle, Car, Truck, Ambulance) • Improvement for Public Transportation Service (Bus, Metro) • Reasons for Congestion (All) • Solution for the Traffic and Transportation Problems (All) • Introduction of Congestion Charging for Congested Area (All, Ambulance) • Improvement for Public Transportation Service (Bus, Metro)
Car User	150	Same as Motorcycle User	
Bus User	150	Santi Nagar Bus Terminal, Hebbal Juction, Sivaji Nagar, Majestiic Bus Terminal, Corporation Circle, BTM Layout Bus stop, Yeshwanthpur, Jaynagar(Fourth Block), Yelahanka Bus Terminal, KR Puram	
Metro User	150	MG Road station to Baiyappanahalli station, Peenya Industry to Mantri Square Sampige Road, Bayapanahalli, Swami Vivekananda, Indira nagar, Halasuru, Trinity, M G Road, Kempu nagar, Peenya	
Truck Driver	150	Same as Motorcycle User	
Ambulance Driver	50	St. John's, Narayana Hrudhayalaya, Jeydeva, Nimans, Manipal, Sanjeevini	

(Source: JICA Study Team)

(2) Summary of ITS Opinion Survey Results

Various issues have been identified by the ITS Opinion Survey. The results of the survey are summarised in the Table 2.32.

Table 2.32 Summary of ITS Opinion Survey Results

Target	Required Information and ITS Facilities	Traffic and Transportation Problems	Solutions	Congestion Pricing	Other Problems
Motorcycle User	• Travel Time to Destination • Congestion Length • Information Provision to Mobile Phone and VMS	• Insufficient Road Capacity • Too Many Vehicles	• Strict Enforcement of Traffic Rules • Improvement of Public Transport Service • Real time Traffic Information • Congestion and Route Guidance Information	• 46% Agreed	• Inconvenient Public Transport
Car User	• Congestion Location • Travel Time to Destination • Congestion Length • Alternative Route • Traffic Incident	• Insufficient Road Capacity • Too Many Vehicles	• Strict Enforcement of Traffic Rules • Improvement of Public Transport Service • Realtime Traffic Information	• 46% Agreed	• Inconvenient Public Transport
Bus User	• Smartcard • Information at Bus Stop and on Board Bus • Realtime traffic Information	• Insufficient Road Capacity • Too Many Vehicles	• Strict Enforcement of Traffic Rules • Improvement of Public Transport Service • Realtime Traffic Information	• 65% Agreed (for private vehicles only)	• Congested Bus • Long Waiting Time at Bus Stop • Expensive Fare • Absence of Route, Time and Fare Information at Bus Stop
Metro User	• Common Prepaid Card • Transfer Facility	• Insufficient Road Capacity • Too Many Vehicles • Bad Driving Manners	• Strict Enforcement of Traffic Rules • Improvement of Public Transport Service • Realtime Traffic Information	• 79% Agreed (for private vehicles only)	
Truck Driver	• Traffic incident • Alternative Route • Car Navigation System	• Insufficient Road Capacity • Too Many Vehicles	• Strict Enforcement of Traffic Rules • Improvement of Public Transport Service	• 1% Agreed • 99% Disagreed	• Current Traffic Information System
Ambulance Driver	• Congested Location • Alternative Route • Travel Time to Destination • Car Navigation System		• Awareness to Public • Improvement of Driving Manners • Clearance of Traffic on the Road • Command Control Room for Ambulance	• 100% Agreed (for private vehicles only)	• Current Traffic Information System

(Source: JICA Study Team)

(3) Travel Time by Different Mode and Mode Shift

(a) Average Travel Time by Transport Mode

The travel time from origin (home) to destination (schools, work place) by transport mode is shown in the Figure 2.46. One major observation is that the majority of average travel time of all transport modes lies in the range of 30 - 59 minutes. Average travel time for bus tends to take more time than others. This is because bus users have to wait the bus on the bus stops. As shown in the Figure 2. 47, half of bus users spend over 10 minutes at bus stops. More than half of metro users are also taking 30-59 minutes. However, it is expected that travel time of metro users will be reduced along with expansion of metro network.

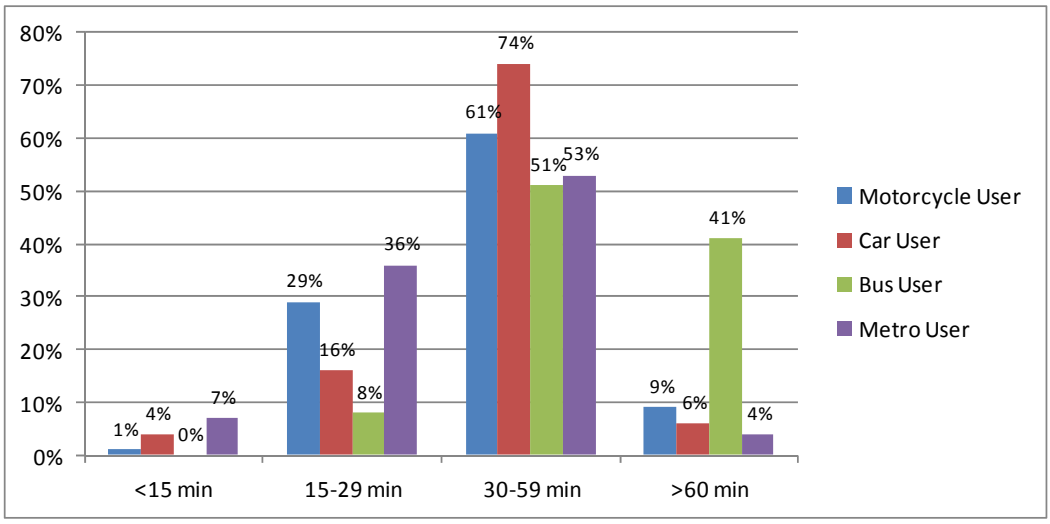


Figure 2.46 Average Travel Time by Transport Mode

(Source: JICA Study Team)

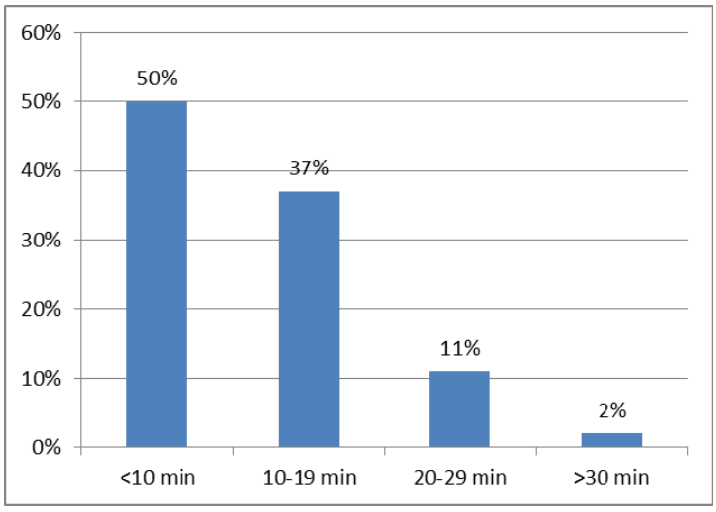


Figure 2.47 Waiting Time at Bus Stop

(Source: JICA Study Team)

(b) Mode Shift

This analysis was carried out to understand the mode shift situation of each transport mode. The car users and motorcycle users tend to travel without shifting public transport. The bus users also take buses as their primary transport means. This result implies that the bus network in Bengaluru covers sufficient area including residential roads. However it can also be construed that improving transfer facilities such as parking near bus stations may lead more bus usage by the current motorcycle/car users, making their motorcycle/car last-mile connection method. The metro users take different mode more frequently. This indicates that the present metro network is still limited and the metro users cannot reach their destination/ metro stations without mode shift.

