REPUBLIC OF INDIA
TAMIL NADU INFRASTRUCTURE DEVELOPMENT BOARD
GOVERNMENT OF TAMIL NADU

DATA COLLECTION SURVEY

FOR

CHENNAI METROPOLITAN REGION

INTELLIGENT TRANSPORT SYSTEMS

FINAL REPORT

January 2017

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)

JICA STUDY TEAM Consisting of

NIPPON KOEI CO., LTD.
EAST NIPPON EXPRESSWAY CO., LTD.

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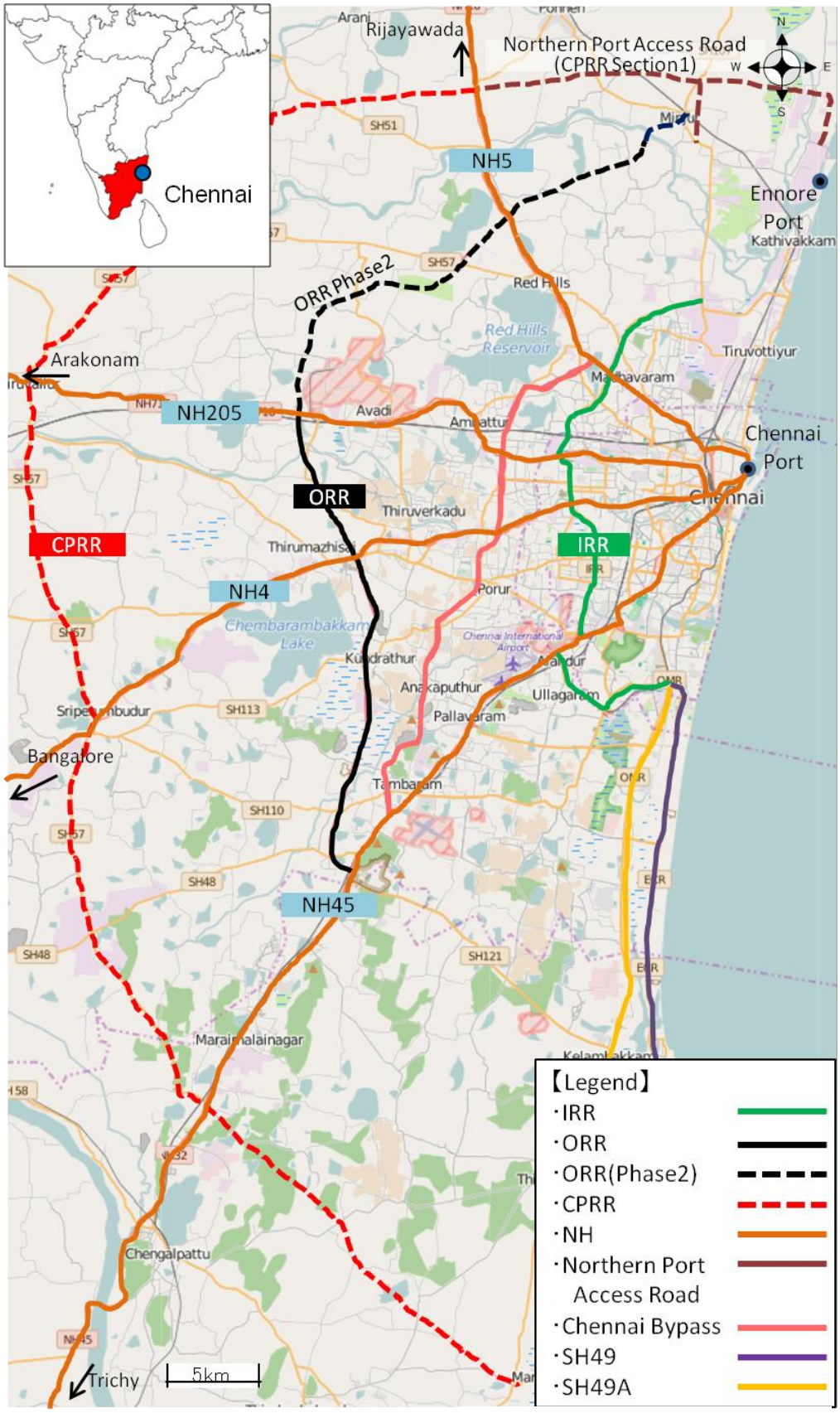

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(Source: JICA Study Team)

Location Map

Summary

1 Study Background

India has undergone rapid urbanization in recent years. However the transportation infrastructure has not developed sufficiently to keep pace. In Chennai Metropolitan Area including the areas of neighboring local governments of Chennai City, the population has been increased from approximately 6,560,000 in 2001 to approximately 8,700,000 in 2011 (Ranked 4th in India: Census 2011). Vehicle traffic in the city is continuously increasing and the chronic traffic congestion has become a serious issue. Chennai Peripheral Ring Road is planned to address the increasing traffic demand in the future. The introduction of Intelligent Transport Systems (referred to as ITS hereinafter) to promote use of Chennai Peripheral Ring Road and to assist to alleviate the chronic congestion in the city has been under consideration.

The Construction of Chennai Peripheral Ring Road is planned. However as to ITS, the basic policy of comprehensive development of ITS in Chennai metropolitan area has not yet been formulated since ITS consists a variety of components. Therefore, this Study, 'Data Collection Survey for Chennai Metropolitan Region ITS', collects the necessary information and formulates the basic policy (draft) for the development of ITS in Chennai Metropolitan Area.

2 Study Outline

The outline of the Study is summarised below.

Table I Study Outline

Item	***Details***
Study Name	*Data Collection Survey for Chennai Metropolitan Region ITS*
Study Period	*From January 2016 to February 2017*
Study Objective	*To collect data/information necessary for setting out the basic policy for development of ITS (City ITS and ITS for Chennai Peripheral Ring Road)* *To formulate the basic policy (draft) for development of ITS in Chennai Metropolitan Area in the state of Tamil Nadu*
Study Area	*Chennai Metropolitan Area in Tamil Nadu, India*
Relevant Authorities	*Highways & Minor Ports Department of Tamil Nadu* *Tamil Nadu Infrastructure Development Board* *Other related organizations in transport sector in Chennai Metropolitan Area*

(Source: JICA Study Team)

3 General Overview of Chennai Metropolitan Area

Chennai is the capital city of Tamil Nadu and is located along Coromandel Coast of Bay of Bengal in the north east of Tamil Nadu state. The region is called 'Gateway in South India' and there are two major ports: Chennai port and Ennore port. The Chennai port handles the second largest volume of containers in India after the Jawaharlal Nehru port in Mumbai. The Ennore port is located approximately 15 km north of the Chennai port and it mainly handles bulk materials such as coal and iron ore. The region is also called 'Detroit of South Asia'. There are major automobile manufacturers including BMW, Ford, Renault-Nissan and related companies in the industrial parks in the suburbs such as ORAGADAM and Mahindra World City. There are also a number of Information Technology companies along SH49A in the south and the road is called 'Information Technology corridor'. Chennai has been selected as one of the twenty cities to be developed as a smart city under the Smart City Initiative of Prime Minister Narendra Modi.

4 Related Existing Organizations in Chennai

The existing organizations related to ITS and urban transport sector in Chennai are as listed in the table below.

Table II ITS and Urban Transport Related Organizations

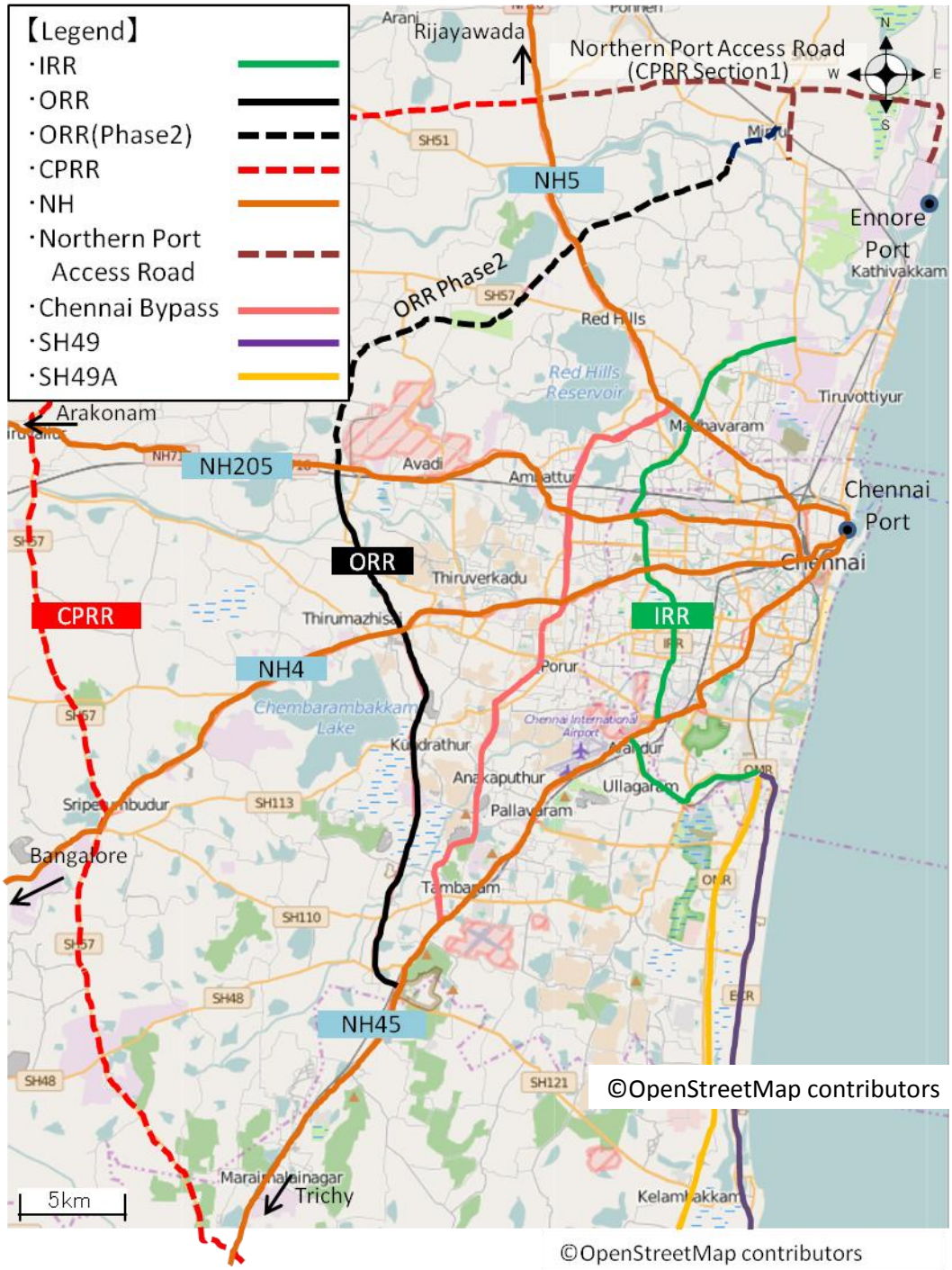
Organization Name	***Function***
Tamil Nadu Infrastructure Development Board (TNIDB)	*Coordination authority to promote the infrastructure development project in Tamil Nadu*
Chennai Traffic Police	*Traffic administrator*
Chennai Metropolitan Development Authority (CMDA)	*Planning authority for urban development and urban transportation in Chennai Metropolitan Area*
Greater Chennai Corporation (GCC)	*City road administrator and in charge of construction and maintenance of associated road facilities in the city*
Tamil Nadu Urban Infrastructure Financial Services Limited (TNUIFSL)	*Authority that manages the donors related to urban infrastructure investment*
Chennai Metro Rail Limited (CMRL)	*Management and operation of Chennai metro rail*
Metropolitan Transport Corporation Ltd. (MTC)	*City bus operator*
State Express Transport Corporation Ltd. (SETC)	*Inter-city bus operator*
Department of Highways & Minor Ports	*In charge of highways including Chennai Peripheral Ring Road and minor ports in Tamil Nadu.*
Tamil Nadu Road Development Company (TNRDC)	*Government corporation for implementation of tolled state highway under Department of Highways & Minor Ports. Implementation agency for Section-1 of Chennai Peripheral Ring Road.*
Tamil Nadu State Transport Authority (TN-STA)	*Management of vehicle safety inspection, vehicle registration and number plates*
Chennai Unified Metropolitan Transport Authority (CUMTA)	*Authority consisting of related organizations in urban transport sector for making decisions and coordination for planning and implementing urban transport measures.*
Tamil Nadu Urban Finance and Infrastructure Development Corporation Ltd (TUFIDCO)	*Governmental corporation for providing financial assistance to implementing agencies such as local municipalities for specific governmental missions including Smart City Mission, Jawaharlal Nehru National Urban Renewal Mission, etc.*
Tamil Nadu State Data Centre (TNSDC)	*Central data centre of Tamil Nadu State government*
Electronics Corporation of Tamil Nadu (ELCOT)	*Implementing agency that manages TNSDC and offers such services as server operation and maintenance.*
National Highways Authority of India (NHAI)	*National highway administrator*
Indian Institute of Technology, Madras & Anna University	*ITS related research and development*
Chennai Smart City Limited	*SPV for Implementation of Smart City Projects*

(Source: JICA Study Team)

5 Road Network in Chennai

Four (4) National Highways which are NH4, NH5, NH45 and NH205 radiate toward Kolkata, Bengaluru, Tiruchirappalli and Madanapalli from Chennai. Three (3) semi-circle ring roads which are Inner Ring Road, Chennai Bypass Road and Outer Ring Road connect the four radial NHs. Section-1 of Outer Ring Road is opened and the section-2 is under construction. Chennai Peripheral Ring Road is planned to build outside the Outer Ring Road. It starts from the Ennore Port at north end and links to major radial roads such as NH5, NH205, NH4, NH45 and SH49 at the south end, with a total length of 133.65 km. It is expected that the connectivity to the Chennai Port and the Ennore Port from the industrial hubs such as ORAGADAM around Chennai will be improved by the completion of the Chennai Peripheral Ring Road.

The major road network is shown on the map below.



(Source: JICA Study Team)

Figure I Major Road Network in Chennai

6 Public Transport in Chennai

The major public transport mode used by people in Chennai is City bus. There are approximately 3,800 city buses with more than 800 bus routes and they cover the major trunk roads except Outer Ring Road and Chennai Bypass. The phase 1 section with a total length of 45.1 km of Chennai Metro is under development. Approximately 55% of the section will be underground and the rest will be

elevated structure. The operation has been commenced on the stretch of approximately 21 km of the elevated section since June in 2015. The phase 2 with a total length of 88 km is under planning. There are four (4) suburban railway lines: namely North line, West line, South line and Mass Rail Transit System line. The whole stretch of Mass Rail Transit System line is constructed as elevated structure. The monorail with a total length of 43.68 km and Bus Rapid Transit System which covers 96.7 km are being planned.

7 ITS in Chennai

The current condition of ITS in Chennai is summarised in the table below.

Table III Current Condition of ITS in Chennai

ITS Component	***Description***
Traffic Control Room	• *It is a small control room for traffic management prepared and operated by Chennai Traffic Police.* • *It monitors the traffic condition by CCTV.*
Variable Message Sign (VMS) Board	• *There are 31 VMS boards in the city.* • *It provides static messages for raising traffic awareness such as wearing helmet for motorcycle but not dynamic traffic information.*
Traffic Signals	• *There are 383 signalised intersections in the city.* • *The fixed signal cycles are manually set.* • *The functions such as automatic adjustment of signal timing are not equipped.*
CCTV Cameras	• *Some intersections in the core area of the city are equipped with CCTV.* • *It is operated by Chennai Traffic Police for monitoring the site condition.*
E-Challan System	• *It is an enforcement system for violated vehicle.* • *The handheld device is provided to police officer and used for recording, printing out the notice for penalty.*
Electronic Payment System of Chennai Metro	• *Token and contactless smartcard are introduced to Chennai Metro.* • *Introduction of common mobility card is under consideration.*
Highway Traffic Management System	• *VMS, Emergency Call Box and Weather Monitoring Systems are introduced by concessionaire on Outer Ring Road (ORR).*
Toll Management System (TMS)	• *RFID based TMS (FASTag) is introduced on the BOT section of NH45 and Chennai Bypass*

	• *IC Card based TMS is introduced on the BOT section of NH5, SH49 and SH49A. But they are not commonly used.*
Accident Data Base	• *It has been developed with assistance of fund of World Bank.* • *It is used by such department as Transport Department, Chennai Traffic Police, etc.*
Road Management System	• *Road Management System for National Highways and State Highways have been developed and used by road administrators.*
Vehicle Database	• *It is a database to manage vehicle information developed under the policy of e-governance of India.*
R&D Activities on ITS	• *Various R&D activities are carried out by IIT Madras such as traffic counting, pre-trip information, etc.*
IT Services Offered by Private Taxi Companies	• *Such services as Uber and Ola Cabs for taxi service are available*

(Source: JICA Study Team)

8 Related Studies and Major Development Plans

The related studies and major development plans in Chennai are summarised in the table below.

Table IV Related Studies and Major Development Plans

Studies and Development Plans	***Description***
National Urban Development Plan (NUTP)	*It is a national policy for urban transport formulated under National Urban Renewal Mission (NURM) by Government of India*
2nd Chennai Master Plan	*It was prepared by Chennai Metropolitan Development Authority (CMDA) in 2008. It identifies the issues and sets out the directions of the measures for the target year of 2026.*
Comprehensive Traffic and Transportation Study (CTTS)	*It was prepared by Chennai Metropolitan Development Authority (CMDA) in 2010. It sets out the urban transportation strategies for the target year of 2026.*
Vision Tamil Nadu 2023	*It was announced by the Chief Minister of Tamil Nadu State in 2014. It envisages the vision of physical and social infrastructure by the target year of 2023.*
Smart City Mission	*It is a mission launched under Prime Minister Narendra Modi. The Mission states to develop 100 smart cities in India. 20 cities were shortlisted as the first round of the mission and Chennai is included in the shortlisted cities. ITS is also included in the Mission.*

(Source: JICA Study Team)

9 Summary of Issues, Required Measures and ITS Menus for Required Measures

Based on the studies, the issues in Chennai are summarised in Table V. The urban transport issues cannot be solved only by ITS. Thus, they are grouped by the required measures which are 'Scheme/Act', 'Infrastructure' and 'ITS'. ITS Menus for the required measures are shown in Table VI.

Table V Summary of Issues and Required Measures

Category	***Issue***	***Measures***		
		Scheme/Act	***Infrastructure***	***ITS***
(1) Road Traffic	*a) High proportion of motorcycle and auto rickshaw*	○		
	b) Road construction/improvement not catching up with urbanization		○	○
	c) A large number of accidents	○	○	○
	d) High ratio of large-size vehicle		○	○
	e) Chronic long queue of large-size vehicles waiting for entering Chennai port		○	
	f) Resident living in the village in suburb in Chennai endangered by a number of large-size vehicles continuously passing through		○	○
(2) Road Infrastructure	*a) Reduced number of lanes on the major roads due to Metro construction (Temporal during the construction)*		○	
	b) Complicated structure of grade separation at many major junctions in the city (e.g. clover-leaf structures causing confusion to the road users due to complexity in structure)		○	
	c) Absence of grade separation at some major junctions		○	○
	d) Various factors which accelerate deterioration of road surface conditions such as damaged pavement, lack of drainage systems, etc.		○	○
	e) A number of on-road parking cars occupying the road spaces	○		○

	f) Limited number of off-road parking facilities		○	○
	g) Flooding when it rains heavily	○	○	○
	h) Absence of foot-path on many major roads		○	○
	i) Absence of bicycle ways		○	○
	j) Not constant road width		○	
	k) Shortage of skywalk		○	○
	l) Insufficient drainage system and lack of proper maintenance		○	
(3) Traffic Manners	*a) Lack of awareness of importance of traffic discipline and traffic rule*	○		
	b) Pedestrians crossing anywhere on arterial road	○	○	
	c) Lack of traffic discipline to follow lane marking, stop line, traffic signals, etc.	○	○	
(4) Traffic Management	*a) Lane block by barricade to reduce speed which suddenly appears on the road*	○	○	
	b) A number of traffic signals which are not working	○	○	
	c) A number of traffic signals which are not sufficiently visible (e.g. insufficient height, not proper location, etc.)		○	
	d) Absence of smart card which can be commonly used for toll collection at toll plazas under different road operators	○	○	○
	e) Lack of knowledge and experience on proper road management and traffic management	○	○	

(5) Public Transport	*a) Inefficient or not proper connectivity among different transport modes*		○	○
	b) Improper location of bus stops		○	
	c) Limited awareness of both bus drivers and passengers for safety	○		
	d) Absence of information on expected time of bus arrival and operation status at bus stops/terminals		○	○
	e) Poor condition of public bus		○	
	f) Inconvenience and inefficiency due to lack of ticketing system	○	○	○
	g) Delay of metro construction	○		
(6) Others: Facilities and Information	*a) A number of broken/damaged roadside facilities*	○	○	○
	b) Absence of systems and data to support traffic and road management			○
	c) Limited road asset management			○
	d) Absence of useful road traffic data/information	○	○	○
	e) Insufficient toll payment system resulting in frequent long queue of vehicles	○	○	○

(Source: JICA Study Team)

Table VI ITS Menu to Realize the Measures

Required ITS Component \ Issues		Road Traffic				Road Infrastructure								Traffic Management	Public Transport			Other Facilities and Information					Responsible Agency / Remarks
		b)*	c)	d)	f)	c)	d)	e)	f)	g)	h)	i)	k)	d)	a)	d)	f)	a)	b)	c)	d)	e)	
1)	Chennai Traffic Information Centre (C-TIC)	●				●			●	●											●		Smart City Ltd.(C-TIC) C-TIC: Newly established agency to provide city traffic information.
2)	Traffic Management Centre for Traffic Police	●						●													●		Chennai Traffic Police
3)	Highway Traffic Management System for CPRR (TCC)	●																			●		TNRDC (TCC) TCC: Newly established agency to manage traffic for CPRR.
4)	Probe System	●				●															●		MTC / Smart City Ltd.(C-TIC) GPS data will be collected from MTC bus and used for both MTC and C-TIC.
5)	Automatic Traffic Counter-Cum-Classifier System	●				●															●		Smart City Ltd(C-TIC)., TNRDC(TCC)
6)	CCTV Traffic Monitoring System																				●		Chennai Traffic Police, TNRDC(TCC)
7)	CCTV Enforcement System for Violated Vehicle							●															Chennai Traffic Police This system is used for enforcement purpose and it has already been introduced.
8)	No. Plate Recognition System		●	●				●															Chennai Traffic Police This system requires number plate standardisation. Tender for vender was announced by Transport Dept.
9)	Flood Measurement and Warning System									●											●		Smart City Ltd.(C-TIC) This system is mainly composed of water level measure, CCTV and VMS at underpass.
10)	Variable Message Sign System	●																			●		Chennai Traffic Police, TNRDC (TCC)
11)	Toll Management System (for existing toll plazas or for CPRR)																					●	NHAI, TNRDC
12)	Information Provision Through Internet/SMS	●							●	●	●	●	●	●							●		Smart City Ltd.(C-TIC), TNRDC (TCC)
13)	Area Traffic Signal Control System	●																					Chennai Traffic Police
14)	Weigh in Motion System for CPRR			●																			TNRDC(Toll Plazas of CPRR) This system is mainly composed of weigh-in motion, static weigh-bridge and CCTV.
15)	Road Accident Data Management System		●																		●		Chennai Traffic Police, Transport Department Accident database has already been developed.
16)	Command Control Centre for City Bus	●								●						●					●		MTC
17)	Bus Monitoring System	●								●						●					●		MTC
18)	Passenger Information System (PIS)	●								●						●							MTC
19)	Electronic Ticket Management System (ETM)	●													●		●						MTC
20)	Clearinghouse and Common Smart Card Card	●							●			●		●	●		●						Metro (CMRL) and related agencies (MTC, MRTS)
21)	Parking Management System	●							●												●		GCC , CMRL This system is managed by off-road parking owner.
22)	Road Inventory Database						●											●	●	●			GCC, NHAI, Highway Department, TNRDC Road inventory database has already been developed by road administrators.
23)	Footpath/Bicycle Way Information Provision System										●	●	●										GCC
24)	Bicycle Sharing System											●											GCC
25)	Commercial Vehicle Tracking System				●																		This system is usually developed by private companies.

*Corresponding to Alphabetic Code of Issue Items in Table V Summary of Issues and Required Measures

(Source: JICA Study Team)

10 Development Policy

Based on the current condition and identified ITS Menus, the phasing policy and implementation schedule are proposed as development policy.

Table VII Recommended Staged Development Policy

Term	***Year***	***Policies***
Short Term	*2017 – 2021* *(1-5 years)*	• *To use existing ITS more effectively* • *To introduce ITS which can be implemented in short period* • *To start operation of the introduced ITS* • *To start preparation of development of ITS which require longer period for implementation*
Mid Term	*2022 – 2026* *(6-10 years)*	• *To expand and upgrade ITS which are developed in short term as necessary* • *To start operation of ITS which started preparation in short term due to necessity of longer period for implementation*
Long Term	*2027 –* *(After 10 years)*	• *To upgrade functions and introduce new system, adopting new technologies*

(Source: JICA Study Team)

Table VIII Proposed Implementation Schedule

Technical Prerequisit For ITS and Major Event			Short Term					Mid Term					Long	Remark
			2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	
Standardisation of Vehicle Number Plate			(Expected period required for replacing existing plates)											- Procurement of vendor for standardised number plate is underway
Clearing house and Common Mobility Card														
Chennai Peripheral Ring Road														
Outer Ring Road (Phase-2) (Completion of Entire Stretch)														
Metro Phase-1														Metro Phase-2 is under planning
Metro Phase-1 Extension														
MRTS Phase-2 Extension														
Selected ITS Components			Short Term					Mid Term					Long	Remark
			2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	
Short Term : City ITS	C-TIC	Chennai Traffic Information Centre (C-TIC)							(Expansion)					C-TIC will be expanded in the future e.g. probe data from taxies and commercial vehicles, additional ATCC according to expansion of road network, change in traffic pattern and etc.
		Probe System												
		Automatic Traffic Counter-cum-classifier System (ATCC)												
		CCTV Traffic Monitoring System												
		Flood Measurement and Warning System												
		Information Provision Through Internet/SMS												
	Traffic Police	Traffic Management Centre for Traffic Police (TMC)												Brown line in the chart indicates modification of existing centre
		Variable Message Sign System												
		Area Traffic Signal Control System (ATSC)	(Stage-1 :150ATSC)											ATSC will be installed in 2 stages. -1st stage: Installing 150 ATS in core area -2nd stage: Installing 230 ATS in the area encompassed by Ennore port, Channai Bypass and Siruseri
			(Stage-2 :230ATSC)											
	MTC	Command Control Centre for City Bus (CCC)												-MTC systems need to be completed before C-TIC starts operation.
		Bus Monitoring System(BMS)												
		Passenger Information System (PIS)												
		Electronic Ticket Management System(ETM)												
Mid Term	CPRR ITS	Highway Traffic Management System for CPRR												
		Toll Management System for CPRR												
		Weigh in Motion System for CPRR												

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

:Operation

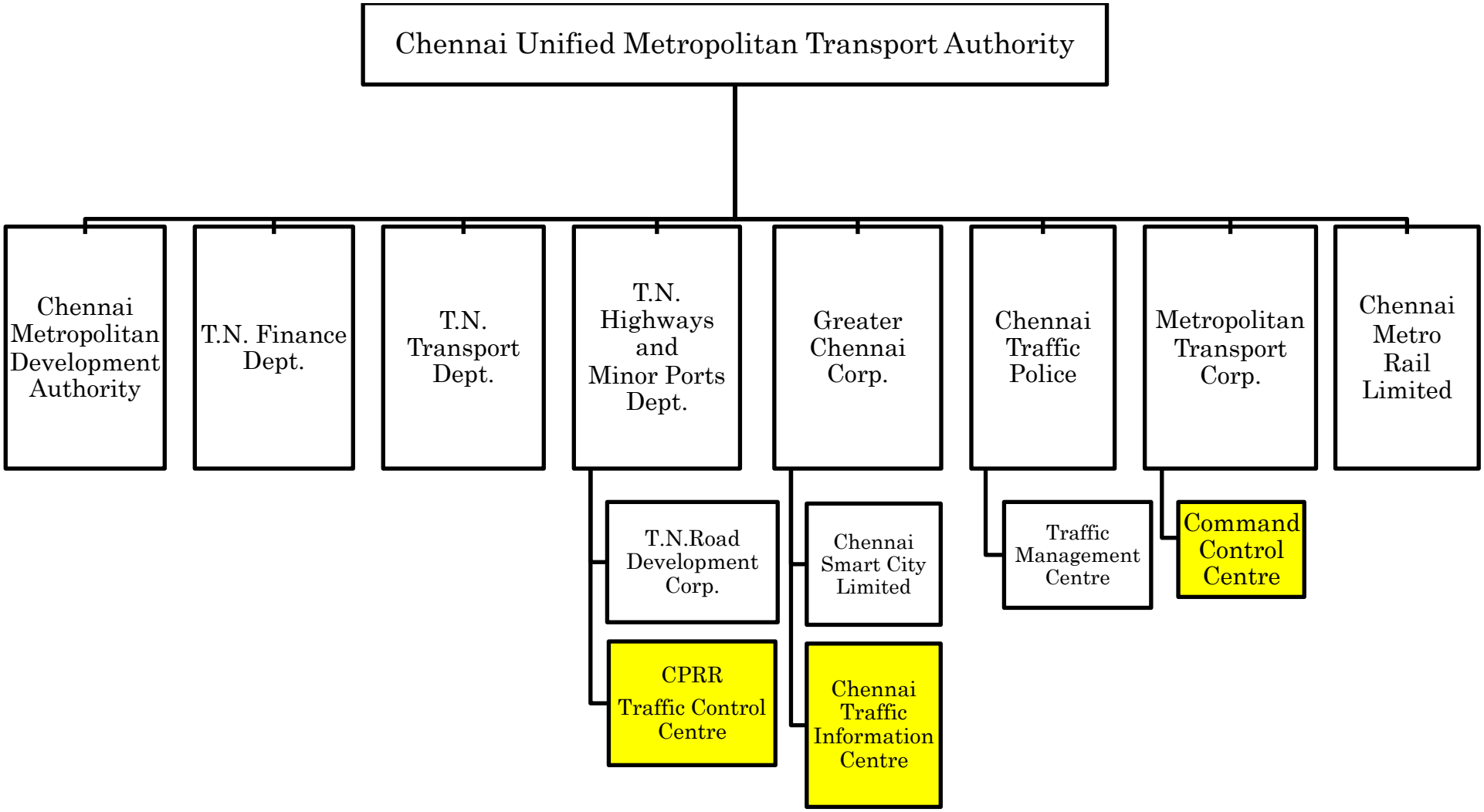
(Source: JICA Study Team)

11 Organization

Based on the ITS to be introduced to Chennai, the organization structure is proposed as shown in Figure II.

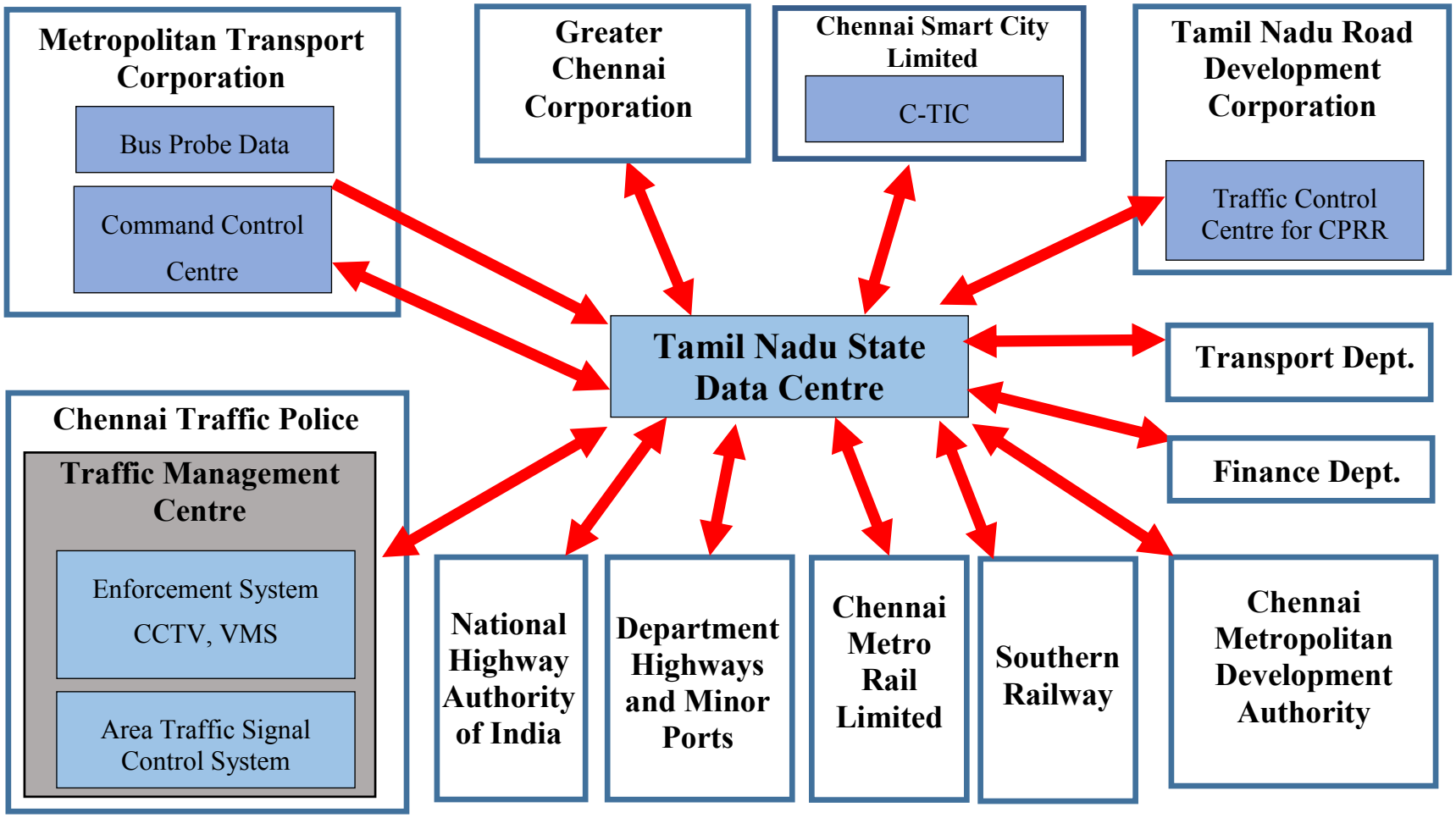
The Study proposes to set up new centres for the selected ITS components, namely Chennai Traffic Information Centre, Traffic Control Centre for Chennai Peripheral Ring Road, and Command Control Centre for City Bus. Chennai Unified Metropolitan Transport Authority has been set up in Chennai for the purpose of decision making on urban transport issues and coordination amongst related agencies in the transport sector in Chennai. ITS requires to address cross-cutting issues for sustainable and proper operation, maintenance, planning and upgrading, and accordingly involvement and coordination of the related agencies are important. Therefore, the proposed new centres are recommended to prepare under the individual responsible agencies under the framework of Chennai Unified Metropolitan Transport Authority as shown in the figure.

Figure III shows the involved agencies and relation for information/data exchange. Centre servers of the new centres are recommended to install in Tamil Nadu State Data Centre, a data centre of Tamil Nadu State Government, because of good environment e.g. high security, favourable maintenance, etc. Data and information will be exchanged through the centre servers installed in Tamil Nadu State Data Centre with the relevant agencies as depicted in the figure.



(Source: JICA Study Team)

Figure II Entire Image of Proposed Organization Structure for ITS in Chennai



(Source: JICA Study Team)

Figure III Involved Agencies and Data/Information Exchange

12 Rough Cost Estimate

The rough cost has been estimated as shown in Table IX. The cost for the long-term is not calculated because of uncertainty of various aspects in the future.

Table IX Rough Cost Estimate

Unit=INR crore

ITS Component		Equipment Cost	O&M Cost(Annual)	Equipment Cost	O&M Cost(Annual)	Equipment Cost	O&M Cost(Annual)
		Short Term (stage-1)		Short Term (stage-2)		Mid Term	
Chennai Traffic Information System (C-TIC)	Centre System (including Probe System, Internet System)	43.5	**7.3**		**7.3**	1.4	**7.4**
	Automatic Traffic Counters-cum-classifier (ATCC) System	22.6					
	Flood Measurement and Warning System	7.0					
Subtotal		**73.1**				**1.4**	
City Bus System (MTC)	Bus monitoring System	14.6	**13.0**		**13.0**		**13.0**
	Passenger Information System	38.7					
	Electronic Ticket ManagementSystem	76.6					
Subtotal		**129.9**					
Traffic Management System (Chennai Traffic Police)	Traffic Management Centre	8.7	**18.2**	0.6	**40.5 (18.2+22.3)**		**40.5**
	Area Traffic Signal Control System	146.6		222.6			
	CCTV Traffic Monitoring System	4.7					
	Variable Message Sign (VMS) System	21.9					
Subtotal		**181.9**		**223.2**			
ITS for Chennai Peripheral Ring Road (CPRR)	Highway Traffic Management Sytem (HTMS)					150.1	15.0
	Toll Management System (TMS)					30.6	3.1
Subtotal						**180.7**	
Grand Total		**384.9**	**38.5**	**223.2**	**60.8**	**182.1**	**79.0**

Total (Equipment)	**790.2**

※The above cost includes contingency at 10%.

※The cost for minimal civil work for improvement of intersection is included in Advanced Traffic Signal Control System

※The cost for operation and maintenance is calculated at 10% of the equipment cost.

(Source: JICA Study Team)

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Abbreviations

Abbreviation	Official Name
AADT	Annual Average Daily Traffic
AFC	Automatic Fare Collection
ANPR	Automatic Number Plate Recognition
ATC	Area Traffic Control
ATCC	Automatic Traffic Counter-Cum-Classifier
ATCS	Area Traffic Signal Control System
AVC	Automatic Vehicle Classifier
BAU	Business As Usual
BOT	Built-Operate-Transfer
BRT	Bus Rapid Transit
BRTS	Bus Rapid Transit System
BSNL	Bharat Sanchar Nigam Limited
CA	Commercial Area
CBD	Central Business District
CCC	Command Control Centre
CCTV	Closed Circuit Television
CDAC	Centre for Development of Advanced Computing
CMA	Chennai Metropolitan Area
CMC	City Municipal Councils
CMDA	Chennai Metropolitan Development Authority
CMRL	Chennai Metro Rail Limited
CN	Cellular Network
CORR	Chennai Outer Ring Road
CPCB	Central Pollution Control Board
CPRR	Chennai Peripheral Ring Road
C-TIC	Chennai Traffic Information Centre
CTP	Chennai Traffic Police
CTTP	Comprehensive Traffic and Transportation Plan
CTTS	Comprehensive Traffic and Transportation Study

CUMTA	Chennai Unified Metropolitan Transport Authority
CWR	Carriage Way Road
DOP	Department of Personnel
DOT	Department of Transport
DPR	Detailed Project Report
DRM	Digital Road Map
DSRC	Dedicated Short Range Communication
ECB	Electronic Call Boxes
EIRR	Economic Internal Rate of Return
ELCOT	Electronic Corporation of Tamil Nadu
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
GCC	Greater Corporation of Chennai
GDP	Gross Domestic Product
GIS	Geographic Information System
GNSS	Global Navigational Satellite System
GPS	Global Positioning System
GSMC	Global Service Management Centre
HCV	Heavy Commercial Vehicle
HOV	High Occupancy Vehicle
HSRP	High Security Registration Plate
HTMS	Highway Traffic Management System
IA	Industrial Area
IC	Integrated Circuit
ICT	Information Communication Technology

IIT-M	Indian Institute of Technology- Madras
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
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
MORTH	Ministry of Road Transport and Highways
MRTS	Mass Rail Transit System
MTC	Metropolitan Transport Corporation
NFC	Near Field Communication
NH	National Highway
NHAI	National Highway Authority of India
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
PWD	Public Works Department
RA	Residential Area
RADMS	Road Accident Data Management System
RBI	Reserve Bank of India
RFID	Radio Frequency Identification
ROW	Right of Way
SA	Sensitive Area
SETC	State Express Transport Corporation
SRW	Smartcard Reader/Writer
SH	State Highway
SO2	Sulphur Dioxide
SPV	Special Purpose Vehicle
STA	State Transport Authority
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
TIDCO	Tamil Nadu Industrial Development Corporation
TLC	Toll Lane Controller

TMC	Traffic Management Centre
TMS	Toll Management System
T&G	Touch & Go
TNIDB	Tamil Nadu Infrastructure Development Board
TNRDC	Tamil Nadu Road Development Company
TNSDC	Tamil Nadu State Data Centre
TNSWAN	Tamil Nadu State Wide Area Network
TNUIFSL	Tamil Nadu Urban Infrastructure Financial Services Limited
TOD	Time-of-Day
TTC	Travel Time Cost
TUFIDCO	Tamil Nadu Urban Finance and Infrastructure Development Corporation Ltd
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
WIM	Weight in Motion

1 Introduction

1.1 Study Background

India has undergone rapid urbanization in recent years. However, since road traffic accounts for approximately 57% of transportation share, the transportation infrastructure has not developed sufficiently to keep pace. Hence traffic congestion has become serious problem in the metropolitan areas and economic loss has become a major obstacle for the economic development. In particular, the population of Chennai Metropolitan Area has been increased from approximately 6,560,000 in 2001 to approximately 8,700,000 in 2011 (Ranked 4th in India: Census 2011). The vehicle traffic in the city is continuously increasing and the chronic traffic congestion has become a more serious issue. The Outer Ring Road was planned to mitigate the traffic congestion in central area of Chennai and it has been partially in service since 2010. Chennai Peripheral Ring Road outside the Outer Ring Road is planned to address the increasing traffic demand in the future to promote further development of the local economy. Further, the introduction of Intelligent Transport Systems (referred to as ITS hereinafter) has been under consideration to promote use of Chennai Peripheral Ring Road. The development of ITS in the city has also been in consideration to assist to alleviate the chronic congestion in the city.

The Construction of Chennai Peripheral Ring Road is planned. However as to ITS, the basic policy of comprehensive development of ITS in Chennai metropolitan area has not yet been formulated since ITS consists a variety of components. Therefore, this Survey, 'Data Collection Survey for Chennai Metropolitan Region ITS', will collects the necessary information and formulate the basic policy (draft) for the development of ITS in Chennai Metropolitan Area.

1.2 Study Outline

The outline of the Study is summarised below.

Table 1-1 Study Outline

Item	Details
Study Name	Data Collection Survey for Chennai Metropolitan Region ITS
Study Period	From January 2016 to February 2017
Study Objective	To collect data/information necessary for setting out the basic policy for development of ITS (City ITS and ITS for CPRR) To formulate the basic policy (draft) for development of ITS in Chennai Metropolitan Area in the state of Tamil Nadu
Study Area	Chennai Metropolitan Area in Tamil Nadu, India
Relevant Authorities	Highways & Minor Ports Department of Tamil Nadu Tamil Nadu Infrastructure Development Board Other related organizations in transport sector in Chennai Metropolitan Area

(Source: JICA Study Team)

1.3 Work Items

The work items of the Study are as follows:

Table 1-2 Work Items of Study

No.	Item
(1)	Reviewing Socio Economic Condition and Urban Transportation
1)	Reviewing Socio Economic Conditions
2)	Reviewing Urban Transport Policy and Development Plan
3)	Reviewing Traffic Condition
(2)	Reviewing Condition of ITS
1)	Reviewing Current Condition of ITS and Future Plan
2)	Reviewing Relevant Organization for ITS
(3)	Traffic Survey and Demand Forecast
1)	Reviewing Existing Data and Materials
2)	Traffic Survey
3)	Traffic Demand Forecast
(4)	Study on Basic Policy on ITS (Draft)
1)	Identifying and Summarizing Issues in Terms of Transport Infrastructure and Traffic Management
2)	Study on Basic Policy on ITS (Draft)
3)	Study on ITS Menus
4)	Estimating Effect of ITS
(5)	Study on Organization of ITS Operation and Management

(Source: JICA Study Team)

1.4 Joint Meeting and Major Relevant Organizations

1.4.1 Joint Meeting

There are many organizations related to ITS in Chennai metropolitan region. Thus the joint meetings participated by the relevant authorities are organised to facilitate execution of the Study. It functions as a platform to exchange opinions and have a common understanding on such factors as proposed ITS menus, basic policy on ITS for Chennai metropolitan area, required organizational measures, etc. The joint meeting are held at the major milestones of the Study including at the timing of Interim Report and Draft Final Report. The meetings are convened by the counterpart of the Study, Tamil Nadu Infrastructure Development Board.

1.4.2 Major Relevant Organizations of the Study

The major related organizations of the Study are listed below.

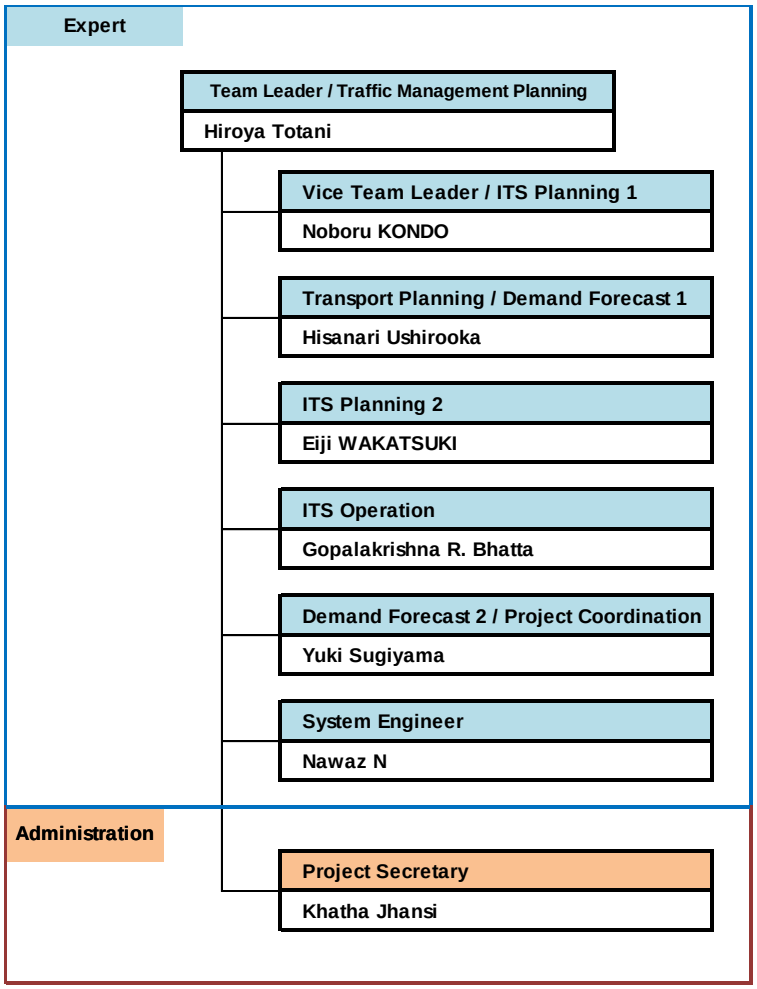
Table 1-3 Related Organizations of the Study

Organization Name	Function
Tamil Nadu Infrastructure Development Board (TNIDB)	Coordination authority to promote the infrastructure development project in Tamil Nadu
Chennai Traffic Police	Traffic administrator
Chennai Metropolitan Development Authority (CMDA)	Planning authority for urban development and urban transportation in Chennai Metropolitan Area
Greater Chennai Corporation (GCC)	City road administrator and in charge of construction and maintenance of associated road facilities in the city
Tamil Nadu Urban Infrastructure Financial Services Limited (TNUIFSL)	Authority that manages the donors related to urban infrastructure investment
Chennai Metro Rail Limited (CMRL)	Management and operation of Chennai metro rail
Metropolitan Transport Corporation Ltd. (MTC)	City bus operator
State Express Transport Corporation Ltd. (SETC)	Inter-city bus operator
Department of Highways & Minor Ports	In charge of highways including Chennai Peripheral Ring Road and minor ports in Tamil Nadu.
Tamil Nadu Road Development Company (TNRDC)	Government corporation for implementation of tolled state highway under Department of Highways & Minor Ports. Implementation agency for Section-1 of Chennai Peripheral Ring Road.
Tamil Nadu State Transport Authority (TN-STA)	Management of vehicle safety inspection, vehicle registration and number plates
Chennai Unified Metropolitan Transport Authority (CUMTA)	Authority consisting of related organizations in urban transport sector for making decisions and coordination for planning and implementing urban transport measures.
Tamil Nadu Urban Finance and Infrastructure Development Corporation Ltd (TUFIDCO)	Governmental corporation for providing financial assistance to implementing agencies such as local municipalities for specific governmental missions including Smart City Mission, Jawaharlal Nehru National Urban Renewal Mission, etc.
Tamil Nadu State Data Centre (TNSDC)	Central data centre of Tamil Nadu State government
Electronics Corporation of Tamil Nadu (ELCOT)	Implementing agency that manages TNSDC and offers such services as server operation and maintenance.
National Highways Authority of India (NHAI)	National highway administrator
Indian Institute of Technology, Madras & Anna University	ITS related research and development
Chennai Smart City Limited	SPV for Implementation of Smart City Projects

(Source: JICA Study Team)

1.5 Study Members and Study Team Structure

JICA Study team members and Team structure are shown in the following figure.



(Source: JICA Study Team)

Figure 1.1 Members and Structure of JICA Study Team

1.6 Report Submission and Study Schedule

The Reports which have been prepared and the study schedule are shown in following table.

Table 1-4 Submitted Report

Report Name	Submission Date	Number of Copies
Inception Report	January,2016	8 copies in Japanese,10 copies in English
Interim Report	July,2016	8 copies in Japanese,10 copies in English
Draft Final Report	November ,2016	8 copies in Japanese,10 copies in English
Final Report	February,2017	8 copies in Japanese,10 copies in English,3 pieces of CDs

(Source: JICA Study Team)

2 Current Conditions, Plans and Issues in Chennai

2.1 Socio-Economic Conditions

2.1.1 General Overview of Chennai Metropolitan Area

Chennai is the capital city of Tamil Nadu and is located along Coromandel Coast of Bay of Bengal in the north east of Tamil Nadu state. Chennai metropolitan area consists of Chennai district, Kanchipuram district and a part of Tiruvallur district. It has the fourth largest population and economy, and third highest GDP' per capita in India. The region is called 'Gateway in South India' and there are two major ports: Chennai port and Ennore port. The Chennai port handles the second largest volume of containers in India after the Jawaharlal Nehru port in Mumbai. The Ennore port is located approximately 15 km north of the Chennai port and it mainly handles bulk materials such as coal and iron ore.

There are more than ten special economic zones (SEZ) in Chennai metropolitan area. A number of domestic and foreign companies such as automobile, Information Technology, bio-technology are increasingly moving there. In particular, as the regions is also called 'Detroit of South Asia', there are major automobile manufacturers including BMW, Ford, Renault-Nissan and related companies in the industrial parks in the suburbs such as ORAGADAM and Mahindra World City. There are also a number of Information Technology companies along SH49A in the south and the road is called 'Information Technology corridor'. Chennai has been selected as one of the twenty (20) cities to be developed as a smart city under the Smart City Initiative of Prime Minister Narendra Modi.