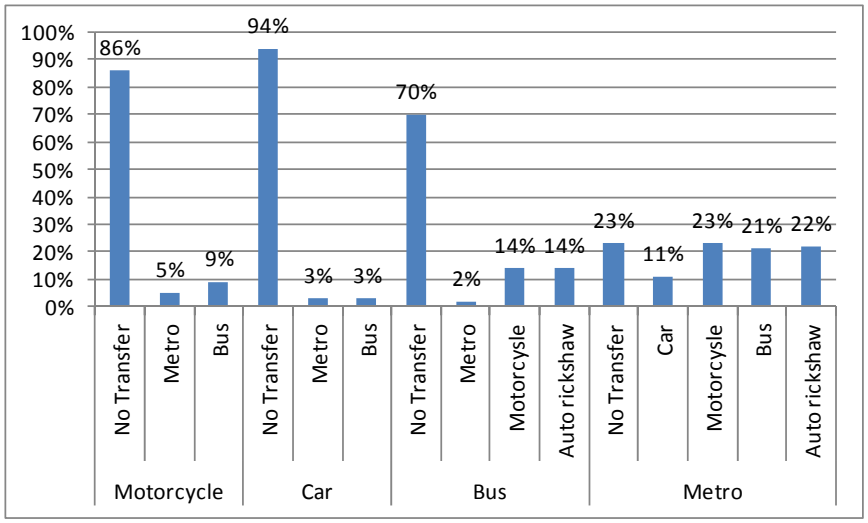


Figure 2.48 Mode Shift Situation of Each Transport Mode User

(Source: JICA Study Team)

Figure 2.49 shows the reasons why the car users and motorcycle users do not use public transport (bus). Inconvenience of the public transport (bus) was raised as a primary reason, followed by longer travel time.

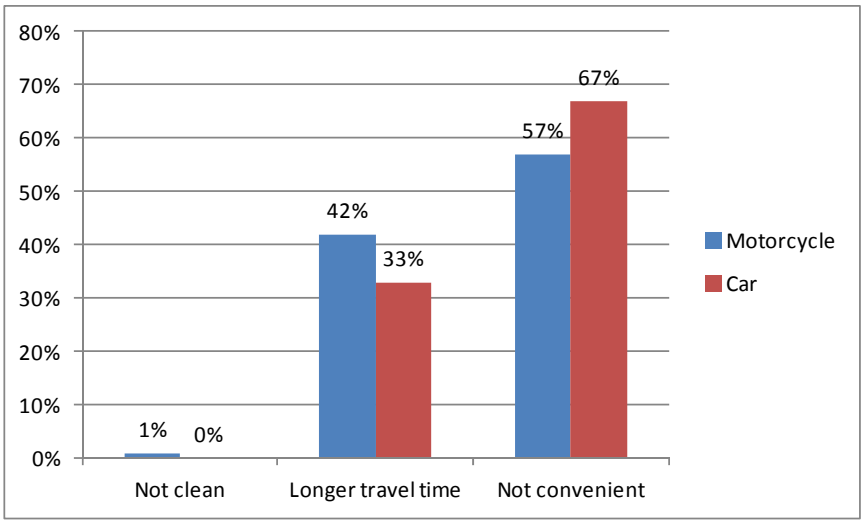


Figure 2.49 Reasons of Not Using Public Transport (Bus)

(Source: JICA Study Team)

Improvement of these two aspects is considered to encourage modal shift to bus. Other major concerns of bus users were found as follows:

- Congestion in the bus
- Long waiting time at bus stop
- No information at bus stop, e.g. bus route, arrival time, bus fare information, and etc.
- Bad driving manner of bus driver
- Long and unclear travelling time on bus
- Expensive fare
- Inconvenience of transfer / connection to other transport mode

(4) Issues and Solutions

(a) Traffic Problems and Solutions

The survey revealed that almost everyone considers the traffic situation in Bengaluru bad condition, mainly due to congestion. The chart below shows the reasons of the congestion that the users consider, responded by different transport user. Increasing number of vehicles as well as insufficient capacity of roads is considered major causes of congestion by the majority of users. A few users responded too many one ways, bad pavement and traffic manners as other reasons.

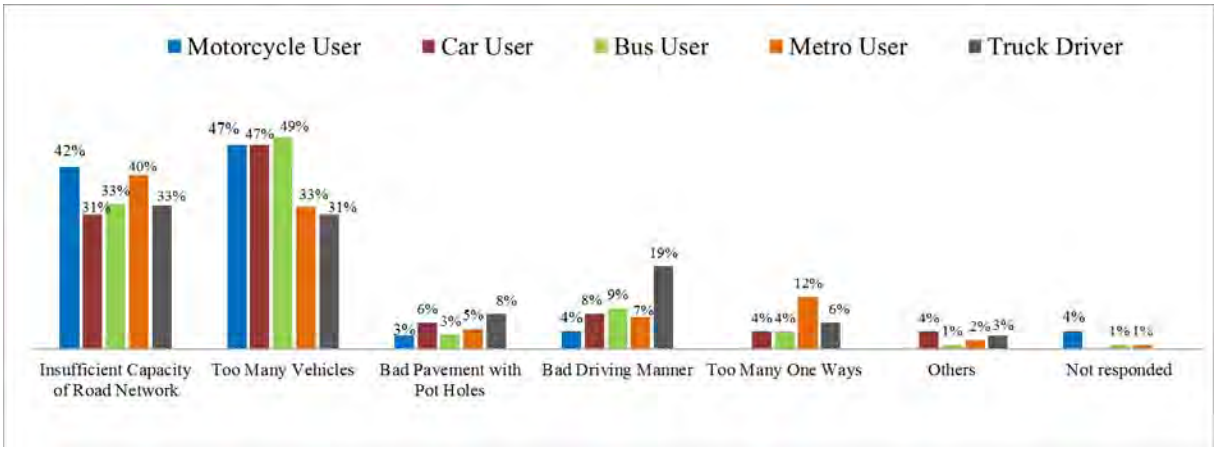


Figure 2.50 Reasons Mentioned for Bengaluru Congestion

Note (1): Others includes humps, traffic accidents, jaywalking and roadside parking.

Note (2): The users were requested to select one item for which they consider mostly causing congestion.

(Source: JICA Study Team)

Six different solutions for improvement of traffic problems were questioned. The users were requested to choose; (i)Very Necessary, (ii)Necessary, (iii)Maybe, (iv)Not Necessary or (v) Don't Know. 'Very Necessary' and 'Necessary' can be considered positive answer. The questioned solutions are:

- Construction of flyover at junction
- Provision of real time traffic congestion information
- Improvement of bus and metro services
- Strict enforcement of traffic rules
- Traffic signal improvement
- Provision of traffic congestion information and route guidance

The answers of users of all transport modes were found similar. The figures below show the results of the answers of car users and truck drivers.

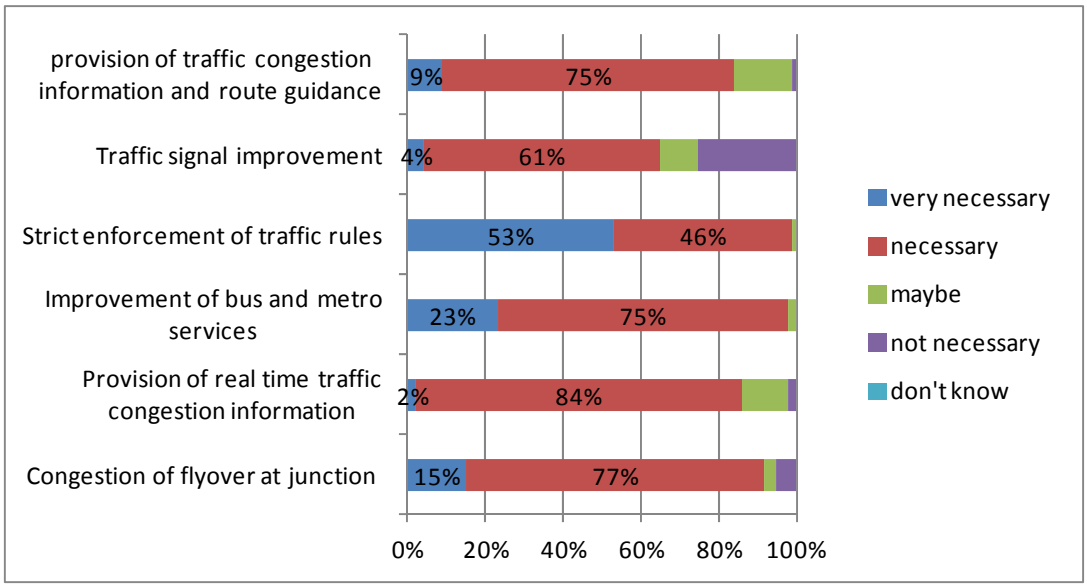


Figure 2.51 Opinions on Solution for Traffic Problems by Car Users

(Source: JICA Study Team)

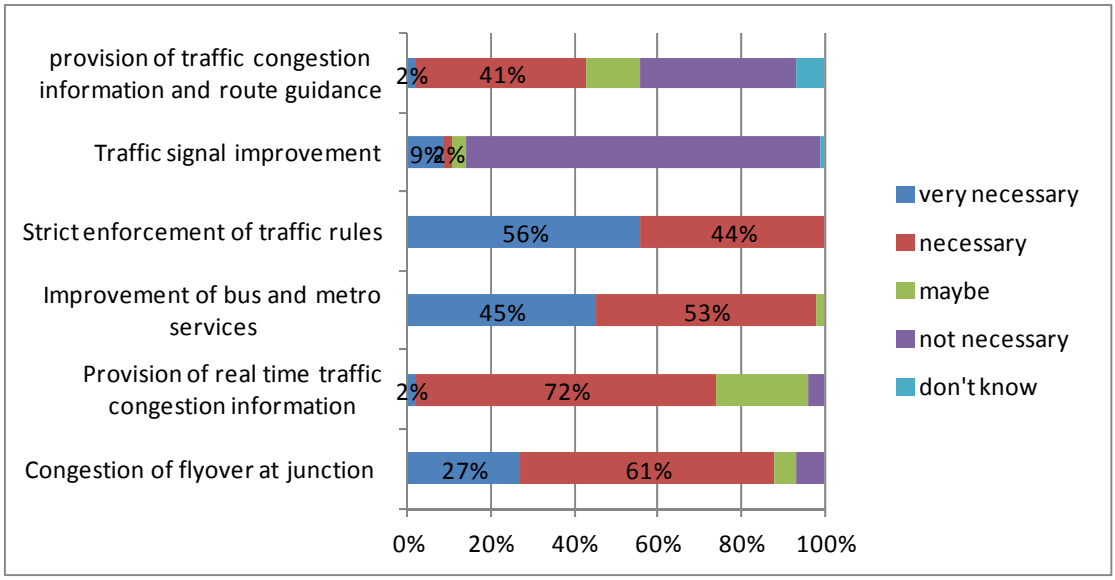


Figure 2.52 Opinions on Solution for Traffic Problems by Truck Drivers

(Source: JICA Study Team)

The majority of users opined ‘strict enforcement of traffic rules’ as mostly required solution, followed by ‘improvement of bus and metro service’ and ‘construction of flyover at junction’. ‘Provision of traffic congestion information and route guidance’ and ‘provision of realtime traffic congestion information’ were also considered required solutions by many users.

(5) Fare Payment Method and Connection Facility of Public Transport

A smartcard which can be used for metro (not for other transport) is available in Bengaluru. Transfer facilities between different transport modes are not sufficiently developed in Bengaluru yet. Considering such situation, the necessity of the following items was questioned:

- Introduction of smartcard commonly used amongst different transport modes
- Transfer facilities between metro and bus/auto rickshaw
- Park and ride facility

All these were highly necessitated by the users. In particular, majority of users opined that the common smartcard was greatly in need.