2.1.2 Demographic Outlook

According to Census 2011, the population of Tamil Nadu state, Chennai metropolitan area and Chennai city are 72.14 million, 8.7 million and 4.6 million respectively. The decade growth of population in Tamil Nadu state and Chennai city are 15.61% and 6.98%. The population density in Chennai city is 26,553/km2 and this is one of the most densely populated metropolis in the world. The literacy rate in Tamil Nadu state is 80.09% and in Chennai 90.03%. These figures are above national average which is 74.04%. However, it is said that the slum population in Chennai metropolitan area is the fourth largest among metropolises in India and it accounts for almost 20% of the population in the region. The major ethnic group in Chennai is Tamil, followed by Telugu. The major language is Tamil but English is also widely spoken among white-collar workers. Other languages are Telugu, Hindi, Malayalam and Kannada.

Table 2-1 Demographic Features

No.	Item	Chennai City*1	Tamil Nadu State*1	India*2
1	Geographical Area (km2)	426	130,058	3,287,263
2	Population (million)	4.64	72.14	1210.57
3	Decade Growth Rate of Population (%)	6.98	15.61	17.68
4	Population Density (people /sq.km)	26,553	555	383
5	Literacy Rate(%)	90	80	73
6	GDP (USD)	1,870	2,464	1,581
7	Foreign Tourists visits arrival (Million)	0.63	4.0	7.7

* 1 : Based on census of Tamil Nadu 2011 and The Times of India Web Site.

* 2 : Based on Ministry of Foreign Affairs of Japan Website and Japan National Tourism Organization Website (The number of the foreign tourists is calculated by every each country's statistics standard).

(Source: Edited by JICA Study Team based on census of Tamil Nadu 2011, The Times of India Web Site, Ministry of Foreign Affairs of Japan Web Site, Japan National Tourism Organization Website)

2.1.3 Japanese Companies in Chennai and Tamil Nadu State

There were 577 business establishments of Japanese companies in Tamil Nadu state in 2014. This is the second largest number of Japanese companies among the states in India. 450 out of 577 establishments are located in Chennai. According to the type of business, the highest number are service businesses (135), followed by automobile (113), machinery (83), logistics (63) etc. The numbers of Japanese companies are rapidly increasing in recent years and it became 2.4 times in 2014 from 2010 as summarized below.

Table 2-2 Number of Business Establishment of Japanese Companies

	2010	2014
India	1236	3,961
Tamil Nadu State	240	577
Chennai	-	450

(Source: Summarized by JICA Study Team based on Website of JETRO and Embassy of Japan in India)

2.1.4 Climate of Chennai

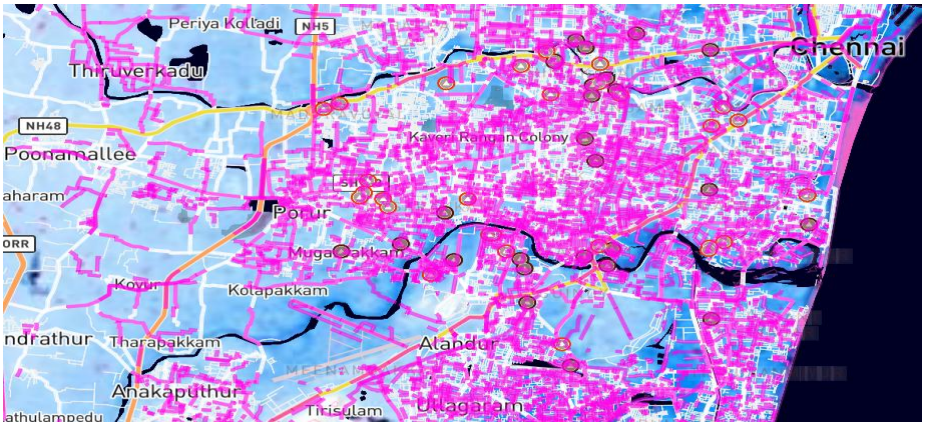
Chennai is located on the eastern coast of the Bay of Bengal in India. The climate is generally hot and humid with little variation of temperature throughout the year. The rainy season, called the Monsoon season, starts from the middle of September and lasts until the middle of December. Cyclones developing in the Bay of Bengal sometimes hit the city and cause heavy rainfall over a large area. The average annual rainfall is about 1,500 mm. Floods occur in many places of the city during the rainy season. The hottest season is from the end of May to the beginning of June, with maximum temperature ranging from around 35 to 40 ºC. The coolest month is January, with minimum temperature ranging from around 15 to 22 ºCs. The highest and lowest temperatures ever recorded are 45ºC and 13.8ºC respectively.

Flood in Tamil Nadu 2015

The torrential rains by Monsoon caused flooding in many places in South India during November and December 2015. It caused serious damage over large areas along the Coromandel Coast. The damaged areas include the State of Tamil Nadu, Andhra Pradesh, and Union Territory Pondicherry. Chennai in Tamil Nadu was the worst area where more than 500 lives were lost and over 1.8 million people had to be evacuated. The approximate cost for the flood damage was reportedly between INR 50,000 crores (INR 500 billion) and INR 1 lakh crores (INR 1 trillion). Due to such situation, Tamil Nadu government places importance on construction of bund, bridges and bypass to assure road network on the occasion of floods. The damage situation of devastated area in 2015 in Chennai is shown below.

(Source: http://www.newindianexpress.com)

Figure 2.1 Flood in Chennai 2015



(Source: Flooded Streets Maps)

Figure 2.2 Flood Affected Areas in Chennai 2015

2.1.5 Relevant Acts and Regulations on Road Transport

The major relevant acts and regulations on road and transport are: (1)Motor Vehicle Act, (2)Indian Road Congress, (3) National Highway Act,1956, and (4)National Highways Fee Rules, 2008. Motor Vehicle Act was revised in 1939, and prescribes emission control and car inspection, license, fine and automobile tax. Indian Road Congress prescribes the standards such as for structure of road/bridge/tunnel etc. These are published by Indian Road Congress in subordination to Ministry of Road Transport and Highways (MoRTH). National Highway Act, 1956 prescribes construction and administration of National Highway such as land acquisition, compensation. It includes legal grounds of the toll collection. National Highways Fee Rules, 2008 prescribes rules such as the pricing for the road user.

The outline of these acts are shown in the tables below.

Table 2-3 Contents of Motor Vehicle Act

No	Title
1	PRELIMINARY
2	LICENSING OF DRIVERS OF MOTOR VEHICLES
3	LICENSING OF CONDUCTORS OF STAGE CARRIAGES
4	REGISTRAION OF MOTOR VEHICLES
5	CONTROL OF TRANSPORT VEHICLES
6	Special Provisions Relating To State Transport Undertakings
7	CONSTRUCTION, EQUIPMENT AND MAINTENANCE OF MOTOR VEHICLES
8	CONTROL OF TRAFFIC
9	MOTOR VEHICLES TEMPORARILY LEAVING OR VISITING INDIA
10	LIABILITY WITHOUT FAULT IN CERTAIN CASES
11	INSURANCE OF MOTOR VEHICLES AGAINST THIRD PARTY RISKS
12	CLAIMS TRIBUNALS
13	OFFENCES, PENALTIES AND PROCEDURE
14	MISCELLANEOUS

(Source: Edited by JICA Study Team based on THE MOTOR VEHICLES ACT, 1988)

Table 2-4 List of Publications of Indian Road Congress

	Items	Number
1	IRC SPECIFICATIONS, STANDARDS, DESIGN CODES	111
2	IRC SPECIAL PUBLICATIONS	87
3	MINISTRY OF SURFACE TRANSPORT PUBLICATIONS (Now Ministry of Road Transport & Highways)	33
4	National Highways Authority of India	2
5	MINISTRY OF RURAL DEVELOPMENT (National Rural Roads Development Agency)	3
6	IRC SEMINAR PUBLICATIONS	20
7	HIGHWAY RESEARCH BOARD PUBLICATIONS	14
8	OTHER PUBLICATIONS	9
9	PERIODICALS	4
10	CDs OF TECHNICAL PAPERS	5

(Source: Edited by JICA Study Team based on LIST OF IRC PUBLICATIONS AVAILABLE FOR SALE,2008)

Table 2-5 Contents of National Highway Act, 1956

No	Contents
1	Short title, extent and commencement
2	Declaration of certain highways to be national highways
3	Definitions
4	National highways to vest in the Union
5	Responsibility for development and maintenance of national highways
6	Power to issue directions
7	Fee for services or benefits rendered on national highways
8	8A.Power of Central Government to enter into agreements for development and maintenance of national highways 8B.Punishment for mischief by injury to national highway
9	Power to make rule
10	Laying of notifications, rules, etc, before Parliament

(Source: Edited by JICA Study Team based on National Highway Act,1956)

Table 2-6 Contents of National Highways Fee Rules, 2008

No	Contents
1	Short title, extent and commencement
2	Definitions
3	Levy of fee
4	Base rate of fee
5	Annual revision of rate of fee
6	Collection of fee
7	Remittance and appropriation of fee
8	Location of toll plaza
9	Discounts
10	Rate of fee for overloading
11	Exemption from payment of fee
12	Display of Information
13	Unauthorised collection
14	Failure to pay fee
15	Power of Central Government to verify records
16	Collection of fee in respect of Private Investment Project
17	Bar for installation of additional barrier

(Source: Edited by JICA Study Team based on National Highways Fee Rules, 2008)

2.1.6 Relevant Acts and Regulations on ITS

The major relevant acts and regulations on ITS are (1) A part of Indian Road Congress which prescribes the standards of minimum requirement in terms of capacity per hour of the Toll Collection Method of the Expressway and Variable Message Sign (referred to as 'VMS' hereinafter), etc. (2) Regulation on prepaid fare system issued by central bank of India. (3) Recommendation of Electronic Toll Collection method (referred to as 'ETC' hereinafter) on notional highway, this is not ministry ordinance. However Radio Frequency Identification (referred to as 'RFID' hereinafter) is recommended by Government of India.

(1)Indian Road Congress

The Indian Road Congress prescribe the standards of minimum requirement in terms of capacity per hour of the Toll Collection Method of the Expressway and VMS, etc. The minimum requirement of capacity per unit hour is shown in the table below.

Table 2-7 Required Capacity per Hour of Toll Collection Method

Toll Collection Method	Capacity per Hour
Manual toll collection	240unit/hour
Smart Card	360unit/hour
ETC	1200unit/hour

(Source: Edited by JICA Study Team based on IRC : SP:99-2013:MANUAL OF SAND ST FOR EXPRESSWAYS)

(2)Regulation on Prepaid Fare System Issued by Central Bank of India

The regulation categorizes the prepaid fare system according to degree of interoperability: (a) Closed System which is used within a single organization, (b) Semi-Closed System which uses card readers introduced by a single card issuer, (c) Semi-Open System which uses card readers that are introduced by several different card issuers and (d) Open System which uses smart card combined with bank card. It stipulates that the banking license is required for the settlement for the above (c) Semi-Open System and (d) Open System.

(3) Recommendation of ETC Method on National Highway

ETC method to be adopted is not prescribed by any government orders. However, introduction of RFID method based on ISO 18000-6C for ETC on national highway is recommended by the

committee under the Ministry of Road Transport and Highways (MoRTH), Government of India. 'Indian Highways Management Company Ltd.' has been established by the Government of India for the purpose of ensuring implementation of ETC. The ETC method to be adopted is subject to the decision of the State Government. However, RFID method recommended by the committee is increasingly adopted to ETC on the national highways in India.

2.2 Related Existing Organizations in Chennai

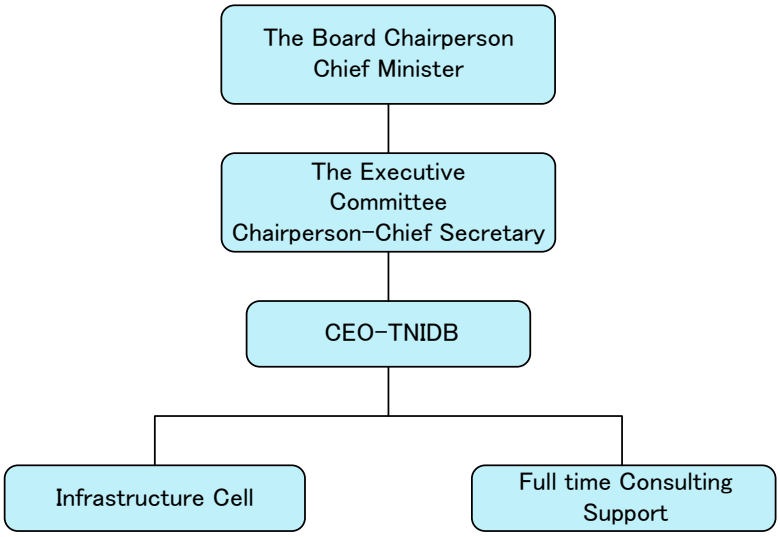
2.2.1 Tamil Nadu Infrastructure Development Board

Tamil Nadu Infrastructure Development Board is a nodal agency for planning and coordination of infrastructure development in Tamil Nadu state. It was established to facilitate the infrastructure development projects under the Ministry of Finance according to the Tamil Nadu Infrastructure Development Act 2012. It formulates, prioritizes, evaluates the projects and coordinates with the related departments to acquire the state budgets and financial support from the central government. It also prepares feasibility study reports and detailed project reports and monitors the projects.

Tamil Nadu Infrastructure Development Board involves in the projects undertaken by the government (public project) and through Public Private Partnership (PPP project). The act stipulates that Tamil Nadu Infrastructure Development Board involves in the public project with more than INR 500 crores of the project cost and the PPP project with more than INR 10 crores.

The chair person is the Chief Minister and the vice-chair person is the Finance Minister. Under the chair person, the executive committee is formed. The executive committee is chaired by Chief Secretary. It consists of 10 concerned departments with officials and experts. The chief executive officer (CEO) under the executive committee deals with the day-to-day duties of Tamil Nadu Infrastructure Development Board. Under the CEO, there are a core in-house team, external consultants and experts.

The organization structure is shown below.



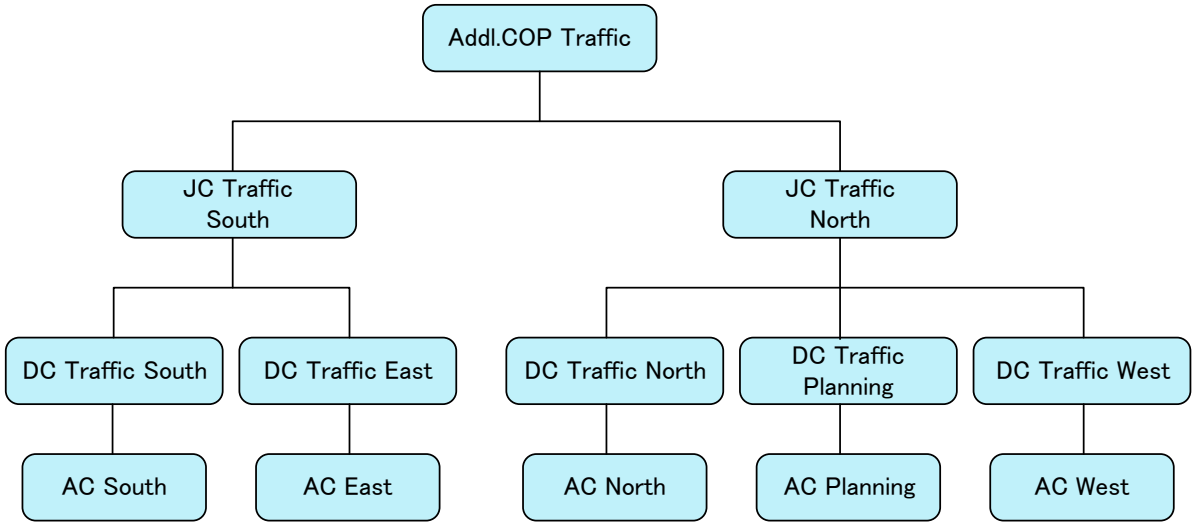
(Source: Edited by JICA Study Team based on TNIDB's website)

Figure 2.3 Organization Structure of Tamil Nadu Infrastructure Development Board

2.2.2 Chennai Traffic Police

Chennai Traffic Police under Chennai Police manage traffic. They are responsible for regulating traffic and enforcing traffic rules in Chennai district. The Chennai Police is under the Ministry of Home, Prohibition and Excise and is headed by the Commissioner of Police. The Chennai Traffic Police is headed by the Additional Commissioner of Police. The jurisdiction area is divided into four (4) regions; North, South, East and West and each region is represented by Deputy Commissioner. There is also a Planning Division of Traffic Management under Chennai Traffic Police.

The organization structure is shown below.



※Addl.COP: Additional Commissioner of Police, JC: Joint Commissioner , DC: Deputy Commissioner, AC: Additional Commissioner

(Source: Edited by JICA Study Team based on Website of Tamil Nadu Police Department)

Figure 2.4 Organization Structure of Chennai Traffic Police

2.2.3 Chennai Metropolitan Development Authority

Chennai Metropolitan Development Agency is a planning agency for Chennai metropolitan area including Chennai district, Kanchipuram district and part of Thiruvallur district. Chennai Metropolitan Development Authority prepares plans such as Master Plan, New Town Development Plan, etc. The plan is implemented by the individual government agencies in charge. Minister of Housing and Urban Development represents Chennai Metropolitan Development Authority and there are following members for decision making.

Table 2-8 Members of Chennai Metropolitan Development Authority

a) Honorable Minister for Housing and Urban Development	Chairman
b) Vice- Chairman, CMDA	Vice Chairman
c) Member-Secretary, CMDA	Member
d) Secretary to Government H&UD, Finance, Industies, Transport	Member
e) Commissioner, Corporation of Chennai	Member
f) Managing Director CMWSS Board	Member
g) Director , Town & Country Planning	Member
h) Chief Urban Planner , CMDA	Member
i) Chief Engineer, Highways & Rural Works Department	Member
j) Chief Architect to Government	Member
k) Joint Director, Town & Country Planning	Member
l) Chairman, Tamil Nadu Housing Board	Member
m) Chairman Tamil Nadu Slum Clearance Board	Member
n) Member of the State Legislative Assembly	Member

(Source: Summarized by JICA Study Team based on the Information on Website of CMDA)

There are following units under the members

- Area Plans Unit
- Area Development Unit
- Master Plan Unit
- Road and Rail Unit
- Enforcement Cell (dealing with permission and authorization such as issuance of completion certificate of project, etc.)
- Construction Wing and General Unit.

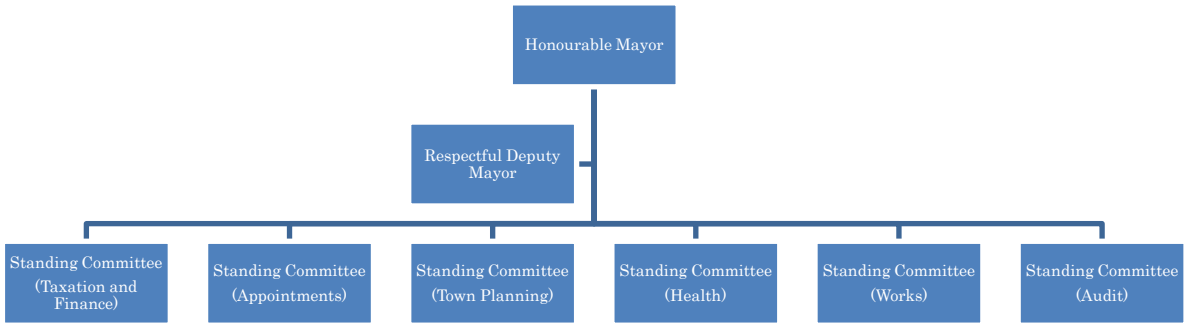
2.2.4 Greater Chennai Corporation

Greater Chennai Corporation is an autonomous body of Chennai, a designated city by government ordinance in Tamil Nadu. Greater Corporation of Chennai consists of Administrative Agency headed by Mayor and the City Council with 200 members. Mayor and each City Council member are chosen by direct election and Deputy Mayor is elected among the City Council members by vote casted by these members. The Mayor and Deputy Mayor preside over several Standing Committees. The Commissioner represents the Administrative Agency and controls each administrative service department such as Education, Insurance and Health.

Greater Corporation of Chennai has jurisdiction over development and maintenance of city roads with a total length of approximately 5,560 km excluding national roads and state roads in Chennai and roadside facilities such as bus stops, street lights, road signs, markings, drainage, sidewalks, and

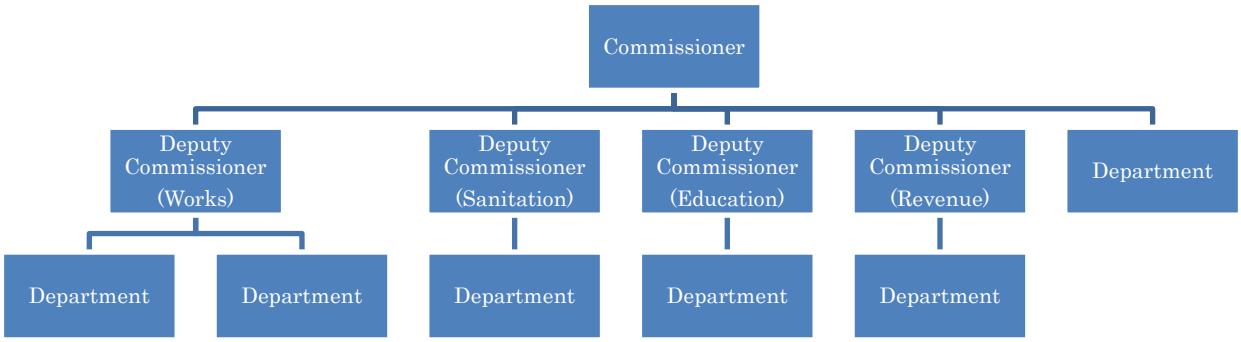
skywalks. The ownership of these facilities belongs to Greater Corporation of Chennai. As for traffic signals, Chennai Traffic Police carries out the maintenance and the ownership belongs to them.

The organization structure is shown below.



(Source: Edited by JICA Study Team based on Website of Greater Corporation of Chennai)

Figure 2.5 Organization Structure of Executive Committee of Greater Corporation of Chennai



(Source: Edited by JICA Study Team based on Website on Greater Corporation of Chennai)

Figure 2.6 Organization Structure of Administrative Body of Greater Corporation of Chennai

2.2.5 Tamil Nadu Urban Infrastructure Financial Service Limited

Tamil Nadu Urban Infrastructure Financial Service Limited is an agency for fund raising and financial services for the infrastructure projects in Tamil Nadu state. They involve in the projects which are undertaken by municipal bodies; namely corporation, towns and panchayat, such as construction of

roads, bridges, drainages, etc. Their financial services include financial advising, feasibility study, financial management, etc. in addition to fund raising.

Tamil Nadu Urban Infrastructure Financial Services Limited was formed by Government of Tail Nadu and private financial agencies; ICIC Bank, Housing Development Finance Corporation Limited and IL & FS Financial Services Limited.

2.2.6 **Chennai Metro Rail Limited**

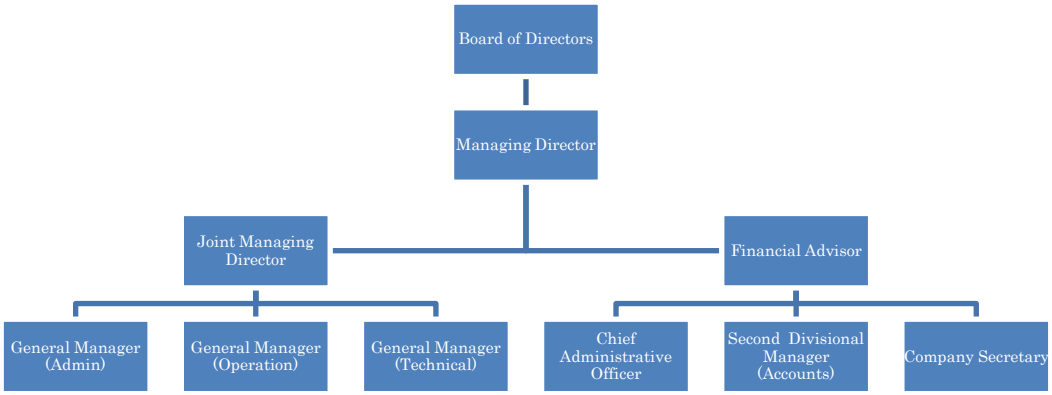
Chennai Metro Rail Limited is a Special Purpose Vehicle for construction and operation of Chennai Metro. It was formed in March 2007 by the Government of India and Government of Tamil Nadu with equal equity.

The Chennai Metro Rail is a rapid transit system in Chennai. The project is divided into two phases. The phase 1 is under construction and partially in operation. There are two corridors in phase 1 totalling 45 km in length. 55% of the phase 1 corridor is under ground and the rest are elevated structure. These corridors are along with the arterial roads in the core area of Chennai city; Anna Salai (Mount Road or NH45), E.V. R Periyar Salai (P.H Road or NH4) and Nhru Salai (100 Ft Road or Inner Ring Road). The first stretch began operation in June 2015. It is along Nehru Salai from Koyambedu to Alandur with 10 stations of approximately 10 km in length.

2.2.7 **Metropolitan Transport Corporation**

Metropolitan Transport Corporation is a public city bus operator in Chennai metropolitan area. It is a government agency under the Ministry of Transport. Metropolitan Transport Corporation offers almost 48,000 daily bus services on 842 bus routes. They own approximately 4,000 buses and approximately 3,700 buses are operated. There are 32 bus depots, 71 bus terminals and 151 major bus stops. There are also a number of small bus stops across Chennai. They carry approximately 4.5 million daily passengers. They operate several different types of bus with different fare such as ordinary, express deluxe, express and volvo AC services.

Metropolitan Transport Corporation is headed by Board of Director. There are several departments and wings such as administration and operation. Approximately 24,480 employees work. The organization structure is shown below.



(Source: Edited by JICA Study Team based on Website of Greater Corporation of Chennai)

Figure 2.7 Organization Structure of Metropolitan Transport Corporation

2.2.8 State Express Transport Corporation

State Express Transport Corporation is an inter-city/state bus operator. It is a government agency under the Ministry of Transport. They connect the major cities in Tamil Nadu state, Andhra Pradesh State, Karnataka State, Kerala State and union state of Pudhucheery. They offer several different types of bus with different fare such as semi-deluxe, super deluxe, video coach, air-conditioned bus, etc.

2.2.9 Department of Highways and Minor Ports

Department of Highways and Minor Ports controls state highways and minor ports in Tamil Nadu state. Chennai Peripheral Ring Road is a state highway and the implementation agency for construction of Chennai Peripheral Ring Road is the Department of Highways and Minor Ports (excluding the section 1 from NH5 to Ennore port). The national highway inside Chennai city comes under the jurisdiction of this department.

2.2.10 Tamil Nadu Road Development Company

Tamil Nadu Road Development Company is a government company for implementation of tolled state highway in the state which has been established under the Department of Highways and Minor Ports. It raises fund, constructs, operates and maintains. It is a joint venture corporation of Tamil Nadu Infrastructure Development Company and Tidel Park Ltd. (TIDEL). Tamil Nadu Industrial Development Corporation and TIDEL are 100% government owned companies and have equal share of Tamil Nadu Road Development Company.

Tamil Nadu Road Development Company is the implementation agency for construction of Section 1 (from NH5 to Ennore Port) of Chennai Peripheral Ring Road.

The projects which were completed, on-going and under planning are listed as follows;

a) **Completed Project:**

- Construction of SH49A

b) **On-going Planned Projects:**

- Construction of Outer Ring Road: Phase-1
- Construction of Outer Ring Road: Phase-2
- Chennai Ennore Port Road Connectivity Project
- Construction of SH49 Planned Project:
- Construction of Chennai Peripheral Ring Road: Section 1 from NH4 to Ennore Port (Northern Port Access Road)

2.2.11 Tamil Nadu State Transport Authority

Tamil Nadu State Transport Authority (TN-State Transport Authority) is in charge of vehicle registration, vehicle inspection, vehicle number place, driver license, etc. under the Ministry of Transport. The broad objectives of TN-State Transport Authority are:

- Promoting traffic safety
- Controlling vehicular emission
- Maximizing revenue of the Government by ensuring that all taxes and fees on vehicles are collected
- Delivering all services of the authority to the citizens

The major activities of the TN-State Transport Authority are:

- Issuance of driving licenses
- Registration of motor vehicles
- Inspection of vehicles and renewal of certificate
- Granting permission of forwarding business
- Collection of motor vehicle tax and fees
- Inspection of accident vehicle
- Implementation of road safety measures and controlling vehicular emission
- Granting licence to run driving school
- Granting License to set up testing centre of vehicular emission

The above activities are executed according to the Motor Vehicle Act, 1988, Central Motor Vehicle Rules, 1989, Tamil Nadu Motor Vehicle Rules, 1989 and Tamil Nadu Motor Vehicle Taxation Act and Rules 1974.

2.2.12 Chennai Unified Metropolitan Transport Authority

There are a number of related organizations in the sector of urban transport. Planning and implementing independently by these organizations are not efficient and the roles of the agencies are overlapped in many cases. Proper coordination is important to effectively plan, construct, operate and maintain. Chennai Unified Metropolitan Transport Authority was established for the purpose of achieving consensus, making decisions and coordination for planning and implementing the urban transport measures in 2010.

The Minister of Transport is a chair person and Chief Secretary and Chairman of Chennai Metropolitan Development Authority are vice chair persons. A total of 14 organizations in transport sector constitute permanent participant organization of Chennai Unified Metropolitan Transport Authority and they are represented by high level officials. The external person also constitute one post.

The table below shows the permanent participating organizations and positions of the representative.

Table 2-9 Constituent Organizations and Representative

No.	Organization	Representative
1	Transport Department	Secretary
2	Finance Department	Secretary
3	Housing and Urban Development Department	Secretary
4	Highways Department	Secretary
5	Home Department	Secretary
6	Municipal Administration and Water Supply	Secretary
7	Greater Chennai Police	Commissioner
8	Greater Chennai Corporation	Commissioner
9	Transport Authority	Commissioner
10	Chennai Metropolitan Development Authority	Member Secretary
11	Southern Railway	General Manager
12	Southern Railway (Chennai Division)	Divisional Manager
13	Metropolitan Transport Corporation	Managing Director
14	Chennai Metro Rail Limited	Managing Director
15	(Nominated Expert)	

(Source: Summarized by JICA Study Team based on interview)

The following four working groups for important areas are formed under Chennai Unified Metropolitan Transport Authority as shown in the table below.

Table 2-10 Working Group and Organization in Charge

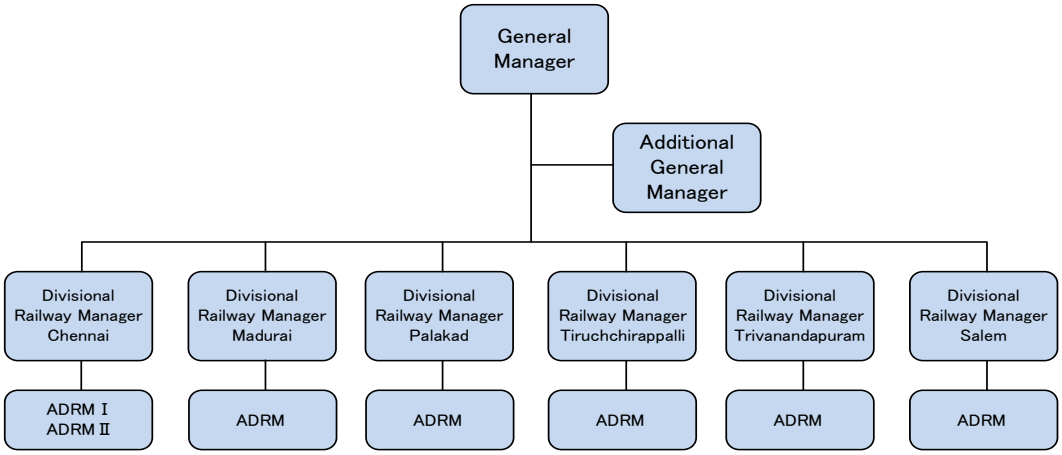
No.	Working Group	Organization in Charge	Representative
1	Multimodal Integration	Chennai Metro Rail Limited	Managing Director
2	Non-motorized Transport	Greater Chennai Corporation	Commissioner
3	Resource Mobilization	Chennai Metropolitan Development Authority	Commissioner
4	Traffic Safety	Transport Authority	Commissioner

(Source: Summarized by JICA Study Team based on interview)

2.2.13 Southern Railways

The railways in India are state-owned and they are under the jurisdiction of Ministry of Railway, Government of India. The total length is approximately 62,000 km and is ranked at fifth in the world. The jurisdiction area is divided into 16 zones such as north, south, east, west, etc. The railway in Chennai metropolitan area is under the jurisdiction of 'Southern Railway'. The Southern Railway covers Tamil Nadu state, Kerala state, Andhra Pradesh state, Union territory of Pudhucherry and part of Karnataka state. This area is further divided into six regional controlling zones. The headquarters of Southern Railway is located in Chennai. Mass Rapid Transit System in Chennai is also controlled by the Southern Railway.

The organization structure is shown below.



※ADRM: Additional Divisional Railway Manager

(Source: Edited by JICA Study Team based on Website of Indian Railways)

Figure 2.8 Organization Structure of Southern Railways

2.2.14 Tamil Nadu Urban Finance and Infrastructure Development Corporation Ltd

Tamil Nadu Urban Finance and Infrastructure Development Corporation Ltd has been incorporated under the Companies Act, 1956 on 21-03-1990. The main objective of the Tamil Nadu Urban Finance and Infrastructure Development Corporation Ltd is providing financial assistance to implementing agencies of infrastructure development such as local municipalities etc. It is also a nodal agency to implement government programme in the State.

Some of the funds that are managed by the Tamil Nadu Urban Finance and Infrastructure Development Corporation Ltd are:

- Smart City Mission
- Jawaharlal Nehru National Urban Renewal Mission
- Urban Infrastructure Development Scheme for Small and Medium Towns
- Metropolitan Infrastructure Development Scheme

2.2.15 Tamil Nadu State Data Centre and Electronics Corporation of Tamil Nadu

Tamil Nadu State Data Centre is an ISO certified data centre of Tamil Nadu State Government. It has been established under 'National e-Governance Initiative' of Government of India. It offers single-point service for e-governance of Tamil Nadu state such as providing server rooms equipped with cooling system, electric supply system by UPS and generators and data communication network, operation/maintenance of servers, user applications, etc. for computer services of various departments of the state government.

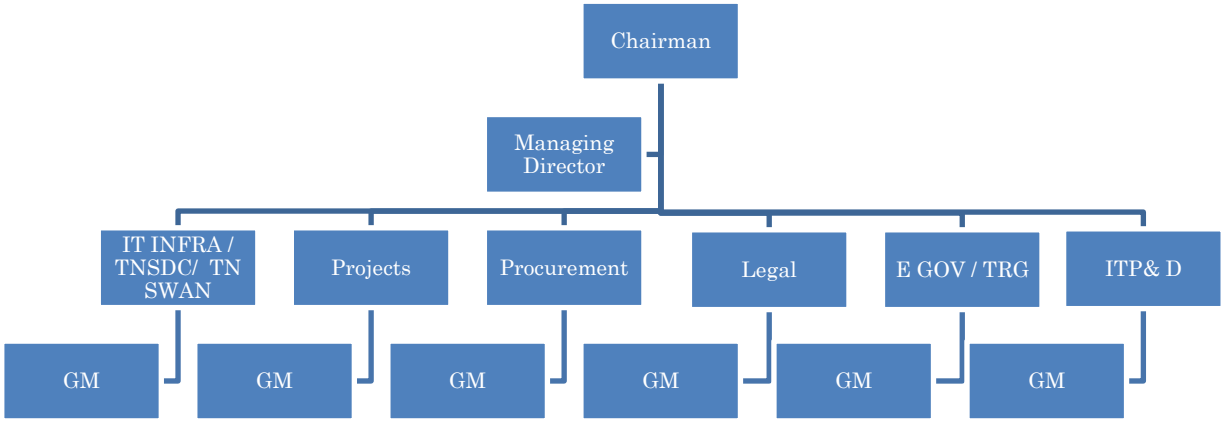
Tamil Nadu State Wide Area Network is established in Tamil Nadu State and it is a major backbone network used for Tamil Nadu State Data Centre. Bharat Sanchar Nigam Limited communication network is also used. A security policy for data protection is applied such as fire-wall. Under the security policy, two backup data centres have been prepared, one in Bharat Sanchar Nigam Limited data centre in Chennai and the other in Pune for disaster measure. Another backup centre is planned in Tirchy in Tamil Nadu State.

The basic services offered by Tamil Nadu State Data Centre are to provide the server spaces in the protected environment as above and operation/maintenance of servers for each department. And in some cases depending on the service agreement with the department, user applications are also prepared/procured, hosted on the server and maintained by Tamil Nadu State Data Centre. The examples of the applications hosted include the services for tax collection/management, government's

revenue management, land registrations, medical records of public hospital, etc. The servers of Chennai metro system are also located in Tamil Nadu State Data Centre.

Electronics Corporation of Tami Nadu, established under Government of Tamil Nadu, is an implementing agency that manages Tamil Nadu State Data Centre and offers these above services.

The figure below shows an organization structure of Electronic Corporation of Tamil Nadu and Tamil Nadu State Data Centre.



※TRG: Technical Resource Group, ITP&D: Information Technology Promotion and Development,

GM: General Manager, TNSDC: Tamil Nadu State Data Centre, TNSWAN: Tamil Nadu State Wide Area Network

(Source: Edited by JICA Study Team based on details of ELCOT website)

Figure 2.9 Organization Structure of Electronic Corporation of Tamil Nadu and Tamil Nadu State Data Centre

2.3 Current Conditions and Plans of Road and Transport

2.3.1 Overview of Road and Transportation Conditions in Chennai

Chennai, known as "the Gateway to South India", is an important transport node in the South India. The four National Highways which are NH4, NH5, NH45 and NH205 radiate toward Kolkata, Bengaluru, Tiruchirappalli and Madanapalli from Chennai. NH4 and NH5 constitute a part of the Golden Quadrilateral. Inner Ring Road, Chennai Bypass Road and Outer Ring Road connect these four radial National Highways. Chennai Peripheral Ring Road is planned to build on the outside of the Outer Ring Road. It is expected that the connectivity to the Chennai Port and the Ennore Port from the industrial hubs such as ORAGADAM around Chennai will be improved by the completion of the Chennai Peripheral Ring Road.

The Chennai Mofussil Bus Terminal (CMBT) is a terminal for city buses and inter-city buses and it is the largest bus terminal in South India. The buses connect to the major towns in the State of Tamil Nadu and adjoining states such as Kerala, Karnataka, Andhra Pradesh, and Union Territory Pondicherry, as well as various locations in the city.

There are two major railway terminals in Chennai. One is Chennai Central Railway Station that connects cities in India. This is the largest railway station in the region. The other is Egmore Railway Station that connects the various places of Tamil Nadu. A particular feature of the railway system in Chennai is Mass Rapid Transit System running in the city. It is the elevated structure railway for the whole line, so that no railway crossings exist in the central area of Chennai.

The Chennai Metro Rail Project is currently under construction and the operation of Phase 1 (Green Line) has been partially commenced in June, 2015. The metro network along NH45 and NH4 which are the major arterial roads in the city will be further developed in the future. The construction of monorail network has been also planned. The project will be carried out using Built-Operate-Transfer method. The bidding process has been already started and a concessionaire will be selected soon.

Public transportation railway network in Chennai has been relatively considered well to have the multimodal transit facilities such as bus terminals and parking space adjacent Chennai Metro Station, comparing to other large cities in India.

Road traffic is currently the main mode of transportation in Chennai. However, it is expected that the road traffic demand will be shifted to the public transportation by the development of these public transportation railway network in the near future.

2.3.2 **Road Network**

(1) Current Condition of Road Network in Chennai

Chennai has radial and ring pattern of road network. The major radial roads are:

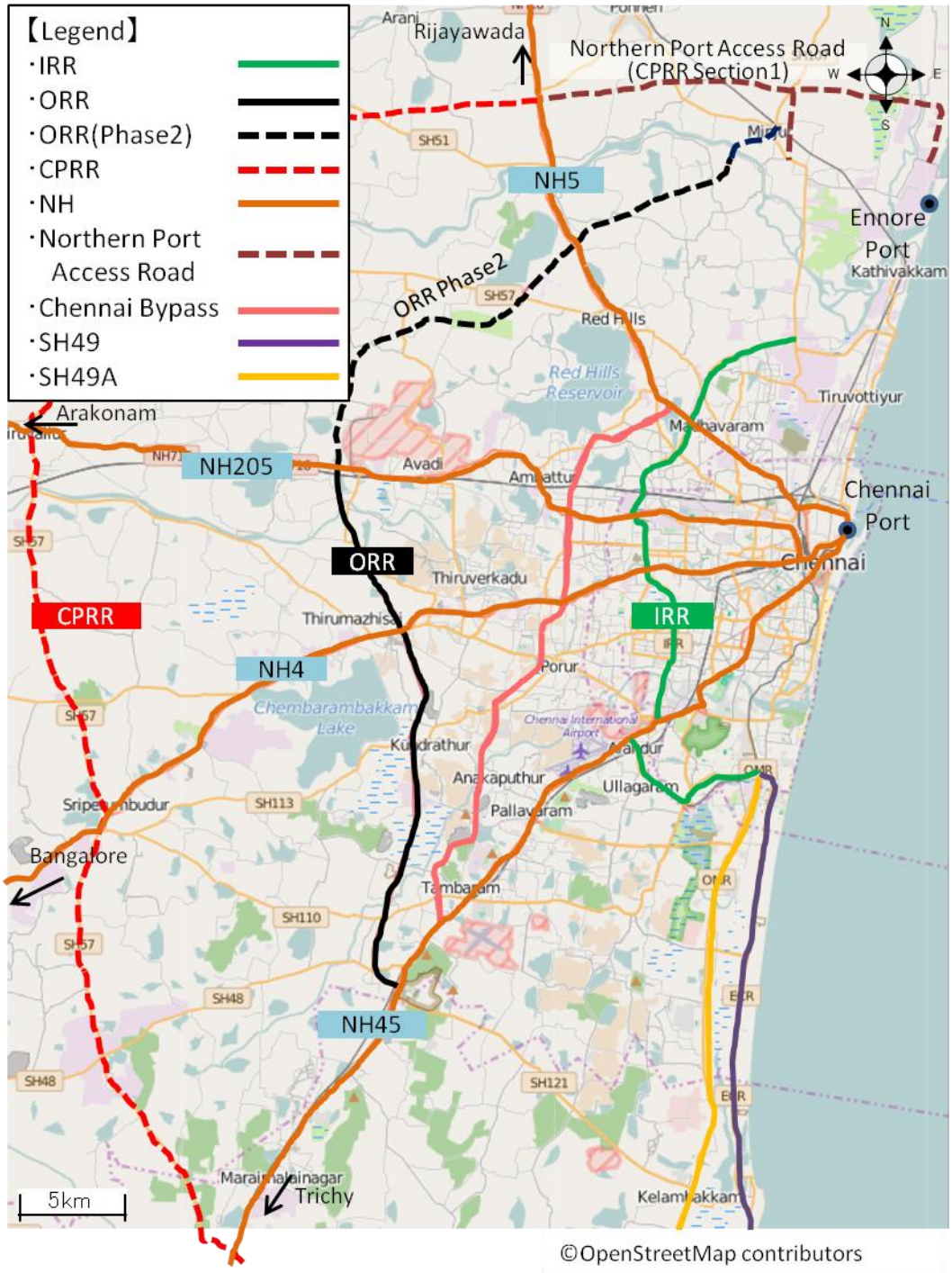
- NH45
- NH4
- NH5
- NH205

Chennai is connected to Mumbai by NH4, Kolkata by NH-5, Theni by NH-45 and Madanapalli by NH205. Chennai is also connected to other districts in Tamil Nadu state and union territory of Pondicherry by the State Highways.

Other major state highways are SH49 and SH49A.

The ring road network was developed as per the 1st Chennai Master Plan. It includes Inner Ring Road and Chennai By-pass Road and Outer Ring Road-Phase -1.

The major road network is shown on the map below.



(Source: Prepared by JICA Study Team)

Figure 2.10 Major Road Network in Chennai

The table below summarizes the major roads in Chennai and the connected cities.

Table 2-11 Major Road in Chennai and Connected Cities/Areas

Road Class	Road Name	Connected Major Areas/ Cities	Remarks
National Highways	NH-5	Vijyayawada, Red Hills, Thachur, Chennai Port	Forming a part of Golden Quadrilateral
	NH-205	Avadi, Thiruvallur, Arakonam	
	NH-4	Bengaluru, Poonamalle, Koyembedu	Forming a part of Golden Quadrilateral
	NH-45	Tambaram, Tirchy	
	Chennai Bypass	Tambaram, Ambathur	
State Highways	Inner Ring Road (IRR)	Alandur, Koyambedu, Padi	
	SH49A	Adyar, Mahaballipuram	IT Corridor
	SH49	Thiruvanmiyur, Mahaballipuram, Pondicherry	
	Outer Ring Road (ORR)	Vandalur,Nemillicherry, Tiruninravur, Minjur.	Phase 1 & phase 2
	Chennai Peripheral Ring Road (CPRR)	Ennore Port, Minjur, Thachur, Singaperumalkoil, Sriperambathur, Mahabalipuram.	Under Planning

(Source: Summarized by JICA Study Team based on Interview)

(2) Major Road under Planning / Construction in Chennai

The following roads are under planning/ construction in Chennai.

Table 2-12 Major Road under Planning / Construction in Chennai

Road	Section	Status
ORR- Phase 2	NH205 to Minjur	Under Construction
CPRR	NH45 to NH5	Under Planning

(Source: Summarized by JICA Study Team based on Interviews and Various Materials Collected)

a) **Outer Ring Road**

The Outer Ring Road is being constructed in phases. The section of phase 1 of Outer Ring Road which has been opened is from Vandalur on NH45 to Nemilinchery on NH205. The section of phase 2 of Outer Ring Road which is made construction Under Construction is from Nemilinchery on NH205 to Minjur on NH5. The project is being implemented by Tamil Nadu Road Development Corporation which was formed under Department of Highways and Minor Ports.

(Source: JICA Study Team)

Figure 2.11 Construction of Outer Ring Road

b) **Chennai Peripheral Ring Road**

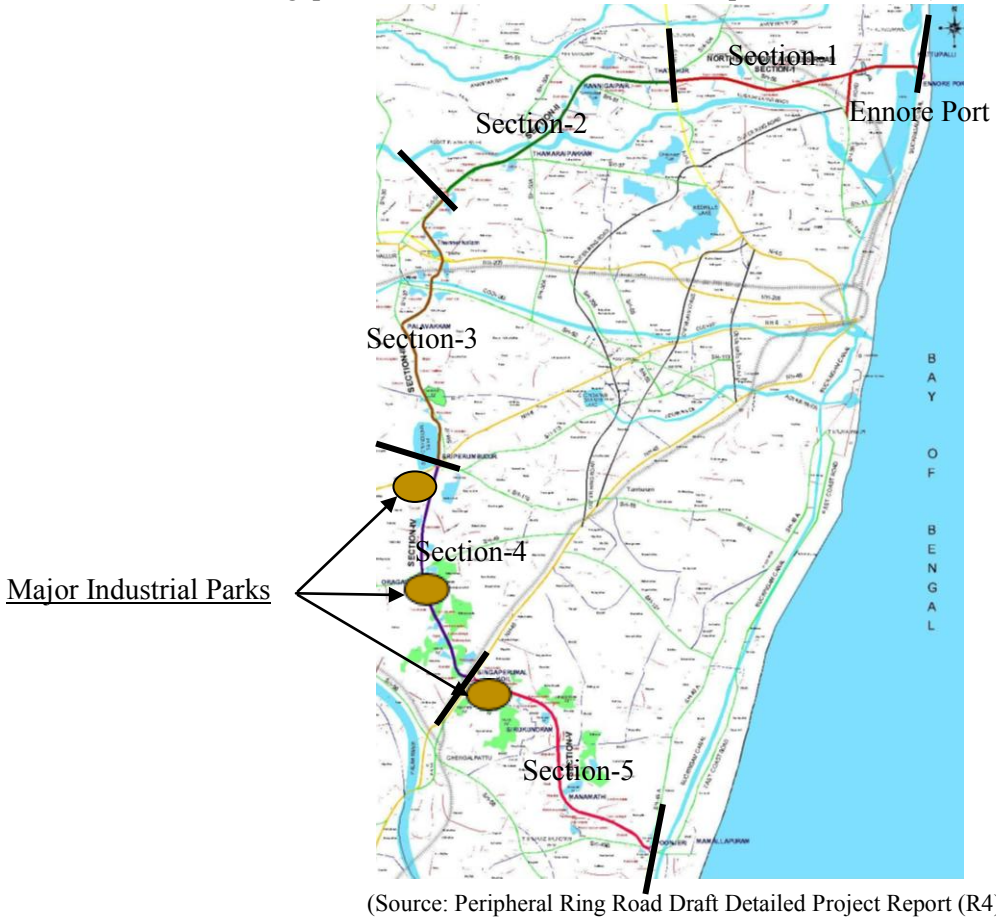
The Chennai Peripheral Ring Road is a semi-circle road surrounding Chennai at a distance of 25 to 55 km from the city centre and total length of Chennai Peripheral Ring Road is 133.65 km. It improves the connectivity around the city catering future traffic requirements. Especially, connectivity of container movement from southern industrial district to Ennore & Kattupuli Port is expected to be drastically improved. It starts at the Ennore Port at north end and link to major radial roads such as NH5, NH205, NH4, NH45 and SH49 at the south end. Chennai Peripheral Ring Road is divided into following five sections.

- Section 1: Ennore Port to Thatchur on NH-5 (25.50 km)
- Section 2: Thatchur on NH-5 to Start of Thiruvallur Bypass (26.25 km)
- Section 3: Start of Thiruvallur Bypass to Sriperumbudur on NH-4 (29.55 km)

(Thiruvallur Bypass is planned to be a part of Section 3 of Chennai Peripheral Ring Road)

- Section 4: Sriperumbudur on NH-4 to Singaperumalkoil on NH-45 (24.85 km)

- Section 5: Singaperumalkoil on NH-45 to Mahabalipuram on SH49 (27.50 km)



(Source: Peripheral Ring Road Draft Detailed Project Report (R4))

Figure 2.12 Alignment and Sections of Chennai Peripheral Ring Road

There are a large number of large sized vehicle in surrounding area of Chennai. Thus the construction of Chennai Peripheral Ring Road is expected to greatly contribute to the following aspects by guiding these large-sized vehicles to Chennai Peripheral Ring Road.

- It reduces accidents involving vulnerable road users such as pedestrians, motorcycles and auto rickshaws in both suburban area and urban area,
- Chennai Peripheral Ring Road is a high-standard road and it allows the vehicle to run at constant speed and thereby accordingly reduce vehicular emission such as NOx, SOx, etc.
- Shifting the traffic of large sized vehicle to Chennai Peripheral Ring Road reduces the damages of pavement of the roads in urban area and villages in suburban area.

The planning of each section of Chennai Peripheral Ring Road are:

Section-1

The entire stretch will be a new road which consists of two parts. One is a main line with length of 21.1 km from Ennore port to NH-5 and the other is a branch line with length of 4.4 km which is

separated from the main line and ends near Minjur. This branch line will be connected to the bypass of Minjur. The section-1 is planned as 4-lane carriageway with 2-lane service roads on both sides. The width for 6-lane carriageway is acquired. But it is planned to open with 4-lane at first and expand to 6-lane in the future according to increase in traffic. The section-1 is considered, by Tamil Nadu State Government, as the first phase of construction of Chennai Peripheral Ring Road. Currently there is no detail plan of tolling, but the section-1 is mostly expected to be a tolled section.

Section-2

The entire stretch will be a new road with length of 26.3 km from NH-5 to starting point of Thiruvallur Bypass. This section is planned as 6-lane carriageway with 2-lane service roads on both sides. Thiruvallur Bypass will be a bypass of existing SH-57 and is expected to significantly reduce the number of large-sized vehicles passing through Thiruvallur town.

Section-3

The entire stretch will be 29.6 km in length and consist of new alignment and widening of the existing SH-57 with length of 9.6 km. It is from the starting point of Thiruvallur Bypass to NH-4. (Thriruvallur Bypass is planned to be a part of the section-3) This section is planned as 6-lane carriageway with 2-lane service roads on both sides.

Section-4

The entire stretch will be widening of the existing SH-57 and almost 80% of the widening work has been completed. This section is from NH-4 to NH-4. It is planned as 6-lane carriageway with 2-lane service roads on both sides and passes through major industrial parks in the region such as ORAGADAM, Mahindra Industrial Park, etc. Therefore, completion of connectivity from this section to Ennore port is expected to greatly contribute to enhancement of logistic activities and consequently strengthening of regional economy.

Section-5

The entire stretch will be 27.5 km in length and consisted of new alignment and widening of the existing SH-49B with length of 2 km. This section is from NH-45 to SH49 and planned as 6-lane carriageway with 2-lane service roads on both sides.

The table below shows the outline of Chennai Peripheral Ring Road by section.

Table 2-13 Outline of Chennai Peripheral Ring Road by Section

Sl. No.	Description	Section - 1	Section - 2	Section - 3	Section - 4	Section - 5
1	Right of way (RoW)	100m	60m	60m	40-60m	60m
2	Number of lanes in Main Carriageway	2 X 2-lane with paved shoulder	2 X 3-lane with paved shoulder	2 X 3-lane with paved shoulder	2 X 3-lane with paved shoulder	2 X 2-lane with paved shoulder
3	Central Median	4.00m	4.00m	4.00m	1.0m	4.00m
4	Service Road	2 X 2-lane	2 X 2-lane	2 X 2-lane	2 X 2-lane	2 X 2-lane
5	Footpath/Drain/ Utility Corridor	2 X 2m & 2 X 3m	2 X 3m	2 X 3m	2 X 2.5m	2 X 3m
6	Width of Main Carriageway in Structures	2 X 12.5m	2 X 12.5m	2 X 12.5m	2 X 12.5m	2 X 12.5m

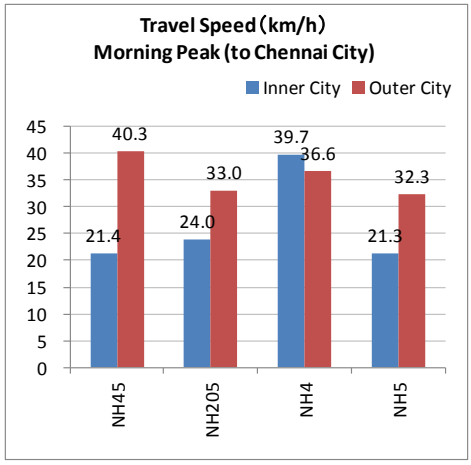
(Source: Peripheral Ring Road Draft Detailed Project Report (R4))

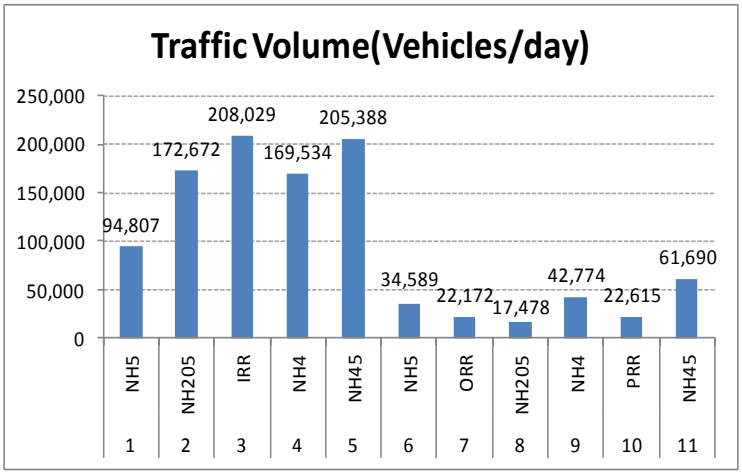
(3) Issue of Road Traffic in Chennai

a) Concentration of Traffic in Core Area of Chennai

The figures below show the result of the traffic survey carried out by this study. As shown below, the traffic is concentrated particularly in the core area of Chennai. It was found more than 200,000 vehicles per day are passing on NH45 and Inner Ring Road. On the other hand, the traffic volume in the suburbs is less than 70,000 per day. The similar characterises were found on other major roads as the figure shows.

As a result, the travel speed of traffic towards Chennai City in the morning peak hour becomes less than 30 km/hr in the inner city.

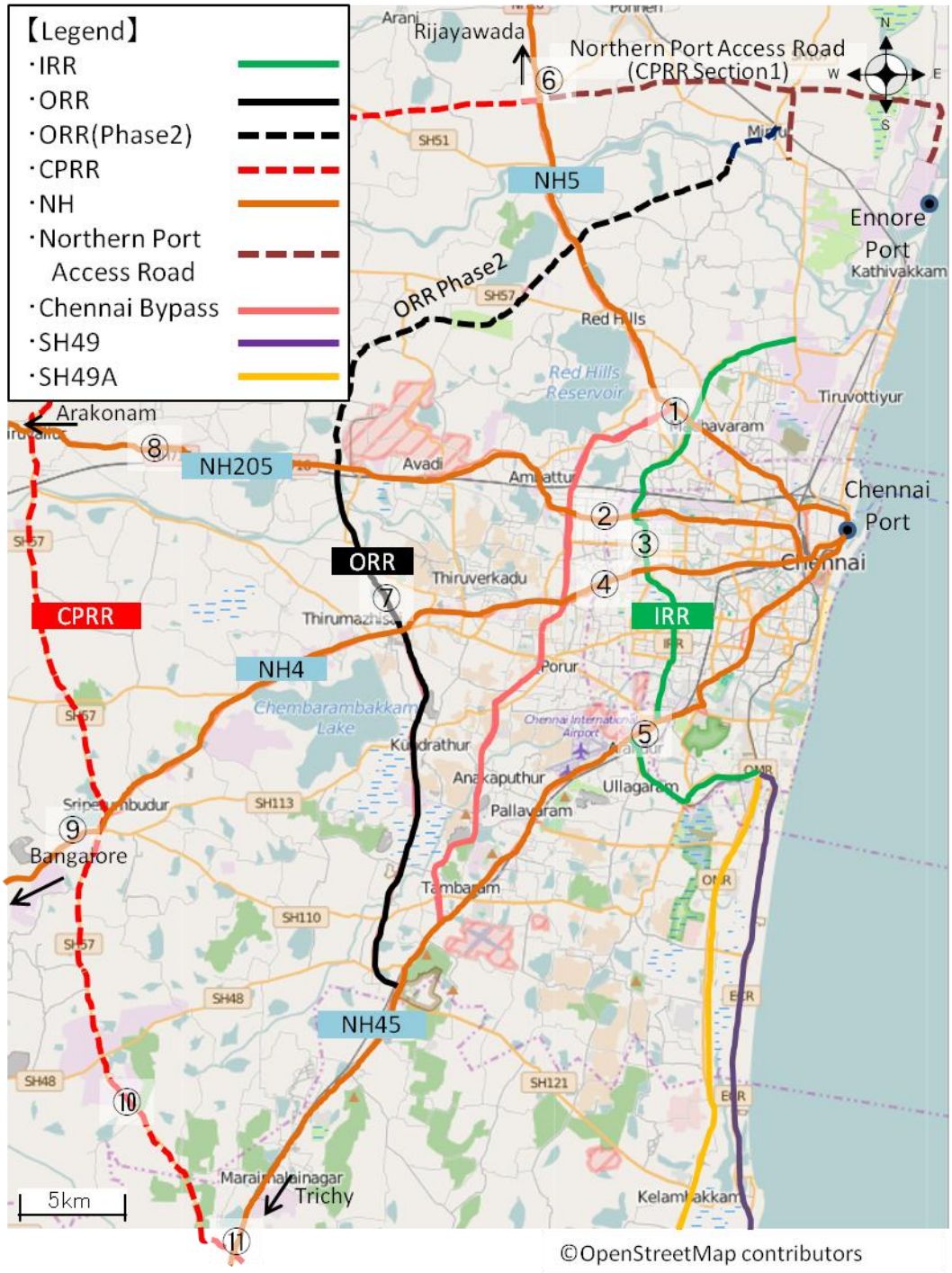




(Source: JICA Study Team)

Figure 2.13 Result of Traffic Survey

The locations of the traffic volume survey conducted by this study are shown on the map below.



(Source: JICA Study Team)

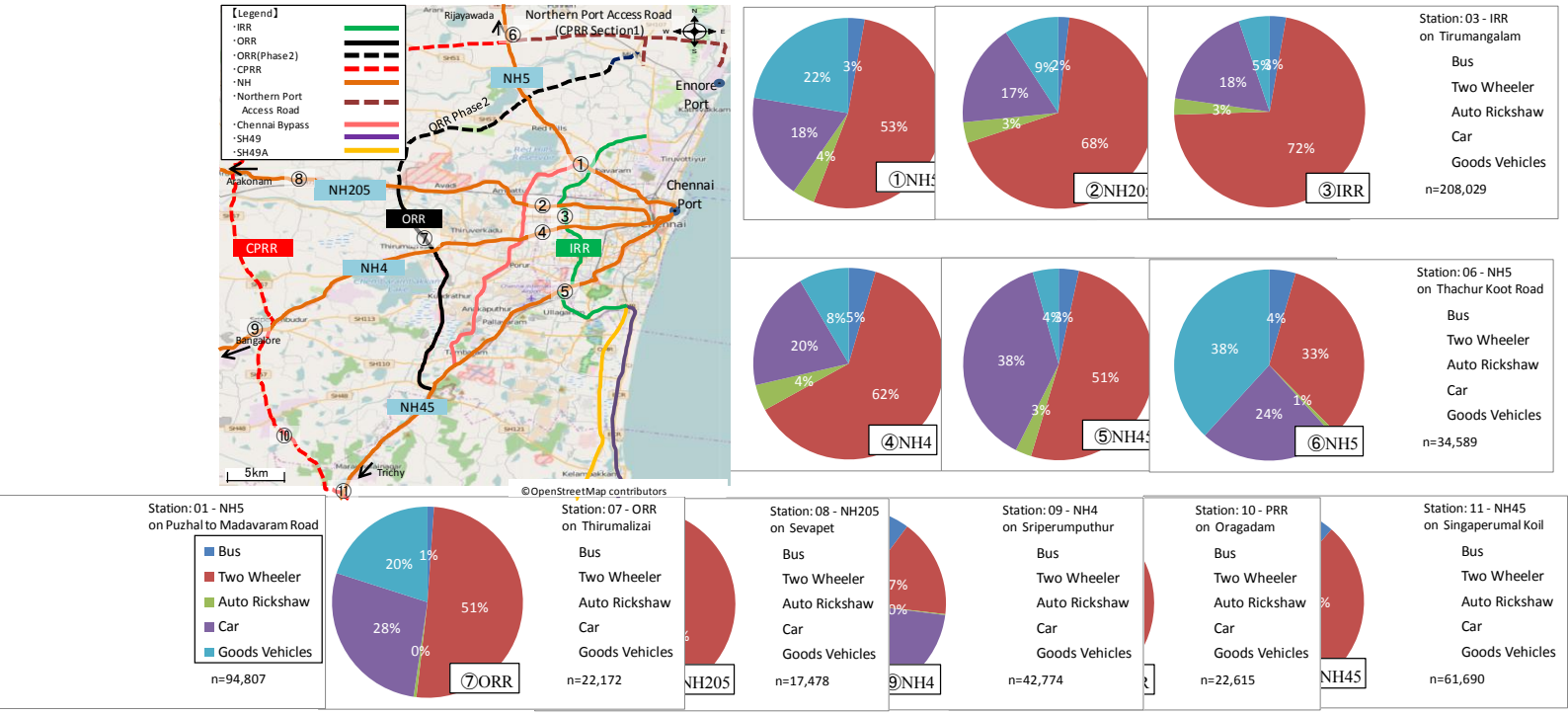
Figure 2.14 Locations of Traffic Volume Survey

b) High Proportion of Motorcycles

The proportion of motorcycle is very high, comparing to other modes. In particular, it was found that almost 70% of traffic is motorcycles on Inner Ring Road and NH205 in Chennai City. Further, there is a great concern of safety due to such facts that many people do not wear helmet, more than three people ride the motorcycles and so on.

The pie charts below show the proportion of mode at the survey locations which are shown on the map below. The motorcycle is indicated in red in the pie chart.

The picture below shows the traffic condition on Inner Ring Road.



*Two-wheeler means motorcycle.

(Source: JICA Study Team)

Figure 2.15 Proportion of Traffic Mode at Survey Locations

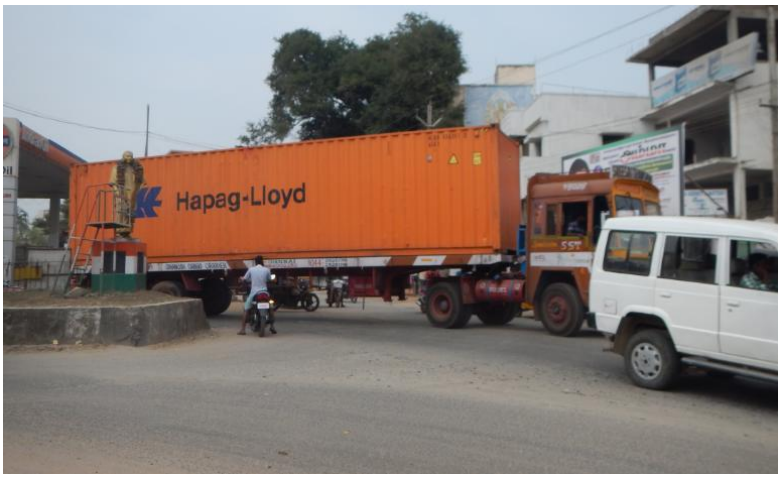
(Source: JICA Study Team)

Figure 2.16 Traffic Condition on Inner Ring Road

c) **High Proportion of Large-size Vehicle**

The pie charts on the previous page show the high ratio of large-size vehicle on the suburban section of NH5, NH4, NH45 and Chennai Peripheral Ring Road (Under Planning)which connects the industrial areas in the suburbs. This indicates that these roads are used by a large number of commercial vehicles such as containers to access the industrial areas and Ennore/ Chennai ports. The high proportion of the large-size vehicles causes decreasing the travel speed of traffic on the road because their speed is generally slow.

A large number of the large-size vehicles are frequently passing through the small villages in the suburbs. There are a lot of pedestrians and motorcycles in the villages and they are always facing a great danger of traffic accidents, as shown in the picture below.



(Source: JICA Study Team)

Figure 2.17 Container Blocking the Road

More than 3,000-4,000 container trucks go in and out of Chennai Port every day. However, only one entrance exists at north side of the port. Therefore chronic traffic congestion occurs on the access roads to the port as shown in the picture below. The average waiting time of the container trucks is 30-40 hours, according to the interviews.

(Source: JICA Study Team)

Figure 2.18 Containers Waiting for Entering the Chennai Port

d) **Outer Ring Road Not Effectively in Use**

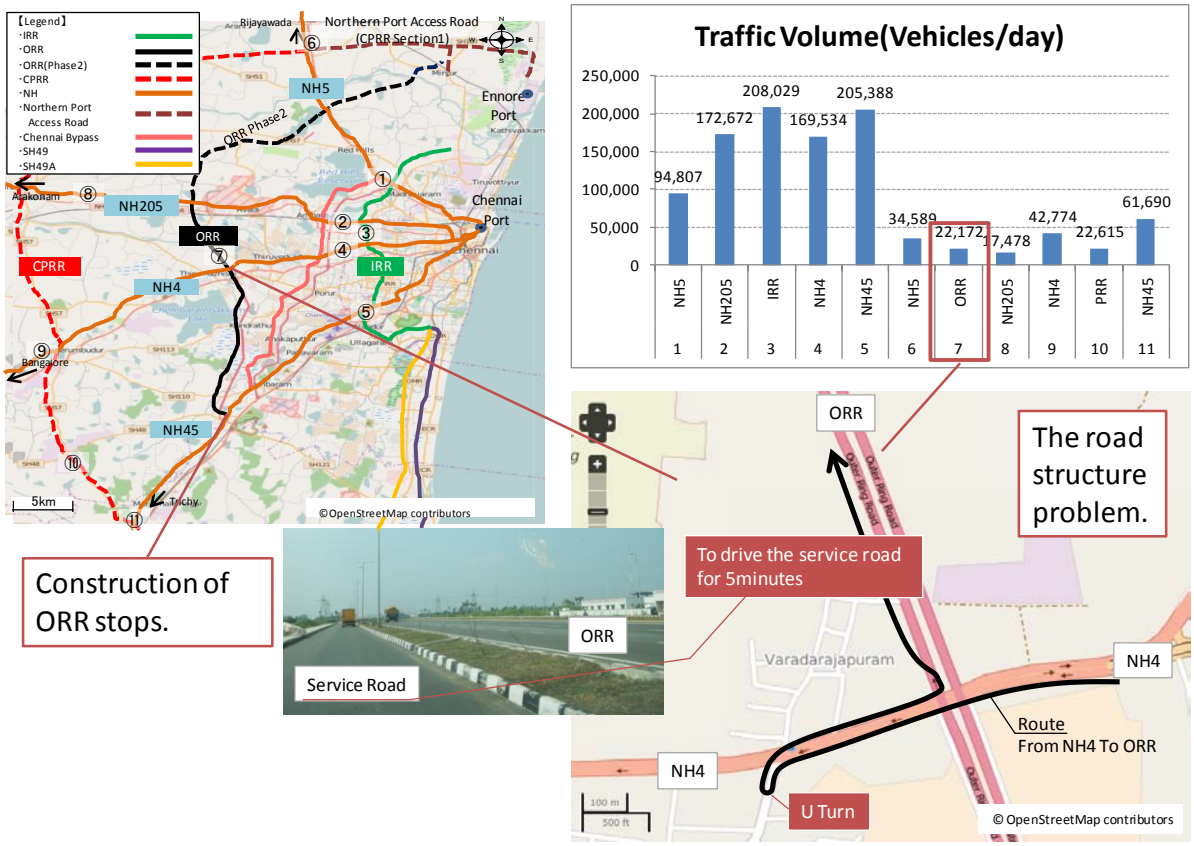
The traffic volume on the Outer Ring Road is almost one-tenth of the Inner Ring Road, both of which are same ring road in the city. This indicates that the Outer Ring Road is not effectively used. This is because some sections of the Outer Ring Road have not been completed yet. In addition importantly, the following structural problems of connection with the major radial roads are also considered major reasons:

- Connection with NH4:

  The drivers have to pass over the Outer Ring Road once and make U-turn to travel to the north on the Outer Ring Road from NH4. Then the drivers are further required to drive the service road along the Outer Ring Road for about five minutes to get on the Outer Ring Road.

- Connection with NH45:

  The construction at the connection point of the Outer Ring Road and NH45 has been suspended. Thus these roads are not directly connected yet. Therefore, the drivers need to take detour using the road which passes through the village nearby.



(Source: JICA Study Team)

Figure 2.19 Issues of Connectivity between Outer Ring Road and Radial Roads

e) Lowered Travel Speed

The morning peak hour is from 8:00 to 11:00 and evening peak hour is from 17:00 to 21:00 according to the result of the traffic survey. There is a tendency that the travel speeds in the direction from the suburbs to Chennai port district in the morning peak hour and in the opposite direction from Chennai port district to the suburbs in the evening peak hour are low. The travel speed on NH5 in the morning peak hour is the lowest, 26.4 km/h, among the major roads as shown in the figures below.

(Source: JICA Study Team)

Figure 2.20 Result of Travel Speed Survey

f) Pedestrians Crossing the Road

It was observed that there are pedestrian crossings at very limited locations in the city. There are also many cases that the pelican signals are not available at the pedestrian crossings on the major roads of six (6) lanes or more with a large amount of traffic volume. The pedestrians are forced to cross such roads during the moment when there is no passing vehicles. These are seriously dangerous situation and such conditions are always seen across the city. The photo below shows a barricade on the pedestrian crossing. The barricade is set up to segregate the traffic lane. However, this obstructs pedestrians' crossing.

(Source: JICA Study Team).

Figure 2.21 Barricade on Pedestrian Crossing

g) **Intersection at the Main Road**

There are some cases that the traffic cannot go straight on the road which is connected to the main road at some intersections. For example in the case of the figures below, the drivers are only allowed to make turn left and required to make a detour of approximately 1.8 km. Such conditions cause inefficient traffic flow and deteriorate the situation of congestion in the city.

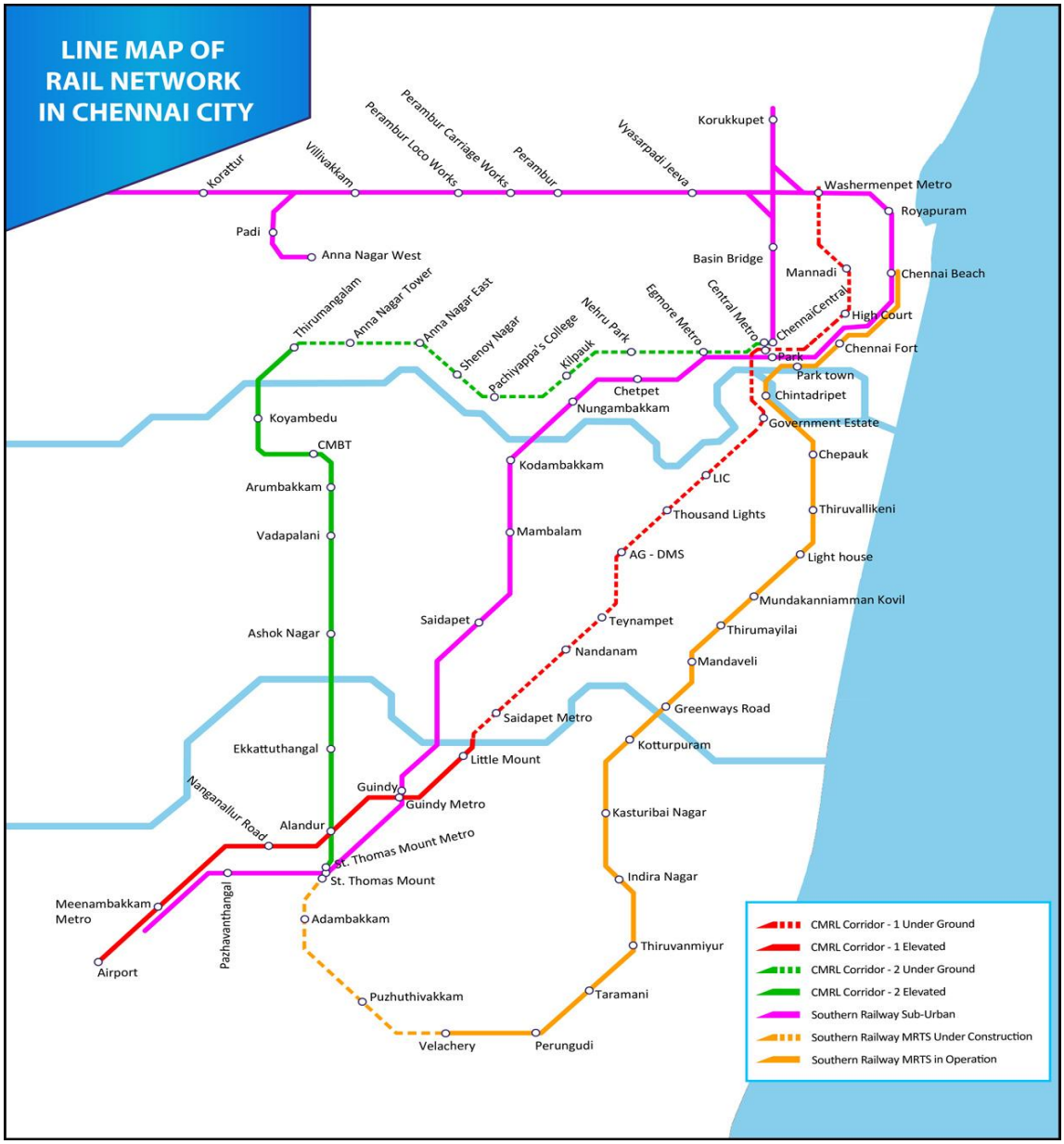
(Source: JICA Study Team)

Figure 2.22 Restricted Intersection

2.3.3 Rail Network

(1) Outline of Rail Network

The rail network is better planned comparing to other metropolises in India. There are four suburban railway line:, namely North line, West line, South line and Mass Rail Transit System line. Chennai metro rail is being implemented in phases and the operation has been already started on the limited sections. The mono rail is planned to complement other railway transport in the city. The railway network in Chennai is shown in the figure below.



(Source: Website of Chennai Metro Rail Limited)

Figure 2.23 Railway Network in Chennai

(2) Suburban Railway

Chennai Suburban Railway is administered by Southern Railways which is one of the department of Indian Railways. It is operated by the Southern Railway which is one of the operating railway zones of Indian Railways.

It consists of the following lines

- Chennai Beach – Tambaram line: Running south-west
- Chennai Central –Tiruvallur line: Running east-west
- Chennai Central – Gummidipoondi line: Running north-south
- Mass Rapid Transit System from Chennai Beach – Velachery (approx. 20 km in length)

The entire stretch of the Mass Rail Transit System is constructed as elevated structure and there is no railway crossing along the corridor. The Chennai Suburban Railway Network is shown below.

(Source: Website of Chennai Metro Rail Limited)

Figure 2.24 Suburban Rail Network in Chennai

(3) Chennai Metro

Chennai Metro is under development by Chennai Metro Rail Corporation Limited. It will be developed in Phases; phase 1 and phase 2. The phase 1 is now under development. The cost of the phase 1 is estimated at approximately INR 14,000 crores. Approximately 40% of the cost is covered by the Government of India and the Government of Tamil Nadu. The balance is financed by Japanese yen loan.

a) Chennai Metro Phase –2

The phase 1 corridor consists of two corridors; corridor 1 and corridor 2. The length in total together with both corridors is 45.1 km. Approximately 55% of both corridors is underground and the remaining is elevated. The operation on the elevated section of section 1 has been commenced since June 29 in 2015 and , the elevated stretch of 20.4 km in length is presently in service.

The number of daily passenger is estimated at 7.56 lakh in 2016 and 10.64 lakh in 2026.

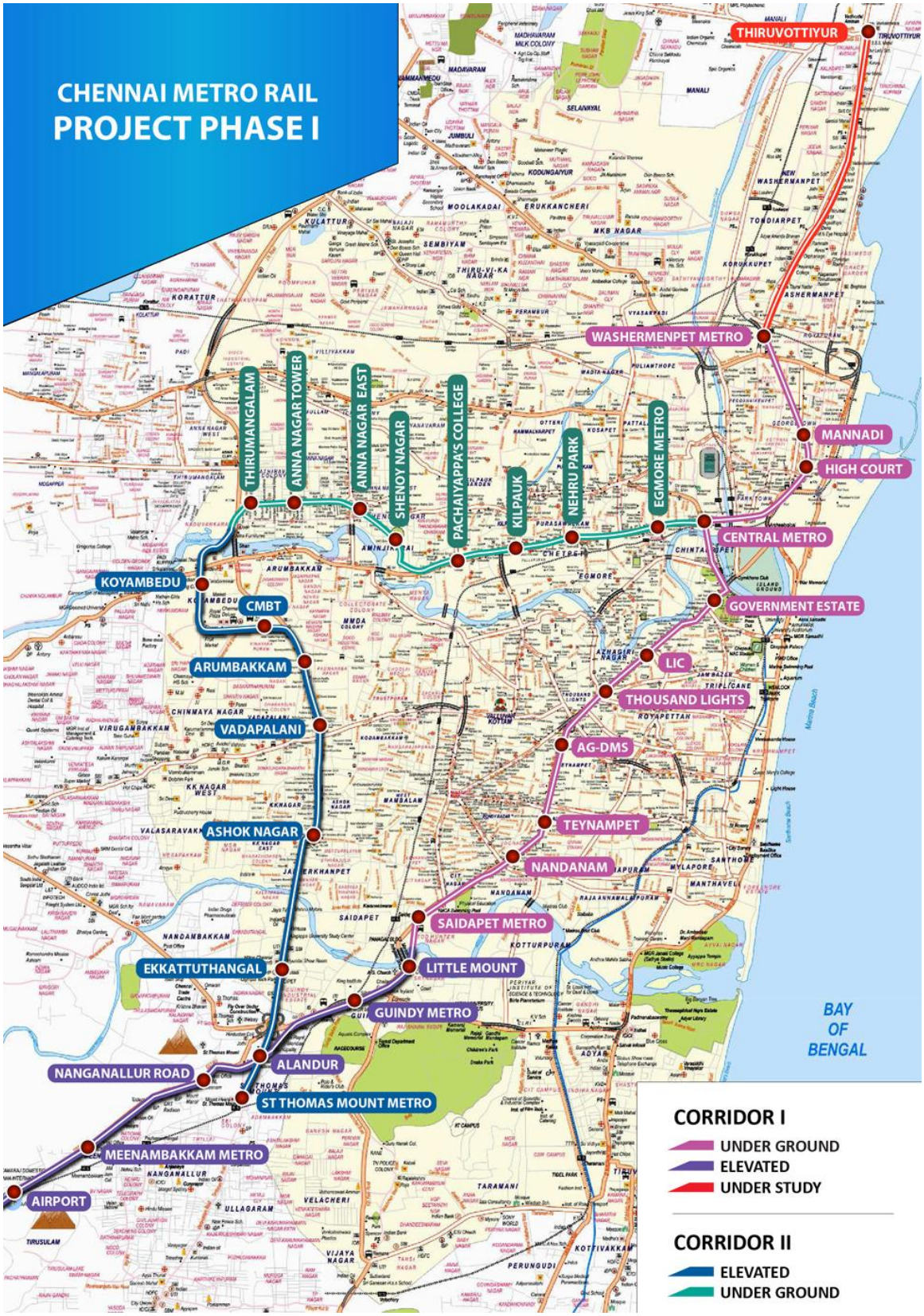
The outline of Chennai Metro in the phase 1 is summarized in the table below.

Table 2-14 Outline of Chennai Metro in Phase 1

Items	Corridor 1 Washermanpet to Airport	Corridor 2 Central to St. Thomas Mount	Total
Underground Length	14.300 km	9.695 km	23.995 km
Elevated Length	8.785 km	12.266 km	21.051 km
Total Route Length	23.085 km	21.961 km	45.046 km
Underground Stations	11	9	20
Elevated Stations	6	8	14
Total Stations	17	17	34

(Source: Website of Chennai Metro Rail Limited)

Chennai Metro network of phase 1 is shown on the figure below.



(Source: Website of Chennai Metro Rail Limited)

Figure 2.25 Chennai Metro Network of Phase-1

b) **Chennai Metro Phase –2**

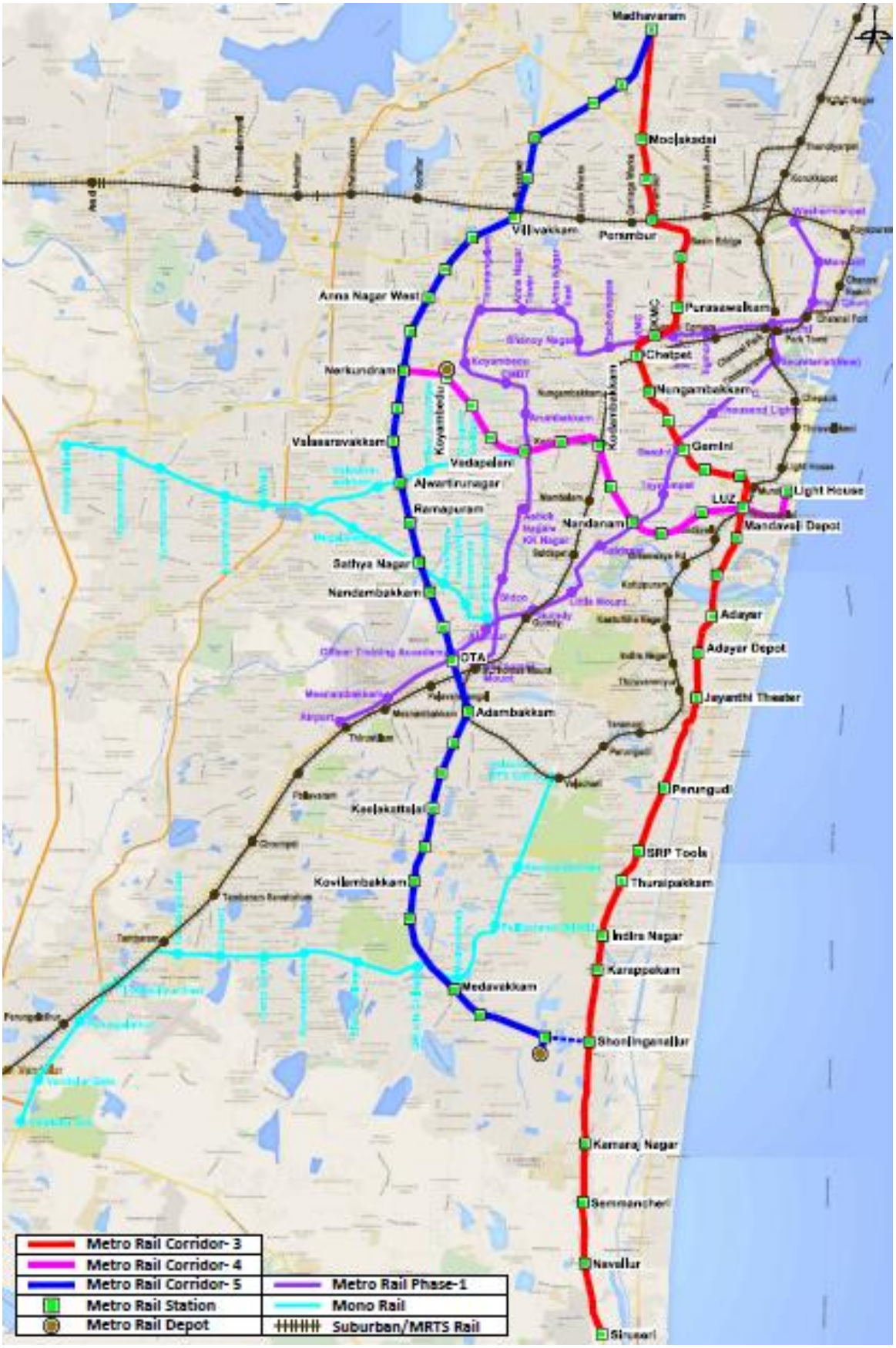
The phase 2 of Chennai Metro is under planning. Three corridors are planned; corridor 3, corridor 4 and corridor 5. The total length of the three corridors is 88 km. The outline is summarized in the table below.

Table 2-15 Outline of Chennai Metro Phase 2

Corridor	Stretch	Length
Corridor 3	From Madhavaram – Siruseri	40.2 km
Corridor 4	From Nerkundram- Light House	14.0 km
Corridor 5	From Madhavaram - Perumbakkam	34.7 km

(Source: Summarized by JICA Study Team based on Website of Chennai Metro Rail Limited)

The planned network of Chennai Metro in phase 2 is shown in the figure below.



(Source: Chennai Metro Rail Limited)

Figure 2.26 Chennai Metro Network in Phase 2

c) Issue of Vehicle Parking at Metro Stations and Information Provision

Currently 13 metro stations are in service and the parking spaces adjacent 11 metro stations are available. The parking fee is affordable. However these parking spaces are usually almost full during daytime on weekdays. In the future when the number of Metro passenger increases, it is expected that the capacity of the existing parking space will not be able to cater the parking demand. The information on the parking availability is not provided. Therefore, increasing the parking space and providing the information on the parking availability will be required.

The pictures below show the parking space at the metro station.

(Source: JICA Study Team)

Figure 2.27 Parking Space at Metro Stations (Above : For Vehicles, Below : For Motorcycle)

(4) Chennai Mono Rail

The construction of mono rail, which can be constructed along the limited road space, is planned in Chennai to complement the metro rail network. It is planned to be developed in phases. The planned stretch in the phase 1 starts from Poonamallee and it is divided into two corridors towards Vadapalani and Kathipara from Porur Lake. The total length is 20.68 km. The project cost is estimated at INR 3,235 crores.

The phase 1 project is being implemented on Design, Build, Finance, Operate and Transfer (DBFOT) basis. The tender was recently announced and the contractor is expected to be selected soon.

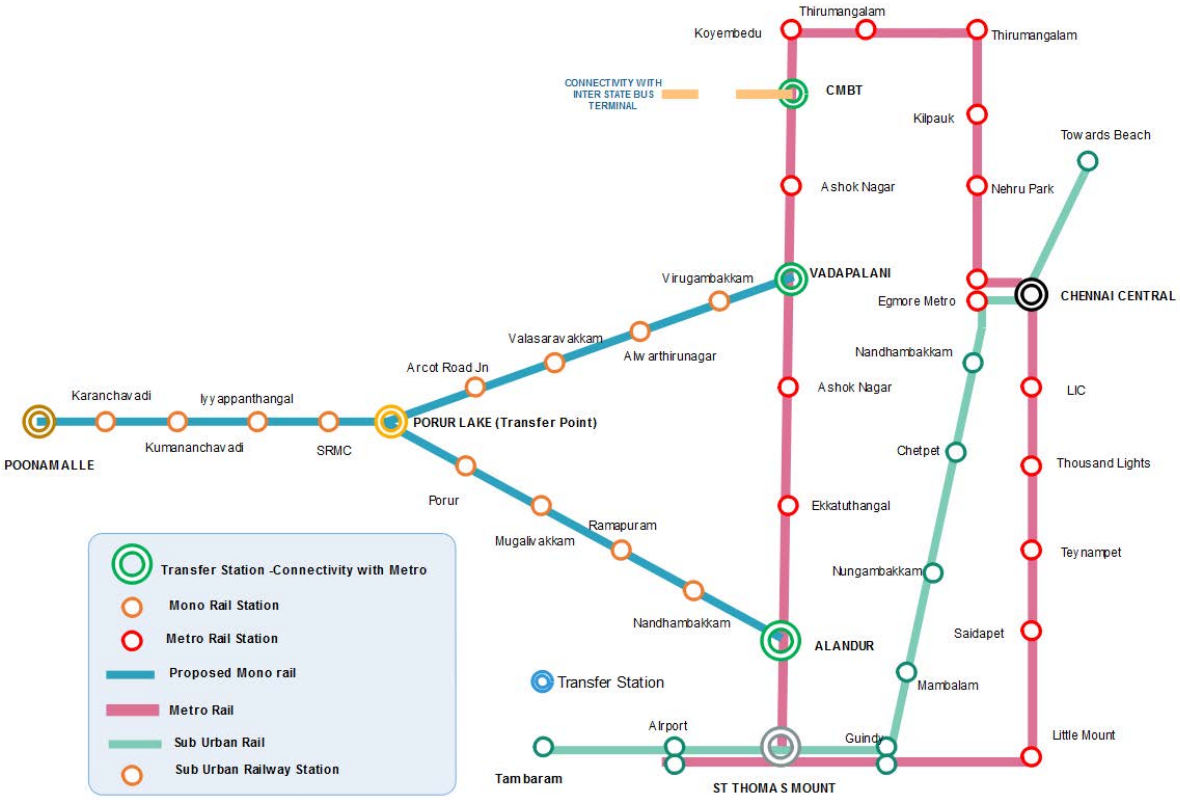
The planned corridor of the phase 2 starts from Vandalur to Velachery, totalling 23 km in length. The cost is estimated at approximately INR 4,000 crores.

The planned corridor of the phase 1 is shown in the figure below.

(Source: Website of Chennai Mono Rail Project)

Figure 2.28 Planned Corridor of Chennai Mono Rail (Phase 1)

The connection points among Chennai Metro, Chennai Mono Rail and Suburban Railway are summarized in the figure below.



(Source: Prepared by JICA Study Team based on Interviews with Relevant Agencies)

Figure 2.29 Connection Points among Chennai Metro, Chennai Mono Rail and Suburban Railway

2.3.4 Bus Network

(1) Outline of Bus Network in Chennai

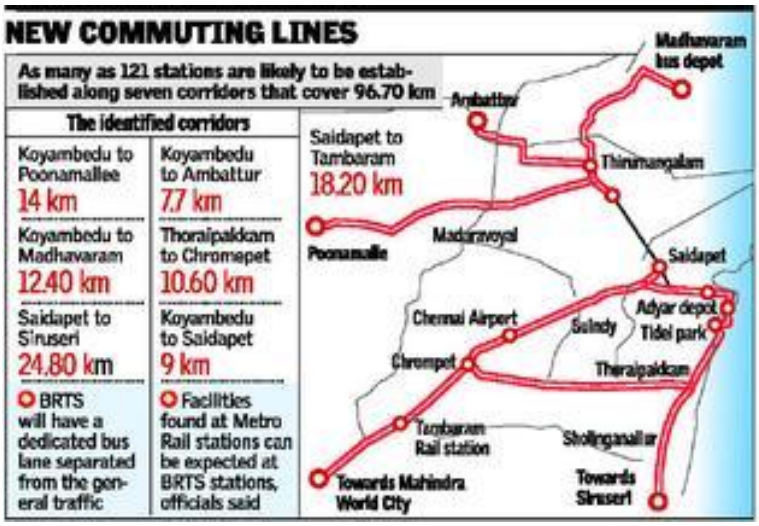
The bus transport service in Chennai is offered by Metropolitan Transport Corporation and State Express Transport Corporation. Metropolitan Transport Corporation is a city bus operator. They cover more than 800 routes approximately up to 50 km in distance from central area of Chennai. Thus, Metropolitan Transport Corporation buses run on almost all arterial routes in the city. State Express Transport Corporation is a long-distance bus operator.

The intermodal connectivity in Chennai is well considered. There are some connectivity points between Metropolitan Transport Corporation and Chennai Metro. CMBT station of Chennai Metro is constructed adjacent the largest bus terminal in the region which is both for city buses and long-distance buses.

(2) Bus Rapid Transit System

Seven routes of Bus Rapid Transit System in Chennai are planned. These seven corridors cover 96.70 km and 121 stations have been identified as outlined below.

- Koyambedu to Poonamallee (14 km)
- Koyambedu to Ambattur (7.7 km)
- Koyambedu to Madhavaram (12.40 km)
- Saidapet to Siruseri (24.80 km)
- Saidapet to Tambaram (18.20 km)
- Thoraipakkam to Chromepet (10.60 km)
- Koyambedu to Saidapet (9 km).



(Source: The Hindu -Newspaper)

Figure 2.30 Planned Routes of Bus Rapid Transit System in Chennai

(3) Issue of Bus Network in Chennai

Though there are a large number of buses are running in the city, any information such as bus arrival time is not provided to the passengers. It is also important to provide the users with the transfer information together with other transportation modes.

Information Provision at CMBT Station

A large bus terminal is located next to CMBT metro station. There are signboards to guide to the bus terminal from the station and the walking path with roof to the bus terminal is constructed at the CMBT station as shown in the pictures below. Therefore, a preferable access environment is in place. However, the information of bus operation is not provided. It is

desirable that useful information for the passengers such as expected arrival time and delayed status due to accident be provided.

(Source: JICA Study Team)

Figure 2.31 Sign Boards and Walking Path from Metro Station to Bus Terminal

(Source: JICA Study Team)

Figure 2.32 Koyembedu – Bus Terminal

2.3.5 **Other Transportation System**

There is a transport method for last mile connectivity. The major examples in Chennai are taxi, auto-rickshaws, shared-auto, motor cab, etc. The taxis and auto-rickshaws travel directly from the origin to the destination, a door-to-door travel. The shared-auto and motor cab travel on the determined routes. The typical examples of these transport modes are shown in the pictures below.

(Source: JICA Study Team)

Figure 2.33 Auto-Rickshaw and Taxi: For Door-to-Door Travel

(Source: JICA Study Team)

Figure 2.34 Motor Cab and Shared Auto: On the Determined Route

2.4 Current Condition and Plan of ITS

2.4.1 Overview of ITS Conditions in Chennai

The traffic condition in Chennai city is presently monitored to a limited extent by Closed Circuit Television (referred to as 'CCTV' hereinafter) at the limited number of intersections. The traffic signals are available in the city. But there are many cases that they are not working. ITS facilities of city bus such as bus monitoring system are increasingly introduced in other major cities such as Mumbai, Ahmadabad ,Bangalore in India in recent years. The introduction of such facilities is being considered in Chennai. The introduction of smart card which can be used for different public transport have been considered in such cities as Mumbai and Bangalore. The introduction of such common smart card has also been considered in Chennai.

The quantitative data on traffic is important for ITS because it can be used for providing dynamic traffic information and urban transport planning. Likewise, other cities in India, the mechanism/system which collects and utilises the quantitative traffic data is not available.

As described in the previous section, the physical connectivity of public transport is well planned in Chennai. Some metro stations are constructed together with parking spaces and large hub bus terminal and transfer facilities with suburban railway and metro railway are planned. This implies that there is a potential that convenience will be enhanced and modal shift to the public transport will be encouraged if the information technology is properly utilized by such measures as providing information on public transport and introducing common smart card.

2.4.2 ITS Facilities of Chennai Traffic Police

(1) Traffic Control Room

The traffic control room of Chennai traffic police monitors the traffic in entire city by two groups. One is in charge of south and east areas of the city. The other is in charge of north and west areas.

(2) VMS Board

There are 31 VMS boards which are installed at important junctions in the city. Any dynamic traffic information is not provided. Only static messages for raising traffic awareness such as wearing helmet for motorcycle drivers are displayed.

(3) Traffic Signals and CCTV Cameras

There are 383 signalized intersections in Chennai according to the interview to Chennai Traffic Police. But many of the signals on these intersections are broken or not working. The fixed signal cycles are manually set by the police personnel at site. All of them are stand alone and they are not connected to the control room. There is no function of traffic signals to automatically adjust the signal timing. Some intersections are monitored by CCTV.

(Source: JICA Study Team)

Figure 2.35 Variable Message Sign Board

(Source: JICA Study Team)

Figure 2.36 Signal and CCTV

(4) Equipment for Enforcement: E-Challan System

The system for enforcement, called 'E-Challan', is introduced. The police officer is provided with handheld device for enforcement of the violated vehicles. The device is equipped with data input function, camera, barcode reader, communication module, etc. The information on the violated vehicle is input on the device at site. The input information is transmitted to the central server through GPRS network and stored. The penalty ticket is issued by ticketing terminal on the spot.

(Source: Website of Chennai Traffic Police)

Figure 2.37 Handy Terminal and Ticketing Device

(5) Upgrade Plan of Current Traffic Control System (Integrated Traffic Management System Project)

The upgrade of the current system of traffic control of Chennai Traffic Police was planned. The plan is called 'Integrated Traffic Management System Project'. The project includes the components such as installation of 100 CCTV cameras, establishment of traffic control room, signal coordination and automatic number plate recognition, priority signal movement of VIP and emergency vehicles. The project cost was estimated at INR 150 crores and planned to be implemented by Built-Operate-Transfer for 5 years. M/s Purple Infotech Pvt Ltd was awarded the contract. However the project has been suspended due to legal issues with the contractor since April 2014.

2.4.3 ITS for City Bus

The typical facilities of city bus which have been increasingly introduced in the major cities in India are listed below. These systems are not available in Chennai, but introduction is being considered. A series of stakeholder meetings* under initiative of Chennai Smart City Limited are being carried out for introducing these facilities. (* Stakeholder Meetings : Refer to [2.5.4 Smart City Mission])

- Bus Monitoring System:

  It monitors the bus movement based on bus probe data obtained from Global Positioning System (referred to as 'GPS' hereinafter) units installed on the buses. It also manages the bus operations at command centre.

- Passenger Information System:

  It provides the information on expected arrival/departure time of buses through such media as information board at bus terminal / bus stops, Internet, etc.

- Electric Fare Collection System:

  It automates the payment of bus fare in electronic form by such methods as smart card, magnetic cards etc.

Metropolitan Transport Corporation carried out a pilot of installing 500 GPS devices in Metropolitan Transport Corporation Buses and they installed facilities for passenger information system at 100 bus stops. But later the project was stopped by Metropolitan Transport Corporation due to insufficient operation and maintenance cost of the system.

2.4.4 ITS for Chennai Metro

Chennai Metro Rail Limited adopts a distant fare system and introduced electronic fare payment system. Two kinds of payment have been introduced: Smart Token and Contactless Smartcard.

(1) Smart Token

The passengers buy the token at counter or by the token vending machine. One token is valid for a single trip. The passenger touches the pad with the token at the entry gate and drops the token in the slot at exit gate after use.

(2) Contactless Smartcard

The contactless smartcard is available only for Chennai metro. It is used for multiple use of metro and frequent passengers. The passenger touches the card reader at both entry and exit gate. Initial price of smartcard is INR 100 which includes INR 50 for fare and the value can be recharged (top-up) within the range of INR 100 to 3000 at ticket vending machine at metro stations. The card type used for metro fare is Mifare Type A.

Chennai Metro Rail Limited contracted with Nippon Signal Co., Ltd. as a vendor of the Automatic Fare Collection System. The contract includes developing Automatic Fare Collection system, installing equipment such as automatic gate and ticket vending machine at 32 metro stations, supplying the smart card of Type A and having stock of FeliCa. The card reader/writer is applicable to all types of smartcards which are Type A, Type B and FeliCa. This is for security protection measure for the case such that if the Type A cards are exposed to threat, another type of card can be used.

The table below summarises the current status of smartcard system of Chennai Metro Rail Limited.