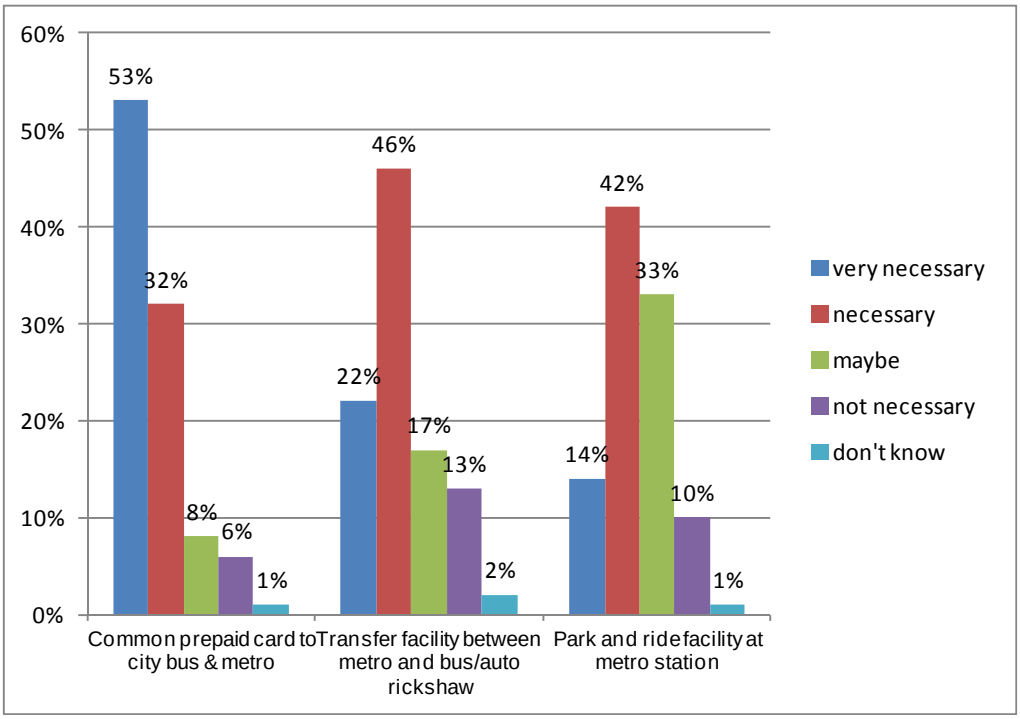


Figure 2.53 Opinions on Fare Payment Method and Connection Facility

(Source: JICA Study Team)

(6) Required Traffic Information

The opinions on the required real time traffic information were interviewed to the motorcycle and car users. The following real time information was asked whether they are (i)Very Helpful, (ii)Helpful, (iii) Not Helpful, or (iv) Don't know:

- Congestion Location,

- Length of Congestion,
- Expected Travel Time to Destination,
- Alternative Route, and
- Traffic Incident

The figure below shows the percentage of motorcycle and car users who answered 'very helpful' on each information category.

The results of the motorcycle and car users were more or less similar. Both users answered that they needed two major kinds of information i.e. information on congested locations and alternative route.

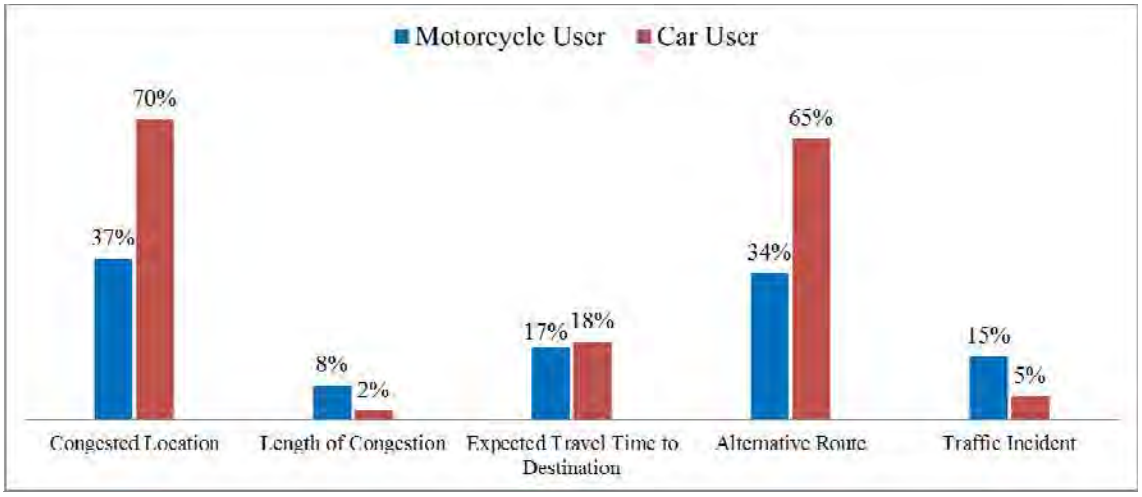


Figure 2.54 Opinions on Fare Payment Method and Connection Facility

Note: The figure shows the percentage of the users who answered 'very helpful' on each item.

(Source: JICA Study Team)

(7) Opinions on Congestion Pricing

The opinions on congestion pricing were also asked. It revealed as follows:

Table 2.33 Response of All Users to Congestion Pricing

Mode	Yes	No	Don't Know
Bus	100% (Private Vehicles)	0%	0%
Metro	79% (Private Vehicles)	19%	2%
Motorcycle	46%	46%	8%
Car	46%	49%	5%
Truck	1%	99%	0%

(Source: JICA Study Team)

The amount of congestion pricing was selected by those users of motorcycle and car who responded positively as shown below.

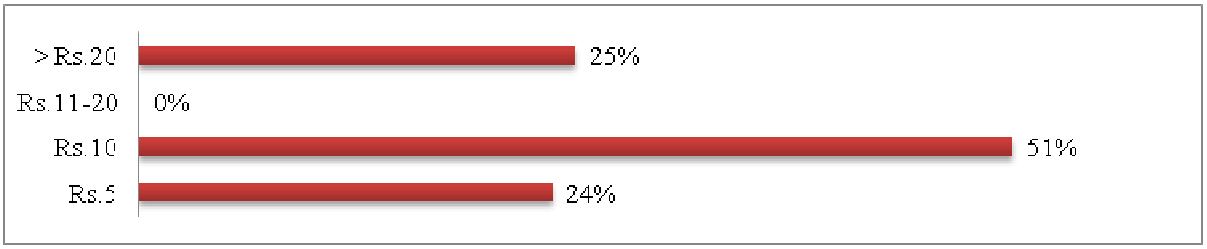


Figure 2.55 Response of Motorcycle Users to Congestion Pricing

(Source: JICA Study Team)

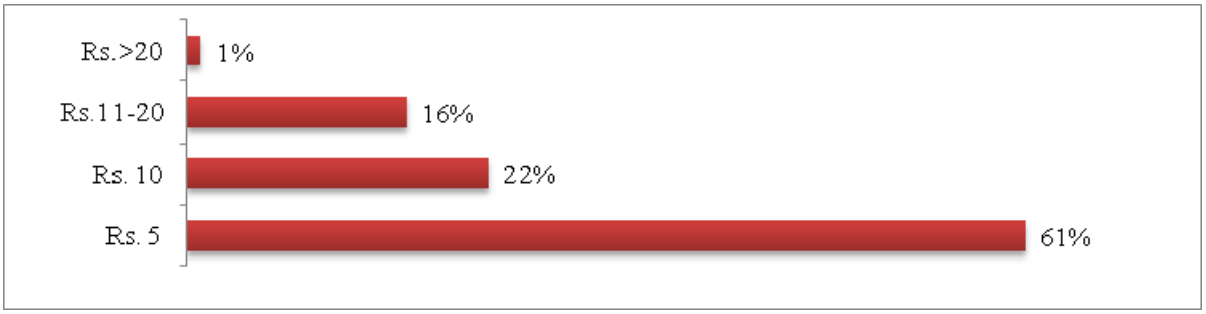


Figure 2.56 Response of Car Users to Congestion Pricing

(Source: JICA Study Team)

The questioned prices have not been derived from any studies.