Table 2-16 Summary of Current Status of Smartcard of Chennai Metro Rail Limited

Item	Deacription
Available Payment Service	• Single Journey Ticket (Token) • Monthly Pass (Smartcard) Prepaid Card (Smartcard)
Smartcard Type	• ISO 14443 Type A (FeliCa: Stocked) • Memory Size is 4 Kb
Card Reader/Writer	Applicable to Type A, Type B and FeliCa
Vendor	Nippon Signal Co., Ltd.
Card Issuer	CMRL
Value Issuer	CMRL

(Source: Edited by JICA Study Team based on Interview)

(Source: Chennai Metro Web Site)

Figure 2.38 Smart Token

(Source: Chennai Metro Web Site)

Figure 2.39 Smart Card

2.4.5 **Common Mobility Card in Chennai**

A common mobility card which can be used across different transport modes has not been introduced yet in Chennai. Consideration of introduction of the card has been recently initiated and the working committees named "Integration of Public Transport" under Chennai Unified Metropolitan Transport Authority was established.

Managing Director of Chennai Metro Rail Limited is a chairman of the working group. Other members of this committee are:

- Managing Director (Metropolitan Transport Corporation)
- Deputy Reginal Manager (Southern Railways)
- Chief Administrative Officer (Mass Rail Transit System)
- Transport Commissioner (Transport Department)
- Commissioner (Greater Corporation of Chennai)
- Chief Engineer (Department of Highways and Minor Port)
- Member Secretary (Chennai Metropolitan Development Authority)
- Chennai City Connect (NGO)

Chennai Metro Rail Limited is an only transport operator that introduced smartcard in Chennai. Although settlement of fare payment across different transport operators is not required yet, Chennai Metro Rail Limited has already developed a Clearinghouse System for settlement, expecting future use such as with Metropolitan Transport Corporation bus, Mass Rail Transit System, etc.

2.4.6 ITS Facilities on Major Highway

(1) Overall Condition of Major Highway

The major highways in Chennai under the jurisdiction of National Highway Authority of India are NH5, NH205, NH4 and NH45 (The sections up to the boundary of Chennai City are under the jurisdiction of Department of Highways and Minor Ports). Outer Ring Road, SH49, and SH49A come under the jurisdiction of Tamil Nadu Road Development Company or Department of Highways and Minor Ports.

The implementation of major highways in Chennai is outlined below.

Table 2-17 Outline of Implementation of Major Highway in Chennai

Road Category		Controlling Agency	Implementing Scheme	Concessionaire
National Highway	NH5	NHAI	BOT (Toll*2)	L&T Co., Ltd.
	NH4	NHAI	BOT(Toll)	Essel Co., Ltd.
	NH45	NHAI	BOT (Annuity *3)	Eagle Co., Ltd.
	NH205	NHAI	BOT(Toll)	Transstory Tirupati Co., Ltd.
	Chennai Bypass	NHAI	Direct Control	
State Highway	Outer Ring Road	TNRDC *1	BOT(Annuity)	GMR Co., Ltd.
	SH49	TNRDC	Direct Control	
	SH49A	TNRDC	Direct Control	
	Inner Ring Road	Department of Highways and Minor Ports	Direct Control	

(Source: Summarized by JICA Study Team based on Interview to Related Organization)

**1: Tamil Nadu Road Development Corporation. A road implementing company established under Ministry of Highways and Minor Ports*

**2: The concessionaire recovers the investment and gains benefit from toll fare which is collected by them.*

**3: The concessionaire is paid the annual fee by the government. The toll fare is collected by them and it goes to the government.*

The map on the next page shows the outline of implementation on the major highways in Chennai.

(Source: JICA Study Team)

Figure 2.40 Outline of Implementation on Major Highway

(2) ITS Facilities

Roads under Jurisdiction of National Highway Authority of India

ETC facilities based on RFID method, called 'FASTag', are deployed on the National Highways and Chennai Bypass Road. The facilities of Touch & Go based on Integrated Circuit card and manual toll collections are also deployed.

Roads under Jurisdiction of TNIDC

ETC facilities such as RFID method are not deployed on SH49A and SH49. Only the facilities of T& G based on Integrated Circuit card and manual toll collection are introduced. There is no facility of toll collection on Outer Ring Road because it is not toll road. The collection of toll on Outer Ring Road is under consideration by the state government.

Roads under Jurisdiction of Department of Highways and Minor Ports

There are no facilities of toll collection on Inner Ring Road because it is not a toll road. The collection of toll on Inner Ring Road is also under consideration by the state government.

Presently, interoperable card system does not exist even T & G system is deployed some highways.

The standard concessioner agreement of National Highway Authority of India stipulates the deployment of Highway Traffic Management System which is composed of Traffic Control Centre, CCTV, Automatic Traffic Counter cum Classifier (referred to as 'ATCC' hereinafter), VMS board and Meteorological Data System (MET). However Highway Traffic Management System are not deployed on any of the above highways except a limited facilities on Outer Ring Road.

The table below outlines ITS facilities on major highways in Chennai.

Table 2-18 Outline of ITS Facilities on Major Highway

Road Category		Length	Traffic Control System	Toll Collection System
National Road	NH5	―	―	Manual Collection IC Card
	NH4	―	―	Manual
	NH45	―	―	Manual Collection FASTag
	NH205	―	―	Manual
	Chennai Bypass Road	32km	―	<North Section> Manual Collection <South Section> Manual Collection and FASTag
State Road	ORR *1 (Phase1) ORR (Phase2: Under Construction)	Phase 1 : 29.7km Phase2 : 33.1km	VMS, ECB, WMS *2	―
	SH49	114km	―	Manual Collection IC Card
	SH49A	20.1km	―	Manual Collection IC Card
	Inner Ring Road	25.2km	―	―

*1 ORR: Outer Ring Road

*2: VMS: Variable Message Sign Board, ECB: Emergency Call Box, WMS: Weather Monitoring System

(Source: Edited by JICA Study Team based on Interview)

The pictures below show the major facilities.

a) **Chennai Bypass Road**


(Source: JICA Study Team)

Figure 2.41 Toll Plaza in Surapattu

b) **Outer Ring Road**



(Source: JICA Study Team)

Figure 2.42 Variable Message Sign Board, Emergency Call Box, Meteorological Data System

c) **SH49A**


(Source: JICA Study Team)

Figure 2.43 Toll Plaza in Perungudi (left), Siruseri (right)

d) **SH49**


(Source: JICA Study Team)

Figure 2.44 Toll Plaza in Uthandi (left) and SH49 (right)

2.4.7 FASTag in India

(Source: IHMCL Web Site)

FASTag is RFID based ETC System and it has been implemented in India under the initiative of Ministry of Road Transport and Highway and National Highway Authority of India. RFID method was recommended as a national standard of ETC on national highway in India in September 2011. Since then, RFID based ETC has been increasingly deployed on the national highway. The outline of FASTag is described below.

(1) Steps towards Standardization of ETC in India

The following steps were taken for recommendation of RFID as standard.

Table 2-19 Steps towards Recommendation of RFID as Standard in India

Period	Description
2010.4.20	'Committee on ETC Technology for Use on National Highway' was constituted under Ministry of Road Transport and Highways. The Technical Committee was also formulated under Chairperson.
2010.6.28	RFID method was recommended due to such factors as usability, easy maintenance etc. by the Technical Committee after investigation
2011.3.8	The operational proposal was made by the Technical Committee.
2011.6.14	Work shop was convened for decision of technical standard, inviting major stakeholders.
2011.9	Report by Apex Committee for ETC Implementation was approved.
2012.12	Indian Highways Management Company Limited (IHMCL) was established as implementation agency. 50% equity is held by 22 private concessionaires, 25% by NHAI and rest by five banks.

(Source: JICA Study Team)

The opinions of various stakeholders such as National Highway Authority of India, ETC vendors, user group, etc. were reflected. The ETC technologies in other countries were also weighed. The reviewed ETC technologies include: Active/Passive Dedicated Short Range Communication, Active/Passive RFID, Communication Air-Interface: Long/Medium Range (CALM), Global Navigation Satellite System/Cellular Network, Automatic Number Plate Recognition, etc. After consideration/discussion of such factors as required system architecture, technical level for operation and maintenance, cost, interoperability, availability of suppliers, etc., the RFID for ETC was determined to be recommended as national standard and named as 'FASTag'.

	ETC Technology	Cost	Suppliers	In use	Comments
DSRC	Active Microwave 5.8 GHz	About Rs 2000 per OBU About Rs 5 Lac per Reader	Limited	Yes (Japan)	Due to higher bandwidth and data speed, supports many ITS applications
DSRC	Passive Microwave 5.8 GHz	~ Rs 1000 for OBU ~ Rs 2L for Reader	Multiple	Yes (Europe)	Very Simple OBU
DSRC	Infrared ISO-CALM	Rs 1000 for OBU ~Rs 2L for Reader	Limited	Yes (Austria and Malaysia)	Can be easily extended to a contactless card and useful for other ITS applications
RFID	Passive RFID	About Rs 100 per Tag About Rs 2 Lac per Reader	Multiple	Yes (South America, Georgia, US)	Allows tamper resistant "stickers" Small, light, very cheap, almost unlimited life
RFID	Active RFID	About Rs 1000 per On Board Unit (OBU)	Limited	Yes (Florida)	On-board transmitter, higher range, expensive Finite life as the battery has to be replaced
	GNSS/CN	About Rs 2 Lac per Reader About Rs 2000 per OBU	Limited	Yes (in Germany)	Too sophisticated and due to absence of toll plazas, enforcement on violations is very difficult in India.

(Source: Ministry of Road Transport and Highways :ETC Report 28/6/2010)

Figure 2.45 Technical Comparison of ETC Technology Made by Technical Committee for Standardization of ETC in India

(2) Equipment and How It Works

A unique ID which is linked to vehicle information is registered and tag which has ID information is pasted on the windshield. This tag is called FASTag. The dedicated lane for ETC, FASTag lane, is developed and the associated facilities such as RFD antenna and sensors are deployed. The communication between the antenna and tag is made and the toll fare according to vehicle type is charged. The users of FASTag register the vehicle information and setup online account before usage of the system.

The unique ID is read by communication between antenna and tag. The read information is sent to the central server of the bank which issues the tag. Then the toll fare is deducted from the online account. The tag is designed to be disabled on such occasion as intentional removal or damaged once it is pasted on the windshield. It is said that the tag can be read/detected by the antenna at the speed of 150 km/h.

(Source: JICA Study Team)

Figure 2.46 RFID Tag (FASTag) on the Wind Shield

(3) Implementing Outline

The tag is sold at the branches of ICIC Bank and Axis Bank now. These two banks are outsourced for such businesses as selling/registering tags, clearinghouse, etc. by two-year contract.

The tag is sold at INR 250 after adding the required overhead cost to the original producing cost at INR 100. The tags are embedded on the new car in recent years according to the policy of the Government of India.

Indian Highways Management Company Limited (IHMCL) was established as implementation agency. 50% equity is held by 22 private concessionaires, 25% by National Highway Authority of India and the rest by five banks.

The cost for development of the FASTag lanes and installation of the roadside equipment such as antenna are to be borne by the concessionaire. The FASTag lanes and equipment have been deployed at 275 toll plazas among 350 toll plazas in total in entire India as of April in 2016.

(4) Current Situation of FASTag

A number of tags are considered to have been issued due to the policy of embedding on the new car. However it is said that the actual number of the registered users are quite limited. (A news article reported that approximately only 2,000 users have been registered.) Further, the commission charges for clearinghouse are to be covered by the concessionaires and it is said that this is one of the obstacles that the usage ratio still remains quite small.

Thus it is expected that it may still take time for the FASTag to be prevailed among the road users despite the recent measures of 10% cashback to the FASTag users for the usage in 2016 and 2017.

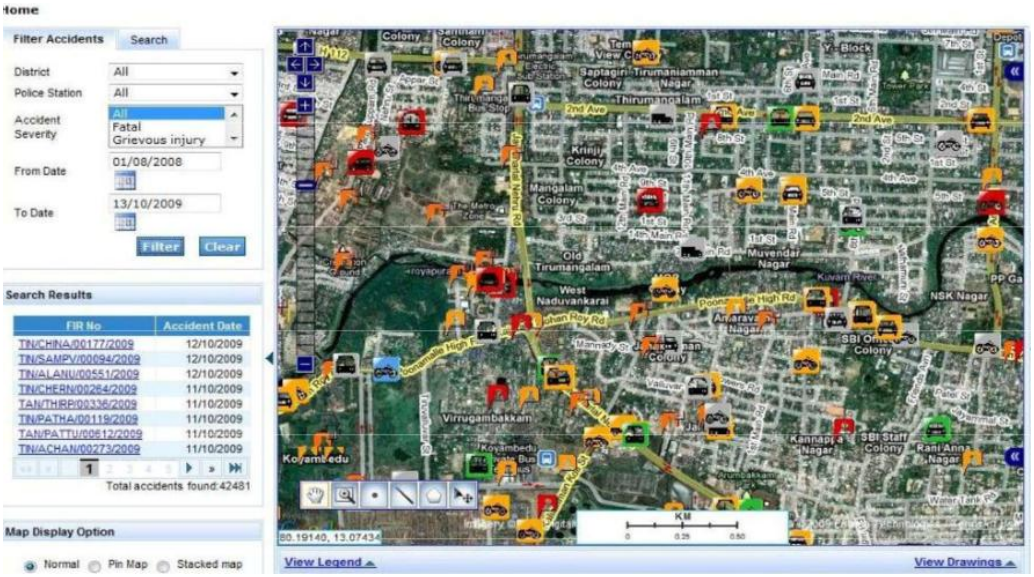
2.4.8 **Accident Database**

The accident database which is called "Road Accident Data Management System" has been developed and funded by World Bank. The system is being used by various departments of state government such as Chennai Traffic Police, Department of Highways and Minor Ports and Transport Department. It is used for analysis of traffic accident and studying remedial measures for the accident.

It is a GIS (Geographic Information System) based system and has functions of statistics analysis and display on the map summarized by cause of accident, type of vehicle, etc. It also aggregates and creates daily, monthly and yearly reports.

The system is also equipped with functions such as aggregating by cause of accident, location of accident, type of accident, vehicle type involved in the accident, etc., showing the areas in the city in the form of grid display by frequency of occurrence of accident, etc.

The figures below are the examples of screen shots of RADMS which show the locations of the accidents plotted on the map and the grid display by frequency of occurrence of accident.



(Source: Website of Transport Department)

Figure 2.47 Screen Shot of the Road Accident Data Management System:Location of Accident

(Source: Website of Transport Department)

Figure 2.48 Screen Shot of the Road Accident Database Mangement System:Divided Grids Accoring to the Number of Accidents of Each Severity

2.4.9 Standardization of Number Plate

The government of India decided to introduce the standardized vehicle number plate step-by-step from June 1, 2005. The plate is named as High Security Registered Plate. The abbreviated state name, district code, font, character size, etc. are standardized and hologram is equipped to prevent illegal copy. The position to place the plate on the vehicle is also stipulated.

(Source: Department of Transport)

Figure 2.49 High Security Registration Plate Number Plate for Tamil Nadu State

High Security Registration Plate number plates have already been introduced in the State of Meghalaya, Sikkim and Goa. They are being introduced in Tamil Nadu State as well, but there are still a number of non–standardized number plates. There exists various kinds of number plate using different materials, fonts, size of character and language and position placed on a vehicle varies in Chennai. Standardized number plates are especially important for enforcement using ITS. Under the situation with no standards, it is technically difficult to automatically recognize the number plate, fully utilizing ITS technology.

The bidding process for HSPR number plate supplier has been already started by Department of Transport, Tamil Nadu. The plates will be issued by Regional Office for Department of Transport, Tamil Nadu through the supplier. The standardization of vehicle number plate should be steadily progressed.

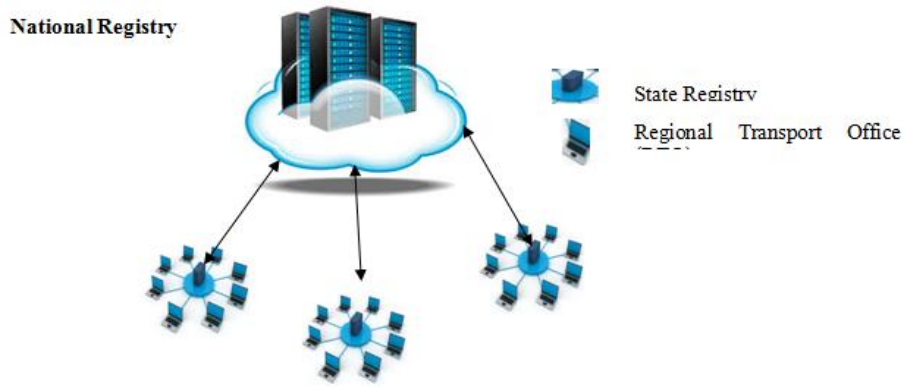
(Source: JICA Study Team)

Figure 2.50 Number Plates Currently Used

2.4.10 Vehicle Database

Under the policy of e-governance of India, the Government of India developed a system to collect, store and manage the vehicle data registered across India. It has been implemented in collaboration of Ministry of Road Transport and Highways (MoRTH) and National Informatics Centre (NIC) under Ministry of Information Technology and Communications.

The database has hierarchical architecture. The vehicle data registered in the state level database which is located in each state, called 'State Registry" is aggregated to the central national database, called 'National Registry'. The National Registry shares the registered vehicle information with the concerned agencies such as Department of Highways and Minor Ports, Regional Transport Office, Interstate check post, Traffic Police, etc. The image of database architecture is shown below.



(Source: Edited by JICA Study Team based on Website of Ministry of Road Transport and Highways)

Figure 2.51 Database Architecture

At state level of Tamil Nadu, Department of Transport is in charge of registration of motor vehicles, issuance/management of driving licence and vehicle related taxes. The vehicle owners are required to register their vehicle in the office of the department at the time of purchasing the vehicles. The registration information is name of owner, address, vehicle type, date of purchase, etc. and this information is shared with Chennai Traffic Police. Chennai Traffic Police use the shared motor vehicle information for enforcement of traffic violations. For example, E-Challan system uses the information provided by Department of Transport.

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

The prime reason could be that (i) the owner of private vehicle is required to pay only 'one time' vehicle tax at the time of purchasing and (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.

2.4.11 Activities of Indian Institute of Technology -Madras

Indian Institute of Technology-Madras is undertaking several activities of research and development on ITS. These research and development activities are carried out under the initiative of central government, Ministry of Urban Development and Department of Information Technology under Ministry of Communication and Information Technology.

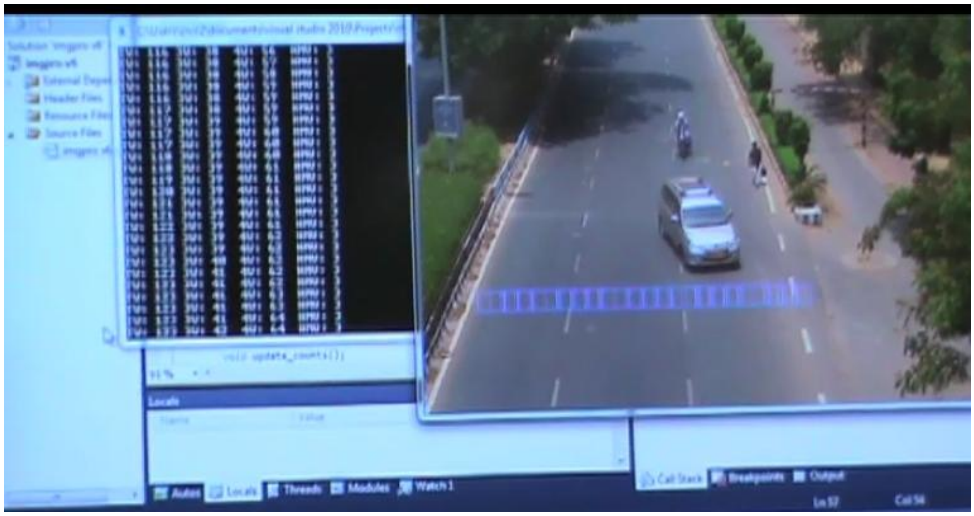
The control centre has been established in Indian Institute of Technology- Madras sponsored by Ministry of Urban Development and R & D activities are carried out this centre such as analysing traffic data as follows.

(1) Research on Traffic Counting and Classification

Detecting the traffic is the important factor for efficient utilization of ITS. However, counting vehicles by sensor in Indian road is very much challenging issues under heterogeneous traffic conditions and the absence of lane discipline. Indian Institute of Technology- Madras is carrying out R & D on detection of vehicles to fit into Indian local conditions by various technologies as follows;

a) **Grid-based Realtime Image Processing (GRIP)**

It is in-house developed software of image processing. It counts the number of vehicles by classifying into four categories such as motorcycles, light vehicle, heavy and auto rickshaw. It detects the vehicle which crosses the virtual detecting zone.



(Source: IIT- Madras)

Figure 2.52 Image Processing Using GRIP Software

b) **Wavetronix Smart Sensor**

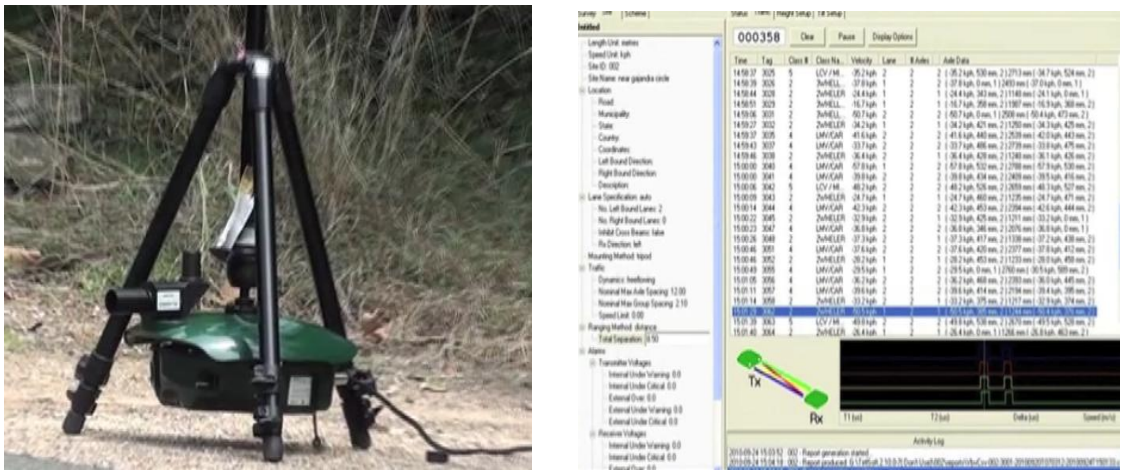
It is a radar based technology which uses radio waves for vehicle detection. It is capable of detecting the traffic on 10 lanes simultaneously and measuring bi-directional traffic. It collects vehicle count, speed, vehicle length, etc.

(Source: IIT- Madras)

Figure 2.53 Radar Equipment (left) and Software (right)

c) **TIRTL**

It uses infra-red waves for vehicle detection. It is capable to measure uni-directional/bi-directional and multi lane traffic. It consists of transmitter and receivers units on opposite side of carriageway. It uses two parallel and two cross light beams to detect the number and height of axles. It is capable of measuring vehicle count, speed, classification and direction.



(Source: IIT- Madras)

Figure 2.54 TIRTL Equipment (left) and Software (right)

(2) Research on Traffic Information Provision

The following applications for information provision were developed by Indian Institute of Technology- Madras.

a) **Bus Monitoring Software**

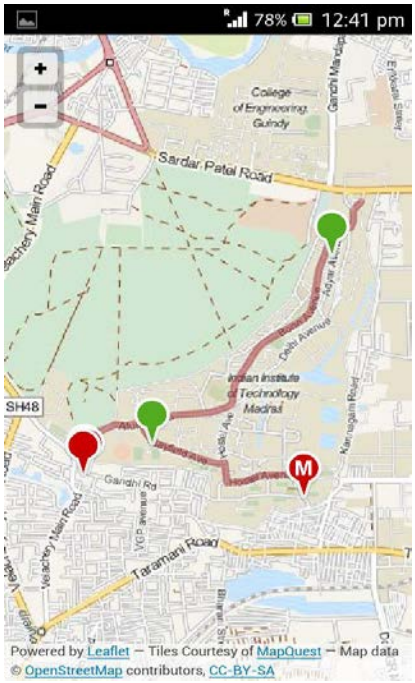
The software for bus monitoring based on probe data obtained from GPS devices were developed by Indian Institute of Technology- Madras. The GPS devices have been installed on 100 Metropolitan Transport Corporation buses and on some campus buses as a pilot basis. The location of the buses is continuously recorded for every 10-15 seconds at centre. The locations of buses are displayed on the map on realtime basis.

(Source: IIT- Madras)

Figure 2.55 GPS Unit Installed on Metropolitan Transport Corporation Buses

b) **Bus Arrival Prediction**

The bus arrival time is calculated based on the GPS probe data. It uses the data of two previous buses to predict the next bus arrival time. The application has also been developed to provide the information by VMS, website, smartphone, and display at KIOSK.

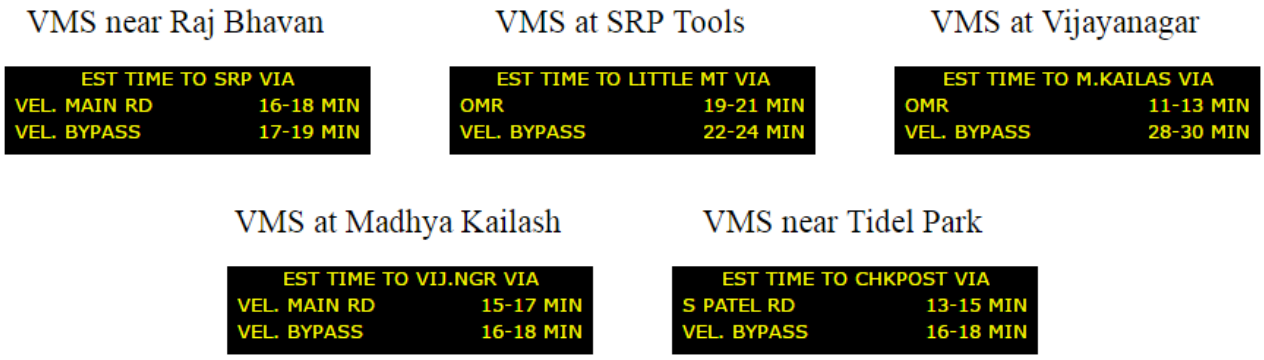


(Source: IIT- Madras)

Figure 2.56 Android Application for Mobile Phones

c) Travel Time Information Provision

The Travel Time Information Provision System provides the information on alternative routes with the expected time to arrive the major destinations from the locations where the VMS are installed. The travel time is calculated in consideration of congestion status and historical data of travel time. It is intended to enable the user to select the optimum route to the destination.



(Source: IIT- Madras)

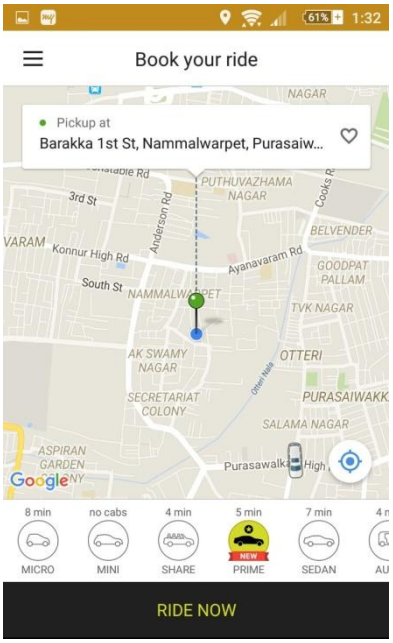
Figure 2.57 Information Provided by VMS

2.4.12 Information Technology Services Offered by Private Taxi Companies

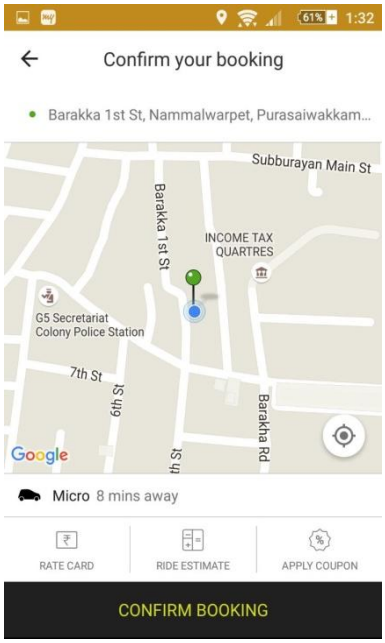
The major private taxi companies in Chennai offer the taxi services using information technology. The major features are:

- Users book the taxi by selecting origin and destination on the mobile application.
- The driver of the taxi standing/running on the nearest location is automatically notified the booking information of the user through mobile application.
- The drivers drive the taxi to the destinations according to the navigation guidance of such applications as Google navigation.
- The billing is automatically generated and the details are sent to the registered e-mail address of the users.
- The qualities of service and driver are evaluated by the user on the application after use.
- The auto rickshaws can also be booked and used by such services.

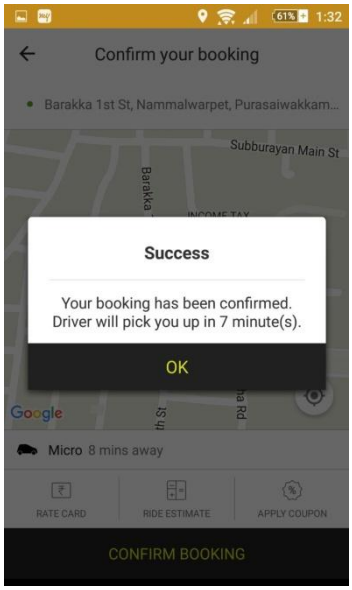
The images below show step by step procedure to book the taxi through OLA Cab Mobile application which is one of the major private taxi companies.



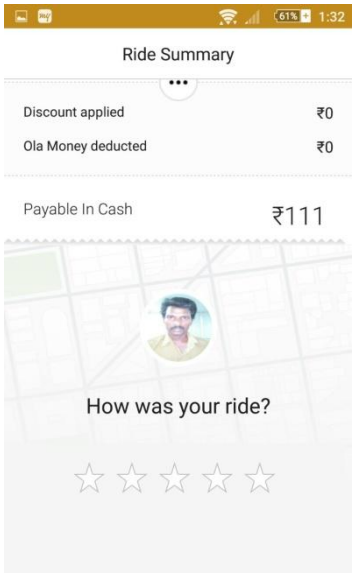
(1) Booking the ride and selecting the vehicle type



(2) Confirmation of the booking with pick up location.



(3) Notification of arrival of the vehicle for the ride



(4) Payment for ride and feedback of the ride after use

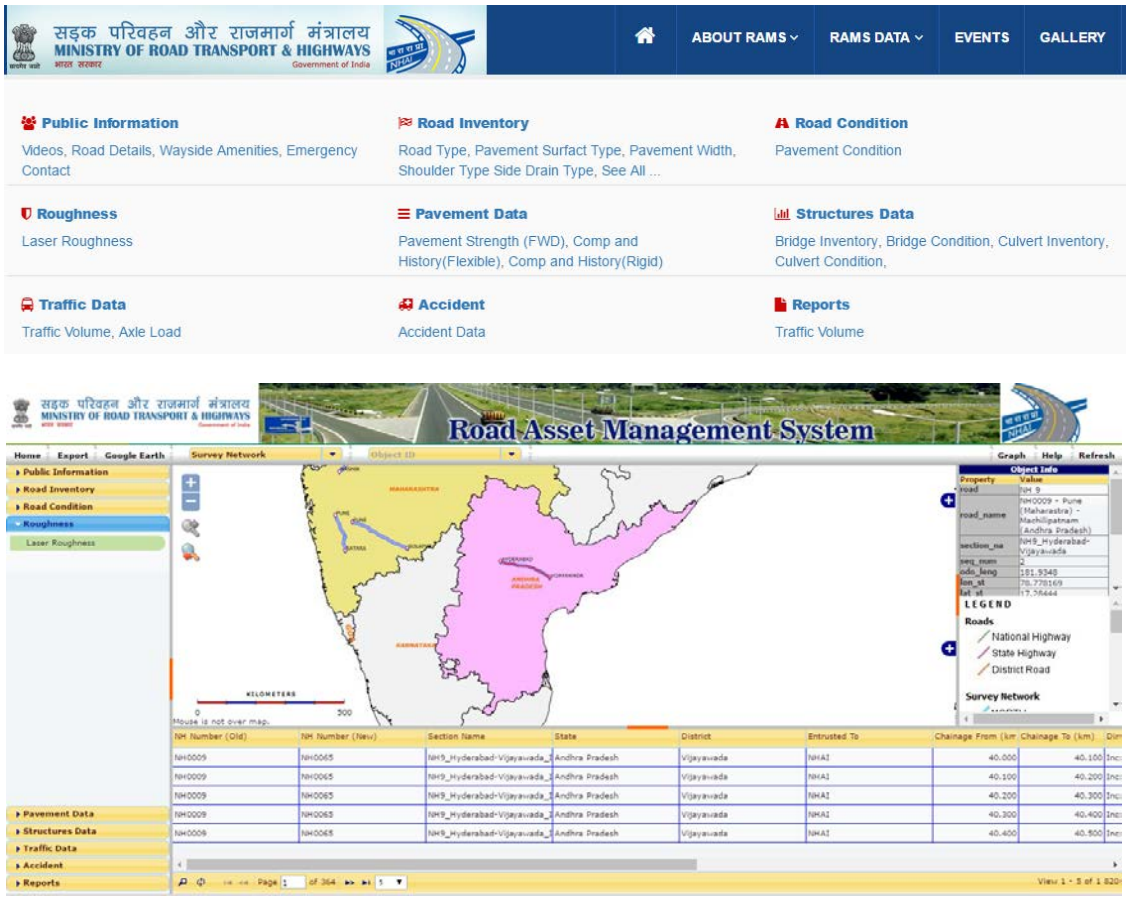
(Source: OLA Cabs – Mobile Application)

Figure 2.58 Examples of Steps for Using OLA Mobile Application Taxi Service

2.4.13 Road Management System (RMS)

(1) Road Asset Management System (RAMS) for National Highways

The development of Road Asset Management System for entire national highways is underway by the National Highways Authority of India. The development of the system is funded by the World Bank and it has been commenced as a part of Digital India Initiative of the Prime Minister Narendra Modi. The system will manage the road and asset information of National Highways such as pavement, road condition, planned /completed road works, accident, traffic volume, etc. by section for the road management.

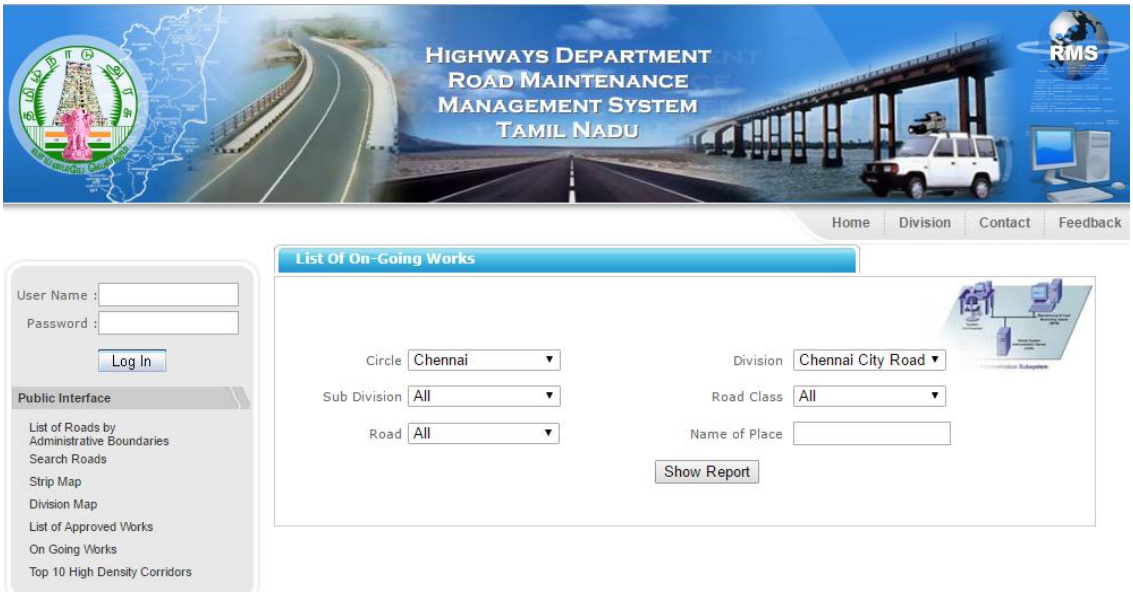


(Source: Ministry of Road Transport and Highways Website)

Figure 2.59 Image of Road Asset Management System for National Highways

(2) Road Management System (RMS) for State Highways in Tamil Nadu State

The Road Maintenance and Management System was developed by Department of Highways and Minor Ports. It covers the state highways in Tamil Nadu state and manages the road information such as road inventory, jurisdiction details in map, highly dense corridors, ongoing projects, etc. The system is designed for manager level to assist to comprehend the road condition and evaluate the road project. The information of the system is available on the website for the public.



(Source: Website of Department of Highways and Minor Ports)

Figure 2.60 Image of Road Management System for State Highways

2.4.14 Best Practices of ITS Implementation in India

a) Traffic Information System in Ahmadabad

Traffic Information System has been introduced by Nagoya Denki Co., Ltd. and Zero-Sam, Ltd. by JICA project, named 'Projects under the Collaboration Program with the Private Sector for Disseminating Japanese Technology' in Ahmadabad city Gujarat state. It generates dynamic traffic congestion information on a cloud server and provides traffic information through a variable message signboard. The information is generated based on a probe data collected by taxies or mobile phones and traffic volume data collected by image-type traffic counters installed on roadside. The traffic congestion information is displayed on the right half of the variable message sign board. This information enables drivers to choose an optimum route. The other left half is rent to a company as a digital signage for advertisements. The advertisement profit is allocated for maintenance and operation of the project. Traffic police can constantly grasp the traffic situation in the city from information terminal device. In the case of emergency such a traffic accident, the device can send information messages to variable message sign board. The collected and accumulated traffic data can be utilized to plan an infrastructure development and to evaluate a project. This is the first project providing dynamic traffic information in India.

(Source: Nagoya Denki Co., Ltd. and Zero-Sam, Ltd)

Figure 2.61 Variable Message Sign Boards Providing Dynamic Traffic Information in Ahmadabad

b) **Bus Monitoring System and Passenger Information System in Mysore**

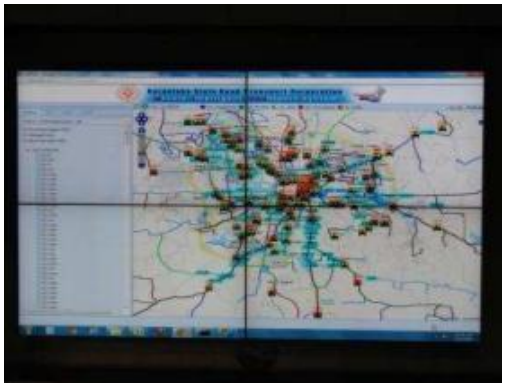
The Karnataka State Road Transport Corporation (KSRTC) is a major inter-city and intra-city bus service provider in Mysore, the second largest city in State of Karnataka. KSRTC currently operates 500 buses on 384 routes and provides services to about 179,000 commuters per day.

KSRTC implemented Mysore Intelligent Transport called 'MITRA' in August 2012 at a cost of INR 20.13 Crore. The project is composed of tracking KSRTC buses based on GPS technology, providing realtime information to passengers, and introducing electronic ticketing system. The project is implemented under the Sustainable Urban Transport Programme with financial assistance from World Bank's Global Environment Fund, Government of India's JNNURM Fund of Ministry of Urban Development, Government of Karnataka and KSRTC.

The KSRTC ITS project include the following components:

(Source : JICA Study Team)

Figure 2.62 Providing Bus Information at Bus Terminal and Bus Stop



(Source : JICA Study Team)

Figure 2.63 Bus Management Centre

The improvement of bus service is an urgent issue for many cities since bus is the most popular transport made for people in India. Therefore, similar systems as Mysore are increasingly introduced or planned to introduce in many cities such as Ahmedabad, Bengaluru, and Chennai.

2.5 Major Development Plans

2.5.1 National Urban Transport Policy

The National Urban Transport Policy is a high level urban transport policy in India. It was formulated by the Government of India, Ministry of Road Transport and Highways in 2006. The urban transport planning and implementation which are under the jurisdiction of state government are to be carried out under the policy of the National Urban Transport Policy. The prime focuses are given to the following policies:

- To develop urban mass transport systems in the metropolises in India
- To develop urban transport infrastructure harmonized with urban development plans
- To implement a various measures to shift the demand to the public transport
- To utilize ITS to solve the issues of urban transport
- To develop road spaces for the pedestrian and parking space
- To develop the bicycle pass
- To set Unified Metropolitan Transport Authority (UMTA) for the cities with more than 40 lakhs (4 million) population.

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

2.5.2 2nd Chennai Master Plan

Chennai Second Master Plan was prepared by Chennai Metropolitan Development Authority in 2008. This is a comprehensive urban development plan of Chennai metropolitan area including transport sector for the target year of 2026. The issues and directions of the measures in transport sector are summarized below.

(1) Major Issues

- The urban transport such as roads, suburban railways, Mass Rail Transit System, Chennai Metro, etc. are administered by different agencies and sufficient coordination is not made.
- The development/improvement of transport infrastructures do not keep pace with the growth of traffic demand.
- The traffic is not properly managed and the enforcement is not sufficiently implemented.
- There is a huge gap between demand and supply of parking and it deteriorates the congestion.
- The increasing vehicular emission badly affects the environment and the traffic accidents are increasing.

(2) Measures

- To set up Chennai Unified Metropolitan Transport Authority
- To implement a various measures to shift the traffic demand to the public transport such as constructing Chennai Metro
- To accelerate the improvement of infrastructures such as development of grade separation railway stations skywalks dedicated bus lanes and road widening
- To harmonize the urban transport planning with land use plans
- To place priority on Non-Motorized Transport
- To maximise the use of the existing road transport infrastructure utilizing ITS
- To formulate a parking policy
- To segregate the freight traffic from the passenger traffic
- To implement a various measures of Traffic Demand Management
- To promote monorails, Light Rail Transit, etc.

2.5.3 Comprehensive Traffic and Transportation Study

The Comprehensive Traffic and Transportation Study has been prepared by Chennai Metropolitan Development Authority in 2010. It envisages the vision, sets out the target and strategies for the target year of 2026 as follows;

(1) Vision Envisaged by Comprehensive Traffic and Transportation Study

Comprehensive Traffic and Transportation Study states the vision under the framework of second Chennai Master Plan and Vision Tamil Nadu 2026 as shown below.

"Provide safe, efficient, affordable and modern transport choices to people and businesses integrating economic, land use and transport concerns of Chennai Metropolitan Area to be fully prepared to take on the transport challenges of Chennai - the Mega polis."

(2) Goals

The following indicators of modal share for the target year of 2026 are set as goals of Comprehensive Traffic and Transportation Study.

Table 2-20 Target Figure of Modal Share in 2026 against 2008

Index	2008	Goal(2026)
Public Transport	41%	70%
IPT (Auto, Taxi, etc.)	11%	8%
Private Transport	48%	22%

(Source: Summarized by JICA Study Team based on CTTS, Chennai)

Note: The above table excludes non-motorized transport.

Note: Construction of Mass Rail Transit, Metro Rail, Mono Rail, Light Rail Transit, Bus Rapid Transit based on plan is required, so that the public transport share rises to 70%. In addition, it is also important that Parking lot, transfer station, traffic information system, etc adjacent to the transport hub such as a bus stop or the railroad station is constructed. Besides, as measures of the policies, improvement of the user convenience by the introduction of the common card and securing regular schedule of trains are required. Most of city buses which are citizen's main transportation are timeworn vehicles having low comfort. Thus, it is recommended that a new vehicle is introduced to improve the comfort of the user. It is necessary for these measures to be carried out totally so that public transport share rises to 70%.

(3) Strategy

The infrastructure development in phases (short, mid and long term) is proposed to realize the vision and achieve the goal above as shown in the table below.

Table 2-21 Proposed Infrastructure Development: Short, Mid and Long Term

Term	Proposed Development
Short Term (2010-2015)	Pedestrian Facilities (footpaths), Bicycle Network, Traffic Management, Parking Regulation, Signal Improvement, Junction Improvements, Road Markings and Signage
Medium Term (2016-2021)	Pedestrian Subways, Multi-level Parking Facilities, Grade Separators, Flyover and Underpass, Traffic Management Centres and Skywalks
Long Term (2022-2026)	MRTS, Metro, Mono Rail, LRT, Suburban Rail and BRT, Intermodal Stations, Truck Terminals, Intercity Bus Terminals, Elevated Roads, Freight Corridors, Missing Roadway Links and Major Road Widening.

(Source: Summarized by JICA Study Team based on CTTS, Chennai)

The above developments are estimated as shown in the table below.

Table 2-22 Estimated Investment Cost

Term	Estimated Investment Cost
Short Term (2010-2015)	Rs.52,689 crore
Medium Term (2016-2021)	Rs.21,899 crore
Long Term (2022-2026)	Rs.7,532 crore
Total	Rs.82,120 crore

(Source: Summarized by JICA Study Team based on CTTS, Chennai)

2.5.4 **Smart City Mission**

The Government of India announced that they would develop 100 smart cities under the Smart City Mission launched by Prime Minister Narendra Modi. The purpose of the Smart City in India is to realize sustainable development of economy and improvement of the quality of life by managing social infrastructure properly and efficiently and developing environmentally friendly communities with good governance.

The Smart City will be developed by Ministry of Urban Development, the Central Government of India in cooperation with the State Government of the targeted city. At least one city is to be selected from each State and Union Territory and 98 cities have already been identified. Among those cities, the 20 cities including Chennai and Coimbatore in the State of Tamil Nadu have been shortlisted for the first round city.

INR 48,000 crores (INR 480 billion) have been budgeted for the development of the Smart City and will be spent for the next five years.

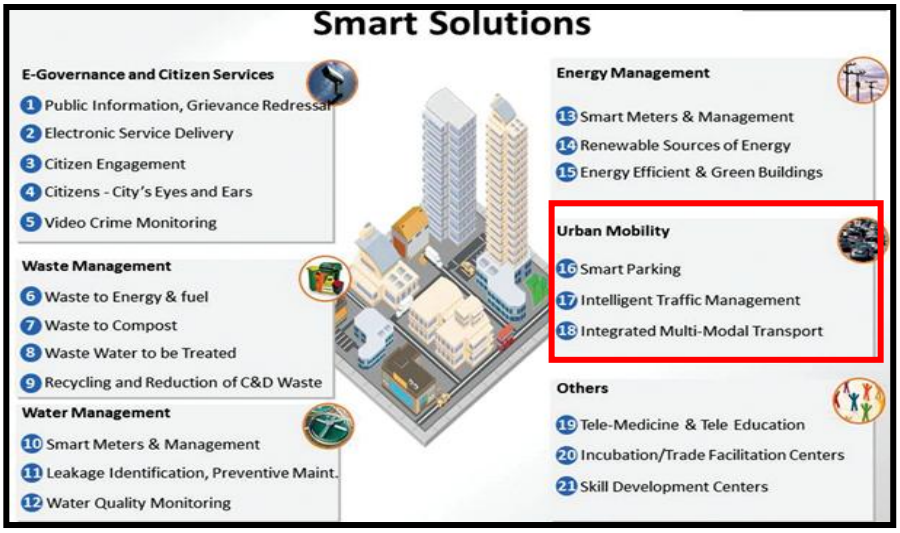
The list of the 20 cities shortlisted for the first round city is shown below.

Table 2-23 Cities Shortlisted for Smart City

S. No.	State	Shortlisted cities	S. No.	State	Shortlisted cities
1	Odisha	Bhubaneswar	11	Madhya Pradesh	Indore
2	Maharashtra	Pune	12	New Delhi	New Delhi
3	Rajasthan	Jaipur	13	Tamil Nadu	Coimbatore
4	Gujarat	Surat	14	Andhra Pradesh	Kakinada
5	Kerala	Kochi	15	Karnataka	Belgaum
6	Gujarat	Ahmadabad	16	Rajasthan	Udaipur
7	Madhya Pradesh	Jabalpur	17	Assam	Guwahati
8	Andhra Pradesh	Visakhapatnam	18	Tamil Nadu	Chennai
9	Maharashtra	Sholapur	19	Punjab	Ludhiana
10	Karnataka	Davangere	20	Madhya Pradesh	Bhopal

(Source: Ministry of Urban Development)

The Greater Chennai Corporation will implement the Smart City in Chennai as the Executing Agency. The figure below shows the major components of the Smart City. 'Urban Mobility using ITS' is one of the important components.



(Source: Ministry of Urban Development of India)

Figure 2.64 Major Components of Smart City

A special purpose vehicle for implementation of Smart Cities Mission has been formed and registered as 'Chennai Smart City Limited'. It will plan, appraise, approve, obtain funds, implement and manage the smart city development projects.

The managing director of Tamil Nadu Urban Finance and Infrastructure development corporation Limited is the Mission Director for the Smart City Mission. Deputy Commissioner of works division of Greater Chennai Corporation has been appointed as Chief Executive Officer (CEO) of the Chennai Smart City Ltd.

The board of directors for the Special Purpose vehicle consists of the officials of the following organizations.

Table 2-24 Organization of Board of Directors for Chennai Smart City Limited

a)	Greater Chennai Corporation (Chairperson)
b)	Chennai Smart City Limited
c)	Ministry of Urban Development, Government of India
d)	Finance Department, Government of Tamil Nadu
e)	Chennai Metro Water Supply and Sewerage Board
f)	Tamil Nadu Urban Infrastructure Financial Services Limited
g)	Greater Chennai Corporation
h)	Tamil Nadu Slum Clearance Board
i)	Tamil Nadu Generation and Distribution Corporation
j)	Chennai Police
k)	Electronics Corporation of Tamil Nadu Limited
l)	Chennai Metropolitan Development Authority
m)	Urban Expert (External Specialist)
n)	Independent Woman Director

(Source: Edited by JICA Study Team based on the Government Order of SPV Formation)

Incorporating public opinions, T Nagar has been selected as the demonstration area for the Smart City Mission. A series of stakeholder meetings are being carried out for planning of Smart City. Some of the plans that are discussed by the meeting are:

- On street parking management in T Nagar
- Non-motorized transportation plan
- Development of bus terminal in T Nagar
- ITS for city bus (City Bus Tracking System, City Bus Passenger Information System (PIS), Electronic Ticket Management System for City Bus (ETM))

The participants of the stakeholder meeting include government organizations such as Greater Chennai Corporation and Metropolitan Transport Corporation Ltd., major universities in Chennai (i.e. Indian Institute of Technology Madras and Anna University and NGO), and they are holding the meetings on regular basis.

2.5.5 **Vision Tamil Nadu 2023**

"Vision Tamil Nadu 2023" for infrastructure development in the State of Tamil Nadu has been announced by the Chief Minister in 2014. The physical and social infrastructure will be developed in the sectors such as energy, transportation (roads, trains, ports, airports), industry, agriculture and education by the target year of 2023. The budget for 217 projects is currently about INR 15 lakh crores (INR 15 trillion) in ten years. The vision was prepared with assistance of Asian Development Bank. Tamil Nadu Infrastructure Development Board will take a central role for implementation of the Vision.

The following developments in the road sector have been proposed in Chennai Metropolitan Area.