The majority of public transport users responded that it was required to reduce congestion. However, it should be noted that they responded on the condition that the charging be imposed on the private vehicles. Nearly half the users of motorcycle and car responded that congestion charging was required. This implies that people regard the congestion in the city very seriously. However it should be noted that the responded prices were low.

2.1.8 Summary of Identified Issues in Bengaluru

According to the studies so far, the issues in Bengaluru are identified and summarised in the Table 2.34.

Table 2.34 Identified Issues in Bengaluru

Category	Issues \ Sources	CTTP	CTTS	Opinion Survey	Other Sources ※1	Observed by JICA Study Team※2
Road Traffic	High proportion of motorcycle and auto rickshaw	●	●			
	Chronic traffic congestion	●	●	●	●	
	A large number of accidents		●		●	
	Increasing air pollution and noise	●			●	
Road Infrastructure	Complex road network due to many roads converted for one-way driving					●
	Insufficient road infrastructure to accommodate traffic demand	●		●		
	Deteriorated road surface conditions such as Ill-paved , speed breakers, unclear lane markings		●		●	
	On road parking occupying road spaces	●	●			
	Limited off road parking facilities	●	●			
	Water logging when it rains				●	
	Absence of vulnerable-friendly spaces such as separate sidewalks, crash barriers, slopes, narrow space of footpath etc	●	●		●	
	Limited bicycle ways	●				
Public Transport	Inefficient connectivity between different transport modes			●		
	Many ground-level railway crossings blocking road traffic				●	
	Insufficient information of the public transport			●		
	Improper location of bus stops					●
	Poor condition of public bus				●	
	Inconvenience to purchase ticket due to lack of efficient ticketing system					●
	Consequently high demand of road traffic	●				
Traffic Manner	Lack of traffic discipline			●	●	
	Lack of awareness of importance of traffic discipline		●	●	●	
Facilities	Number of broken roadside facilities				●	
	Absence of systems and data to support traffic and road management					●
	Absence of asset management					●
	Absence of sufficient traffic information			●		
	Inefficient toll payment system resulting in frequent long queue of vehicles					●

Category	Issues / Sources	CTTP	CTTS	Opinion Survey	Other Sources ※1	Observed by JICA Study Team※2
Management and Coordination	Uncoordinated manner amongst concerned agencies for infrastructure planning, traffic management and road management		●			
	Haphazard road works and planning due to above		●			
	Complex administrative structure of facility management through procurement, installation, operation and management		●			
	Unclear responsibility amongst involved agencies due to above		●			
	Inconsistent operation and maintenance due to above		●			
	Lack of sufficient engineering expertise and knowledge and capacity building opportunities			●		

※1 : Information and materials that have been obtained by JICA Study Team, other than sources listed above. News articles are also included.

※2 : Observations by JICA Study Team on the items which are not covered by above listed sources.

(Source: JICA Study Team)

2.2 Policy for ITS for Bengaluru Metropolitan Area

2.2.1 Visions of ITS Master Plan

Based on the studies so far, ITS Master Plan for Bengaluru Metropolitan Area sets out its vision as stated below.

- **Enhance quality of life by utilising latest technologies to deliver convenience and comfort of mobility**
- **Optimize efficiency to achieve sustainable urban growth and greater productivity**
- **Achieve greater travel efficiency and safety in harmony with environment**

(1) Goals of ITS for Bengaluru

Under the visions of ITS for Bengaluru, the goals are set out to be achieved. They are accessibility, efficiency, safety and reduced environmental impact as shown in Table 2.35 below.

Table 2.35 Goals of ITS

Goal	Description
Accessibility	To reduce travel time and cost To provide travel/traffic information To support vulnerable people
Efficiency	To enhance road/traffic management To enhance intermodal connectivity To enhance efficiency of road use
Safety	To reduce traffic accidents To enhance response for emergency To enhance pedestrian facilities
Environment and Energy	To reduce air pollution To reduce CO_2 emissions To reduce energy consumption

(Source: JICA Study Team)

2.2.2 Strategies and ITS Components

(1) Strategies

In order to achieve the goals, the following 9 strategies shall be executed in Bengaluru metropolitan area.

(a) Quantitative Data Collection, Analysis, Storage and Provision

A mechanism which enables to collect real time traffic data, analyse the data, generate and provide dynamic traffic information to road users, store and utilise the data for measures on urban transport such as traffic management, road network planning, etc. shall be put in place. The real time traffic data includes traffic conditions such as traffic volume, travel time, occupancy by section, etc.

(b) Integration and Utilisation of Data and Information Available in Various Sources

A mechanism which enables to collect, integrate, utilise and share data and information available in various sources shall be put in place. The examples of sources include roadside equipment, traffic administrator such as traffic police, road administrators, public transport operators, etc. Such information which is available in the individual entities shall be integrated and made use of.

(c) Centrally Coordinated Administrative Structure to Realise Proper Coordination

A mechanism which enables sufficient central coordination amongst the involved agencies shall be put in place. Taking measures for urban transport such as improvement of road infrastructures, public transport and traffic management shall be considered together with ITS. For example, the data collected by different agencies needs to be made available and utilised in a unified manner so that coordinated and integrated measures for urban transport are realised. A centrally coordinated body shall be responsible for this. It is important to incorporate diverse set of the involved agencies into decision making process on urban transport together with collaborated ITS initiatives under such body.

(d) Proper Decision Making on Urban Transport

A mechanism which enables proper decision making on measures for urban transport shall be put in place. For example, a result of historical analysis of congested locations, accident prone spots could be used for improvement of road infrastructure. Making policies for short, mid and long term on urban transport shall be reasonably made based on objective data and facts. This is important in terms of accountability to public as well.

(e) Proper Traffic Control and Management

A mechanism which enables to properly control traffic shall be put in place. For example, the road traffic needs to be controlled according to the traffic condition which continuously changes. In order to realise this, for example, facilities such as dynamic real time traffic monitoring and advanced traffic signal system are important.

(f) Proper Road Management

A mechanism which enables proper road management shall be put in place. Major bottleneck on road network needs to be quantitatively comprehended by traffic volume and travel speed. Necessary actions such as improvement of road network, construction and maintenance need to be taken.

(g) Traffic Demand Management

A mechanism shall be in place to control traffic demand by discouraging usage of vehicles such as imposing congestion charges, higher parking fee, and encouraging flex time for commuters and etc.