- Outer Ring Road (Phase 2)
- Northern Port Access Road (from NH5 to Ennore Port)
- Chennai-Bengaluru Highway
- Chennai Peripheral Ring Road

The budget for each sector has been estimated below.

Table 2-25 The Budget of Each Sector for Vision Tamil Nadu 2023

Sector	Estimated Cost (Unit=Crore)
Energy	389,335
Transport	368,123
Industry, Commercial	171,285
Urban Infrastructure	263,350
Agriculture	121,400
Insurance, Hygiene, Education	59,140
Others	127,367
Total	**1,500,000**

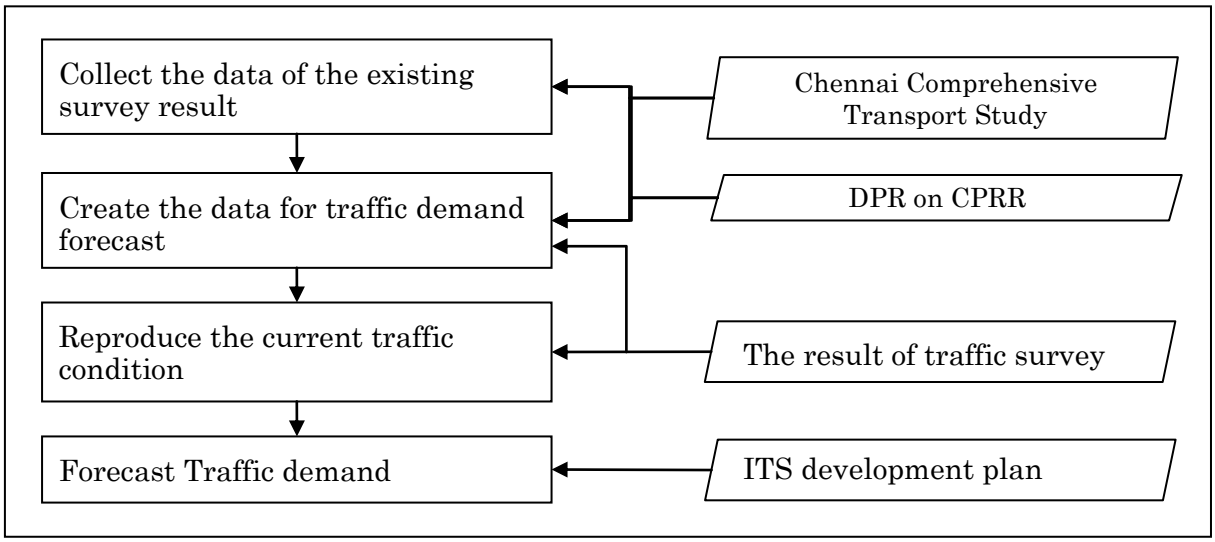
(Source: Summarized by JICA Study Team based on VISION Tamil Nadu 2023)

3 Study on Future demand projection

3.1 Objective and Procedure

In order to measure the effect of ITS, it is necessary to check the traffic situation before and after ITS is introduced and to compare the data using the traffic demand forecast. Origin-Destination data and network data to use in the traffic demand forecast is created based on the existing survey results. The target year of demand forecast is set to match the ITS development plan.

The flow of traffic demand estimates is shown in Figure 3.1. The first step is to collect the data of the existing survey result and to arrange it. Based on the data of the existing research, the data necessary for the traffic demand forecast is created in accordance with the format of JICA STRADA:the JICA System for Traffic Demand Analysis. After reproducing the current traffic conditions to create future data, the future traffic demand forecast is carried out.



(Source: JICA Study Team)

Figure 3.1 Flow of Traffic Demand Estimate

3.2 Arranging Existing Survey Data

An overview of the existing survey (Chennai Comprehensive Transport Study, Detail Project Report on Peripheral Road) is shown in Table 3-1.

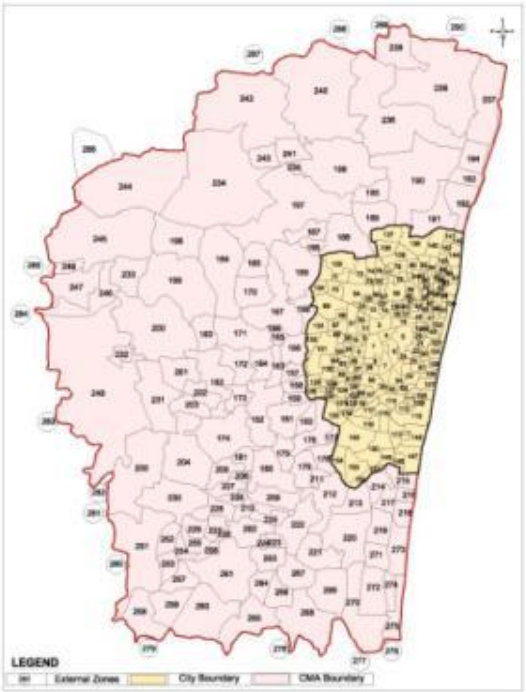
The current Origin-Destination and network data is based on the Chennai Comprehensive Transport Study. The future demand estimate is based on the method of Detail Project Report on Chennai Peripheral Ring Road.

Table 3-1 Arranging Existing Survey Data

	Chennai Comprehensive Transport Study		**Detail Project Report on** CPRR	
Traffic volume	2008	Screen line：43 location Inner Cordon：15 location CBD Cordon：11 location Outer Cordon：15 location	2013	19 location 7days Only around CPRR
OD	290 zones※		20 zones	
Network	Target : inside CPRR		Nothing	
Demand forecast method	Four step estimation method		Traffic demand elasticity method	
Data for demand forecast	Parameter value is unknown		The growth rate of car type	

※The data described in the report was not available.

(Source: Compiled by JICA Study Team)



Zone No.	Zone
1	Chennai city (includes Tambaram, Sholinganallur, Porur, Ambattur, Puzhal)
2	Kelambakkam, Kovalam
3	Vandalur
4	Poonamallee
5	Avadi, Patabiram
6	Redhills
7	Minjur
8	Ennore Port
9	Thiruporur, Korambakkam
10	Singaperumal Koil
11	Oragadam
12	Sriperumbudur
13	Thiruvallur
14	Thamaraipakkam
15	Periyapalayam
16	Thatchoor, Puduvoyal & Andhra Pradesh (Expert Tripathi) & Northern India
17	Mamallapuram, Pondy and upto Vedaranayam
18	Chengalpattu and upto Trichy, Thajavur, Dindigul, Madurai & Southern Tamilnadu
19	Vellore, Kanchipuram, Coimbatore region & Kerala, Bangalore & Karanataka, Mahasharata & Gujarat
20	Triupathi & Trithani

（Source: Chennai Comprehensive Transport Study） （Source：Detail Project Report on CPRR）

Figure 3.2 Zone of the Existing Survey

3.3 Traffic Survey

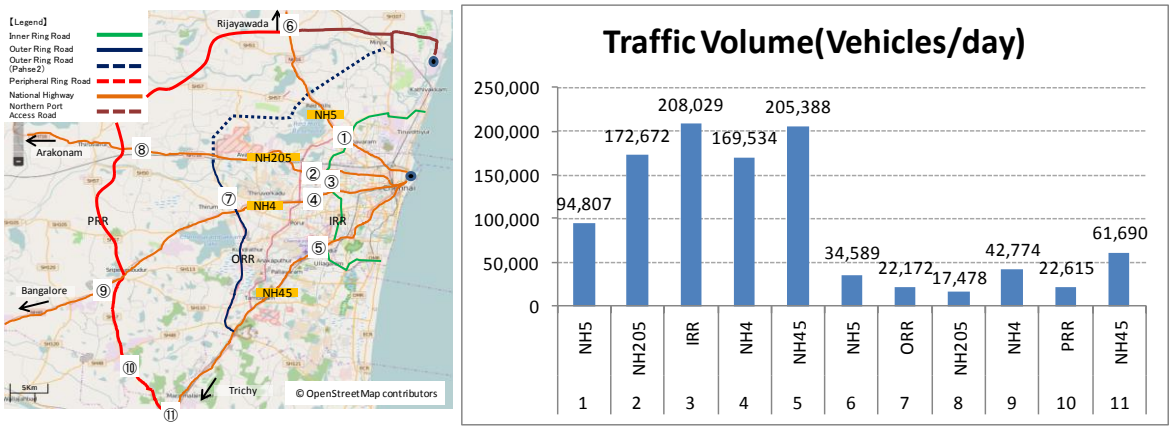
Summary of traffic volume survey and travel speed survey carried out in this study is shown below.

3.3.1 Traffic Volume Survey

The outline and the summary of the result of the traffic volume survey are shown in the table and figure below. The survey was carried out for 24 hours at 11 points.

Table 3-2 Outline of Traffic Volume Survey

Survey point	Road name	Survey date
1	NH5	2016/3/31 6:00a.m.～next 6:00 a.m.
2	NH205	2016/3/30 6:00 a.m.～next 6:00 a.m.
3	IRR	2016/3/29 6:00 a.m.～next 6:00 a.m.
4	NH4	2016/3/29 6:00 a.m.～next 6:00 a.m.
5	NH45	2016/3/29 6:00 a.m.～next 6:00 a.m.
6	NH5	2016/4/6 6:00 a.m.～next 6:00 a.m.
7	ORR	2016/4/5 6:00 a.m.～next 6:00 a.m.
8	NH205	2016/4/5 6:00 a.m.～next 6:00 a.m.
9	NH4	2016/3/31 6:00 a.m.～next 6:00 a.m.
10	CPRR	2016/4/5 6:00 a.m.～next 6:00 a.m.
11	NH45	2016/3/30 6:00 a.m.～next 6:00 a.m.



(Source: JICA Study Team)

Figure 3.3 Survey Points and Results

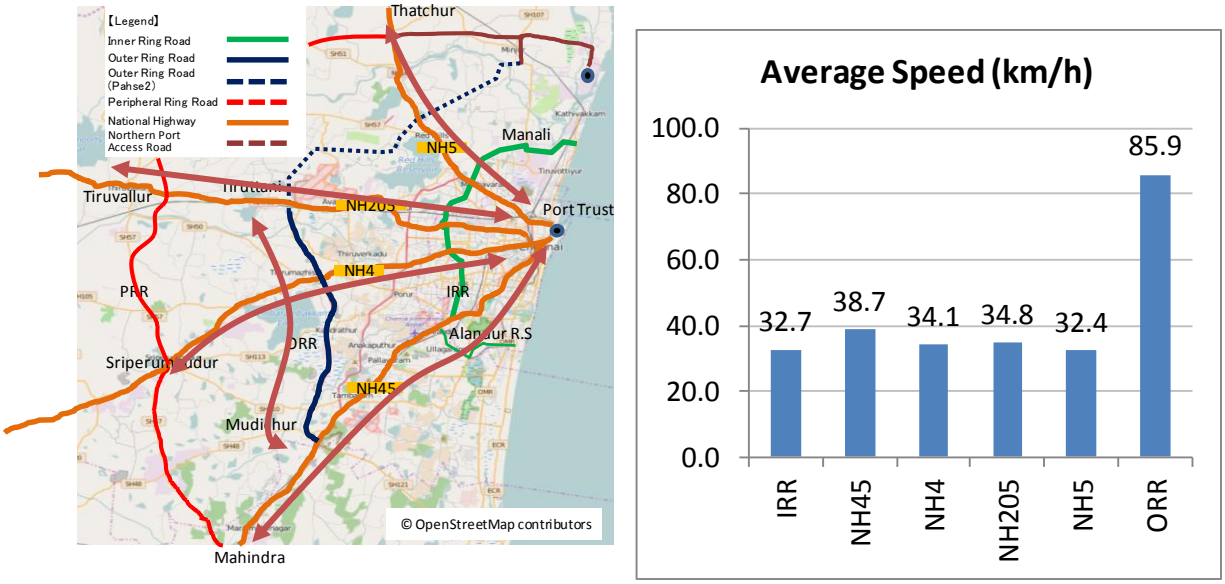
3.3.2 Travel Speed Survey

The outline and summary of travel speed survey are shown in the table and figure below. The survey was carried out at three times (at morning peak, off peak, evening peak) on 5 routes forward and return.

Table 3-3 Outline of Travel Speed Survey

Survey route	Road name	Survey date
1	NH5	2016/4/6
2	NH205	2016/3/17
3	IRR	2016/3/24
4	NH4	2016/3/22
5	NH45	2016/3/23

(Source: JICA Study Team)



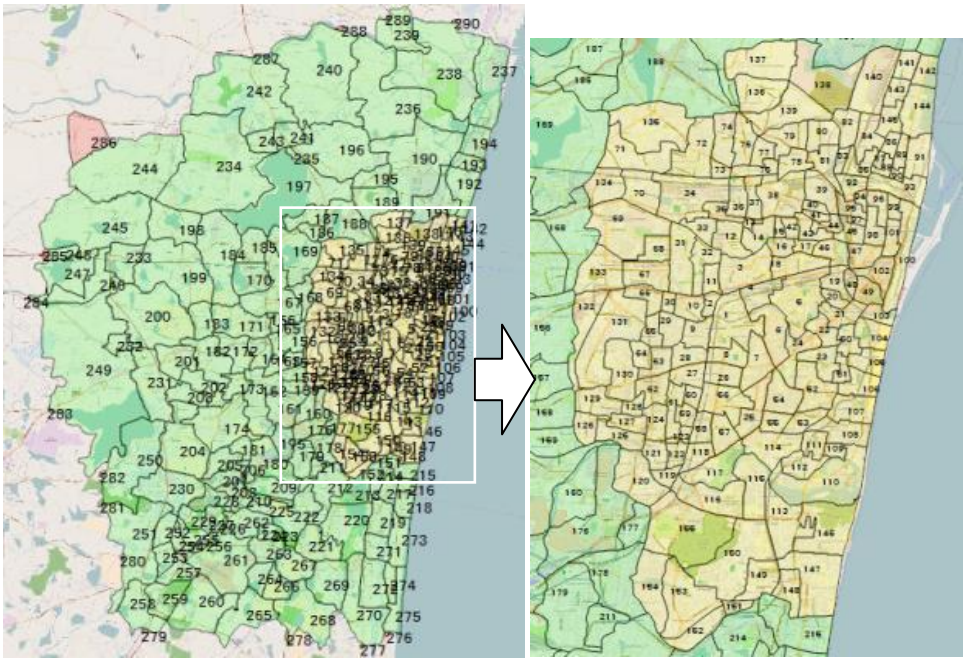
(Source: JICA Study Team)

Figure 3.4 Survey Routes and Results

3.4 Data of Traffic Demand Forecast

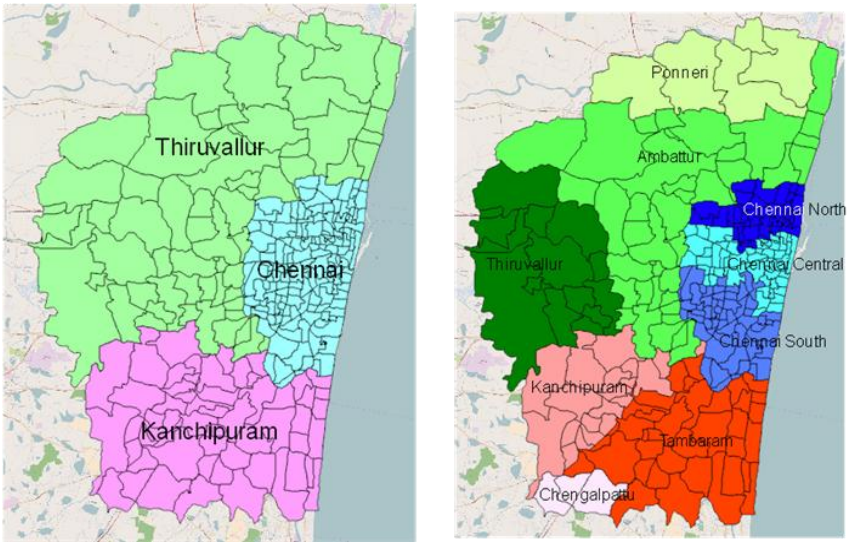
3.4.1 Origin-Destination Data Creation

The zones of this study were set based on the zone division used by Chennai Comprehensive Transport Study. The traffic analysis zones were divided as follows: city area 155 zones, rest of Chennai Metropolitan area 120 zones, External Zones 15 zones, totalling 290 zones.



(Source: JICA Study Team)

Figure 3.5 Zone Divisions



(Source: JICA Study Team)

Figure 3.6 Intensive Zone Division

Table 3-4 Comparison List

Zone	Large	Middle	Small
1	Chennai	Chennai Central	Nungambakkam
2	Chennai	Chennai Central	Kilpauk (South)
3	Chennai	Chennai Central	Kilpauk (North)
4	Chennai	Chennai Central	Chetpet
5	Chennai	Chennai Central	Egmore,Pudupet
6	Chennai	Chennai South	Thousand Lights
7	Chennai	Chennai South	Nakkeerar Nagar
8	Chennai	Chennai South	Ko.Su. Mani Nagar
9	Chennai	Chennai South	Periyar Nagar (North),Periyar Nagar (South)
10	Chennai	Chennai Central	Aminjikarai (East)
11	Chennai	Chennai Central	Shenoy Nagar
12	Chennai	Chennai Central	Panneerselvam Nagar
13	Chennai	Chennai North	Maraimalai Adigal Nagar (North)
14	Chennai	Chennai North	Maraimalai Adigal Nagar (South)
15	Chennai	Chennai North	Anjugam Ammaiyar Nagar
16	Chennai	Chennai Central	Purasawalkam
17	Chennai	Chennai Central	Kannappar Nagar
18	Chennai	Chennai Central	Gangadaraeswarar Koil,Dr. Ambedkar Nagar
19	Chennai	Chennai Central	Adikesavapuram
20	Chennai	Chennai Central	Chintadripet
21	Chennai	Chennai Central	Nehru Nagar
22	Chennai	Chennai Central	Komaleeswaranpet,Balasubramaniam Nagar
23	Chennai	Chennai Central	Azad Nagar (North),Ameer Mahal
24	Chennai	Chennai South	Azagiri Nagar
25	Chennai	Chennai South	Sathyamurthi Nagar
26	Chennai	Chennai South	Kalaivanar Nagar
27	Chennai	Chennai South	Navalar Nedunchezhian Nagar(East)
28	Chennai	Chennai South	Vadapalani (East)
29	Chennai	Chennai Central	Aminjikarai (Central)
30	Chennai	Chennai Central	Aminjikarai (West)
31	Chennai	Chennai Central	Anna Nagar (Central)
32	Chennai	Chennai Central	Anna Nagar (East)
33	Chennai	Chennai Central	Ayanavaram
34	Chennai	Chennai Central	Viduthalai Guru Samy Nagar
35	Chennai	Chennai Central	Nagamma Ammaiyar Nagar (South)
36	Chennai	Chennai North	Thiru Vi. Ka. Nagar
37	Chennai	Chennai North	Nagamma Ammaiyar Nagar (North)
38	Chennai	Chennai North	Wadia Nagar
39	Chennai	Chennai North	Dr. Sathyavanimuthu Nagar
40	Chennai	Chennai North	Pulianthope
41	Chennai	Chennai Central	Dr. Beasant Nagar
42	Chennai	Chennai North	Kosapet,Perumalpet
43	Chennai	Chennai Central	Choolai,Pattalam,Arivazhan Nagar
44	Chennai	Chennai Central	Thattankulam
45	Chennai	Chennai Central	Elephant Gate
46	Chennai	Chennai Central	Park Town
47	Chennai	Chennai Central	Edapalayam

48	Chennai	Chennai Central	Nehru Nagar
49	Chennai	Chennai Central	Nehru Nagar
50	Chennai	Chennai Central	Thruvateeswaranpet,Dr. Natesan Nagar,Zambazaar,
51	Chennai	Chennai Central	Umaru Pulavar Nagar,Bharathi Nagar
52	Chennai	Chennai Central	Azad Nagar (South)
53	Chennai	Chennai Central	Vivekanandapuram,Thiruvalluvar Nagar
54	Chennai	Chennai South	Royapettah,Teynampet
55	Chennai	Chennai South	Alwarpet (North)
56	Chennai	Chennai South	Theagaraya Nagar
57	Chennai	Chennai South	V. O. C. Nagar
58	Chennai	Chennai South	Rajaji Nagar
59	Chennai	Chennai South	Kamaraj Nagar (South)
60	Chennai	Chennai South	Kamaraj Nagar (North)
61	Chennai	Chennai South	M.G.R. Nagar
62	Chennai	Chennai South	Ashok Nagar
63	Chennai	Chennai South	Vadapalani (West)
64	Chennai	Chennai South	Saligramam
65	Chennai	Chennai Central	Aminjikarai (Central)
66	Chennai	Chennai Central	Aminjikarai (West)
67	Chennai	Chennai Central	Anna Nagar (West)
68	Chennai	Chennai Central	Anna Nagar (West)
69	Chennai	Chennai Central	Villivakkam (south)
70	Chennai	Chennai Central	Villivakkam (North)
71	Chennai	Chennai North	Kulathur
72	Chennai	Chennai North	Agaram (North)
73	Chennai	Chennai North	Agaram (South)
74	Chennai	Chennai North	Sembiam
75	Chennai	Chennai North	Perambur (South)
76	Chennai	Chennai North	Siruvallur
77	Chennai	Chennai North	Perambur (North)
78	Chennai	Chennai North	Elango Nagar
79	Chennai	Chennai North	Perambur (East)
80	Chennai	Chennai North	Vyasarpadi (North)
81	Chennai	Chennai North	Vyasarpadi (South)
82	Chennai	Chennai North	Kumarasamy Nagar (South)
83	Chennai	Chennai North	Kumarasamy Nagar (North)
84	Chennai	Chennai North	Korukkupet
85	Chennai	Chennai North	Dr. Radhakrishnan Nagar (South)
86	Chennai	Chennai North	Sanjeeviroyanpet
87	Chennai	Chennai North	Mottai Thottam,Dr. Vijayarahavalu Nagar
88	Chennai	Chennai North	Narayanappa Naicken Garden,Dr. Radhakrishnan Nagar (North)
89	Chennai	Chennai North	Grace Garden
90	Chennai	Chennai North	Singara Garden
91	Chennai	Chennai North	Ma.Po.Si. Nagar,Royapuram
92	Chennai	Chennai North	Basin Bridge
93	Chennai	Chennai North	Meenakshiammanpet
94	Chennai	Chennai Central	Kondithope
95	Chennai	Chennai Central	Peddu Naickenpet
96	Chennai	Chennai Central	Seven Wells (south)

97	Chennai	Chennai Central	Perumal Koil Garden
98	Chennai	Chennai Central	Seven Wells (North),Amman Koil,Sowcarpet
99	Chennai	Chennai Central	Muthialpet
100	Chennai	Chennai Central	Vallal Seethakathi Nagar
101	Chennai	Chennai Central	Katchaleeswarar Nagar
102	Chennai	Chennai Central	Nehru Nagar
103	Chennai	Chennai Central	Nehru Nagar
104	Chennai	Chennai Central	Chepauk
105	Chennai	Chennai Central	Thiruvallikeni,Marina
106	Chennai	Chennai Central	Krishnampet,Bharathidasan Nagar
107	Chennai	Chennai Central	Madha Perumal Puram,Karaneeswarapuram
108	Chennai	Chennai South	Santhome,Mylapore
109	Chennai	Chennai South	Avvai Nagar (North)
110	Chennai	Chennai South	Raja Annamalai Puram
111	Chennai	Chennai South	Bheemannapet
112	Chennai	Chennai South	Avvai Nagar (South)
113	Chennai	Chennai South	Adayar (West)
114	Chennai	Chennai South	Alwarpet (South)
115	Chennai	Chennai South	G.D. Naidu Nagar (East)
116	Chennai	Chennai South	G.D. Naidu Nagar (West)
117	Chennai	Chennai South	G.D. Naidu Nagar (West)
118	Chennai	Chennai South	Kalaignar Karunanithi Nagar
119	Chennai	Chennai South	saidapet (East)
120	Chennai	Chennai South	Guindy (west)
121	Chennai	Chennai South	saidapet (West)
122	Chennai	Chennai South	Kumaran Nagar (south)
123	Chennai	Chennai South	Kumaran Nagar (North)
124	Chennai	Chennai South	Navalar Nedunchezhian Nagar(West)
125	Chennai	Chennai South	Kodambakkam (south)
126	Chennai	Chennai South	Virugambakkam (South)
127	Chennai	Chennai South	Kodambakkam (North)
128	Chennai	Chennai South	Kodambakkam (North)
129	Chennai	Chennai South	Virugambakkam (South)
130	Chennai	Chennai South	Saligramam
131	Chennai	Chennai South	Virugambakkam (North)
132	Chennai	Chennai South	Virugambakkam (North)
133	Chennai	Chennai Central	Villivakkam (south)
134	Chennai	Chennai Central	Villivakkam (North)
135	Chennai	Chennai North	Kulathur
136	Chennai	Chennai North	Kodungaiyur (West)
137	Chennai	Chennai North	Kodungaiyur (West)
138	Chennai	Chennai North	Jeeva Nagar (South)
139	Chennai	Chennai North	Jeeva Nagar (South)
140	Chennai	Chennai North	Kodungaiyur (East)
141	Chennai	Chennai North	Cherian Nagar (North)
142	Chennai	Chennai North	Cherian Nagar (South)
143	Chennai	Chennai North	Old Washermanpet
144	Chennai	Chennai North	Tondiarpet
145	Chennai	Chennai North	Jeeva Nagar (North)

146	Chennai	Chennai South	Adayar (East)
147	Chennai	Chennai South	Thiruvanmiyur (East)
148	Chennai	Chennai South	Thiruvanmiyur (East)
149	Chennai	Chennai South	Thiruvanmiyur (west)
150	Chennai	Chennai South	Guindy (East)
151	Chennai	Chennai South	Thiruvanmiyur (west)
152	Chennai	Chennai South	Velachery
153	Chennai	Chennai South	Velachery
154	Chennai	Chennai South	Velachery
155	Chennai	Chennai South	Guindy (East)
156	Thiruvallur	Ambattur	Nerkundram ,Maduravoyal
157	Thiruvallur	Ambattur	Valasaravakam
158	Thiruvallur	Ambattur	Valasaravakam, Ramapuram
159	Thiruvallur	Ambattur	Ramapuram
160	Thiruvallur	Ambattur	Namdambakkam
161	Thiruvallur	Ambattur	Manapakkam, Mugalivakkam
162	Thiruvallur	Ambattur	Karambakkam, Porur, Madanandapuram, Kulapakkam
163	Thiruvallur	Ambattur	Maduravoyal
164	Thiruvallur	Ambattur	Maduravoyal, Sivabudam, vanagaram
165	Thiruvallur	Ambattur	Nolambur
166	Thiruvallur	Ambattur	Nolambur
167	Thiruvallur	Ambattur	Kakapallam, Mannur, Athipattu, Mogappair
168	Thiruvallur	Ambattur	Padi
169	Thiruvallur	Ambattur	Korattur
170	Thiruvallur	Ambattur	Pattravakkam, Menambeu
171	Thiruvallur	Ambattur	Ayanambakkam, Perumalagaram ,Adayalampattu ,Koladi
172	Thiruvallur	Ambattur	vanagaram, Chettiyaragaram, Thandalam, Numbal
173	Thiruvallur	Ambattur	Kulathuvancheri, Thelliyarangaram, Ayyappanthangal
174	Kanchipuram	Kanchipuram	Tharapakkam, pentankattalai, Thandalam, Kovur, Gerugambakkam, Peripanicheri, Mouli
175	Kanchipuram	Kanchipuram	Minambakkam
176	Thiruvallur	Ambattur	StThomas Mount
177	Thiruvallur	Kanchipuram	Guindy
178	Thiruvallur	Tambaram	Adayar ward - F
179	Kanchipuram	Tambaram	Palavanthangal,Nanganallur
180	Kanchipuram	Kanchipuram	Cowl Bazaar, Minambakkam cum
181	Kanchipuram	Kanchipuram	Polichalur
182	Thiruvallur	Thiruvallur	Chinnapanicheri, Paraniputhur, Sirinivasapuram, Katturpakkam, Goparasanallur, Senn
183	Thiruvallur	Thiruvallur	Sundrasholavaram
184	Thiruvallur	Ambattur	Ayapakkam, Thirumullaivoyal
185	Thiruvallur	Ambattur	Oragadam
186	Thiruvallur	Ambattur	Puttagaram
187	Thiruvallur	Ambattur	Surappattu , Kathirvedu
188	Thiruvallur	Ambattur	Villakkupattu
189	Thiruvallur	Ambattur	Manjambakkam
190	Thiruvallur	Ambattur	Chinna sekkadu, Amulavoyal, Vaikkadu, Elanthancheri ,Sadayankuppam, Ariyalur, Kada
191	Thiruvallur	Ambattur	Sathangadu

192	Thiruvallur	Ambattur	Tiruvottiyur
193	Thiruvallur	Ambattur	Tiruvottiyur bit
194	Thiruvallur	Ambattur	Ernavur.
195	Thiruvallur	Ambattur	Mathur
196	Thiruvallur	Ambattur	Mathur,Vadapurambakkam, Vadakarai, Layongrant, Naravarikuppam, Layon, Alinjivakkam
197	Thiruvallur	Ambattur	Puzhal Redhills, Tundalkalani
198	Thiruvallur	Ambattur	Kovilpadagai
199	Thiruvallur	Thiruvallur	Palaripattu, Paruthipattu, Sekkadu, Vilinjiambakkam
200	Thiruvallur	Thiruvallur	Thukkanampattu , Pidarithangal, Parivakkam, Kolappancheri, Panavaduthottam, Veerar
201	Thiruvallur	Thiruvallur	Ariyamarundanallur, Agraharam
202	Thiruvallur	Thiruvallur	Kulamanivakkam , Mangadu
203	Thiruvallur	Thiruvallur	Mangadu
204	Kanchipuram	Kanchipuram	Kunrathur, Vengatapuram, Manancheri, Thirunageswaram, Munnankattalai, Kollaicheri
205	Kanchipuram	Kanchipuram	Anakaputur, Polichalur
206	Kanchipuram	Kanchipuram	Pammal
207	Kanchipuram	Kanchipuram	Pammal
208	Kanchipuram	Kanchipuram	Pammal
209	Kanchipuram	Tambaram	Pallavaram
210	Kanchipuram	Tambaram	Pallavaram, Issa Pllavaram
211	Kanchipuram	Tambaram	Thalakkanacheri
212	Kanchipuram	Tambaram	Muvarasampattu, Madipakkam, Perundavakkam
213	Kanchipuram	Tambaram	Pallikaranai
214	Kanchipuram	Tambaram	Perungudi
215	Kanchipuram	Tambaram	Kottivakkam
216	Kanchipuram	Tambaram	Plavakkam, Sivaram
217	Kanchipuram	Tambaram	Perungudi, Plavakkam, Neelangarai
218	Kanchipuram	Tambaram	Neelangarai
219	Kanchipuram	Tambaram	Okkiam thurai pakkam
220	Kanchipuram	Tambaram	Pallikaranai
221	Kanchipuram	Tambaram	Medavakkam, Jaladampettai
222	Kanchipuram	Tambaram	Nanmangalam ,Kulathur, Kovilambakkam, Keelakattaalai
223	Kanchipuram	Tambaram	Sembakkam
224	Kanchipuram	Tambaram	Sembakkam
225	Kanchipuram	Tambaram	Nemilicheri
226	Kanchipuram	Tambaram	Thambaram
227	Kanchipuram	Kanchipuram	Thambaram
228	Kanchipuram	Kanchipuram	Thiruneermalai
229	Kanchipuram	Kanchipuram	Thambaram
230	Kanchipuram	Kanchipuram	Rhirumudivakkam, Palanthendalam
231	Thiruvallur	Thiruvallur	Meppur, Malayambakkam, Melagaram, NazarathPettai, Varadharajapuram
232	Thiruvallur	Thiruvallur	Kattirambakkam,Chettipattu, Palanjur, Kuttambakkam, Chembarambakkam,Madavilagam,Ne
233	Thiruvallur	Thiruvallur	Thandari
234	Thiruvallur	Ambattur	Pottur, Vellanur, Pammadukulam, Alamadi
235	Thiruvallur	Ambattur	Naravarikuppam
236	Thiruvallur	Ponneri	Vichoor,Edayanchavadi, Vellivoyal, Thirunilai,

			Kodipallam, Periamullavoyal, Chinn
237	Thiruvallur	Ambattur	Ennor
238	Thiruvallur	Ponneri	Vallur, Athipattu ,Nandiyambakkam, Kollati, Ariyanvoyal
239	Thiruvallur	Ponneri	Minjur
240	Thiruvallur	Ponneri	Sothupakkam, Perungavur, Kummanur, Marambedu, Ankadu, Arumandai, Kandigai, Pudur,
241	Thiruvallur	Ambattur	Pdiyanallur ,Thiruthakiriyampattu
242	Thiruvallur	Ponneri	Vijayanallur, Pannivakkam, Nallur, Siruniyam, Sembilivaram, Palayaermaivettipalaya
243	Thiruvallur	Ambattur	Attanthangal
244	Thiruvallur	Ambattur	Alathur, Velacheri, Pulikutti, Tenambakkam, Kadavur, Keelakondaiyur, Karlapakkam,
245	Thiruvallur	Thiruvallur	Nadukuttagai, Pakkam, Palavedu, Mittanamalli, Mukthapudupattu
246	Thiruvallur	Thiruvallur	Agraharam, Annambedu, Karunakaracheri, Nemilicheri, Thiruninravur
247	Thiruvallur	Thiruvallur	Thiruninravur
248	Thiruvallur	Thiruvallur	Thiruninravur
249	Thiruvallur	Thiruvallur	Thirumazhisai
250	Kanchipuram	Kanchipuram	Poonthandalam, Nandambakkam, Daravur, Kavanur, Sirukulathur
251	Kanchipuram	Kanchipuram	Mudichur, Varadharajapuram, Naduveerapattu, Erumaiyur
252	Kanchipuram	Kanchipuram	Perungalathur
253	Kanchipuram	Kanchipuram	Perungalathur
254	Kanchipuram	Kanchipuram	Thambaram
255	Kanchipuram	Kanchipuram	Thambaram
256	Kanchipuram	Tambaram	Thambaram
257	Kanchipuram	Tambaram	Peerkankaranai, Perungalathur
258	Kanchipuram	Chengalpattu	Vandalur, Mannivakkam, Kelambakkam
259	Kanchipuram	Chengalpattu	Vandalur
260	Kanchipuram	Chengalpattu	Puthur, Nedukundram, Kulapakkam
261	Kanchipuram	Tambaram	Irumbuliyur,Meppedu, Thiruvanjeri
262	Kanchipuram	Tambaram	Hasthinapuram, Chitlapakkam
263	Kanchipuram	Tambaram	Sembakkam, Gowrivakkam, Rajakilpakkam
264	Kanchipuram	Tambaram	Madambakkam
265	Kanchipuram	Tambaram	Madambakkam, Kaspapuram, Vengambakkam, Agaramten
266	Kanchipuram	Tambaram	Vengavasal
267	Kanchipuram	Tambaram	Madambakkam
268	Kanchipuram	Tambaram	SithalaPakkam ,Arasankalani, KovilanCheri, Madurapakkam, Otiyambakkam, Mulacheri
269	Kanchipuram	Tambaram	Perumbakkam
270	Kanchipuram	Tambaram	Sholinganallur,Uthandi,Semmancheri
271	Kanchipuram	Tambaram	karapakkam ,Okkiam thurai pakkam
272	Kanchipuram	Tambaram	Sholinganallur
273	Kanchipuram	Tambaram	Okkiam thurai pakkam, Injambakkam
274	Kanchipuram	Tambaram	Sholinganallur
275	Kanchipuram	Tambaram	Sholinganallur,Uthandi
276-290	External Zone		

(Source: JICA Study Team)

The travel modes are categorized as shown in the table below to create current Origin-Destination which matched traffic survey using Root Mean Square Error Minimizing Model. Passenger Car Unit and Number of passengers per vehicle are shown in the table below.

Table 3-5 Trip Mode Categories

In Traffic volume count Survey		In Demand Forecasting	
1	Motorcycle	1	Motorcycle
2	Car/Jeep	2	Car
3	Trip van/Maxi Cab/ Share Auto	3	Auto Rickshaw
4	Auto Rickshaw		
5	Bus	4	Bus
6	Mini Bus		
7	LCV	5	LCV
8	Goods Auto		
9	2 axle	6	Truck
10	3 axle		
11	MAV	7	MAV

(Source: JICA Study Team)

Table 3-6 Passenger Car Unit for Trip Mode Categories

Vehicle Type	PCU	Vehicle Type	PCU
Car/ Auto Rickshaw/Taxi	1.0	Truck	3.0
LCV	1.5	MAV	4.5
Bus	3.0	Motorcycle	0.5

(Source: Manual on Economic Evaluation of Highway Projects in India 2009)

Table 3-7 Number of Passengers per Vehicle

Vehicle Type	Number of passengers
Motorcycle	1.5
Car	2.6
Auto Rickshaw/Taxi	2.3
Bus	2.3

(Source: Chennai Comprehensive Transportation Study)

The number of trips based on the vehicle type of current Origin-Destination (2016) is shown in table 3-8.

The comparison table of the modal share of 2008 and 2016 is shown in table 3-9. The value of the Auto Rickshaw in 2016 is 3.6% lower than in 2008. This is because the ratio of the Auto Rickshaw in

traffic volume survey of this study is low. Traffic volume survey was done outside the inner ring road. Therefore, it is thought that the ratio of rickshaw lowered.

The number of vehicles based on the vehicle type of current Origin-Destination (2016) is shown in table 3-10.

Table 3-8 Number of Trips based on Vehicle Type of Current Origin-Destination (2016)

	Motorcycle	Car	Auto Rickshaw	Bus	Train*	Total
Current OD (trip)	7,261,257	2,311,114	819,216	9,870,250	2,767,714	23,029,551

* Train was calculated by multiplying the bus utilization in 2016 by a ratio of train utilization for the bus utilization in 2008.

(Source: JICA Study Team)

Table 3-9 Comparison Table of Modal Share of 2008 and 2016

Transport Mode	2008 (CCTS)	2016 (Current OD)
Public Transport	41%	41.6%
IPT	11%	3.6%
Private Transport	48%	54.9%

(Source: Summarized by JICA Study Team based on CTTS, Chennai)

Table 3-10 Number of Vehicles based on Vehicle Type of Current Origin-Destination (2016)

	LCV	Truck	MAV
Current OD (Vehicle / Day)	160,274	62,039	15,531

(Source: JICA Study Team)

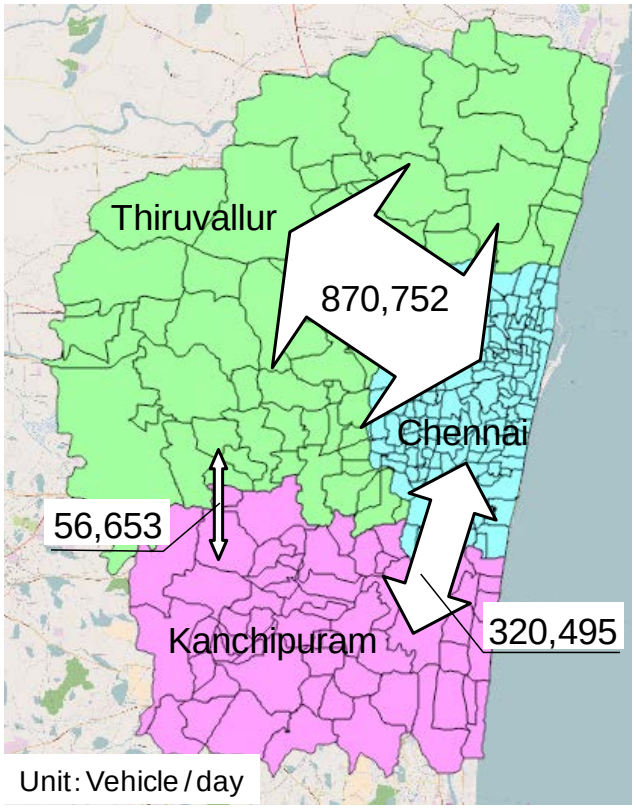
The trip generation and attraction of current Origin-Destination (2016) is shown in table 3-11. The trip generation and attraction in Chennai area account for many ratios.

The interzonal Origin-Destination of current Origin-Destination is shown in figure3-7. There are many Origins-Destinations between Chennai and Thiruvallur.

Table 3-11 Trip Generation and Attraction of Current Origin-Destination (2016)

Origin Area	Destination Area	Trip Generation and Attraction (Vehicle / Day)
Chennai	Chennai	4,492,225
Chennai	Kanchipuram	195,394
Chennai	Thiruvallur	626,350
Chennai	External Zone	193,900
Kanchipuram	Chennai	125,101
Kanchipuram	Kanchipuram	69,490
Kanchipuram	Thiruvallur	30,271
Kanchipuram	External Zone	37,954
Thiruvallur	Chennai	244,402
Thiruvallur	Kanchipuram	26,382
Thiruvallur	Thiruvallur	179,139
Thiruvallur	External Zone	124,509
External Zone	Chennai	60,307
External Zone	Kanchipuram	13,084
External Zone	Thiruvallur	41,040
External Zone	External Zone	16,055
Total		6,475,603

(Source: JICA Study Team)



(Source: JICA Study Team)

Figure 3.7 Interzonal Origin-Destination of Current Origin-Destination

3.4.2 Network Data Creation

Daily traffic capacity was calculated using the formula as shown below. Hourly traffic capacity and free flow speed which were used by Chennai Comprehensive Transport Study was set. The rate of 8.7%, average value of traffic volume which was drawn by the result of the traffic survey conducted by this survey, was applied to the peak rate.

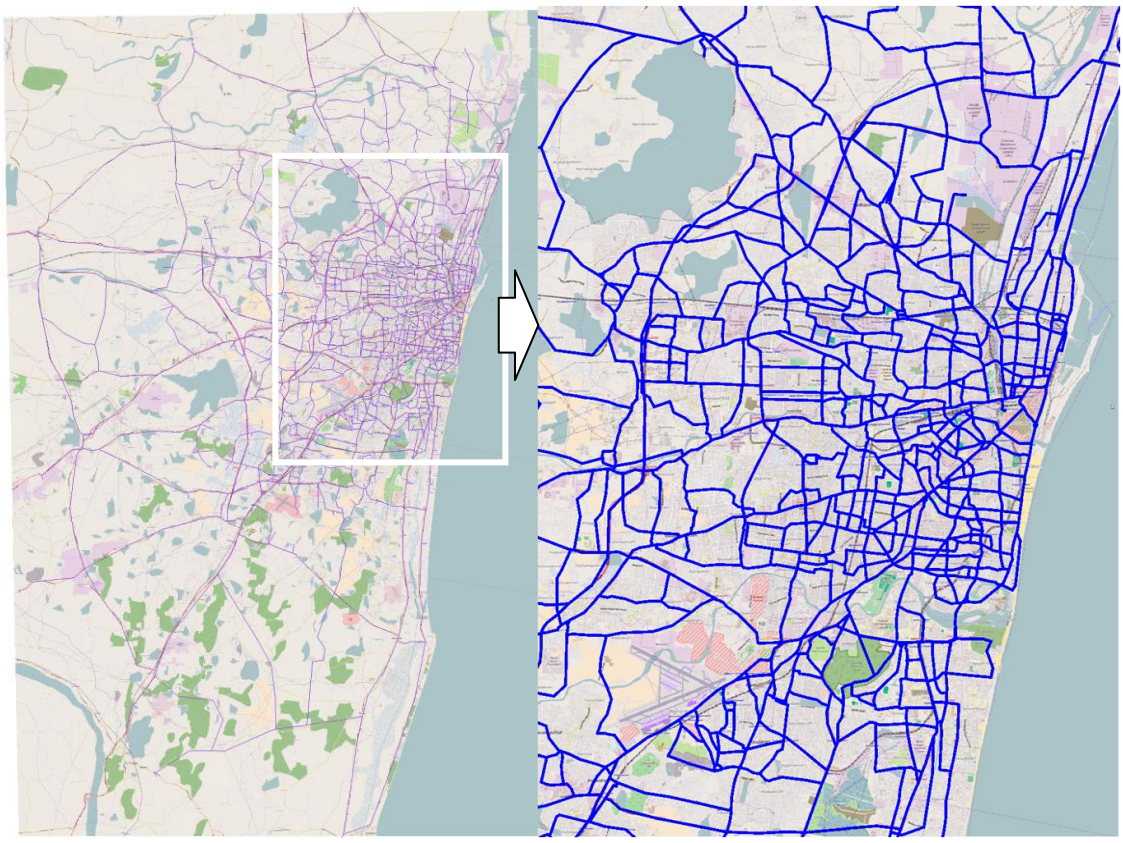
$$Qc = qc \div P \times 100$$

Where,

Qc = Daily Traffic Capacity (Passenger Car Unit / day)

qc = Hourly Traffic Capacity (Passenger Car Unit / hour)

P = Peak Rate (%).



(Source: JICA Study Team)

Figure 3.8 Road Network Data

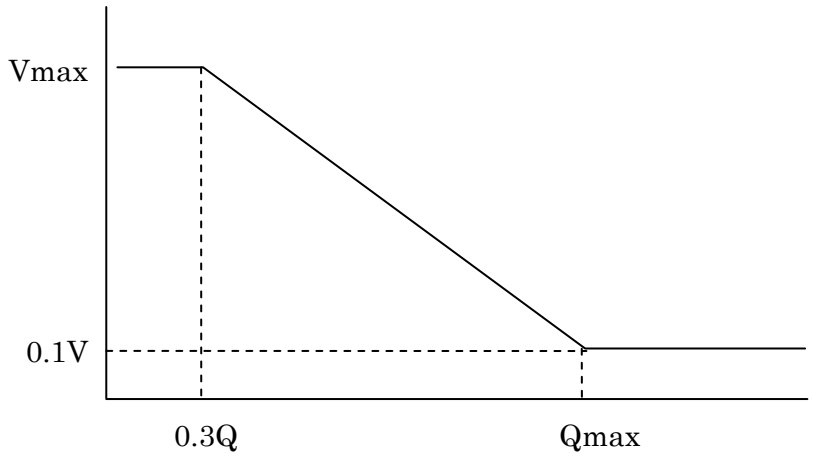
Table 3-12 Road Network Conditions

Id	Line	Divided/Not	Direction	Velocity	Capacity
1	1	Undivided	two way	22 km/h	20,700PCU/day
2	1.5	Undivided	two way	27 km/h	32,200 PCU/day
3	2	Undivided	one way	36 km/h	69,000 PCU/day
4	2	Undivided	two way	35 km/h	43,700 PCU/day
5	3	Undivided	two way	38 km/h	64,400 PCU/day
6	3	Divided	two way	31 km/h	78,200 PCU/day
7	4	Divided	one way	45 km/h	137,900 PCU/day
8	4	Undivided	two way	40 km/h	87,400 PCU/day
9	4	Divided	two way	43 km/h	103,400 PCU/day
10	6	Divided	two way	50 km/h	154,000 PCU/day

(Source: Summarized by JICA Study Team)

3.4.3 QV Conditions

QV conditions for the relationship of capacity and velocity was set as shown in the figure below.

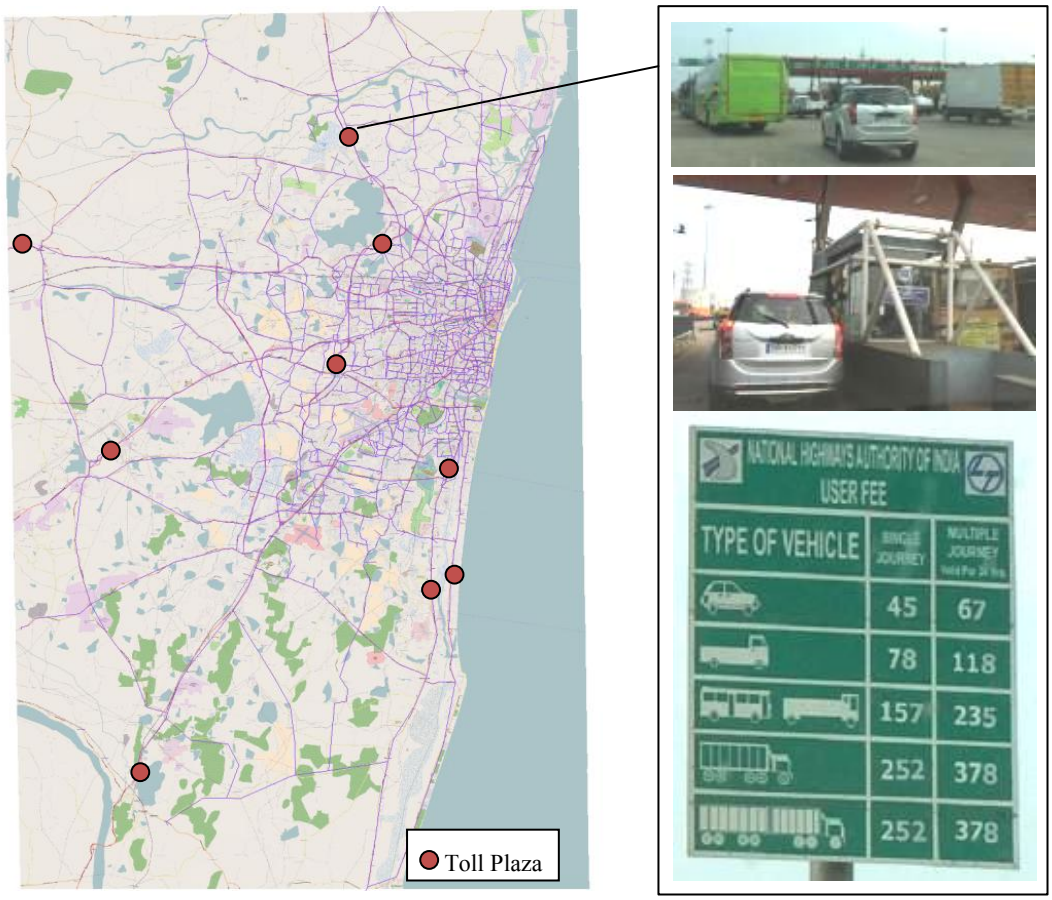


(Source: JICA Study Team)

Figure 3.9 QV Conditions

3.4.4 Toll Plaza and User Fee

There are 9 toll plazas in Chennai, as shown in the figure below. User fee is set as shown in the table below.