(h) Efficient Public Transport Connectivity

A mechanism which enables shift from private mode to public transport shall be put in place. Strong incentives of people are required by enhancing convenience of public transport. In order to achieve this, the connectivity barriers such as between feeder line, trunk line or other modes of transport need to be improved and properly managed.

(i) ITS Promotion and Coordination with ITS National Policy

A mechanism which enables continuous ITS promotion and coordination with ITS National Policy shall be put in place. ITS is not one-time implementation. Once it is deployed, it needs to be sustainably operated and maintained. It shall then be evaluated and planned further in accordance with advancement of technology and changes of traffic conditions as time goes on. Further, it is preferable that the regional ITS is planned/implemented under the framework of National ITS Policy. Although a concrete policy of such kind has yet been in existence in India, coordination will be required with the Government of India in the near future.

(2) ITS Focus Area and ITS Component for Strategies

For the strategies set out in the previous clause, ITS measures and administrative measures such as setting up required organisations need to be taken together with. This clause considers in viewpoint of ITS measures.

In order to execute the strategies, ITS focus areas are defined. ITS Components to realise the ITS focus areas are then identified as shown in Table 2.36.

Table 2.36 ITS Components by ITS Focus Areas

ITS Focus Area	ITS Component (*1)
1) Collecting Quantitative and Effective Information for Traffic	Traffic Data Collection System Highway Traffic Management System
2) Assisting Implementation of Traffic Management	Traffic Data Collection System Traffic Condition Monitoring System Traffic Information Provision System Traffic Accident Management System Parking Management System Area Traffic Signal Control System Electronic Road Pricing System Highway Traffic Management System
3) Assisting Urban Transport and Road Planning	Traffic Data Collection System Traffic Condition Monitoring System Traffic Accident Management System Highway Traffic Management System
4) Assisting Parking Efficiency and Planning	Traffic Data Collection System Parking Management System
5) Assisting Measures on Traffic Accident and Safety	Traffic Condition Monitoring System Traffic Accident Management System Highway Traffic Management System Overloaded Vehicle Monitoring System
6) Assisting Smooth Traffic Flow	Parking Management System Traffic Information Provision System Area Traffic Signal Control System Electronic Road Pricing System Toll Management System
7) Assisting Traffic Enforcement	Traffic Regulation Violation Enforcement System Overloaded Vehicle Monitoring System
8) Assisting Road Management Work	Road Inventory System
9) Providing Pre-Trip and En-Route Road Traffic Information to Road Users	Parking Management System Traffic Information Provision System
10) Assisting Inter-modal Connectivity	Common Smartcard System Passenger Information Provision System
11) Providing Information on Public Transport	Passenger Information Provision System
12) Assisting Vulnerable Road Users	Safety Assistance System for Vulnerable Road Users
13) Assisting Commercial Activities	Traffic Information Provision System Area Traffic Signal Control System Commercial Vehicle Management System
14) Assisting Emergency Vehicle Activities	Area Traffic Signal Control System
15) Assisting Efficiency in Public Transport Operation	Public Transport Operation Management System Public Transport Fare Payment System Common Smartcard System

Note (*1): There are a number of ITS components to realise ITS focus area other than listed above. The ITS components which can contribute more directly to the ITS focus are listed.

(Source: JICA Study Team)

(3) Outline of ITS Component and Current Situation in Bengaluru

The outline of the ITS Components listed in Table 2.36 on the previous page and their current situations in Bengaluru are summarised in Table 2.37.

Table 2.37 Outline of ITS Component and Current Situation

	ITS Component	Outline and Current Situation in Bengaluru
A	Traffic Data Collection System	**1) Outline** This system is for collecting quantitative data on traffic. The system comprises “Probe Car Based Traffic Monitoring System” and “Traffic Volume Measurement System”.
		2) Current Situation in Bengaluru • Probe Car Based Traffic Monitoring System City Bus Company, BMTC, is planning to introduce bus location system, installing GPS devices on 6,700 city buses. They initiated a pilot, installing GPS devices on 220 buses. The collected probe data will be used for the purpose of bus location system of BMTC. However, utilisation of probe data for providing traffic information is not planned in Bengaluru. • Traffic Volume Measurement System The system that quantitatively measures traffic volume does not exist nor is planned in Bengaluru.
B	Traffic Condition Monitoring System	**1) Outline** This system is for monitoring traffic condition by image at traffic control centre. It uses CCTV camera.
		2) Current Situation in Bengaluru The traffic condition is monitored by Bangalore Traffic Police. They monitor the condition at junctions by 179 CCTV cameras in Bengaluru.

	ITS Component	Outline and Current Situation in Bengaluru
C	Traffic Information Provision System	**1) Outline** This system is for disseminating dynamic traffic information to road users. The dynamic traffic information is generated by real time traffic data. The information is disseminated through such media as Variable Message Sing Board (VMS), Internet, SMS, and etc.
		2) Current Situation in Bengaluru Such system does not exist nor is planned in Bengaluru. The traffic information is provided by VMS and Internet by Bangalore Traffic Police. However, the provided information is limited to static messages such as warning for using seat belt.
D	Traffic Accident Management System	**1) Outline** This system is for managing traffic accident information and data. The system comprises data base, user interface, retrieving/statistic functions, and etc.
		2) Current Situation in Bengaluru The traffic accident is manually recoded by Bangalore Traffic Police. The introduction of the system is planned by Bangalore Traffic Police.
E	Parking Management System	**1) Outline** This system is for managing parking and providing parking availability information. The system comprises parking payment system, parking sensors, database, Variable Message Sign Board/Internet and etc.
		2) Current Situation in Bengaluru Development of parking and introduction of parking management system in Bengaluru are under consideration by DULT.

	ITS Component	Outline and Current Situation in Bengaluru
F	Electronic Road Pricing System (ERP)	**1) Outline** This system is for congestion charging which charges vehicles incoming to specific area during peak hours. It aims to reduce congestion and encourage using public transport as one of measures of traffic demand management. The system comprises roadside antenna, onboard unit/Tag on vehicle for charging, cameras for enforcement, centre system, and etc.
		2) Current Situation in Bengaluru The implementation of congestion charging using ERP is under consideration by DULT.
G	Area Traffic Signal Control System	**1) Outline** This system is for optimising signal phase in area wise according to traffic condition to realise smooth traffic flow. It also assists smooth pass of emergency vehicle. The system comprises roadside sensors, traffic signal, centre system, and etc
		2) Current Situation in Bengaluru The existing signals in Bengaluru are manually controlled. The area traffic signal control is not planned.
H	Traffic Regulation Violation Enforcement System	**1) Outline** This system is for enforcing violation of traffic regulation. Major examples are speed violation enforcement system, signal violation enforcement system, and etc. The speed violation enforcement system detects over-speeding. The signal violation enforcement system detects red-signal violation at junction.
		2) Current Situation in Bengaluru The over speed enforcement is implemented by Bangalore Traffic Police, using mobile laser gun. The red-signal violation enforcement is implemented by Bangalore Traffic Police, using the signal violation enforcement system installed at junctions in Bengaluru.

	ITS Component	Outline and Current Situation in Bengaluru
I	Overloaded Vehicle Monitoring System	**1) Outline** This system is for measuring weight of large sized vehicle for enforcement of overloading. There are generally two types of measurement; axle weight measurement and vehicle weight measurement. The system comprises weight measurement sensors, CCTV camera, functions for recording the measured weight/overloaded vehicle information, and etc.
		2) Current Situation in Bengaluru The axle weight measurement system is operated at the border of Bengaluru metropolitan area by DOT.
J	Road Inventory System	**1) Outline** This system is for managing road. The road inventory information, generally by road section, is recorded in the system and used for road management. The road inventory information includes road width, number of lane, design speed, completed/planned road work, and etc. The system comprises road inventory database, user interface, retrieving/statistic functions, and etc.
		2) Current Situation in Bengaluru The development of the road inventory system is planned by BBMP.
K	Highway Traffic Management System for PRR	**1) Outline** This system is for managing traffic on highway. It is mainly composed of the components for information/data collection, processing and provision. These components comprise various systems. The information/data collection includes traffic volume measurement system, traffic condition monitoring system such as CCTV, weather monitoring system, and etc. The collected data/information is processed at traffic control centre. The information provision system includes variable message sign board, Internet, and etc.

	ITS Component	Outline and Current Situation in Bengaluru
		2) Current Situation in Bengaluru Construction of Peripheral Ring Road is planned in Bengaluru. The highway traffic management system on Peripheral Ring Road is planned to introduce.
L	Toll Management System for PRR	**1) Outline** This system is for collecting and managing toll on highway. It mainly comprises manual toll collection, Touch & Go (T&G) and Electronic Toll Collection (ETC). Touch & Go collects toll by touching card. ETC automatically collects toll by communication between roadside antenna and onboard unit in vehicle without stop at gate.
		2) Current Situation in Bengaluru Construction of Peripheral Ring Road is planned in Bengaluru. The toll management system on Peripheral Ring Road is planned to introduce.
M	Public Transport Operation Management System	**1) Outline** This system is for assisting efficiency in operation of public transport as metro and bus. The system comprises control centre, various managing functions and etc.
		2) Current Situation in Bengaluru The metro operation system has been developed in Bengaluru and is operated by BMRCL. The bus operation system is planned to introduce by BMTC.

	ITS Component	Outline and Current Situation in Bengaluru
N	Public Transport Fare Payment System	**1) Outline** This system is for collecting and managing public transport fare. It comprises ticketing machine/device, fare collection database, management functions, and etc. The payment is made by paper ticket issued by the system, token, smartcard and etc.
		2) Current Situation in Bengaluru The fare payment system of Bangalore Metro is operated by BMRCL. The fare is paid by token and smartcard. The fare payment system of city bus is planned to introduce by BMTC. The fare will be paid by paper ticket with handy terminal device.
O	Passenger Information Provision System	**1) Outline** This system is for providing information of public transport to passengers. The information to be provided includes operation status of the public transport, route, expected arrival time, and etc.
		2) Current Situation in Bengaluru The passenger information provision system of Bangalore Metro is operated by BMRCL. The operation status and expected arrival time is provided by variable information board installed on the platform of all metro stations. The passenger information provision system of city bus is planned to introduce by BMTC. The information will be provided by variable message sign board at bus terminals and Internet.
P	Common Smartcard System	**1) Outline** This system is for enhancing convenience of public transport use by smart card which can be commonly used for different transport mode. The transactions across different transport modes is calculated and settled by clearing house according to usage. The system comprises smart card, card reader, card management system, clearing house, and etc.

	ITS Component	Outline and Current Situation in Bengaluru
		2) Current Situation in Bengaluru The smartcard for fare payment of Bangalore Metro has been initiated by BMRCL. The introduction of the smartcard for fare payment of city bus is planned by BMCT. The common smartcard which can be used for both Bangalore Metro and city bus is under consideration by these public transport operators. However current concept is limited to the usage between Bangalore metro and city bus. More holistic consideration of the common smartcard with which other transport and services can use is required.
Q	Safety Assistance System for Vulnerable Road Users	**1) Outline** This system is for assisting safety and convenience for vulnerable road users. Major examples are warning system and walking route guidance system. The warning system alerts the driver in vehicle on existence of pedestrian or bicycle standing/passing behind the corner to avoid hitting. The walking route guidance system provides safe and shortest route to the destination to the pedestrian.
		2) Current Situation in Bengaluru The major car manufactures started embedding the warning system in cars in the world nowadays. The walking route guidance system on Internet or smart phone is increasingly available in the developed countries. However none of these are available yet in Bengaluru.
R	Commercial Vehicle Management System	**1) Outline** This system is for assisting operation of commercial vehicle for improving efficiency. It monitors the locations and operation of the vehicle and manages their operations. The system comprises GPS devices on vehicle, control centre together with various functions for operation, and etc.
		2) Current Situation in Bengaluru The commercial vehicle management systems are operated by various private companies such as taxi, logistic service company, and etc.

(Source: JICA Study team)

(4) ITS Component for ITS Master Plan for Bengaluru Metropolitan Area

ITS Components to be planned in detail by ITS Master Plan for Bengaluru Metropolitan Area are selected by consideration shown in Table 2.38.

Their current situations in Bengaluru summarised by the previous clauses are considered as well.