(Source: JICA Study Team)

Figure 3.10 Toll Plaza and User Fee

Table 3-13 User Fee

Vehicle Type		Fee
1	Motorcycle	—
2	Car	45 Rupees
3	Auto Rickshaw	45 Rupees
4	Bus	157 Rupees
5	LCV	78 Rupees
6	Truck	157 Rupees
7	MAV	252 Rupees

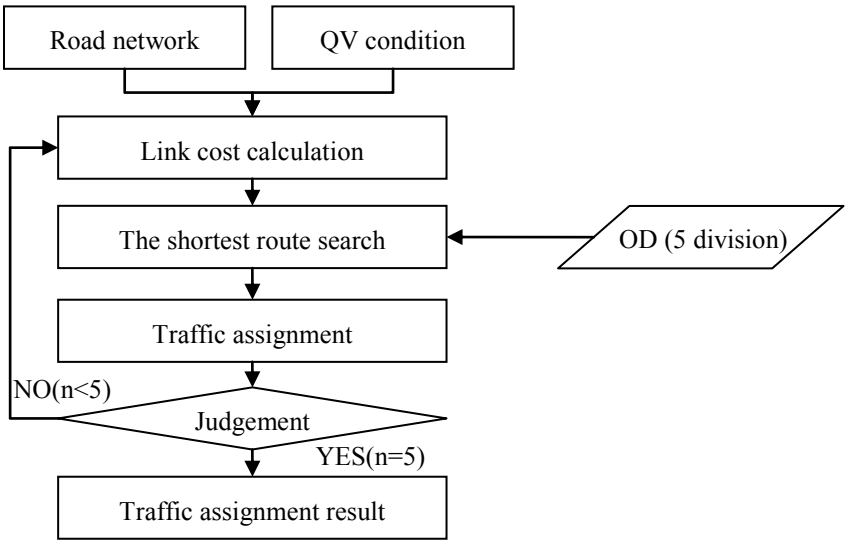
(Source: Summarized by JICA Study Team)

3.5 Current Traffic Situation

3.5.1 Traffic Assignment

Incremental Traffic assignment method was used. The incremental assignment divides the input Origin-Destination traffic data into user-specified increments and assigns each increment to the minimum route where the generalized cost (i.e., the impedance calculated from travel time, distance and so on) is the least.

The Origin-Destination division number is 5 times distribution for each 20%. Road network, QV condition and Origin-Destination data were used as shown below.

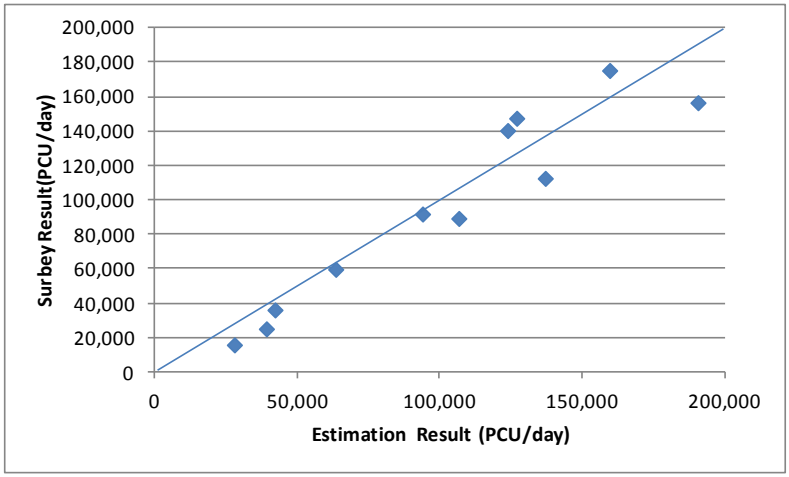


(Source: JICA Study Team)

Figure 3.11 Traffic Assignment Flow

3.5.2 Reproduction of Current Traffic Situation

The result of comparison with reproduction of the present traffic condition and the result of the traffic volume survey is shown in the figure below. It shows that r-squared by Passenger Car Unit is 0.950 in this correlation. Thus it is judged that the reproducibility was mostly obtained.

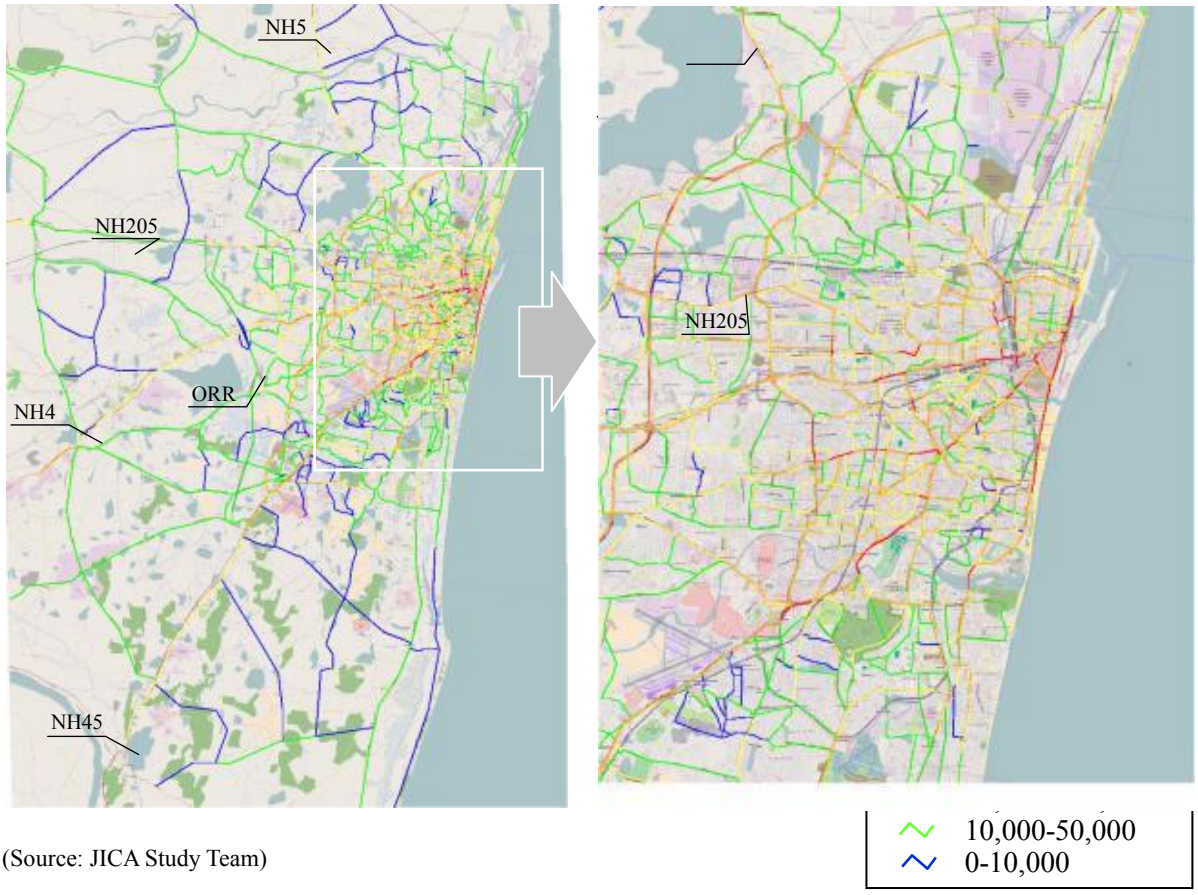


(Source: JICA Study Team)

Figure 3.12 Survey Result and Estimation Result

3.5.3 Current Traffic Situation

The traffic is bottlenecked in the central area of Chennai city, and therefore the traffic congestion occurs especially on the major trunk roads; NH5, NH205, NH4, Inner Ring Road and Chennai Bypass, as shown in the figure below.



(Source: JICA Study Team)

Figure 3.13 Traffic Assignment Result

3.6 Future Traffic Demand Forecast

3.6.1 Future Estimation Year

The future traffic demand forecast was carried out for three target years: Short-term (2021: after five years), medium term (2026: after 10 years), long-term (2036 after 20 years).

3.6.2 Future Origin-Destination Data Creation

The Detail Project Report on Chennai Peripheral Ring Road estimates the traffic demand forecast (Motorcycle, Passenger Auto, Car/Jeep, Bus, Light Commercial Vehicle, 2&3 Axle Trucks, MAV) using economic indicators such as per capita income, population growth rate of Tamil Nadu, etc. The growth rate of traffic demand estimated by Detailed Project Report is shown in Table 3-14. There figures were used for creation of the future Origin-Destination data. The growth rate of future traffic demand by vehicle type was estimated for target years from the current Origin-Destination (2016) as shown in Table 3-15.

Table 3-14 Growth Rate of Traffic Demand Estimated by Detailed Project Report

Year	Motorcycle	Passenger Auto	Car/ Jeep	Bus	LCV	2&3Axle Trucks	MAV
2013-2018	9.37%	5.34%	9.14%	5.55%	13.10%	7.33%	6.22%
2018-2023	8.43%	5.00%	8.22%	5.00%	11.79%	6.59%	5.60%
2023-2028	7.59%	5.00%	7.40%	5.00%	10.61%	5.93%	5.04%
2028-2033	6.83%	3.89%	6.66%	4.05%	9.55%	5.34%	4.53%
2033-2038	6.15%	3.50%	5.99%	3.64%	8.59%	4.81%	4.08%
2038-2043	5.53%	3.15%	5.39%	3.28%	7.73%	4.33%	3.67%

(Source: Detail Project Report on CPRR)

Table 3-15 Growth Rate of Future Traffic Demand for Target Years Estimated by This Study from Current Origin-Destination (2016)

Term	Year	Motorcycle	Passenger Auto	Car/ Jeep	Bus	LCV	2&3Axle Trucks	MAV
Short	2021	8.8%	5.1%	8.6%	5.2%	12.3%	6.9%	5.8%
Mid	2026	16.7%	10.1%	16.3%	10.2%	23.4%	13.1%	11.1%
Long	2036	30.3%	18.1%	29.5%	18.5%	42.3%	23.7%	20.1%

(Source: Detail Project Report on CPRR)

The target value of the modal share is set at 2026 in Chennai Comprehensive Transportation Study (CCTS). The modal share of future target years was set according to CCTS. The modal share of future traffic demand for target years is shown in table 3-16. The modal share of short term was set by liner regression using the modal share of current (2016) and CCTS (2026). The modal share of middle

term was set by target value of CCTS. The modal share of long term was set by assuming the modal share of middle term to go sideways.

The number of trips based on the vehicle type of target years and the number of vehicles based on the vehicle type of target year are shown Table3-17 and Table 3-18.

Table 3-16 Modal Share of Future Traffic Demand for Target Years

	Short	Mid	Long	Current	CCTS
	2021	2026	2036	2016	2026
Public Transport	62%	70%	70%	41.6%	70%
IPT	6%	8%	8%	3.6%	8%
Private Transport	32%	22%	22%	54.9%	22%

(Source: CCTS, Chennai)

Note: The above table excludes non-motorized transport.

Note: Construction of Mass Rail Transit, Metro Rail, Mono Rail, Light Rail Transit, Bus Rapid Transit based on plan is required, so that the public transport share rises to 70%. In addition, it is also important that Parking lot, transfer station, traffic information system, etc adjacent to the transport hub such as a bus stop or the railroad station is constructed. Besides, as measures of the policies, improvement of the user convenience by the introduction of the common card and securing regular schedule of trains are required. Most of city buses which are citizen's main transportation are timeworn vehicles having low comfort. Thus, it is recommended that a new vehicle is introduced to improve the comfort of the user. It is necessary for these measures to be carried out totally so that public transport share rises to 70%

Table 3-17 Number of Trips based on Vehicle Type of Target Years

	Motorcycle	Car	Auto Rickshaw	Bus	Train*	Total
Short (trip)	5,978,224	1,920,524	1,436,118	12,119,095	3,398,312	24,852,274
Mid (trip)	4,408,601	1,409,162	2,115,550	14,457,142	4,053,923	26,444,379
Long (trip)	4,815,261	1,531,090	2,307,764	15,770,682	4,422,253	28,847,049

* Train was calculated by multiplying the bus utilization each target year by a ratio of train utilization for the bus utilization in 2008.

(Source: JICA Study Team)

Table 3-18 Number of Vehicles based on Vehicle Type of Target Years

	LCV	Truck	MAV
Short (Vehicle / Day)	180,567	66,795	18,516
Mid (Vehicle / Day)	198,379	70,634	18,959
Long (Vehicle / Day)	283,141	87,661	23,912

(Source: JICA Study Team)

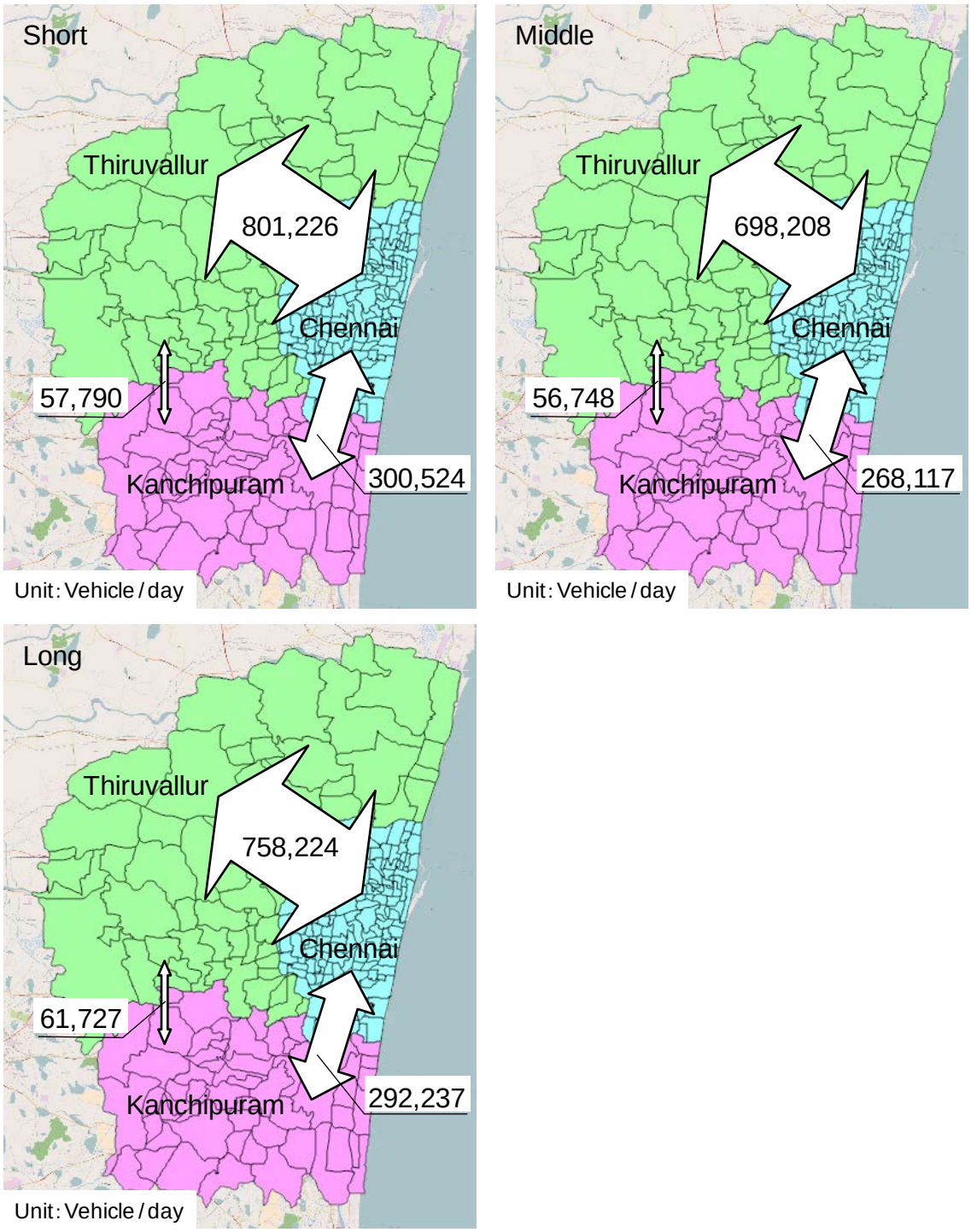
The trip generation and attraction of target year is shown Table3-19. The trip generation and attraction decreased by shifting to public transport for the middle term. The trip generation and attraction increased with increase in number of the trips for the long term.

The interzonal Origin-Destination volume of target year is shown in figure3-13. There are many Origin-Destination between Chennai and Thiruvallur.

Table 3-19 Trip Generation and Attraction of Target Years

Origin Area	Destination Area	Trip Generation and Attraction (Vehicle / Day)		
		Short	Mid	Long
Chennai	Chennai	3,954,681	3,258,902	3,552,773
Chennai	Kanchipuram	176,815	150,569	164,147
Chennai	Thiruvallur	557,363	464,848	505,954
Chennai	External Zone	168,177	134,908	146,072
Kanchipuram	Chennai	123,709	117,548	128,090
Kanchipuram	Kanchipuram	72,067	72,423	78,445
Kanchipuram	Thiruvallur	30,651	29,848	32,472
Kanchipuram	External Zone	33,142	26,670	28,745
Thiruvallur	Chennai	243,863	233,360	252,270
Thiruvallur	Kanchipuram	27,139	26,900	29,255
Thiruvallur	Thiruvallur	180,711	175,099	187,610
Thiruvallur	External Zone	106,268	82,614	89,013
External Zone	Chennai	58,345	53,143	56,142
External Zone	Kanchipuram	11,773	9,692	10,235
External Zone	Thiruvallur	38,644	34,125	36,046
External Zone	External Zone	15,265	13,772	14,634
Total		5,798,613	4,884,421	5,311,903

(Source: JICA Study Team)

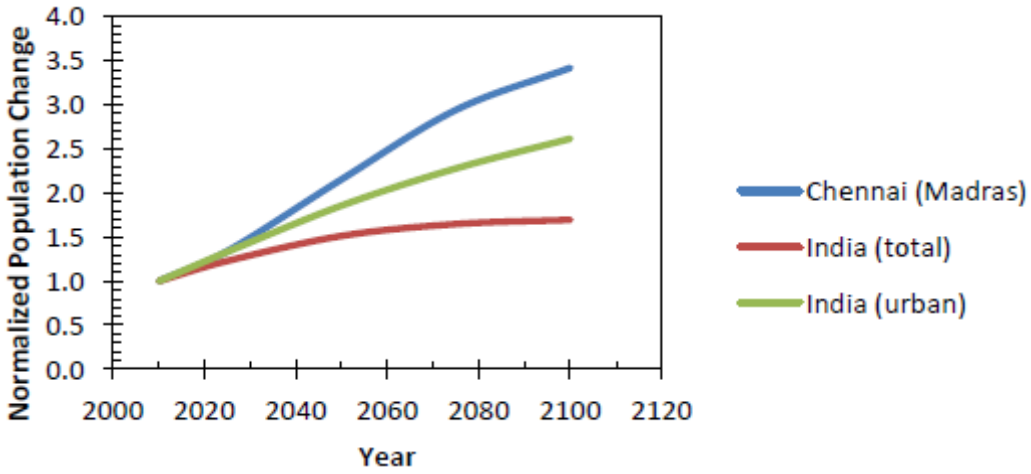


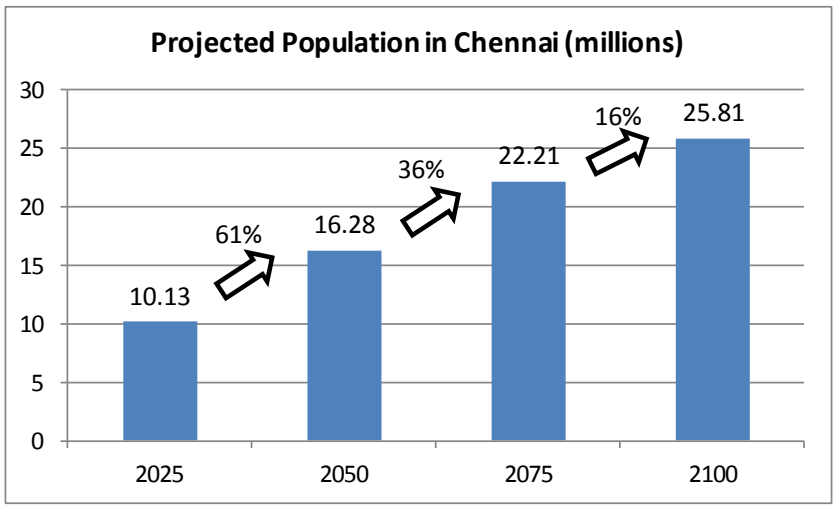
(Source: JICA Study Team)

Figure 3.14 Interzonal Origin-Destination Volume of Target Year

＜ Reference＞

The projected population in Chennai metropolitan area has a higher rate of increase than total population in India and the population in urban cities in India. It is projected to increase to 3.4 times in 90 years, as shown in the figure below. The population will continue to increase in the future and cause traffic volume increases.



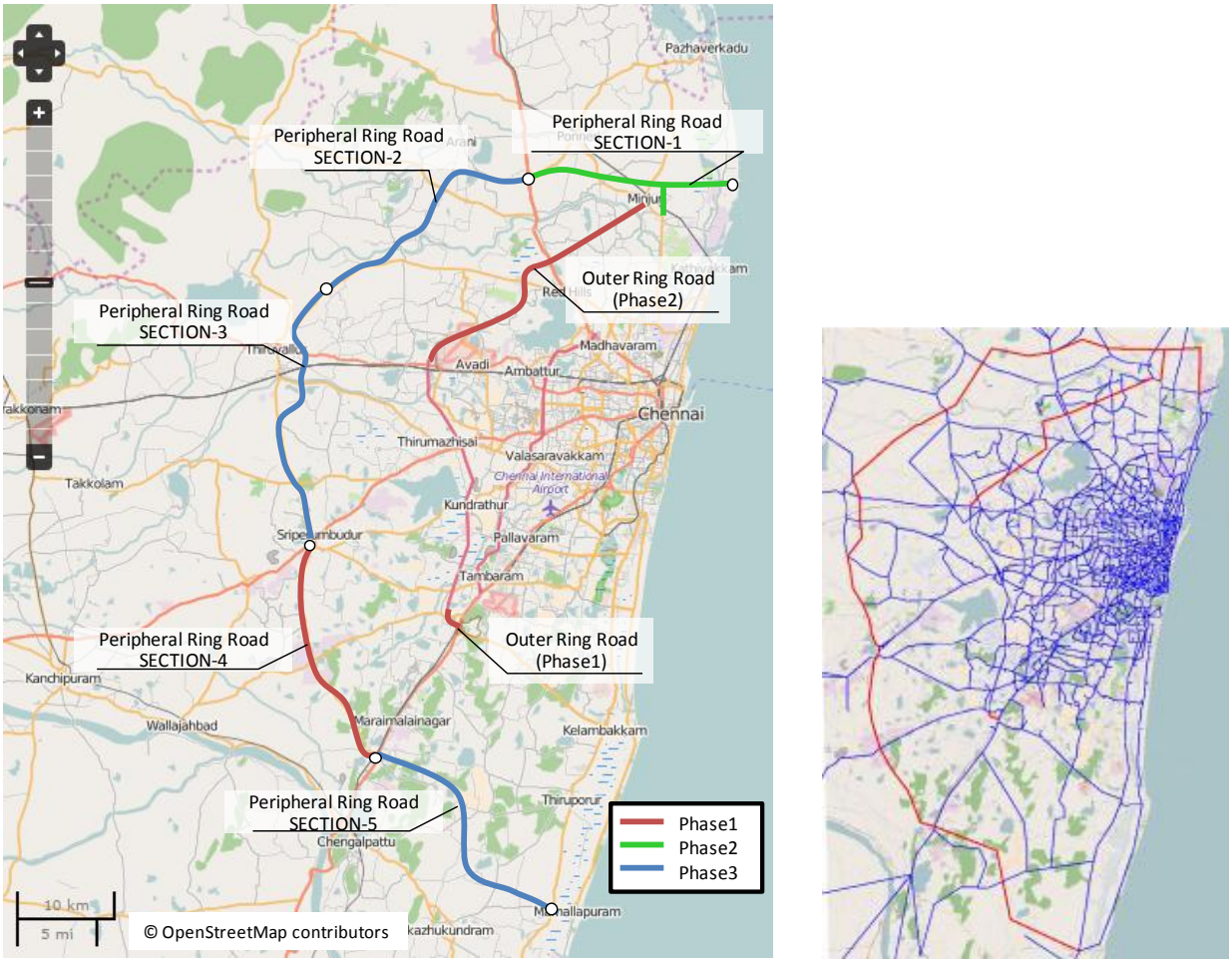


(Source: Compiled by JICA Study Team based on Socioeconomic Pathways and Regional Distribution of the World's 101 Largest Cities, Global Cities Institute (GCI), 2014)

Figure 3.15 Forecasted Population in Chennai

3.6.3 Future Network Data Creation

The planned major roads are Outer Ring Road (phase1 and phase 2) and Chennai Peripheral Ring Road (from section 1 to section 5). These roads were added to the future network data. The opening year of each road is shown in the table below.



(Source: JICA Study Team)

Figure 3.16 Future Road Network

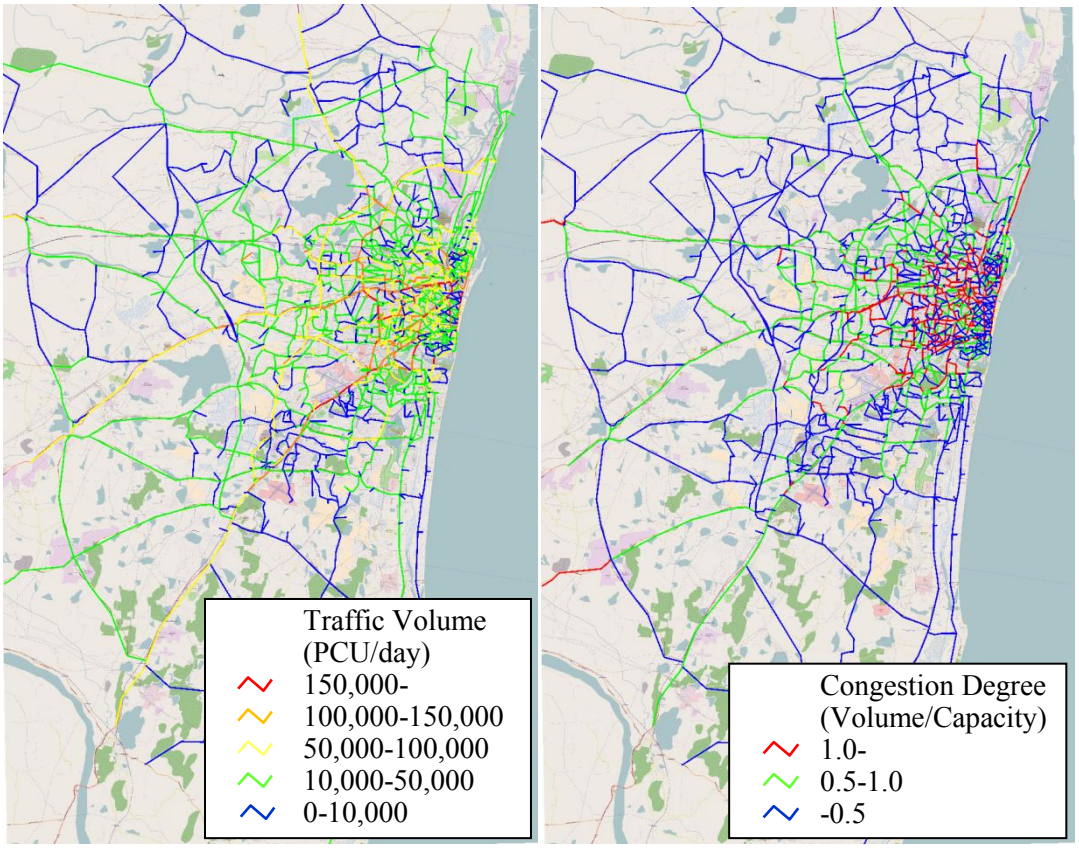
Table 3-20 Opening Year of Major Road

Term	Opening	Road
Short	2021	Outer Ring Road(phase1, phase2), CPRR (SECTION4)
Mid	2026	CPRR (SECTION1)
Long	2036	CPRR (SECTION2, SECTION3, SECTION5)

(Source: JICA Study Team)

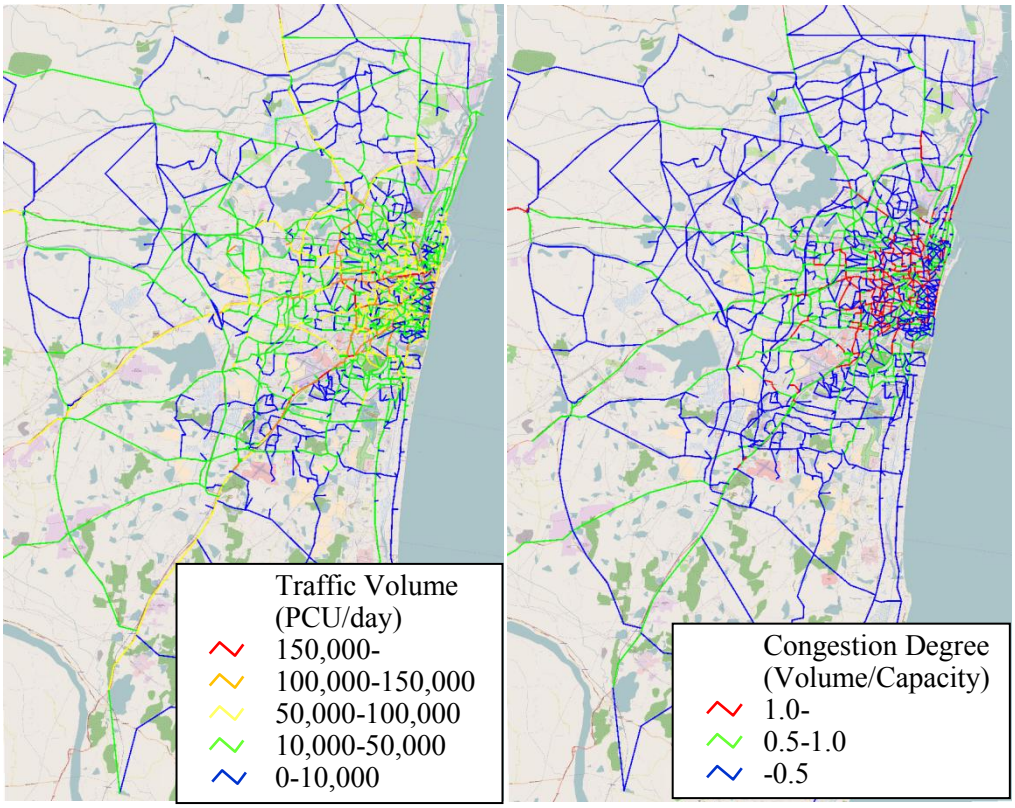
3.6.4 **Future Traffic Demand Forecast**

The results of the future traffic demand forecast for short term, mid term and long term are shown in figure below. They show that the traffic is concentrated in the Chennai city.



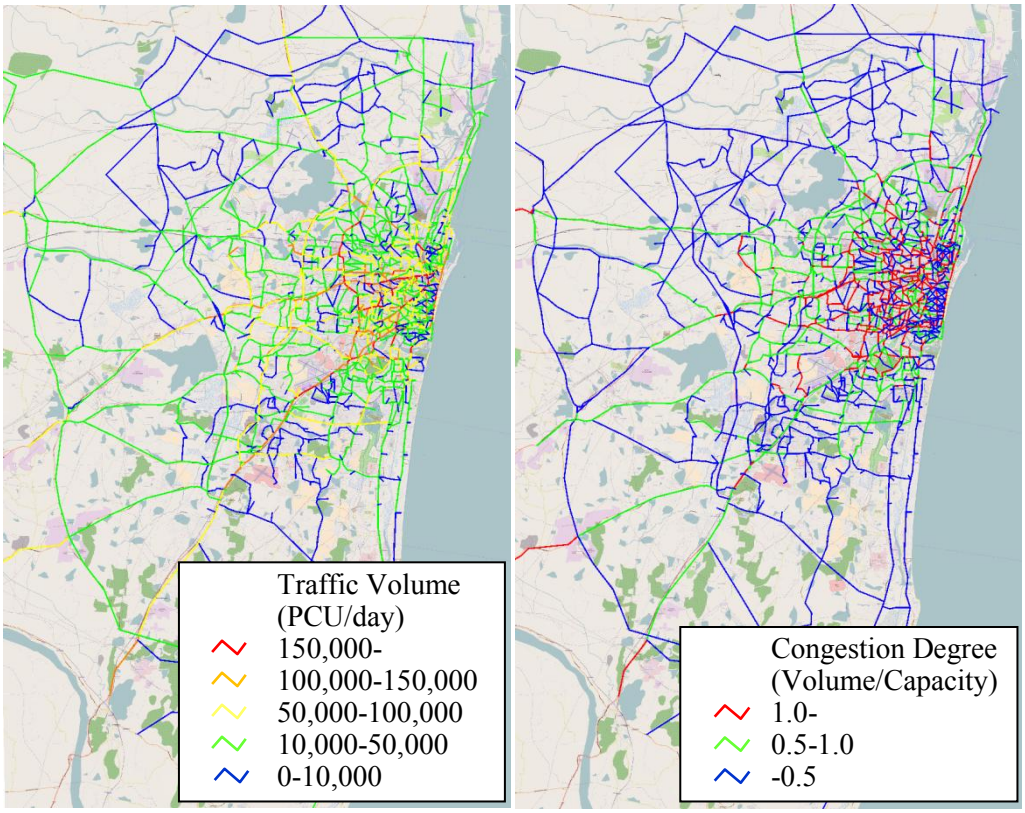
(Source: JICA Study Team)

Figure 3.17 Result of Future Traffic Demand Forecast (Short Term)



(Source: JICA Study Team)

Figure 3.18 Result of Future Traffic Demand Forecast (Mid Term)



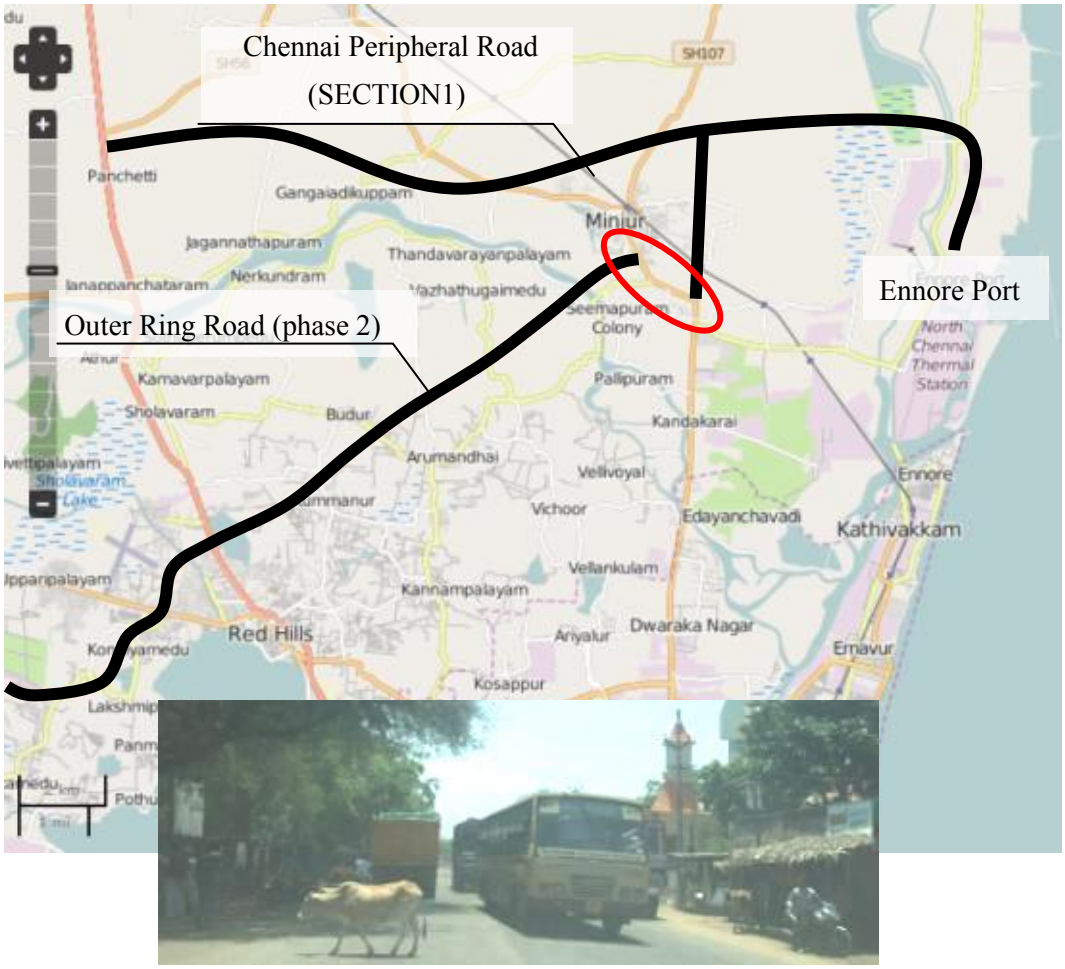
(Source: JICA Study Team)

Figure 3.19 Result of Future Traffic Demand Forecast (Long Term)

3.6.5 **Road and Traffic Issues**

(1) Connection of Outer Ring Road and Chennai Peripheral Ring Road

The section of Outer Ring Road in phase 2 and the section 1 of Chennai Peripheral Ring Road are not planned to connect in the current plan. Both roads are planned to connect to the road in Minjur village. This road in the village is a 2-lane road and there are a number of houses and shops along the road, as shown in the photograph below. It is concerned that this will be a bottleneck and cause traffic accidents because there are many people on the roadside.

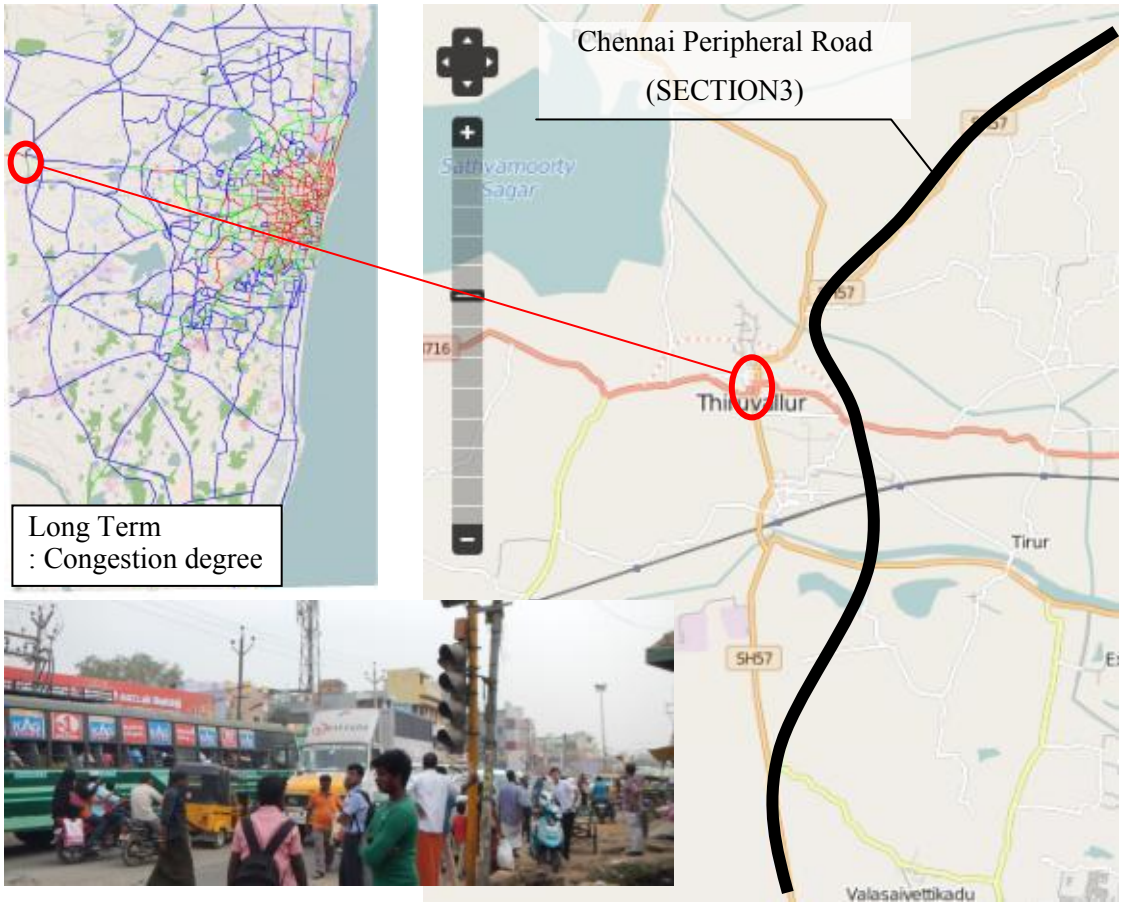


(Source: JICA Study Team)

Figure 3.20 Problem of Connection of Outer Ring Road and Chennai Peripheral Ring Road

(2) Intersection of NH205 and SH57

The section 3 of Chennai Peripheral Ring Road is planned to bypass the intersection of NH205 and SH57 in Thiruvallur. This intersection is a four-lane section and a number of large size vehicles such as buses and trailers are passing as shown in the photograph below. There are a number of houses and shops around the intersection. Thus, the traffic capacity has already been declined significantly. It is concerned that this will be a bottleneck and cause the traffic accidents.



(Source: JICA Study Team)

Figure 3.21 Problems of Intersection of NH205 and SH57

4 Summary of Issues in Chennai

According to the studies so far including site survey, interviews to the related agencies, reviewing existing materials, collection of information from news articles, result of traffic demand forecast and websites, etc., the issues in Chennai are summarised as below.

(1) Road Traffic

- High proportion of motorcycles and auto rickshaws
- Road construction/improvement not catching up with urbanization
- A large number of accidents
- High ratio of large-size vehicle
- Chronic long queue of large-size vehicles waiting for entering Chennai port
- Resident living in the village in suburbs in Chennai endangered by a number of large-size vehicles continuously passing through

(2) Road Infrastructure

- Reduced number of lanes on the major roads due to construction of Chennai Metro (Temporal during the construction)
- Complicated structure of grade separation at many major junctions in the city (e.g. clover-leaf structures causing confusion to the road users due to complexity in structure)
- Absence of grade separation at some major junctions
- Various factors which accelerate deterioration of road surface conditions such as damaged pavement, lack of drainage systems, etc.
- A number of on-road parking cars occupying the road spaces
- Limited number of off-road parking facilities
- Flooding when it rains heavily
- Absence of foot-path on many major roads
- Absence of bicycle ways
- Not constant road width
- Shortage of skywalk
- Insufficient drainage system and lack of proper maintenance

(3) Traffic Manners

- Lack of awareness of importance of traffic discipline and traffic rules
- Pedestrians crossing anywhere on arterial road
- Lack of traffic discipline to follow lane marking, stop line, traffic signals, etc.

(4) Traffic Management

- Lane block by barricade to reduce speed which suddenly appears on the road
- A number of traffic signals which are not working
- A number of traffic signals which are not sufficiently visible (e.g. insufficient height, not proper location, etc.)
- Absence of smart card which can be commonly used for toll collection at toll plazas under different road operators
- Lack of knowledge and experience on proper road management and traffic management

(5) Public Transport

- Inefficient or not proper connectivity among different transport modes
- Improper location of bus stops
- Limited awareness of bus drivers and passengers for safety
- Absence of information on expected time of bus arrival and operation status at bus stops/terminals
- Poor condition of public bus
- Inconvenience and inefficiency due to lack of ticketing system
- Delay of metro construction

(6) Others: Facilities and Information

- A number of broken/damaged roadside facilities
- Absence of systems and data to support traffic and road management
- Limited road asset management
- Absence of useful road traffic data/information

Insufficient toll payment system resulting in frequent long queue of vehicles

5 ITS Development Policy (Draft)

5.1 Required Measures to Solve Issues in Chennai

The issues described on the previous section are shown below by category. Then the required measures are described by issue. There are a number of required measures for solving the issues on urban transport. These measures need to be taken in the various aspects such as scheme, act, infrastructure, etc. Therefore, the required measures are summarized by 'Scheme/Act', 'Infrastructure' and 'ITS' in this study as show in the table below.

Table 5-1 Required Measures to Solve Issues in Chennai

Category	Issue	Scheme /Act	Infra	ITS	Required Measure
(1). Road Traffic	a) High proportion of motorcycles and auto rickshaws	●			• Actual number of existing and disposed vehicles are not comprehended because the vehicle registration scheme is not properly functioning. The legal measures by Gov. such as imposing annual vehicle tax on the vehicle owners are required.
	b) Road construction/improvement not catching up with urbanization		●	●	• The development/improvement of road transport infrastructures such as grade separate intersection, intermodal connectivity, removal of encroachment and restoring design width of the road are required to speed up. • The measures to lead altering travel behaviour of road users by providing useful road traffic information is required. The drivers may change commuting time or select other route by providing such information as congestion, planned road work, etc. Other measures include increasing travel speed in the city by advanced traffic signal and parking availability information, and enhancing convenience and encouraging modal shift by introducing common mobility card for public transport.
	c) A large number of accidents	●	●	●	• Preparing and implementing comprehensive action plan to reduce accident. • Constructing access control road, wide footpath, and sky-walk to segregate vulnerable road users from vehicles. • Maintaining accident database and analysing the cause of accidents for preparation of action

Category	Issue	Scheme /Act	Infra	ITS	Required Measure
					plan including road geometry.
	d) High ratio of large-size vehicle		●	●	• Constructing access roads which directly connect industrial parks and port to segregate vulnerable road users from vehicles and development of container / truck terminals. • Introducing weigh in motion to reduce accident caused by excess weight.
	e) Chronic long queue of large-size vehicles waiting for entering Chennai port		●		• Improving capacity of Chennai port.(Improving efficiency in port procedure, Introducing facilities)
	f) Resident living in the village in suburb in Chennai endangered by a number of large-size vehicles continuously passing through		●	●	• Constructing direct access road from industrial parks to port to segregate vulnerable road users from large sized vehicles. • Reducing deviation of trucks from the specified/allowed route to run by tracking vehicles and providing warning message.
(2). Road Infrastructure	a) Reduced number of lanes on the major roads due to Metro construction (Temporal during the construction)		●		• After completion of construction of underground section, the road space and capacity will increase as the restricted zones will be opened. In addition, modal shift from road to metro can be expected once completed.
	b) Complicated structure of grade separation at many major junctions in the city (e.g. clover-leaf structures causing confusion to the road users due to complexity in structure)		●		• Planning the structures which do not cause confusion of road users. Introducing clear sign boards with sizable letter.
	c) Absence of grade separation at some major		●	●	• Planning proper structures which do not cause confusion of road users.

Category	Issue	Scheme /Act	Infra	ITS	Required Measure
	junctions				• Introducing systems which collect, cumulate and analyse the data to understand the effect of grade separate such as reduced queue length, passing time, etc.
	d) Various factors which accelerate deterioration of road surface conditions such as damaged pavement, lack of drainage systems, etc.		●	●	• Introducing more durable pavement, rumble strip instead of speed breakers and proper planning/maintenance of roadside drainage to lengthen pavement life. • Carrying out periodical inspection to understand the current road condition and properly maintain the road inventory database. Identifying and prioritizing the sections which require improvement becomes easier as well by this measure.
	e) A number of on-road parking cars occupying the road spaces	●		●	• Carrying out stricter enforcement by applying such measures as higher penalty charges • Introducing surveillance cameras at the locations where there are frequently illegal parking and recording the vehicle number plate of illegal parking to support stricter enforcement
	f) Limited number of off-road parking facilities		●	●	• Preparing parking plan such as parking action plan, parking master plan, etc. and constructing multi-story parking in the vicinity of intermodal hub, commercial area, transit point to non-motorized transport and constructing walking path from parking. • Providing parking availability information of several parking lots in the city to enhance users' convenience and alleviate congestion by reducing the moving-around vehicle looking for available parking place
	g) Flooding when it rains heavily	●	●	●	• Implementing traffic regulation such as road closure when the water reaches dangerous level • Developing drainage system and installing facilities such as water pump at flooding prone locations • Alerting road users on the occasion of reaching at dangerous level of flooding by installing flooding measurement equipment
	h) Absence of foot-path on many major roads		●	●	• Constructing spacious flat footpath not obstructed by objects such as trees. • Providing information on walkable and safe route to pedestrians.

Category	Issue	Scheme /Act	Infra	ITS	Required Measure
	i) Absence of bicycle ways		●	●	• Developing bicycle ways and bicycle sharing stations at the transfer locations with public transport and at parking. • Providing information of bicycle ways, location of bicycle sharing station and availability of rent bicycle. Introducing common mobility card for the payment of rental bicycle.
	j) Not constant road width		●		• Improving the road width and providing the warning before the locations where the road width significantly changes as the road width which is not constant causes accidents.
	k) Shortage of skywalk		●	●	• Constructing skywalk at arterial roads and transfer location of public transport • Providing information on walkable and safe route to pedestrians.
	l) Insufficient drainage system and lack of proper maintenance		●		• Developing comprehensive drainage system to the end of drainage flow in the system(In the case of a heavy rain generated with the probability once in ten years, full-scale drainage system are required separately) • Carrying out proper maintenance such as periodic inspection.
(3). Traffic Manners	a) Lack of awareness of importance of traffic discipline and traffic rule	●			• Improving traffic education and increasing opportunity of learning (targeting all generation) to improve traffic manners. Improving the curriculum and raising the acceptable level to pass the exam for driver's licence in the driving school.
	b) Pedestrians crossing anywhere on arterial road	●	●		• Improving traffic education and increasing opportunity of learning (targeting all generation) to improve traffic manners. • Constructing/improving skywalks for crossing arterial road.
	c) Lack of traffic discipline to follow lane marking, stop line, traffic signals, etc.	●	●		• Improving traffic education and increasing opportunity of learning (targeting all generation) to improve traffic manners. Improving the curriculum and raising the acceptable level to pass the exam for driver's licence in the driving school. • Painting robust lane marking and installing traffic signal and sign board at more proper locations for assuring visibility.

Category	Issue	Scheme /Act	Infra	ITS	Required Measure
(4). Traffic Management	a) Lane block by barricade to reduce speed which suddenly appears on the road	●	●		• Implementing more fundamentally efficient measures such as improving intersection, traffic signal, traffic manners, etc. instead of blocking the road by barricade. The barricades on the road are dangerous and cause congestion because they reduce the road capacity. • Improving intersection, traffic signal, road width, etc.
	b) A number of traffic signals which are not working	●	●		• Improving traffic signals and encouraging to follow the traffic signals (There are a number of cases that the traffic signals are intentionally switched off by traffic administrator. This is because that the existing traffic signals are not capable to properly control the traffic during certain time in a day such as peak hours, according to interview. Instead of the traffic signal, the traffic is controlled/guided by traffic personnel at the intersection in such case.) • Replacing to new signals and installing batteries (for the case of power failure)
	c) A number of traffic signals which are not sufficiently visible (e.g. insufficient height, not proper location, etc.)		●		• Installing the traffic signal at more proper locations where sufficient visibility can be assured.
	d) Absence of smart card which can be commonly used for toll collection at toll plazas under different road operators	●	●	●	• Implementing necessary measures by government such as setting out rules for common mobility card, establishing clearinghouse, promoting and raising awareness as to benefit of integration of smart card, etc. • Installing interoperable card readers at entry/exit booths at toll plazas. • Providing information of interoperable facilities to users.
	e) Lack of knowledge and experience on proper road management and traffic management	●	●		• Providing various opportunities to accumulate knowledge such as training in developed countries or hiring trainers. • Establishing training centre for capacity building.

Category	Issue	Scheme /Act	Infra	ITS	Required Measure
(5). Public Transport	a) Inefficient or not proper connectivity among different transport modes		●	●	• Developing connecting infrastructure and walking facilities between parking, bus terminal, railway station, Metro stations, monorail stations, etc. with consideration of traffic line of users. • Introducing common mobility card
	b) Improper location of bus stops		●		• Constructing bus stops at proper location, preparing enough spaces for passengers waiting at bus stops, etc.
	c) Limited awareness of both bus drivers and passengers for safety	●			• Educating bus drivers and passengers on road safety. (For example, it is often observed that the bus drivers park bus away from bus stops. The passengers are required to walk for getting on/off on the main carriageway and exposed to danger to be hit by vehicles.)
	d) Absence of information on expected time of bus arrival and operation status at bus stops/terminals		●	●	• Installing information board at bus stops, terminals, depots to show information of bus operating status/bus schedule/arrival time, etc. • Providing realtime passenger information based on bus tracking system by information board at bus stops, terminals, depots and on the Internet.
	e) Poor condition of public bus		●		• Introducing new buses (Many buses are obsolete and not hygienic. This is considered one of factors making it difficult to shift from usage of motorcycle and private vehicles to buses)
	f) Inconvenience and inefficiency due to lack of ticketing system	●	●	●	• Implementing necessary measures by government such as setting out rules for common mobility card, establishing clearinghouse, promoting and raising awareness as to benefit of integration of smart card, etc. • Installing interoperable card reader at every entry/exit of public transport and card recharge terminals at all major stations, bus terminal, etc. • Introducing common mobility card.
	g) Delay of metro construction	●			• Proper planning and training of in-house engineers.

Category	Issue	Scheme /Act	Infra	ITS	Required Measure
(6). Others: Facilities and Information	a) A number of broken/damaged roadside facilities	●	●	●	• Reviewing existing road asset and training to improve capability of engineers for road asset management. • Carrying out proper periodical inspections for all assets and prioritizing necessary maintenance works. • Properly maintaining inventory database on road and roadside facilities.
	b) Absence of systems and data to support traffic and road management			●	• Properly maintaining inventory database on road and roadside facilities.
	c) Limited road asset management			●	• Properly maintaining inventory database on road and roadside facilities.
	d) Absence of useful road traffic data/information	●	●	●	• Promoting understanding of related agencies (and personnel) as to importance and usefulness of utilization of quantitative traffic data and realtime traffic information. • Developing centres and roadside equipment to collect and process quantitative traffic data. • Sharing the necessity information amongst related agencies and providing realtime traffic information to users.
	e) Insufficient toll payment system resulting in frequent long queue of vehicles	●	●	●	• Planning and implementing measures to increase usage of ETC such as special discount. • Developing ETC dedicated lanes at toll plazas. • Introducing ETC together with proper operation such as leading by system non-ETC car to manual lane not to the ETC dedicated lane.

(Source: JICA Study Team)

5.2 Measures Taken by ITS

The measures taken by ITS shown on the above table are extracted and summarized below.

Table 5-2 Measures Taken by ITS

Category	Issue	Measure
Road Traffic	b) Road construction/improvement not catching up with urbanization	The measures to lead altering travel behaviour of road users by providing useful road traffic information is required. The drivers may change commuting time or select other route by providing such information as congestion, planned road work, etc. Other measures include increasing travel speed in the city by advanced traffic signal and parking availability information, and enhancing convenience and encouraging modal shift by introducing common mobility card for public transport.
	c) A large number of accidents	Maintaining accident database and analysing the cause of accidents for preparation of action plan
	d) High ratio of large-size vehicle	Introducing weigh in motion to reduce accident caused by excess weight.
	f) Resident living in the villages in suburbs in Chennai endangered by a number of large-size vehicles continuously passing through	Reducing deviation of trucks from the specified/allowed route to run by tracking vehicles and providing warning message.
Road Infrastructure	c) Absence of grade separation at some major junctions	Introducing systems which collect, cumulate and analyse the data to understand the effect of grade separate such as reduced queue length, passing time, etc.
	d) Various factors which accelerate deterioration of road surface conditions such as damaged pavement, lack of drainage systems, etc.	Carrying out periodical inspection to understand the current road condition and properly maintain the road inventory database. Identifying and prioritizing the sections which require improvement becomes easier as well by this measure.
	e) A number of on-road parking cars occupying the road	Introducing surveillance cameras at the locations where illegal parking

	spaces	happens frequently and recording the vehicle number plate of illegal parking to support stronger enforcement
	f) Limited number of off-road parking facilities	Providing parking availability information of several parking lots in the city to enhance user's convenience and alleviate congestion by reducing the moving-around vehicle looking for available parking place.
	g) Flooding when it rains heavily	Alerting to the road users on the occasion of reaching at dangerous level of flooding by installing flooding measurement equipment
	h) Absence of foot-path on many major roads	Providing information on walkable and safe route to pedestrians.
	i) Absence of bicycle ways	Providing information of bicycle ways, location of bicycle sharing station and availability of rent bicycle. Introducing common mobility card for the payment of rental bicycle.
	k) Shortage of skywalk	Providing information on walkable and safe route to pedestrians.
Traffic Management	d) Absence of smart card which can be commonly used for toll collection at toll plazas under different road operators	Providing information of interoperable facilities to users.
Public Transport	a) Inefficient or not proper connectivity among different transport modes	Introducing common mobility card.
	d) Absence of information on expected time of bus arrival and operation status at bus stops/terminals	Providing realtime passenger information based on bus tracking system by information board at bus stops, terminals, depots and on the Internet.
	f) Inconvenience and inefficiency due to lack of ticketing system	Introducing common mobility card.
Others: Facilities and Information	a) A number of broken/damaged roadside facilities	Properly maintaining inventory database on road and roadside facilities.
	b) Absence of systems and data to support traffic and road management	Properly maintaining inventory database on road and roadside facilities.
	c) Limited road asset management	Properly maintaining inventory database on road and roadside facilities.

	d) Absence of useful road traffic data/information	Sharing the necessity information amongst related agencies and providing realtime traffic information to users.
	e) Insufficient toll payment system resulting in frequent long queue of vehicles	Introducing ETC together with proper operation such as leading by system non-ETC car to manual lane not to the ETC dedicated lane.

(Source: JICA Study Team)

5.3 ITS Items to Realize the Measures

ITS items to realize the measures are listed in the following table.

Table 5-3 ITS Items to Realize the Measures

Issues / Required ITS Component		Road Traffic				Road Infrastructure								Traffic Management	Public Transport			Other Facilities and Information					Responsible Agency / Remarks
		b)*	c)	d)	f)	c)	d)	e)	f)	g)	h)	i)	k)	d)	a)	d)	f)	a)	b)	c)	d)	e)	
1)	Chennai Traffic Information Centre (C-TIC)	●				●			●	●											●		Smart City Ltd.(C-TIC) C-TIC: Newly established agency to provide city traffic information.
2)	Traffic Management Centre for Traffic Police	●						●													●		Chennai Traffic Police
3)	Highway Traffic Management System for CPRR (TCC)	●																			●		TNRDC (TCC) TCC: Newly established agency to manage traffic for CPRR.
4)	Probe System	●				●															●		MTC / Smart City Ltd.(C-TIC) GPS data will be collected from MTC bus and used for both MTC and C-TIC.
5)	Automatic Traffic Counter-Cum-Classifier System	●				●															●		Smart City Ltd(C-TIC)., TNRDC(TCC)
6)	CCTV Traffic Monitoring System																				●		Chennai Traffic Police, TNRDC(TCC)
7)	CCTV Enforcement System for Violated Vehicle							●															Chennai Traffic Police This system is used for enforcement purpose and it has already been introduced.
8)	No. Plate Recognition System		●	●				●															Chennai Traffic Police This system requires number plate standardisation. Tender for vender was announced by Transport Dept.
9)	Flood Measurement and Warning System									●											●		Smart City Ltd.(C-TIC) This system is mainly composed of water level measure, CCTV and VMS at underpass.
10)	Variable Message Sign System	●																			●		Chennai Traffic Police, TNRDC (TCC)
11)	Toll Management System (for existing toll plazas or for CPRR)																					●	NHAI, TNRDC
12)	Information Provision Through Internet/SMS	●							●	●	●	●	●	●							●		Smart City Ltd.(C-TIC), TNRDC (TCC)
13)	Area Traffic Signal Control System	●																					Chennai Traffic Police
14)	Weigh in Motion System for CPRR			●																			TNRDC(Toll Plazas of CPRR) This system is mainly composed of weigh-in motion, static weigh-bridge and CCTV.
15)	Road Accident Data Management System		●																		●		Chennai Traffic Police, Transport Department Accident database has already been developed.
16)	Command Control Centre for City Bus	●								●						●					●		MTC
17)	Bus Monitoring System	●								●						●					●		MTC
18)	Passenger Information System (PIS)	●								●						●							MTC
19)	Electronic Ticket Management System (ETM)	●													●		●						MTC
20)	Clearinghouse and Common Smart Card Card	●							●			●		●	●		●						Metro (CMRL) and related agencies (MTC, MRTS)
21)	Parking Management System	●							●												●		GCC , CMRL This system is managed by off-road parking owner.
22)	Road Inventory Database						●											●	●	●			GCC, NHAI, Highway Department, TNRDC Road inventory database has already been developed by road administrators.
23)	Footpath/Bicycle Way Information Provision System										●	●	●										GCC
24)	Bicycle Sharing System											●											GCC
25)	Commercial Vehicle Tracking System				●																		This system is usually developed by private companies.

*Corresponding to Alphabetic Code of Issue Items in Table 5-2 Measures Taken by ITS

(Source: JICA Study Team)

5.4 Phasing Policy of Development of ITS

Some ITS components can be implemented in a short period and others require a long period. For example, ITS in the city can be introduced in relatively early stage because they do not require a large scale infrastructure development in many cases. On the other hand, such ITS as facilities for Chennai Peripheral Ring Road need to be installed after certain progress of civil construction work and thus it requires longer period. Further, ITS is based on information technology and the technology is advancing very fast, so upgrades should be introduced in the long term.

Considering these aspects, three-staged development policies are recommended as shown in the table below. Each term is recommended at five years.

Table 5-4 Recommended Staged Development Policy

	Year	Policies
Short Term	2017 – 2021 (1-5 years)	• To use existing ITS more effectively • To introduce ITS which can be implemented in a short period • To start operation of the introduced ITS • To start preparation of development of ITS which require a longer period for implementation
Mid Term	2022 – 2026 (6-10 years)	• To expand and upgrade ITS which are developed in short term as necessary • To start operation of ITS which started preparation in short term due to necessity of longer period for implementation
Long Term	2027 – (After 10 years)	• To upgrade functions and introduce new system, adopting new technologies

(Source: JICA Study Team)

<Short Term>

The proper vehicle registration and standardized vehicle number plate are important factors for ITS. Thus, it is strongly recommended that the vehicle registration system be improved and vehicle number plate be standardized during this period to maximize the effect of ITS.

There are some roadside facilities such as multi-colored VMS, CCTV, etc. in the city. However it cannot be said that they are effectively utilized. Therefore, it is recommended that the basic system which enables more effective utilization of ITS be prepared, improving/removing the obstacles for effective use.

The major events in the transport sector in Chennai during this period are:

(1) Completion of all stretches of Outer Ring Road (phase-2).

(2) Completion of all stretches of Chennai Metro phase-1. The underground section along NH45 and NH4, which are major trunk roads in the city, will be completed and the occupied road spaces on these roads will be released.

(3) The services of various ITS of city bus such as bus tracking system, passenger information system, etc. will be commenced.

(4) The container terminal at Ennore port will commence operation and the load of the container handled at Chennai port will be shared. Thus the concentration of large-sized vehicle traffic in the vicinity of Chennai port is expected to be alleviated.

<Mid Term>

The major events in the transport sector during this period are:

(1) Completion of Section 1 (Section from NH5 to Ennore Port) of Chennai Peripheral Ring Road. The accessibility to Ennore Port is expected to drastically improve.

(2) Completion of bypass which connects Outer Ring Road and Chennai Peripheral Ring Road. The risk that the residents in the village in Minjur where a number of large-sized vehicles are running through the village are involved in the accidents is expected to reduce.

(3) Extension of Chennai Metro network (phase-2).

(4) Extension of Mass Rail Transit System.

(5) Completion of Mono Rail.

(6) The connectivity and efficiency of public transport will be improved by completion of various public transport.

(7) Improvement of other road infrastructures such as elevated road, grade separate junctions, etc. Thus it is recommended that ITS be expanded according to advancement of these road transport infrastructures.

<Long Term>

A number of new technologies which do not exist as of 2016 are expected to be available in this period. The traffic conditions will also be different after completion of public transport network improvement, road network and others, together with urbanization. Hence, reviewing the traffic conditions and revising plans such as upgrading and introducing new systems with new technologies will be required in the long term.

5.5 **Recommended ITS by Term**

Based on consideration in this chapter, ITS by term are recommended as shown in the table below. ITS which have already been developed and which are to be developed by private company are not included in the table below.

Table 5-5 Recommended ITS by Term

	ITS	Purpose / Function
Short Term	1) Chennai Traffic Information Centre	Quantitative traffic data will be collected, processed and cumulated. The dynamic realtime traffic information will be generated. The realtime traffic information will be disseminated to users/related agencies and cumulated quantitative data will be utilized for planning.
	2) Traffic Management Centre for Traffic Police	Signal control system and enforcement system such as automatic number plate recognition will be deployed to assist traffic police.
	4) Probe System	The congestion status on road network and expected travel time will be calculated and the information will be provided to the road users so that they can take actions such as selecting alternative route, changing communing time, etc.
	5) Automatic Traffic Counter-cum-classifier System	The traffic volume on the major trunk road will be measured and cumulated. The measured data will be utilized for road management and planning.
	6) CCTV Traffic Monitoring System	The condition of traffic, road and flood will be monitored by CCTV and the users will be altered when necessary by showing the image on the Internet.
	7) CCTV Enforcement System for Violated Vehicle	The image of the vehicle which violates traffic rules will be captured and recorded by CCTV to assist to reinforce enforcement and reduce traffic violation.
	8) No. Plate Recognition System	CCTV enforcement system will be introduced to assist to minimize the escape of the vehicle which violates traffic rules.
	9) Flood Measurement and Warning System	The waterlogged level at underpass will be measured and the road users will be warned before the flooding reaches dangerous level.
	10) Variable Message Sign System	The dynamic road traffic information with image will be provided to the road users.
	11) Toll Management System	The toll fare will be automatically collected by ETC and also entering non-ETC vehicle into ETC lane will be avoided by automatic segregation.
	12) Information Provision Through Internet/SMS	The road traffic information will be provided through such media as Internet, SMS, etc. to enable the road users to take actions such as selecting alternative route, avoiding travel in peak hour, etc.
	13) Area Traffic Signal Control System	The signal coordination system will be introduced to improve average travel speed in the city.
	16) Command Control Centre for City Bus	The proper management of buses utilizing GPS data will be enhanced and information of expected arrival time will be provided at such location as bus stops.
	17) Bus Monitoring System	The running location and arrival time of buses will be monitored to avoid deviations from the bus route and the bus service according to the schedule will be provided.
	18) Passenger Information System	The information on such as bus operation status, expected arrival time will be provided at bus stations and bus terminals.

	19) Electronic Ticket Management System for City Bus	The payment of bus fare will be automated to enhance convenience and reduce the leakage of payment.
	20) Clearinghouse and Common Smart Card	The common mobility card which can be used among different public transport, different toll road operators, etc. will be introduced to improve the convenience of inter-modal transit and payment.
Mid Term	3) Highway Traffic Management System for CPRR	The traffic/road information will be disseminated to users by such media as VMS and Internet based on collected data through roadside equipment.
	11)Toll management System for CPRR	Toll fare collection will be automated by Touch and GO(T&G)system and ETC.
	14) Weigh in Motion System	The weight of axes of heavy vehicles will be measured to strengthen enforcement of overloading.
	24) Bicycle Sharing System	The bicycle sharing system with common mobility card which can be used for bicycle sharing payment and public transport will be introduced in the vicinity of public transport stations such as Metro and MRTS to enhance usage of non-motorized-vehicle.

(Source: JICA Study Team)

5.6 Selected ITS Component for Conceptual Design

ITS components for "Conceptual Design" prepared by this study are selected from the components listed in the previous section. The concept of selection is as described herein under. Some ITS components are excluded at first according to the reasons shown in the table below.

Table 5-6 Reasons of Excluding ITS Components for Conceptual Design

Reasons		Excluded ITS Components
1.	ITS components which already exist in Chennai are excluded.	6) CCTV Enforcement System for Violated Vehicle 11) Toll Management System for existing toll plazas 15) Road Accident Data Management System (RADMS) 22) Road Inventory Database 25) Commercial Vehicle Tracking System
2.	ITS components which require basic plan or detail study are excluded.	20) Clearinghouse and Common Smart Card 21) Parking Management System
3.	ITS components which require infrastructure development are excluded. *(Note*1)*	21) Parking Management System 23) Footpath/Bicycle Way Information Provision System 24) Bicycle Sharing System
4.	ITS components which are under preparation by Indian authorities are excluded.	8) No. Plate Recognition System (under tender process)
5.	ITS components which are generally developed by private sector are excluded.	25) Commercial Vehicle Tracking System 11) Toll Management System for existing toll plazas

(Source: JICA Study Team)

*Note (*1): ITS for CPRR requires a large scale infrastructure, which is the construction of CPRR. But there are selected because they are expected to greatly contribute to improve traffic flow in Chennai.*

The selected ITS components for the "Conceptual Design for Proposed ITS Components" are as follow:

<Short Term>

1) Chennai Traffic Information Centre

2) Traffic Management Centre for Traffic Police

4) Probe System

5) Automatic Traffic Counter-Cum-Classifier System

6) CCTV Traffic Monitoring System

9) Flood Measurement and Warning System

10) Variable Message Sign System

12) Information Provision Through Internet/SMS

13) Area Traffic Signal Control System

16) Command Control Centre for City Bus

17) Bus Monitoring System

18) Passenger Information System

19) Electronic Ticket Management System for City Bus

<Mid Term>

3) Highway Traffic Management System for Chennai Peripheral Ring Road

11) Toll Management System for Chennai Peripheral Ring Road

14) Weigh in Motion System for Chennai Peripheral Ring Road

5.7 **Implementation Schedule of ITS Component**

The implementation schedule of the selected ITS components is proposed as shown in the following table.

Table 5-7 Proposed Implementation Schedule

Technical Prerequisit For ITS and Major Event			Short Term					Mid Term					Long	Remark
			2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	
Standardisation of Vehicle Number Plate			(Expected period required for replacing existing plates)											- Procurement of vendor for standardised number plate is underway
Clearing house and Common Mobility Card														
Chennai Peripheral Ring Road														
Outer Ring Road (Phase-2) (Completion of Entire Stretch)														
Metro Phase-1														Metro Phase-2 is under planning
Metro Phase-1 Extension														
MRTS Phase-2 Extension														
Selected ITS Components			**Short Term**					**Mid Term**					**Long**	**Remark**
			2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	
Short Term : City ITS	C-TIC	Chennai Traffic Information Centre (C-TIC)							(Expansion)					C-TIC will be expanded in the future e.g. probe data from taxies and commercial vehicles, additional ATCC according to expansion of road network, change in traffic pattern and etc.
		Probe System												
		Automatic Traffic Counter-cum-classifier System (ATCC)												
		CCTV Traffic Monitoring System												
		Flood Measurement and Warning System												
		Information Provision Through Internet/SMS												
	Traffic Police	Traffic Management Centre for Traffic Police (TMC)												Brown line in the chart indicates modification of existing centre
		Variable Message Sign System												
		Area Traffic Signal Control System (ATSC)	(Stage-1 :150ATSC)											ATSC will be installed in 2 stages. -1st stage: Installing 150 ATS in core area -2nd stage: Installing 230 ATS in the area encompassed by Ennore port, Channai Bypass and Siruseri
			(Stage-2 :230ATSC)											
	MTC	Command Control Centre for City Bus (CCC)												-MTC systems need to be completed before C-TIC starts operation.
		Bus Monitoring System(BMS)												
		Passenger Information System (PIS)												
		Electronic Ticket Management System(ETM)												
Mid Term	CPRR ITS	Highway Traffic Management System for CPRR												
		Toll Management System for CPRR												
		Weigh in Motion System for CPRR												

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

:Operation

(Source: JICA Study Team)

6 Conceptual Design

6.1 Chennai Traffic Information Centre

6.1.1 Purpose and Sub-system

Chennai traffic information system will be prepared for the following purposes:

- To grasp traffic condition comprehensively in Chennai metropolitan area by collecting quantitative traffic data
- To provide dynamic traffic information to road users by processing the collected traffic data
- To utilise cumulated quantitative traffic data for planning and evaluation of measures on urban transport
- To warn the road users to avoid driving the flooded underpass.

It will comprise the following sub-systems:

- Probe System
- Automatic Traffic Counter-Cum-Classifier System
- Flood Measurement and Warning System
- Chennai Traffic Information Centre System

The following sections describe these sub-systems.

6.1.2 Probe System

(1) Purpose

The probe system will be prepared for generating traffic condition information to provide users and for utilising the cumulated data as statistics for the measures on urban transport such as traffic management, road planning, etc.

It collects vehicle location information continuously. A probe device installed in vehicle consists of GPS unit, processor unit, communication unit and power supply unit.

The satellites send time signals. The time signals are received by the GPS unit on the earth. The GPS unit receives the signals from several satellites and identifies its location on the earth. The accuracy of the location generally ranges from 10 to 100 m, depending on such factors as quality of GPS unit, high-rise buildings around, etc.

The probe device periodically sends the recorded data such as vehicle location in terms of longitude/latitude and recording time to the centre system. The probe data received periodically at the centre is analysed to generate travel time and travel speed on the road network of digital road map. The analysed data is converted into traffic congestion information and provided to the road users. The cumulated probe data is processed as historical data for higher accuracy of congestion information. It is also utilised as statistics for planning and evaluation of road and traffic measures by the agencies such as planning department, road administrators, etc.

An image of example of congestion on the road network identified by the probe system is shown below.

(Source: Internavi Premium Club, Honda)

Figure 6.1 Example of Identified Congestion by Probe System

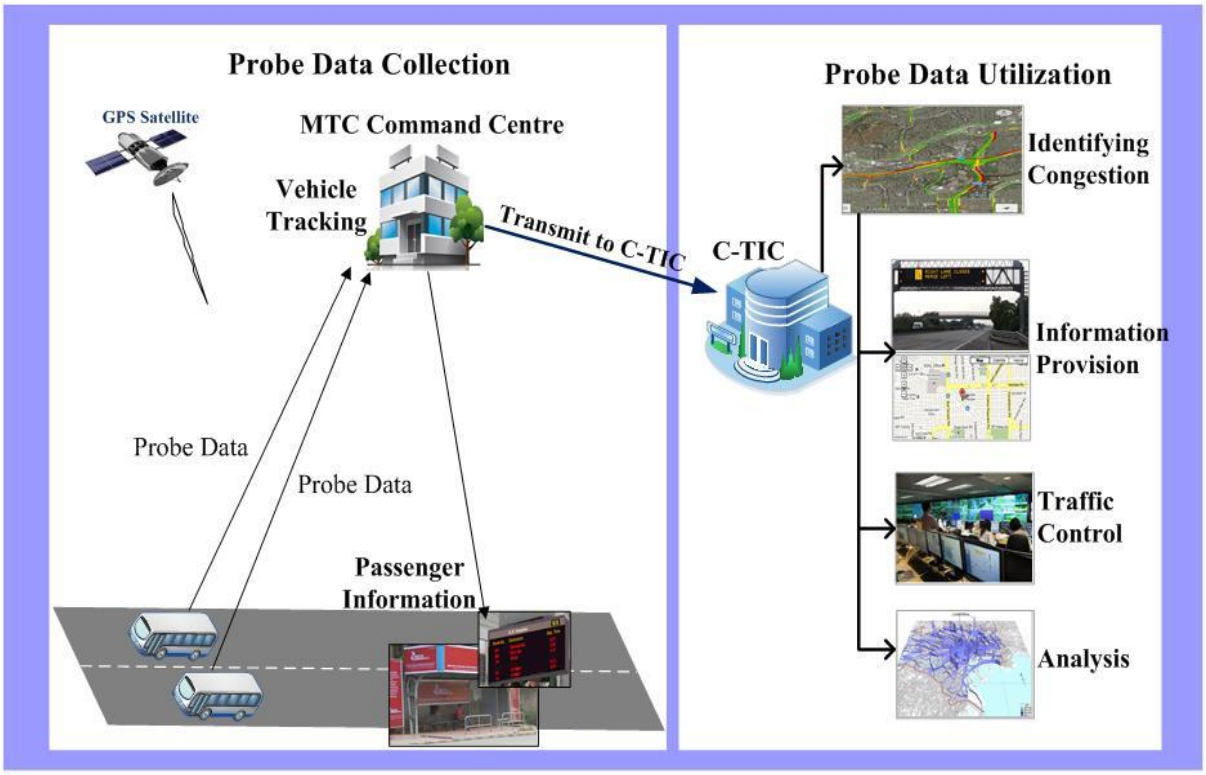
(2) Utilization of Bus Probe Data

Chennai Metropolitan Transport Corporation operates 3,800 buses and these buses run on all arterial roads with high frequency in metropolitan area except Chennai Bypass and Outer Ring Road. ITS systems of city bus have not been introduced at present. However, the Study confirmed the willingness of Metropolitan Transport Corporation to implement such city bus system.

This implies that Chennai city bus network has a potential as data source of probe data for traffic congestion information but it cannot be realised unless Metropolitan Transport Corporation initiates the projects for implementation of these systems. Therefore, implementing these systems by Metropolitan Transport Corporation is a key element for Chennai Traffic Information Centre. Hereafter, the descriptions are made on the condition that city bus systems of MTS are developed.

It is proposed that Chennai Traffic Information Centre will utilise the probe data transmitted from Metropolitan Transport Corporation Command Control Centre in the initial phase. Data source of probe data can be expanded to taxis, autos, etc. in a later phase.

The entire image of the probe system of Chennai Traffic Information Centre is shown below.

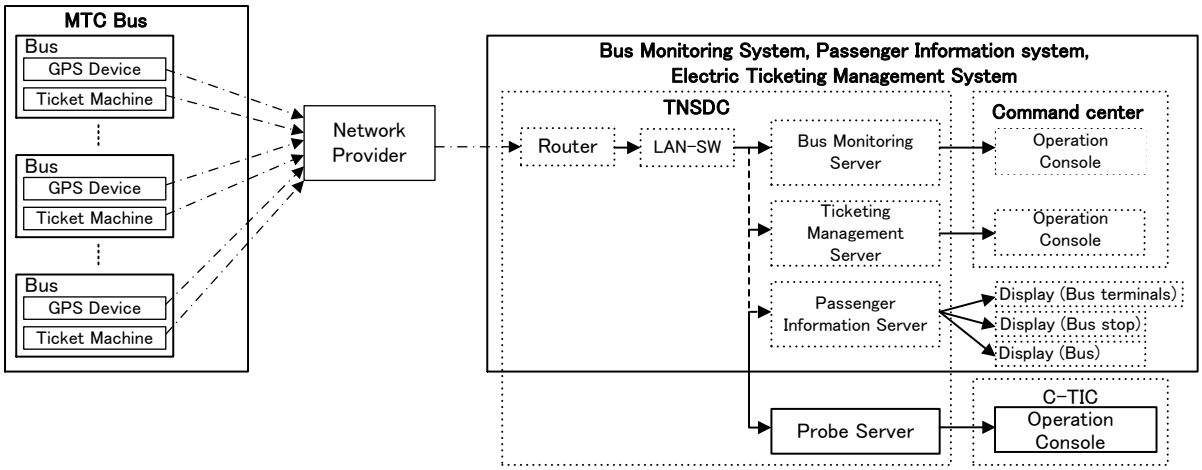


(Source: JICA Study Team)

Figure 6.2 Entire Image of Probe System of Chennai Traffic Information Centre Utilising Bus Probe Data

(3) Communication System Diagram

The following figure shows a communication system diagram of the probe system whose probe data is transmitted from Metropolitan Transport Corporation Command Control Centre to Chennai Traffic Information Centre through Tamil Nadu State Data Centre. Both Metropolitan Transport Corporation server and Chennai Traffic Information Centre server are proposed to set at Tamil Nadu State Data Centre server room since Tamil Nadu State Data Centre provides favourable and adequate management for servers of government agencies with high security. The probe data is sent from bus, called probe car, to Metropolitan Transport Corporation server through mobile network communication. It is then transferred to Chennai Traffic Information Centre server through a LAN Network.



(Source: JICA Study Team)

Figure 6.3 System Diagram of Probe System Communication

6.1.3 Automatic Traffic Counter-Cum-Classifier System

(1) Purpose

It is proposed that Automatic Traffic Counter-Cum-Classifier (ATCC) system will be installed under Chennai Traffic Information Centre for the following purposes:

- ATCC measures the traffic volume by vehicle-size cross sections. The measured data will be collected by Chennai Traffic Information Centre and utilised for proper traffic and road management such as planning/evaluation of new road construction, road-widening etc. In addition to the traffic volume, vehicle speed and occupancy can also be measured. They will also be stored in the Chennai Traffic Information Centre server.
- As described above, ATCC also measures vehicle speed. Metropolitan Transport Corporation buses are not running on Chennai Bypass and Outer Ring Road. So the probe data from city bus cannot be collected on these roads. Therefore, it is proposed that ATCC will be installed along these roads to collect speed data to supplement bus probe data for generating traffic congestion information. The traffic volume and occupancy will also be measured and stored in the Chennai Traffic Information Centre server.

(2) Types of ATCC

There are mainly four different types of ATCC: 1) ultra-sonic type, 2) loop-coil type, 3) image processing type and 4) infrared type. Due to the absence of lane-keeping discipline and roughness of road surface in Chennai, the image processing type is recommended to introduce.

The following items show images of loop coil type and image processing type ATCC.

(Source: Sumitomo Electric Industries, Ltd)

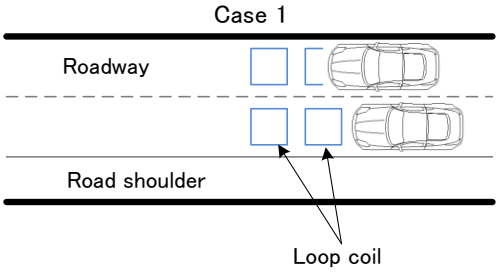
Figure 6.4 Loop Coil Type

(Source: Sumitomo Electric Industries, Ltd)

Figure 6.5 Image Processing Type

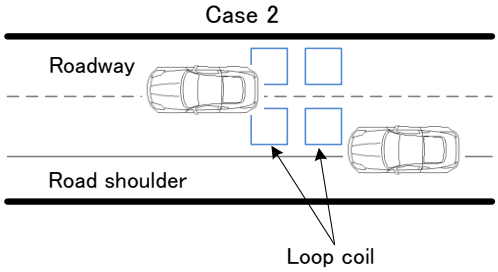
The loop-coil type measures the traffic by lane as shown in the figure on the left below. Therefore, absence of lane-keeping discipline results in low accuracy as depicted in the figure on the right below. Moreover, the loop-coil is embedded in the surface of the road and road excavation is required for maintenance.

The ultrasonic type and infrared type also measure the traffic by lane. Hence, the absence of lane-keeping traffic discipline remains challenging issue as in the case of the loop coil type.



(Source: JICA Study Team)

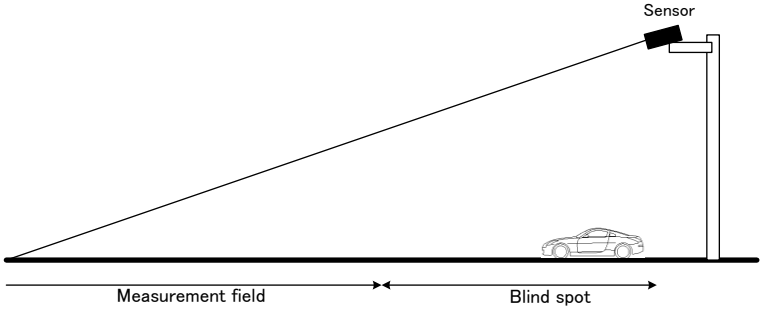
Figure 6.6 Loop Coil Type (Case 1)



(Source: JICA Study Team)

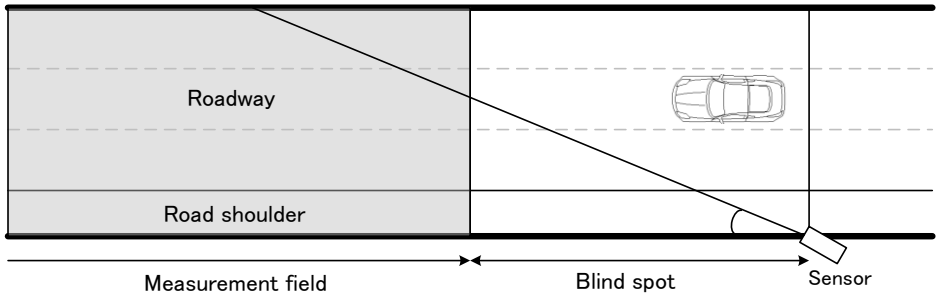
Figure 6.7 Loop Coil Type (Case 2)

On the other hand, the image processing type can measure the traffic on 3 or 4 lanes by one camera because it captures the movements of vehicles and processes it. Typical standard views of installation are shown below.



(Source: JICA Study Team)

Figure 6.8 Image Processing Type: Standard Longitudinal View



(Source: JICA Study Team)

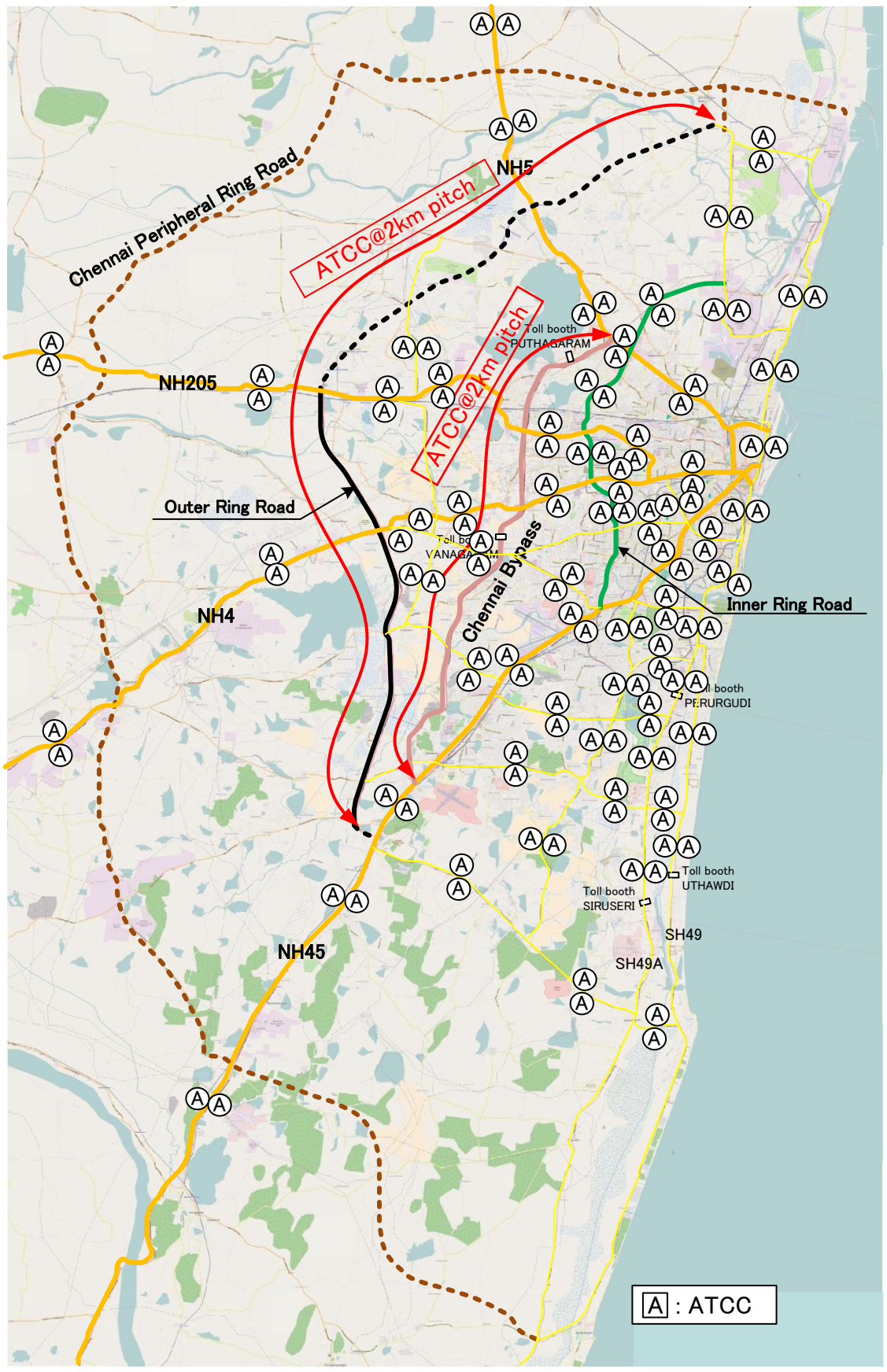
Figure 6.9 Image Processing Type: Standard Plane View

However, it should be noted that counting motorcycles in heterogeneous traffic in the absence of lane-keeping discipline is still challenging for all types of sensors. Nonetheless, higher accuracy can be expected by the image processing type, compared to others.

(3) Development Plan

Installation location of ATCC will be on the midpoint between major intersections of major roads for measuring traffic volume. The major roads include National Highway, State Highway, City roads and Inner Ring Road. In addition to this, ATCC measuring speed for the purpose of supplement of probe data will be installed at 2 km interval on Chennai Bypass and Outer Ring Road. One ATCC unit measures the traffic in one direction. Thus, two ATCCs will be installed at one location to cover both directions.

The following figure shows the proposed locations of ATCC.



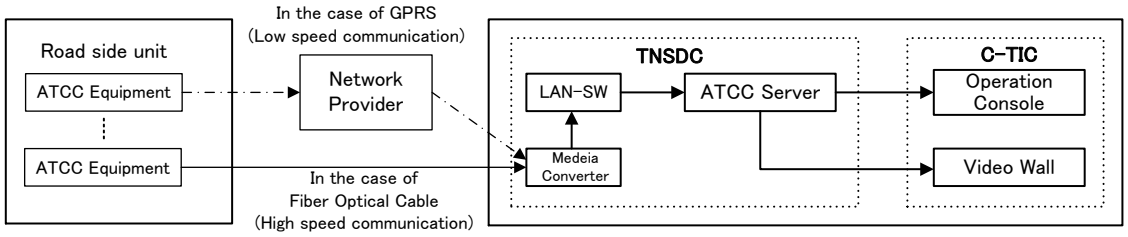
(Source: JICA Study Team)

Figure 6.10 Location Map of ATCC

The number of ATCC can be increased in accordance with expansion/construction of new road or changing traffic situation in the future.

(4) Communication System Diagram

The measured data by ATCC will be transmitted to Chennai Traffic Information Centre through either mobile network or optical fibre network. Optical fibre cable will be used if it is available at the location of roadside terminal equipment. A mobile network will be used if the optical fibre cable is not available nearby. The system diagram is shown below.



(Source: JICA Study Team)

Figure 6.11 System Diagram of ATCC Communication

6.1.4 Flood Measurement and Warning System

(1) Purpose

Chennai metropolitan area was flooded due to heavy rain generated by northeast monsoon in November and December in 2015 and road and transport infrastructures including airport were heavily damaged. The disaster of such scale does not frequently occur but heavy rain usually causes flooding in many places in Chennai. The underpass locations of city road are flooded and road users are exposed to danger on the occasion of heavy rain.

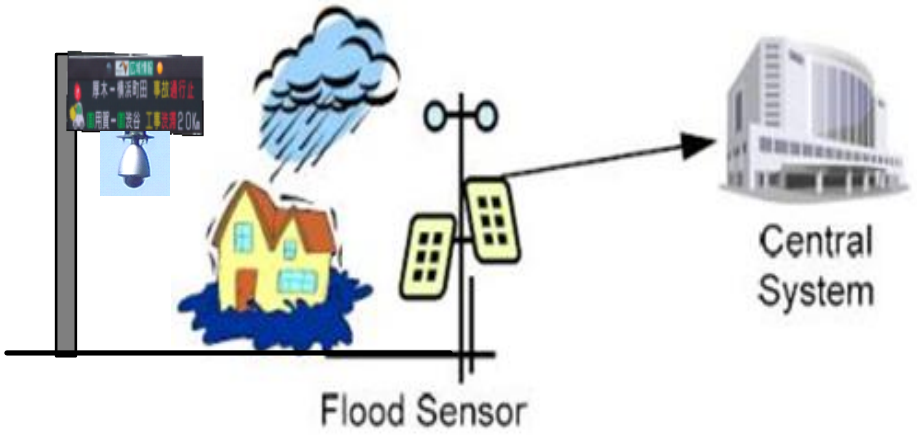
Therefore, Flood Measurement and Warning System is proposed to be introduced in Chennai. It measures water height on the underpass locations of the city road and monitors the site condition by the dedicated CCTV from Chennai Traffic Information Centre. If the water height reaches dangerous level, warning message is provided to the drivers from VMS installed at the location before underpass and other information media. The objectives of the Flood Measurement and Warning System are:

- To detect flooding at underpass locations of city road in the core area of Chennai
- To provide flooding information and warning messages to the drivers so that they can avoid driving such flooded underpass locations
- To utilise measured data for improvement of road facility such as road drainage rehabilitation, etc.,

- To store flood information/data in Chennai Traffic Information Centre server and share it with road administrators, traffic police, planning agencies and other related organizations.

Note: VMS and CCTV of Flood Measurement and Warning System are dedicatedly used for this system only.

The figure below shows an image of Flood Measurement and Warning System

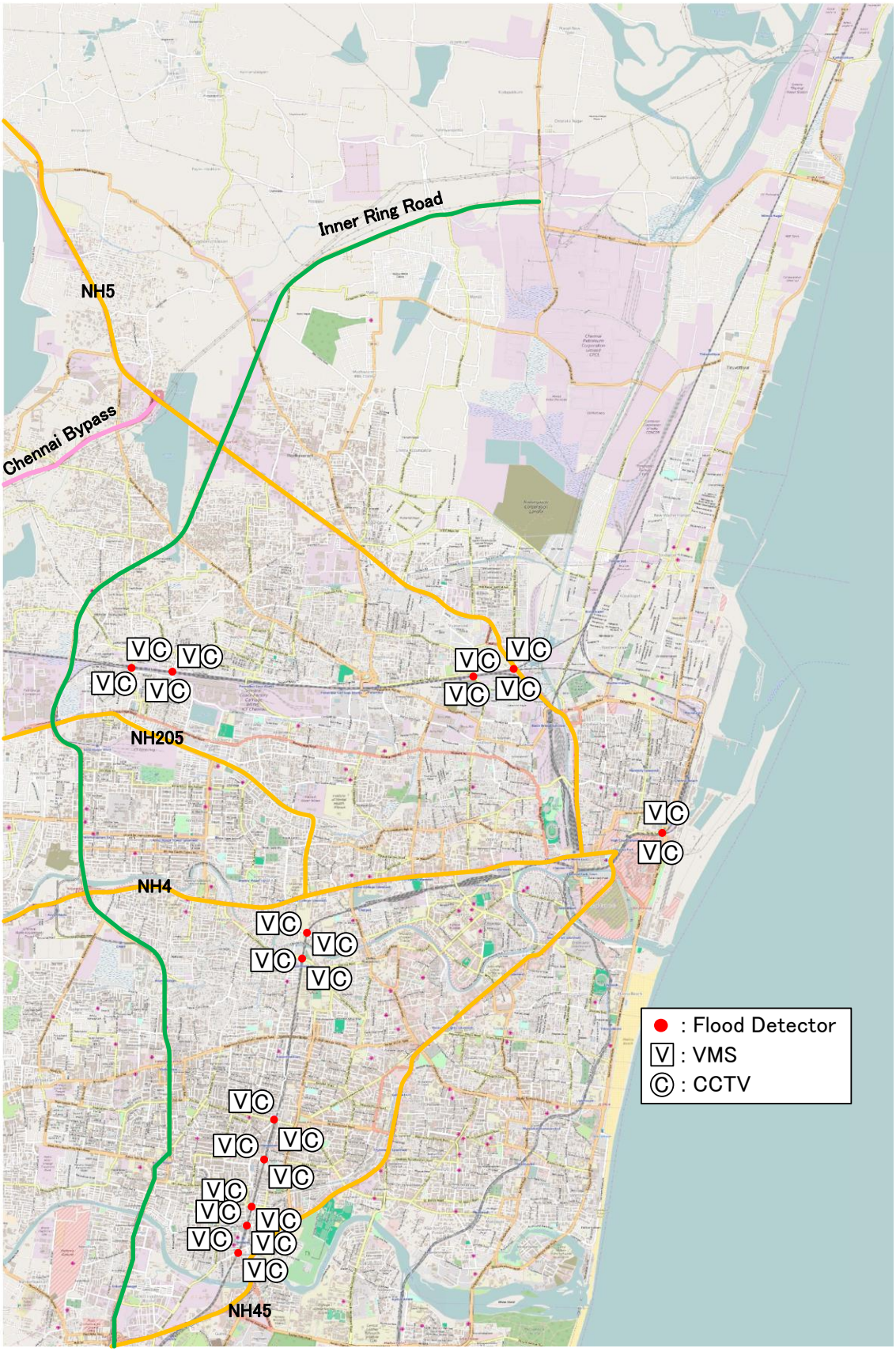


(Source: JICA Study Team)

Figure 6.12 Image of Flood Measurement and Warning System

(2) Deployment Plan

The roadside equipment which are flood measurement sensor, VMS and CCTV will be installed at underpass locations in the core area of Chennai as shown in the figure below.



(Source: JICA Study Team)

Figure 6.13 Location Map of Flood Measurement and Warning System

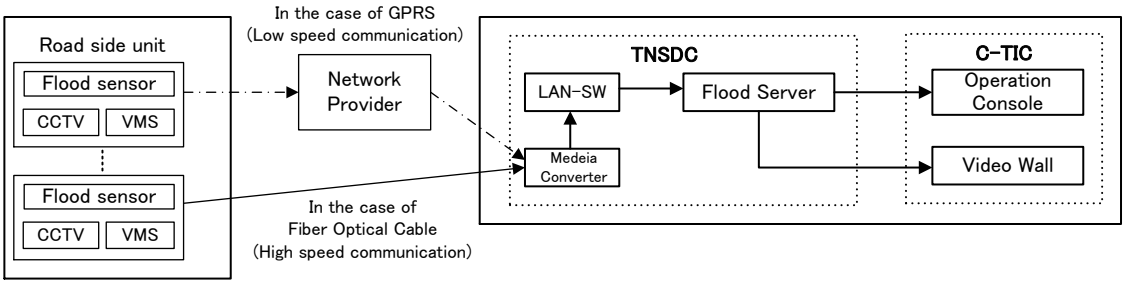
One set of roadside equipment consists of one unit of flood measurement sensor, and two units of VMS and CCTV. VMS will be installed at both sides of the roads to warn the drivers coming in both directions towards the underpass. CCTV will be installed on the poles of VMS and monitor the flood situation from both sides of the road.

12 locations (24 units for VMS and CCTV) of the roadside equipment of Flood Measurement and Warning System are identified as shown on the figure. The number of the roadside equipment can be increased in accordance with expansion/construction of new road or changing traffic situation in the future.

Note: There are a number of flooding locations across Chennai city on the occasion of heavy rain, other than shown in the figure above. However, it is considered that many of these locations may be caused by the problems of the existing infrastructure such as deficiency of drainage system, etc. Such locations are excluded from selecting the installation locations. The proposed locations are considered at the places of underground structure of the road in the city.

(3) Communication System Diagram

The measured data on flood, monitoring image captured by CCTV to Chennai Traffic Information Centre and warning message from Chennai Traffic Information Centre will be transmitted through either mobile network or optical fibre network. The optical fibre cable will be used if it is available at the location of roadside terminal equipment. The mobile network will be used if the optical fibre cable is not available nearby. The system diagram is shown Figure



(Source: JICA Study Team)

Figure 6.14 System Diagram of Flood Measurement and Warning System Communication

6.1.5 Chennai Traffic Information Centre System

(1) Purpose

Chennai Traffic Information Centre is intended to achieve the following objectives:

- To collect realtime data related to road and traffic condition information such as congestion, incident, event, and other information that affects the road traffic
- To process the collected data converted to the information useful for road users as well as road and traffic administrators
- To monitor the collected and processed information on a realtime basis
- To disseminate the processed information to road users so that they can take note of road and traffic conditions such as congested area, incident or hazardous area and take necessary actions
- To compile and store processed data for effective planning, operation/maintenance and evaluation of the projects or measures on urban transport
- To manage the City ITS operation in the Chennai Traffic Information Centre
- To maintain ITS facilities of Chennai Traffic Information Centre

(2) Function of Chennai Traffic Information Centre

Chennai Traffic Information Centre will collect the measured data such as traffic flow, traffic volume, flood level, etc. from the following sub-systems and automatically process the collected data converted to usable road traffic information.

- Probe System
- ATCC System
- Flood Measurement and Warning System.

The usable road traffic information will be provided to road users through VMS, Internet, e-mail and SMS. The e-mail and SMS will be sent to the registered subscribers. The authority of providing traffic information by VMS is expected to be assigned to VMS console in Traffic Management Centre of Traffic Police. Therefore, Chennai Traffic Information Centre will send the result of process to VMS server installed in Traffic Management Centre to display on VMS. The processed data will be stored in the database and utilised for statistical analysis, and shared to the relevant stakeholders such as road/traffic administrators, etc. as necessary.

A video wall for monitoring will be prepared in Chennai Traffic Information Centre. The collected and processed data will be monitored by operators in Chennai Traffic Information Centre. The road and traffic conditions will be displayed on the schematised road network on the video wall in Chennai Traffic Information Centre.

A call centre will be set up in Chennai Traffic Information Centre. It will handle enquiries from public and other agencies and share necessary information/data to the concerned agencies as required.

The traffic data measured by ITS equipment of Chennai Peripheral Ring Road and VMS message being displayed on Chennai Peripheral Ring Road will be shared to Chennai Traffic Information Centre for the purpose of utilising them to guide the traffic to Chennai Peripheral Ring Road as necessary.