Table 2.38 ITS Component for ITS Master Plan for Bengaluru Metropolitan Area

	Consideration for Selection	**A) Traffic Data Collection System**	B) Traffic Condition Monitoring System	**C) Traffic Information Provision System**	D) Traffic Accident Management System	E) Parking Management System	**F) Electronic Road Pricing System**	**G) Area Traffic Signal Control System**	H) Traffic Regulation Violation Enforcement System	I) Overloaded Vehicle Monitoring System	J) Road Inventory System	**K) Highway Traffic Management System for PRR**	**L) Toll Management System for PRR**	M) Public Transport Operation Management System	N) Public Transport Fare Payment System	O) Passenger Information Provision System	**P) Common Smartcard System**	Q) Safety Assistance System for Vulnerable Road Users	R) Commercial Vehicle Management System	Remarks
Reasons to Be Selected	Systems which collect quantitative data on traffic condition	●					●					●	●	●					●		
	Systems which significantly improve traffic flow			●			●	●													F), G): Contribute to improvement of traffic flow more directly than other systems.
	Sytems which require a centre to operate but the centre does not currently exist	●		●		●	●					●	●					●	●		A), C): Requires a centre for quantitative data collection and dynamic information provision. Others: Require separate centres.
	Systems which provide dynamic information on traffic condition			●								●									C), K): Systems to provide dynamic traffic information.
	Systems which ehnance convenience and reliability in time for users			●		●		●				●	●				●	●			C), K): Assist users to avoid congested route/time. G), L): Increase travel spped. O), P): Enhance convenience for public transport users.
	Systems which can be implemented at early stage	●	●	●	●			●	●	●	●			●	●	●	●		●		All Marked Systems: Do not require a large scale infrastructure development. B), D), G), H): To be operated by existing control centre of Traffic Police. M), N), O): Initiated by BMTC and BMRCL. R): Initiated by private companies.
Reasons Not to Be Selected	Systems which are already implemented by agencies		●	●					●	●				●	●	●				●	B), C), H): Implemented by Traffic Police I): Implemented by Department of Transport. M), N), O): Implemented by BMRCL R): Implemented by private companies.
	Systems which are planned by agencies				●	●					●			●	●	●	●				D): Planned by Traffic Police. E): Planned by DULT. J): Planned by BBMT. M), N), O): Planned by BMTC P): Planned by BMTC
	Systems which require a large scale infrastructure development					●						●	●								E): Requires development of parking lot. K), L): Require construction of Pripheral Ring Road.
	Systems which are generally implemented by private sector																		●	●	
	Selected ITS Component	◎		◎			◎	◎				◎	◎				◎				**ITS components selected for ITS Master Plan are highlighted above**

(Source: JICA Study Team)

2.2.3 Phasing Policy of ITS Master Plan

Amongst the selected ITS components, some of them can be implemented in short period. Others require longer period for development. For example, Traffic Data Collection System and Area Traffic Control System can be implemented in early stage because they do not require a large scale infrastructure development. On the other hand, Peripheral Ring Road (PRR) needs to be constructed before Highway Traffic Management System (HTMS) and Toll Management System (TMS) for PRR are introduced.

In addition, advancement of information technology is significantly rapid in nature.

In consideration of such aspects, phased development policies are set out in three phases for five years respectively as shown in the Table 2.39.

Table 2.39 Phased Development Policy

Phases	Year	Policies
Phase-1	2015 - 2019 (1-5 Years)	• To develop ITS components which can be implemented in short period • To start operation of above ITS components • To start preparation of ITS components which require a relatively long period for development
Phase-2	2020 - 2024 (6-10 Years)	• To expand and upgrade ITS components which are implemented in Phase-1 • To start operation of ITS components which started preparation in Phase-1
Phase-3	2025 - (After 10 years)	• To upgrade functions, adopting new technologies

(Source: JICA Study Team)

<Phase-1>

It is recommended that vehicle registration is improved and vehicle number plate is standardised during this period in order for ITS components which start operation in Phase-1 to properly function.

<Phase-2>

Major events in transport sector in Bengaluru are expected in this period. They are: (i) completion of construction of Peripheral Ring Road in 2021, (ii) completion of construction of metro network for Phase II in 2020, and (iii) other infrastructure improvements such as elevated road, flyover construction, etc. Therefore, the coverage area of the ITS components introduced in the Phase-1 will be expanded. The ITS components for PRR will also be introduced.

<Phase-3>

A number of new technologies which do not exist as of 2015 are expected to be available in this period. The traffic conditions will also be different after completion of major public transport network, expressways and others, coupled with continuous urbanisation.

Hence, reviewing the traffic conditions and introduced systems, and revising plans adopting newly available technologies will be required in this phase.

2.2.4 Implementation Schedule of ITS for Bengaluru Metropolitan Area

Based on considerations in this chapter, ITS implementation schedule for the selected ITS components is set out in the Table 2.40.

Table 2.40 Implementation Schedule of ITS for Bengaluru Metropolitan Area

Technical Prerequisite for ITS and Major Event		Phase-1 2015	2016	2017	2018	2019	Phase-2 2020	2021	2022	2023	2024	Phase-3 2025	Remark
Technical Recommendation	Improvement of Vehicle Registration												Recommended for vehicle registration implementation by mid of 2018
	Standardisation of Vehicle Number Plate												Recommended for vehicle number plate implementation by mid of 2018
Major Event Related to ITS	Pripheral Ring Road (PRR)												Preparation process includes land acquisition, civil work, and etc.
	Bengaluru Metro		▲ Completion of Phase-1				▲ Completion of Phase-2						
	ITS Master Plan		▲ Approval of ITS Master Plan				▲ Revising ITS Master			▲ Revising ITS Master			Revising ITS Master Plan is recommended.

Selected ITS Components		Phase-1 2015	2016	2017	2018	2019	Phase-2 2020	2021	2022	2023	2024	Phase-3 2025	Remark
Bengaluru Traffic Information System	Traffic Data Collection System		(Expansion)										- It will be prepared as a component of Bengaluru Traffic Information System. - The coverage area will be expanded in expansion stage.
	Traffic Information Provision System		(Expansion)										- It will be prepared as a component of Bengaluru Traffic Information System. - The coverage area will be expanded in expansion stage.
Traffic Management System (Existing)	Area Traffic Signal Control System		(First Expansion)		(Second Expansion)								- The area control signals will be installed in 3 stages. - They will be prepared under existing Traffic Management System of Bengaluru Traffic Police.
ITS for Peripheral Ring Road	Highway Trafic Management System (HTMS)												- HTMS will be prepared for Peripheral Ring Road. - The operation of HTMS will start at the time of commencement of service of Peripheral Ring Road.
	Toll Management System (TMS)												- TMS will be prepraed for Peripheral Ring Road. - The operation of TMS will start at the time of commencement of service of Peripheral Ring Road.
Electronic Road Pricing System													- ERP will be prepared for CBD area. - The operation of ERP will start at the time of commencement of area charging at CBD.
Parking Management System													The development of parking lots are required before system installation.
Common Smartcard System													The service of Common Smartcard System will start before completion of Metro phase-2.

: Prepration (Design, Procurement, Installation, etc.)

: Operation

Note: (*1), (*2), (*3) : Explained on the next page.

(Source: JICA Study Team)

Note:

*1) Traffic Data Collection System and Traffic Information Provision System which are proposed in Table 2.40, will be prepared as components of Bengaluru Traffic Information System. It will be newly prepared and functions as a single central body for collection of data on traffic, processing and provision of dynamic traffic information to road users. The details are explained in the following chapters.

*2) Traffic management in Bengaluru is the responsibility of Bangalore Traffic Police. The Traffic signals are operated by Bangalore Traffic Police as part of their existing traffic management system called “B-TRAC”. Area Traffic Signal Control System is proposed to prepare under the existing traffic management system of B-TRAC.

*3) The Peripheral Ring Road (PRR) is a semi-circle road surrounding Bengaluru planned by road planning authority, BDA. PRR is expected to be completed by 2020. Highway Traffic Management System (HTMS) and Toll Management System (TMS) which are proposed in Table 2.40 will be prepared as ITS for PRR.