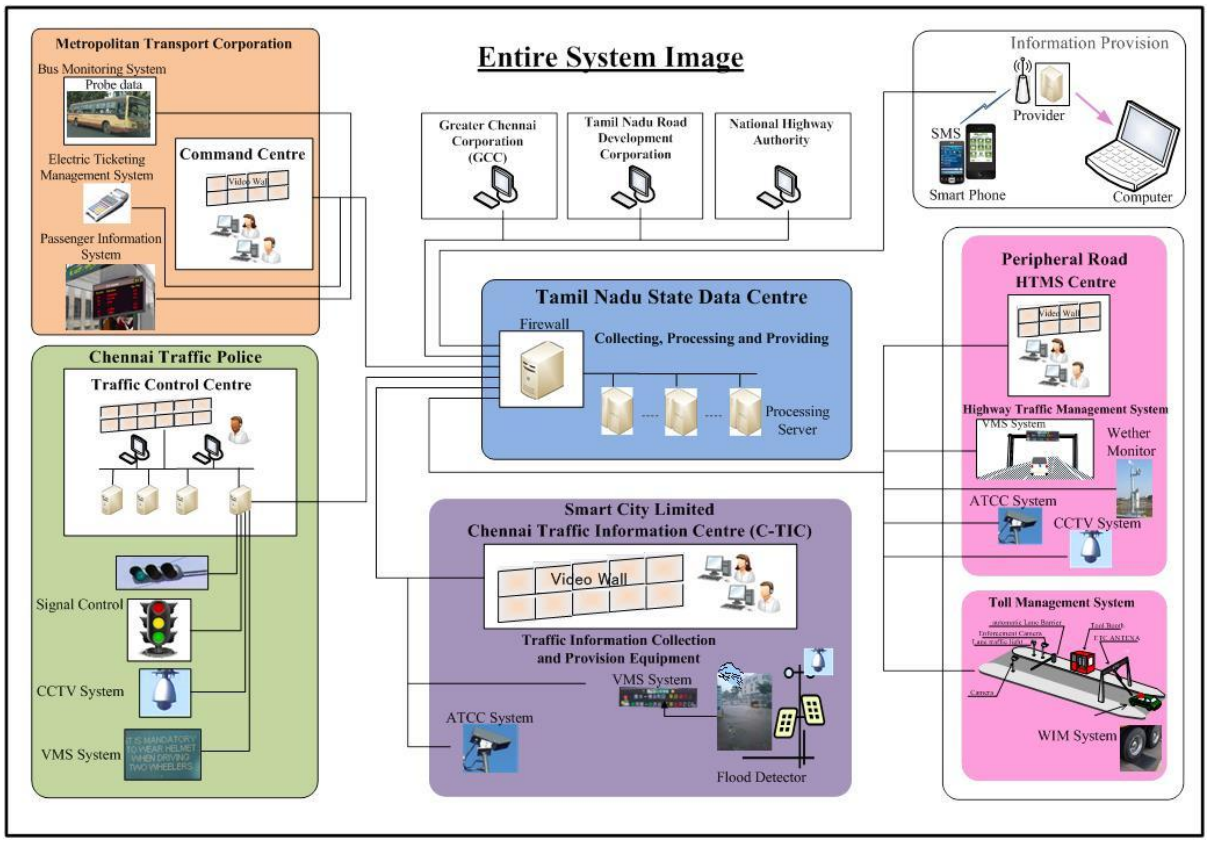
The connections with the centres of the external agencies are summarised in the following Table.

Table 6-1 Connection with Centres of External Agency

Centre	Data to Be Collected	Purpose of Collecting Data
Traffic Control Centre (CRR)	• Traffic volume and average speed • Image being displayed on VMS on CRR	• To divert the traffic which is not destined to central area of Chennai, urging the traffic to shift to CRR
Traffic Management Centre (Chennai Traffic Police)	• Image being displayed on VMS	• To confirm the displayed image on VMS and result of process made in C-TIC are matching or not
Command Control Centre of City Bus (MTC)	• Probe car data	• To generate congestion information

(Source: JICA Study Team)

The conceptual configuration of Chennai Traffic Information Centre is shown in the following figure.



(Source: JICA Study Team)

Figure 6.15 Conceptual Configuration of Chennai Traffic Information Centre

(3) Component of Chennai Traffic Information Centre

Chennai Traffic Information Centre consists of the following components and functions as shown in the following Table.

Table 6-2 Components and Functions of Chennai Traffic Information Centre

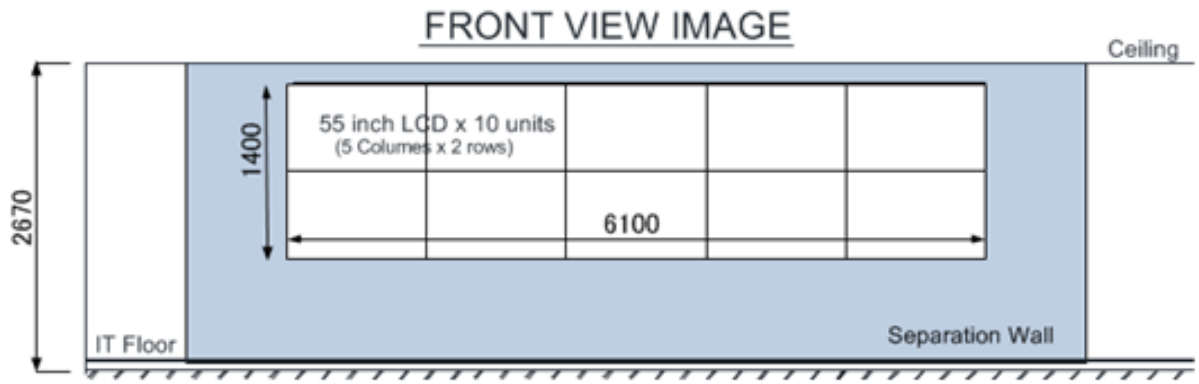
Component	Function
C-TIC Server	Database management Subsystem management Network Management Display and monitoring System parameter management Data exchange with other agencies Report compilation and printing
Probe System Server	Probe car data collection Map matching (*) Vehicle speed calculation Link/section traffic condition data generation
ATCC System Server	ATCC data collection Traffic data analysis
Web Server	Information dissemination through Internet
E-Mail and Message (MSG) Server	Automatic issuance of e-mail and short message service (SMS) to the registered subscribers
Video Wall	Display of schematic road map with traffic condition and other various statistics and dynamic information
Video Wall Server	Video wall operation
Operator Console	Consoles for overseeing activities of C-TIC Consoles for operation of sub-systems of C-TIC Consoles for call centre

(Source: JICA Study Team)

Note (*): Digital Road Map is a road map in electronic form. The road network on Digital Road Map is divided into links and contains coordinate and other property information. They are expressed in numeric form so that the systems are able to recognise them.

The probe data contains location data consisting of longitude, latitude and time. The probe unit records this data at regular interval such as ten seconds, one minute, etc. The collected probe data is consecutively plotted on the map. However, the location is usually measured with some errors ranging between 10 – 100 ms. Therefore, each plotted location is processed to locate onto the link of the road network. Then the route on which the vehicle has passed is visually identified on the road network. This is called Map-Matching. Consequently, the traffic conditions such as travel speed, required travel time, etc. are identified.

The video wall is one of the major components of Chennai Traffic Information Centre. The large-sized monitors and associate equipment will be installed in Chennai Traffic Information Centre to display the traffic conditions and other relevant information. It will be used for sharing information amongst the staff at the centre and necessary action will be taken as required. The schematic image of video wall in Chennai Traffic Information Centre is shown in the following Figure.



(Source: JICA Study Team)

Table 6-3 Schematic Image of Video Wall in Chennai Traffic Information Centre

6.2 Traffic Management System for Traffic Police

6.2.1 Area Traffic Signal Control System

(1) Current Issues and Rationale for New Signal System

The existing traffic signal system is very limited in function. Fixed signal timing is applied to many of the signals in Chennai regardless of change in traffic volume in on/off peak hour, weekday/holiday, etc., causing adverse effect on traffic such as long cycle time resulting in unnecessary delay of queuing vehicles. In addition, no coordination is made between neighbouring signals.

In the road network, especially in the core area of the city where the road is dense and the intersections closely exist, coordination signal between intersections is very important to efficiently manage the heavy traffic volume by reducing the number of stops at each intersection. Furthermore under the traffic situation where the traffic volume in direction between morning and evening peak hours on the trunk road such as Anna Salai (NH-45) is greatly different, applying optimum cycle according to the traffic volume is very effective.

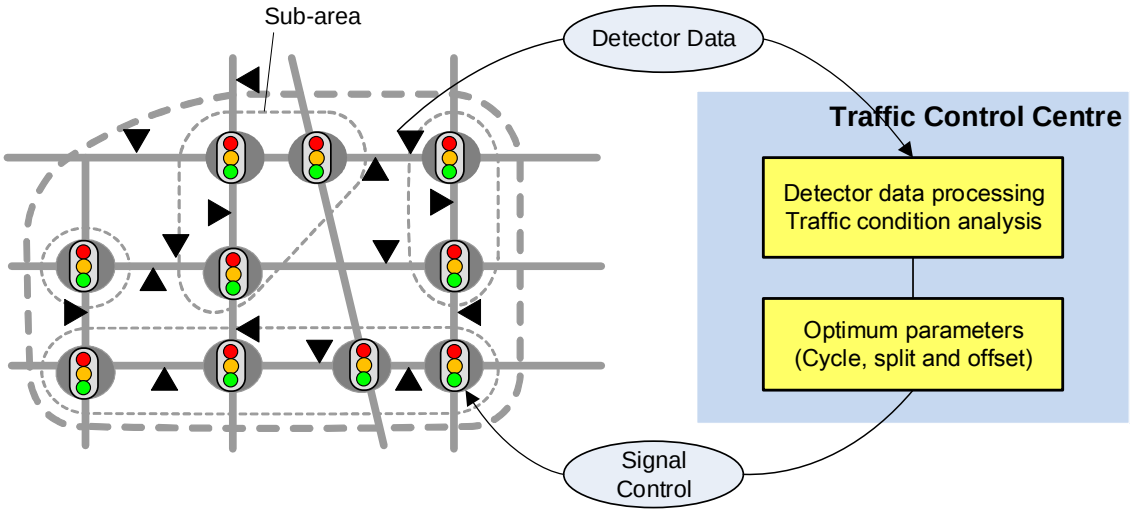
The existing signal system does not have vehicle detector that detects vehicle presence or measures traffic volume, speed. or occupancy that indicates prevailing traffic condition. Thus the system is insensitive to the varying traffic condition. Benefit of centralized signal system is that signal timing can be modified automatically based on the prevailing traffic condition gathered by the vehicle detector.

Signal system can contribute significantly in terms of reduction in travel time, fuel consumption and air pollution. The magnitude of contribution to each vehicle is fractional. But it accumulates a substantial amount since a large number of vehicles run in city a day. The current traffic condition in Chennai warrants earlier introduction of efficient signal system.

(2) Area Traffic Signal Control System

Area traffic signal control system is proposed to be installed, thereby the signal timing will be automatically adjusted based on the prevailing traffic condition gathered by the vehicle detector and in coordination with other signals in the area.

Vehicle detectors are placed at various locations in the road network to collect traffic condition data. Vehicle detector data is sent to the Control Centre for processing and analysis. Based on detector data, optimum signal timing parameter (a combination of cycle[*1], split[*2] and offset[*3]) is then prepared for each signal. As the signals are controlled from the centre, coordination among the signals are maintained. This type of signal system is shown in the figure below.



(Source: JICA Study Team)

Figure 6.16 New Centre Signal System

Note (*1, 2, 3): There are 3 fundamental parameters of traffic signal: Cycle, Split and Offset.

Cycle and Split define the timing of the traffic signal whilst Offset defines the relationship between neighboring two traffic signals.

Cycle Length: Time required for a complete sequence of indications e.g. from green indication to next green indication.

Split: Portion of time allocated to each phase within a cycle at an intersection.

Offset: Time difference of coordinated phases (green indication) between neighboring two traffic signals.

(3) Functions Required

The functions of Advanced Traffic Signal System are realized either at local controller level or at centre level as described below.

a) Local Controller Level

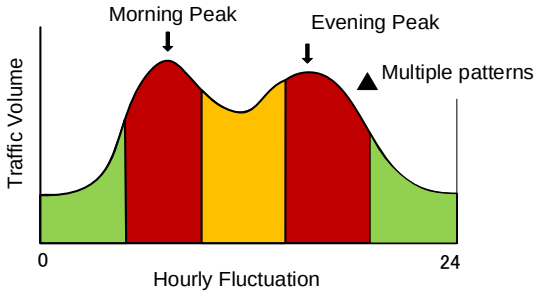
The local controller must have the functions listed below.

Time-of-Day Control

Time-of-day control applies pre-set timing parameters according to the time of day and day of the week. Multiple timing parameter sets for different time of day must be prepared beforehand. They are stored in both controller and central server. In case of interruption of data communication between controller and the centre, controller operates in Time-of-Day mode based on the timing parameters stored in the controller and built-in clock and calendar.

In order to execute Time-of-Day control, controller must have a clock and a calendar. Clock must be a quartz clock or a GPS clock. Holidays can be set in the calendar to apply holiday timing parameters on holidays.

Timing parameter sets must be reviewed periodically, preferably once a year for instance, and updated to the prevailing traffic conditions.



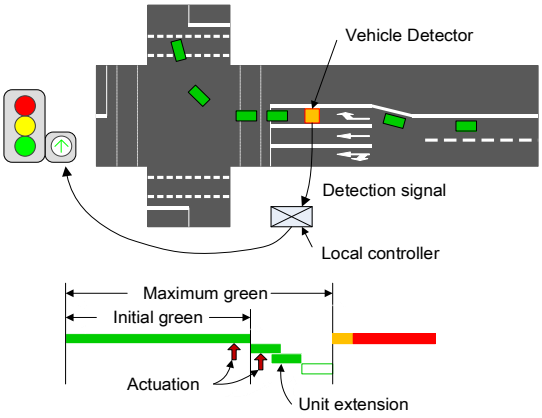
(Source: JICA Study Team)

Figure 6.17 Concept of Time-of-Day Control

Actuation Control

Actuation control is a micro level control within a signal cycle. Duration of a signal display is adjusted based on the arrival or absence of vehicle. If a vehicle approaching to signal during green for that movement is detected, green display is extended to allow the vehicle to pass through the signal without stopping. On the other hand, if no vehicle is detected, green signal is terminated immediately earlier than scheduled to minimize waste of green signal.

Vehicle detector is required for actuation control at approach lane at suitable distance from stop line for detection of approaching vehicle. Typical example of actuation control applied to right turn traffic is shown below.



(Source: JICA Study Team)

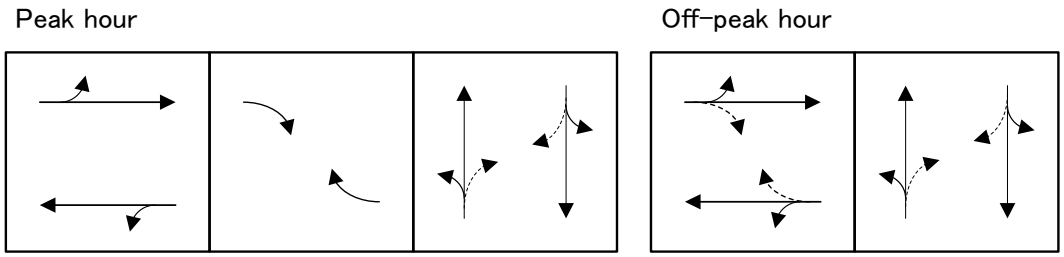
Figure 6.18 Example of Actuation Control

Multiple Phase Sequence

Traffic signal sequentially displays green to vehicles moving in different directions. For a given intersection, multiple signal sequences can be defined to handle the traffic movement. To cope with the change in the traffic demand, different phase sequence would be suitable at different time of day.

Example is shown in (Source: JICA Study Team)

Figure 6.19. Right turn arrow phase is necessary during peak hours when right turn volume is high, while right turn is made by permissive right turn (filtering) without right turn arrow signal phase during off peak hours when right turn volume is small. The controller must have multiple phase sequences that is to be applied at different time of day.



(Source: JICA Study Team)

Figure 6.19 Example of Multiple Phase Sequence at Same Intersection

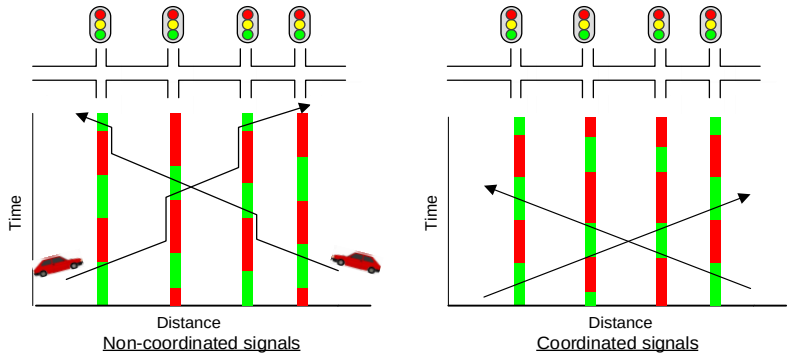
Flashing Operating

One of the phase sequences is designated as flashing operating and signal display either flashing red or flashing yellow. Flashing operating will be applied during night time when traffic volume is extremely small. During flashing operation, pedestrian signal will be extinguished.

Coordination

Signals installed at short distance need to be coordinated to offer green wave, in which vehicle that has passed an intersection during green will be given green at next signal to allow the vehicle to pass through next intersection without stopping. The reduction of waiting time at signals is illustrated in (Source: JICA Study Team)

Figure 6.20. To provide green wave, neighbouring two signals must operate with the same cycle length and they must be coordinated.



(Source: JICA Study Team)

Figure 6.20 Signal Coordination: Image of Green Wave

Signal Operation Monitoring

Normal operation of controller must be guaranteed all the time to prevent dangerous situation caused by malfunctioned signal. For this purpose, signal operation must always be monitored by built-in diagnosis program. The following monitoring and fail-safe functions must be provided.

Green – green conflict: If green signal is shown to two conflicting movements simultaneously, it must be detected by the controller and the signal must be put into flashing operation immediately.

Signal interval monitoring: For each state of signal display, minimum and maximum duration must be specified beforehand. If the controller detects signal indication shorter than minimum or longer than maximum duration, controller must stop three-colour operation and signal is put into flashing operation.

b) **System Level**

At control centre, cycle length, split and offset are specified for each controller and the controllers are instructed to operate with these parameters. System level signal control functions include the following functions

Sub-Area Formation

The signals under the control of control centre will be grouped into sub-area for signal control purpose. Sub-area is the minimum unit for signal control and consists of one to several controllers depending on the size of intersection, traffic volume and direction, distance between signals, etc. The same cycle time is applied to all signals in the same sub-area so that offset is defined between signals in the same sub-area.

Sub-area can be joined together to form a larger control area where the same control is applied if the traffic conditions of two sub-areas are similar. They are separated if traffic condition differs and each sub-area will operate with different timing parameter.

Responsive Control

Based on the traffic condition data gathered by vehicle detector, optimum timing parameter set, which consists of cycle length, split and offset, will be selected or generated at the control centre for each signal.

The timing parameter set is prepared at every five minutes. But the new timing parameters may not be applied immediately. A mechanism must be provided to prevent hunting of signal control parameter at every calculation cycle.

Offset Transition

If new timing parameter requires different offset from the offset currently being applied, offset of the signals must be adjusted to establish the offset specified. This can be done by adjusting cycle length of signal either shortening or lengthening it so that synchronization point in a cycle will shift relative to back ground cycle.

The offset transition must be made in the direction which requires less transition. It is also executed over up to four signal cycles to avoid sudden change of signal indication.

c) **Vehicle Detector Data**

Data Gathering

Vehicle detector data must be gathered by the control centre at the specified interval. There are two ways to collect vehicle detector data. Vehicle detection signal is directly sent to the centre continuously and traffic volume and time occupancy are calculated at the centre at the specified interval. Alternatively, data accumulated for a specified interval by the detector is sent to the centre at the end of the interval. Either methods can be adopted. The former method requires realtime data transmission and amount of data is much larger than the latter method. On the other hand, clock synchronization issue occurs if latter method is applied. The former method is recommended as it simplifies the function of vehicle detector. Frequent data transmission is not a c as detector data can be multiplexed with controller data.

Detector Data Processing

Detection signal from the detector is processed into traffic count and time occupancy data after initial checking of erroneous data. Five minute interval is suggested for data processing for traffic control application.

Based on the count data and occupancy data, traffic condition data in terms of degree of saturation or congestion will be computed for each detector location. The data will be applied to the signal control software to develop optimum timing parameter set for prevailing traffic condition.

Traffic data so processed will be accumulated or averaged and one-hour data will be produced for statistical and recording purpose.

Detector Operation Monitoring

Detector data must go through checking process before sent to signal control applications to avoid errant operation based on abnormal data. Error check may compare data with pre-set minimum and maximum limits of traffic count and occupancy or their combination.

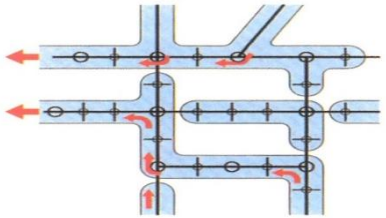
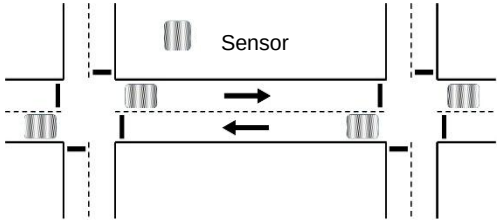
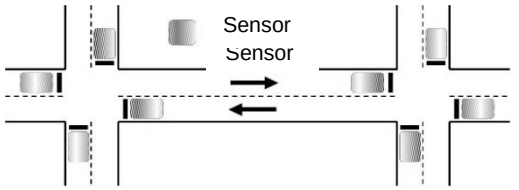
d) **Signal Operation Monitoring**

Operation of signals must be continuously monitored every second. If abnormality is detected by the diagnosis program in the controller, signal must enter into flashing operation. If data communication between centre and controller is interrupted, the signal must operate the same timing parameter being

If a controller recovers or communication link is established, the controller must be automatically put into remote control mode and operate with the command sent from the centre.

The comparison of major traffic signal coordination systems in the world is shown in the table below.

Table 6-4 Comparison of Major Traffic Signal Coordination in the World

Method	Area Wise Control	Line Wise Control	Point Wise Control
Feature	• Area wise traffic signal control based on key intersections • Decrease of congestion volume and queue length	• Line wise traffic signal control • Adjustment of green signal timing by forecasting arrival time of cluster of vehicle	• Mainly point wise signal control • Optimize split by degree of saturation and control offset by the pattern according to traffic volume
Location Image			
Sensor Location	• At entrance of key intersection • Traffic volume sensor at entrance • Queue length sensor at 150m, 300m and 500m from intersection	• At exit of intersection • Traffic volume sensor at 150/200m from intersection	• At entrance of intersection • Traffic volume sensor at entrance of intersection
Control Index	• Traffic volume • Queue length • Travel time	• Arrival time forecast • Traffic Volume • Duration of green signal	• Traffic volume • Duration of green signal
Sub-Area	Sub-area is combined and separated automatically based on traffic situation	Fixed sub-area	No sub-area

(Source: JICA Study Team)

Considering the traffic situation in Chennai, the area wise control method is judged best suited.

e) **Development Plan**

<Coverage Area of Area Traffic Signal Control System>

The proposed entire area where Area Traffic Signal Control Systems will be installed in Chennai are determined to include the following areas:

- The area where congestion degree, a result of traffic demand forecast expressed in terms of traffic volume/capacity, shows more than 1.0
- The area which includes Ennore Port
- The area which includes Tambaram district along NH 45 that is one of most frequently congested area in the city

Based on the above, Area Traffic Signal Control System is proposed to be introduced in stage-wise in the short term as follows:

- Stage-1: Core area of the city where traffic congestion is severe (Area which is encircled by Inner Ring Road, NH4, NH 45 and northern section of SH 49A)
- Stage-2: Remaining area of the above proposed entire area

The general practice of installation of traffic signals is that several parties, each of which is responsible for each intersection, carry out installation work in parallel. In the case that there are too many intersections for installation, it may be difficult for contractor under a single contract to make ready sufficient number of the parties. Further, management of installation work for a large number of intersections will be difficult. It is thus concerned that it may result in deterioration of quality of work and delay of installation completion. It will be also necessary to regulate traffic at a large number of locations in the city during the same period of installation. Therefore, Area Traffic Signal Control System is proposed to be introduced in stage-wise, at least divided into two stages.

The stage-wise development plans at each stage are proposed as follows:

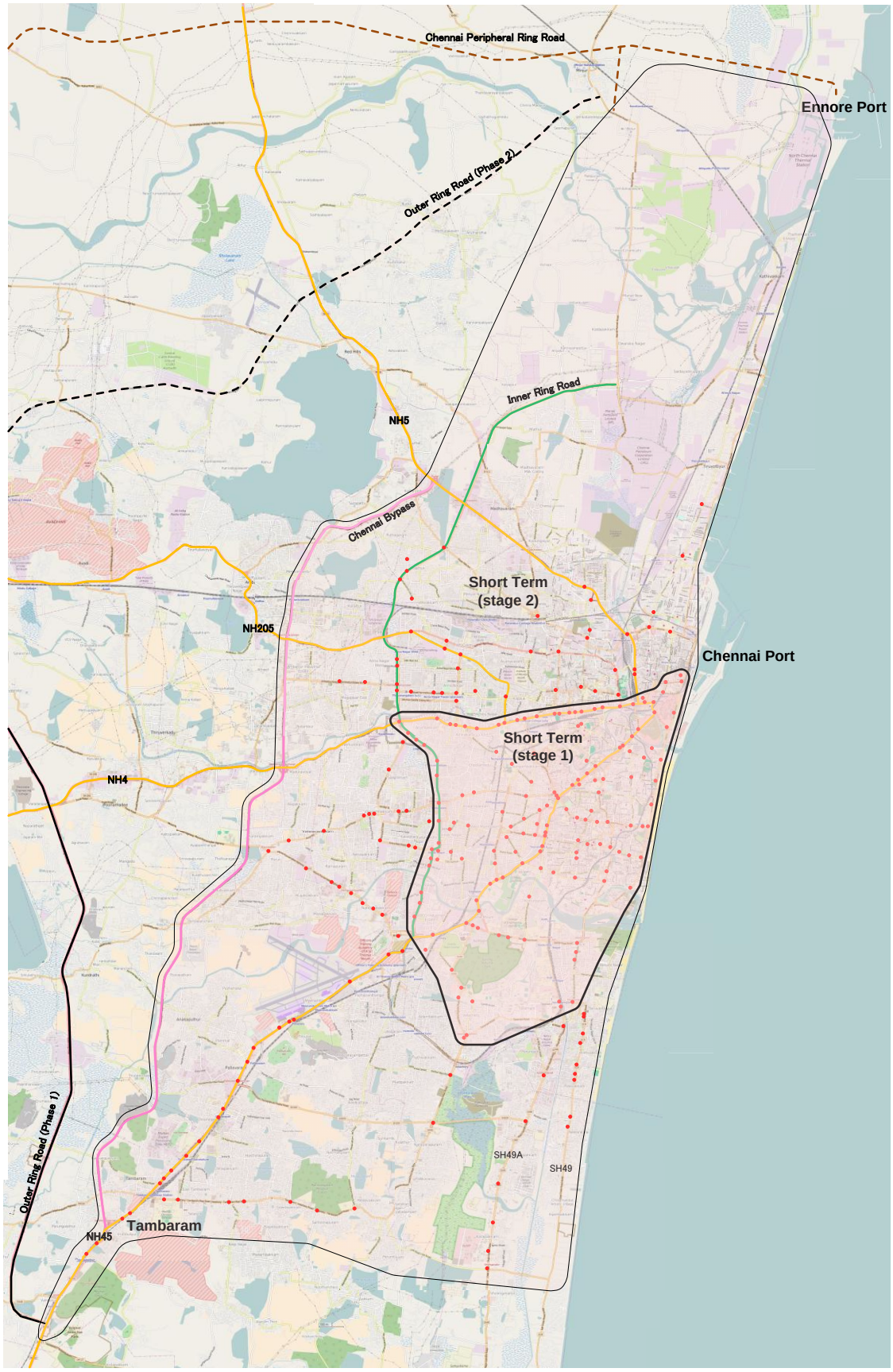
<Short Term>

Stage-1 : The control centre and software for centre system will be developed. The signals will be installed in the core area of the city which is encircled by NH-4, NH-5 and Marina Beach as shown in Figure 6.21, totalling 150 intersections as immediate measure.

Stage-2 : The Signals will be installed in the area as shown in Figure 6.21, totalling 230 intersections.

<After Short Term>

The area for signal installation can be further expanded as necessary according to traffic condition and urban infrastructure development in the future.

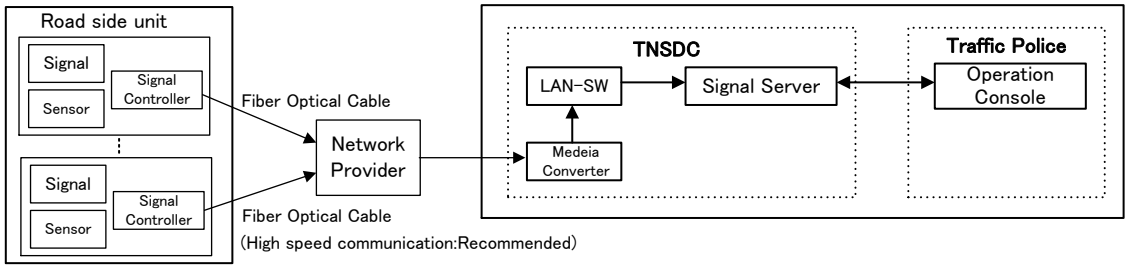


(Source: JICA Study Team)

Figure 6.21 Stage – Wised Location Plan of Area Traffic Signal Control System

f) **Communication System Diagram**

The date measured by vehicle detector will be transmitted to signal server cable and calculation result made by signal server will be transmitted to signal controller on intersection through communication network. The optical fibre cable network is recommended. The communication system diagram is shown in the figure below.



(Source: JICA Study Team)

Figure 6.22 System Diagram of Signal Communication

6.2.2 CCTV Traffic Monitoring System

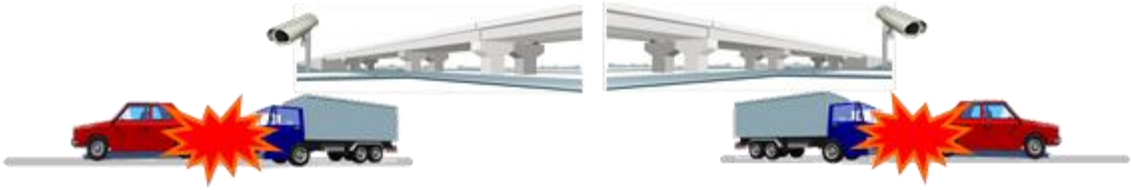
(1) Purpose

The purpose of CCTV traffic monitoring system is to monitor the traffic conditions at site. The necessary measures will be taken upon finding hazardous traffic events. CCTV camera will have functions of pan, tilt and zooming to capture clear image of vehicles and licence plate, if necessary. These captured images will be stored for a certain period.

(2) Development Plan

CCTV cameras are already installed at some major intersections in the city and monitored by Traffic Police. Therefore, additional CCTV cameras are proposed to be installed at other accident-prone locations. These locations are merging points of grade separation and ground level of major roads. In addition to accidents, these locations tend to be a bottleneck of traffic congestion because of merging and diverting activities.

A conceptual image of CCTV and location plan are shown in the figures below.



(Source: JICA Study Team)

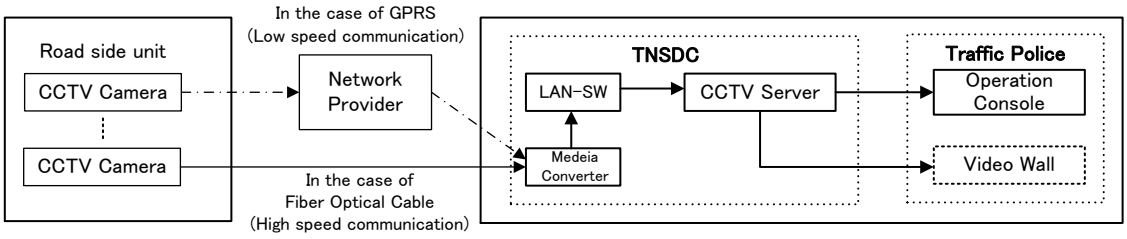
Figure 6.23 Typical Location of CCTV to be Installed

(Source: JICA Study Team)

Figure 6.24 Location Plan of CCTV

(3) Communication System Diagram

The video data by CCTV camera will be transmitted to Traffic Police through communication network. The optical fibre cable will be used if it is available at the location of roadside terminal equipment. The mobile network will be used if the optical fibre cable is not available nearby. The system diagram is shown in the Figure below.



(Source: JICA Study Team)

Figure 6.25 System Diagram of CCTV Communication

6.2.3 Variable Message Sign System

(1) Purpose

The purpose of Variable Message Sign (VMS) system is to provide information on road, traffic and weather conditions to drivers on the road. VMS system is one of the most effective methods for information provision because the information can be provided to all road users on the road even when the vehicle and driver do not possess devices to access the information such as navigation unit, smart phone, etc.

There are several different types of VMS such as text type, graphic type, etc. The graphic type VMS with multi-display and multi-colour is proposed to be installed because it is easier to understand the road/traffic congestion by image without much reading. It is also able to display other information such as incidents and/or time to destination. Thus, drivers can promptly decide whether to take alternative route or not.

Examples of different types of VMS are shown below.

Table 6-5 Examples of Different Types of VMS

Type	Image	Function
Text and Symbols		To inform the road, traffic and weather conditions by text and symbols
Travel Time Display		To inform travel time from VMS location to major destinations
Graphic Information Signboard (Multi-colour, multi-display)		To inform about congested sections to allow drivers to select most suitable travel route by using graphic image. Other information such as incidents and/or time to destination can also be displayed.

(Source: JICA Study Team)

(2) Development Plan

VMS are proposed to be installed at upstream of major intersection with Outer Ring Road, Chennai Bypass, Inner Ring Road, and major radial roads. The radial roads include NH5, NH205, NH4, NH 45, SH49A and SH49. This is for the purpose of diverting the traffic to alternative routes by providing information on congestion and expected travel time to the major destinations ahead to the vehicles.

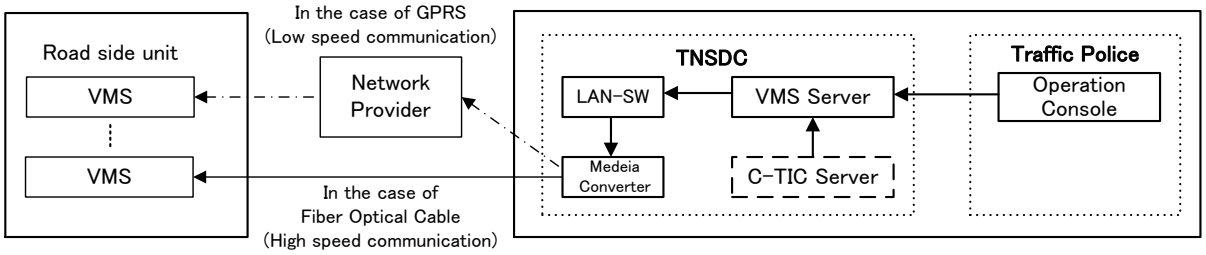
The location plan is shown in the figure below.

(Source: JICA Study Team)

Figure 6.26 Location Plan of VMS

(3) Communication System Diagram

The data for VMS will be transmitted between roadside terminal equipment and VMS server through communication network. The optical fibre cable will be used it is available near roadside terminal equipment. The mobile network will be used if the optical fibre cable is not available nearby. The communication system diagram is shown in the figure below.



(Source: JICA Study Team)

Figure 6.27 System Diagram of VMS Communication

6.3 ITS for Chennai Peripheral Ring Road

The total length of Chennai Peripheral Ring Road is 133.65 km and it is divided into five sections. Although it has not been decided yet, Tamil Nadu state government is considering that the section-1 which is connected to Ennore Port, called 'Northern Port Access Road, will be the first section to be implemented and this section will be the access-controlled and toll road. Therefore, it is recommended to introduce the following two ITS components for Chennai Peripheral Ring Road:

- Toll Management System: Section-1
- Highway Traffic Management System: From Section-1 to Section-5

6.3.1 Toll Management System

(1) Purpose

The completion of Chennai Peripheral Ring Road will contribute to drastic improvement of connectivity from suburban areas to Ennore port. A great amount of large sized vehicle on Chennai Peripheral Ring Road is then accordingly expected. The large-sized vehicle damages the pavement and therefore the maintenance will be very important issue. A Toll Management System enables collecting toll fare and the collected fare can be used for maintenance of Chennai Peripheral Ring Road. Regulating the over-loaded vehicles is also important to protect the pavement. The access-controlled section-1 makes it possible to control the over-loaded vehicles by installing the measurement equipment at the entrances.

Therefore, Toll Management System together with over-load measurement system, Weigh-in-Motion, are proposed to be installed on the section-1 of Chennai Peripheral Ring Road for the purpose of collecting fare and controlling the overload.

(2) Toll Structure

In section-1, toll plazas will be required at least at three locations. They are Thachur, the ending point of section-1 which connects section 2 and NH-5, Minjur that is ending point of branch line of section-1 near north end of Outer Ring Road and other ending point of section-1 which is before the gate of Ennore Port.

The toll fare system to be applied to Chennai Peripheral Ring Road such as distance-base, fixed fare, etc. has not been determined yet. But considering the structure of network in section-1, it is better to adopt the distance-based toll fare which varies the fare according to the travelled distance in view of sense of fairness of the Chennai Peripheral Ring Road users.

In the case of the distance-based toll fare, toll booth will be required at both entry and exit of the toll

road. There are mainly three methods for toll collection; manual toll collection, Touch and Go and ETC. For manual toll collection, a ticket or transit card which describes the information such as vehicle class, entered interchange, date and time, etc. will be given to the driver at the entry. The toll collector confirms this information at the exit booth and required toll fare are charged to the driver. For Touch & Go and ETC, the basic procedure is same and the process is automated by the system.

The figure below shows Section-1 of Chennai Peripheral Ring Road (Northern Port Access Road)

(Source: JETRO, Industrial Map of Greater Chennai Version 4.0)

Figure 6.28 Map of Section-1(Northern Port Access Road)

(3) Toll Collection Method

Three methods of toll collection are recommended to be introduced to Chennai Peripheral Ring Road. They are ETC, Touch & Go, and Manual Toll Collection.

National Highways Authority of India initiated RFID method as national standard of ETC for Indian highways. In this system, an RFID tag, called FASTag, is attached onto the windshield of the vehicle. The unique ID number is assigned to each vehicle and written in the memory on the Tag. The toll collection is automatically done and the vehicles pass without stopping at both entry and exit of ETC toll gates. Nowadays in India, all new cars have this tag as standard equipment. Drivers make user registration and create online account in advance to activate to use FASTag toll collection. When the vehicle passes the gate, the toll fare is deducted from the online account. A toll lane dedicated to ETC will be required because of non-stop toll collection. FASTag system has been introduced on Chennai Bypass in Chennai.

(Source: JICA Study Team)

Figure 6.29 RFID Tag of FASTag System

In the case of Touch & Go, toll fare is deducted from a contactless smartcard when the user touches the card reader/writer installed at toll booth. It will be a prepaid payment system. Touch & Go lane is recommended to be installed at all lanes for manual collection to increase handling speed of toll collection.

Introduction of common mobility card which can be used for Chennai metro, city bus, Mass Rail Transit System, etc. is being considered by Chennai Unified Metropolitan Authority in Chennai. Therefore it is strongly recommend to adopt the smart card which is interoperable with the common mobility card.

When the mobility card is commonly used for different transport modes, the settlement processing among transport operators is required. The system which automatically settles processing is called the clearinghouse system. The clearinghouse system has already been established at headquarters of Chennai Metro Rail Limited. The smartcard needs to comply with ISO 14443 Type A or FeliCa card which has been adopted to Chennai Metro card and applicable for the clearinghouse system. A large number of card holders can be expected at the time of commencement of Chennai Peripheral Ring Road service.

(Source: Highway Industry Development Organization)

Figure 6.30 Touch and Go Booth Image

Indian Road Congress: SP:99-2013 describes the required capacity of toll lane of above systems as follows:

- Semi-automatic Toll Lane (Manual Toll Collection): 240 vehicles/hour
- Smart Card Lane (Touch & Go): 360 vehicles/hour
- ETC Lane: 1,200 vehicles/hour

Handling capacity of Touch & Go and ETC toll lane is much higher than the manual lane. As the number of users of Touch & Go and ETC increases, the congestion at toll gate will be reduced.

(4) System Configuration

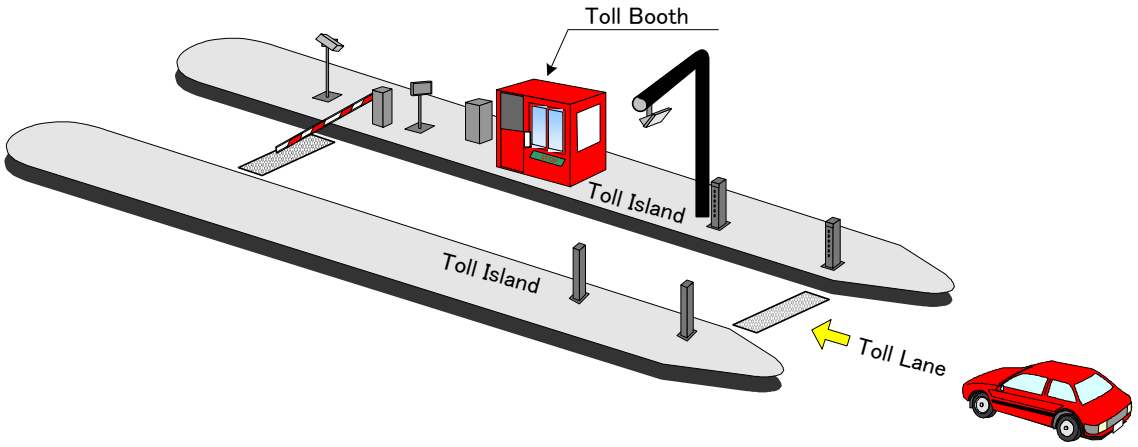
Toll Management System comprises various equipment at three levels.

(i) Toll Plaza (Lane Computer System, Toll Lane Equipment, Toll Booth Equipment)

(ii) Toll Plaza Building (Plaza Computer System)

(iii) Toll Management Centre (Toll Management Centre System)

The image of Toll Plaza is shown below.



(Source: JICA Study Team)

Figure 6.31 Image of Toll Plaza

(i) Toll Plaza

The process of the toll lane equipment will be monitored continuously by a lane computer system. The lane computer system carries out vehicle classification, validation of card and ETC, etc.

(ii) Toll Plaza Building

The plaza computer system will provide management functions such as attendance recording, reconciliation between the amount of toll collection declared by toll collector and measured by the system, handling/managing bank transfer, etc.

(iii) Toll Management Centre

Traffic management centre will be constructed at one of the toll plaza building of Chennai Peripheral Ring Road. It manages and oversees the entire system and operation of Toll Management System. The centre system will have duplex system configuration with the standby server system that takes over the operation in case of stoppage of main server.

It is recommended that the Plaza Computer System be designed as 'autonomous system' which does not require a realtime data communication with Toll Management Centre System and continuously functions on the occasion of breakdown of the data communication.

(5) Toll Lane Equipment

The table below lists the equipment that will be installed in toll booth, at toll lane and island.

Table 6-6 List of Toll Lane Equipment

	Equipment	Purpose
Inside Tollbooth	Toll Lane Controller	It controls and monitors all toll lane equipment. It also stores transaction data and other data necessary for toll collection operation.
	Toll Collector Terminal with receipt printer	It is an interface equipment for toll collector, with display and keyboard. The receipt printer issues receipt.
	Smart card reader/writer	It reads and writes data from/onto smart card used.
	Emergency footswitch	It issues an alarm at toll plaza office in case of emergency.
	Intercom slave communication unit	It is used as verbal communication unit between toll collector and staff in the toll plaza building.
Toll lane	Manual lane barrier	It is a barrier for manual lane.
	Overhead traffic light	It indicates whether a toll lane is open or closed.
	Lane traffic light	It indicates whether a vehicle stopped at tollbooth is allowed to proceed or not.
	ETC antenna	It communicates with RFID Tag pasted on the vehicle and exchanges data for ETC transaction.
	User fare display	It shows amount of toll deducted or balance in the card, and other information as necessary.
	Automatic lane barrier	It controls vehicle movement at toll gate, usually stays at closed position and opens when a vehicle is allowed to pass.
	Amber siren beacon	It indicates emergency activated by toll collector.
	Incident capture camera	It takes images of vehicle on the toll lane.
	Automatic vehicle classifier system	It determines vehicle class based on the physical features of vehicle measured by the system and determines the amount to be charged.
	Weigh in motion system (*1)	It identifies overloaded vehicle measured by the system and records the necessary data. (Detailed below)

*Note (*1): Weigh in Motion System is not Toll Management System. But it is recommended to be installed at entrance of CPRR which will be identical location with above equipment. Thus, the description of Weight in Motion is provided hereunder.*

(Source: JICA Study Team)

Weigh in Motion System, which is a load cell Weight in Motion system, is recommended to be installed at every entry toll gate to detect the weight of vehicles. As a vehicle passes over the platform, the system measures axle weights and sums up each measured weight. When excess weight of the vehicle is detected, the vehicle is lead to static bridge to measure the total weight.

The load cell Weight in Motion system basically consists of:

- Inductive Loop
- Axle Sensor
- Platform with Load Cell
- Monitor
- Static Bridge

(6) Plaza Computer System

A plaza computer system will be introduced in the control room of each toll plaza building The major functions are:

- Data acquisition from toll lane equipment and provision of realtime monitoring via visual display unit in the control room of the plaza building.
- Data processing and plaza management via visual display units, printer terminals and data transfer facilities.

The table below lists the major systems which will compose Plaza Computer System.

Table 6-7 Major Systems of Plaza Computer System

Major Systems	Purpose
Plaza Computer Server	It records all transactions and processes the data for the functions described below in this table.
Audit System and Workstation	It finds out the discrepancy between vehicle types identified by toll operator and measured by automatic vehicle classifier system. It also monitors lane activities.
Point of Sales System and Workstation	It is used for sale and recharge of FASTag and smartcard.
Reporting System and Workstation	It generates necessary management report for analysis and information. It also manages the shift of toll collectors' parties.
Toll Fare Management System and Workstation	It reconciles cash amount between declared by operator and measured by the system. It also manages the toll amount collected at each toll plaza.

(Source: JICA Study Team)

(7) Toll Management Centre System

The Toll Management Centre system will have the following major functions: -

- Management of entire system and operation of Toll Management System for Chennai Peripheral Ring Road
- Data acquisition from Plaza Computer System and management such as collected amount by toll plaza, working/shifting record of staff/toll collector of each toll plaza, major equipment/system failure, etc.
- Revising operation parameters and distributing to Plaza Computer System such as revised toll fare table, latest blacklist, etc.
- Reporting functions of above via visual display units, printer terminals, etc.
- Visual monitoring of toll lanes of each toll plaza via visual display units if it is needed

The Toll Management Centre system will be connected to Plaza Computer System by wide area network over optical fibre cable network.

The table below lists the major systems which will compose Toll Management Centre system.

Table 6-8 Major Systems of Toll Management Centre System

Systems	Purpose
Toll Management Centre Computer Server	It records all transactions and processes the data for the functions described below in this table. It also manages operation parameters such as updating and distributing toll fare table and black list information to all lane computers through PCS.
Monitoring System and Workstation	It monitors toll lanes of each plaza.
Reporting System and Workstation	It generates necessary management report for analysis and information of all toll plazas and revenue details.

(Source: JICA Study Team)

6.3.2 Highway Traffic Management System

(1) Purpose

Highway Traffic Management System assists the management of Chennai Peripheral Ring Road to assure safety and smooth traffic on Chennai Peripheral Ring Road. The system consists of the following major parts:

- Data/Information Collection
- Data Processing and Monitoring
- Information Dissemination.

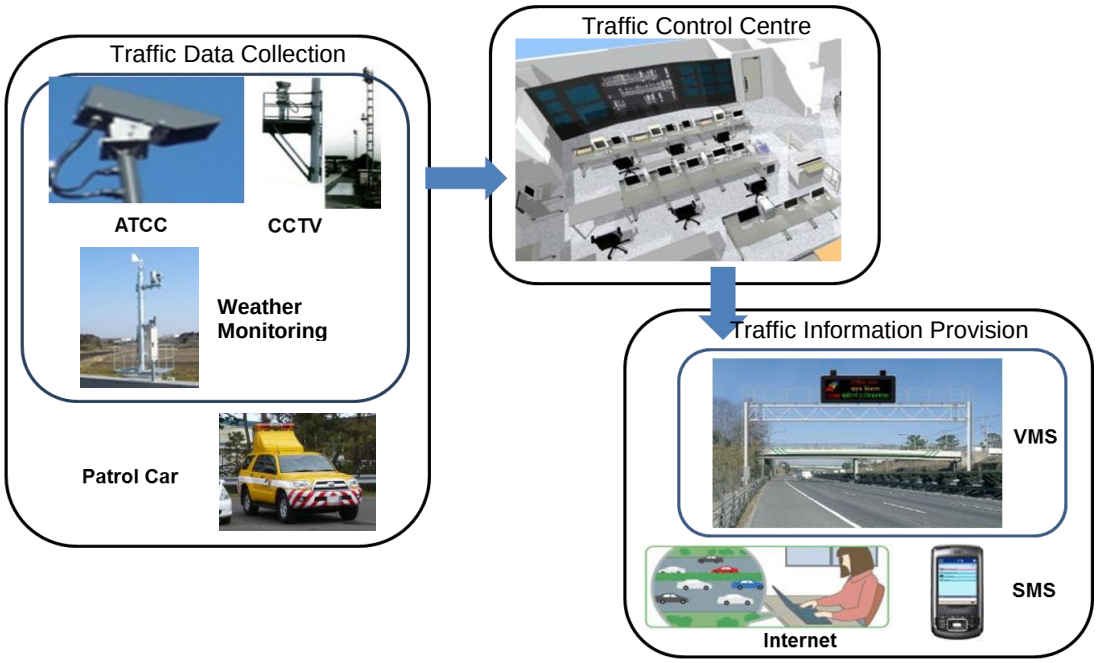
In addition, the information will be exchanged with Chennai Traffic Information Centre and other related agencies.

(2) Outline

Data of the road and traffic condition on the Chennai Peripheral Ring Road is collected by ATCC, video incident detection system (VIDS), meteorological monitoring system (MET) and CCTV camera installed along the Chennai Peripheral Ring Road. The data collected by these devices are sent to the Traffic Control Centre of Chennai Peripheral Ring Road through digital transmission system.

The operators monitor the conditions of the Chennai Peripheral Ring Road through the video wall and workstations at Traffic Control Centre. Measures are taken in case of incident or event such as congestion, accident, road or lane closure, and construction/maintenance work. The information of traffic/road/weather conditions of the Chennai Peripheral Ring Road will be disseminated to Chennai Peripheral Ring Road users through VMS Board installed on the Chennai Peripheral Ring Road and on the access roads to the Chennai Peripheral Ring Road and through Internet. SMS will be sent to the registered users in case of incident. Same data and information is also send to Chennai Traffic Information Centre which is an information centre of all Chennai traffic. Cooperation with relevant organizations such as Traffic Police, ambulance and wrecker services will be arranged so that coordinated operation can be made in case of incident.

The figure below shows an entire image of Highway Traffic Management System.



(Source: Edited by JICA Study Team based on materials provided by East Nippon Expressway Co. Limited)

Figure 6.32 Image of Highway Traffic Management System

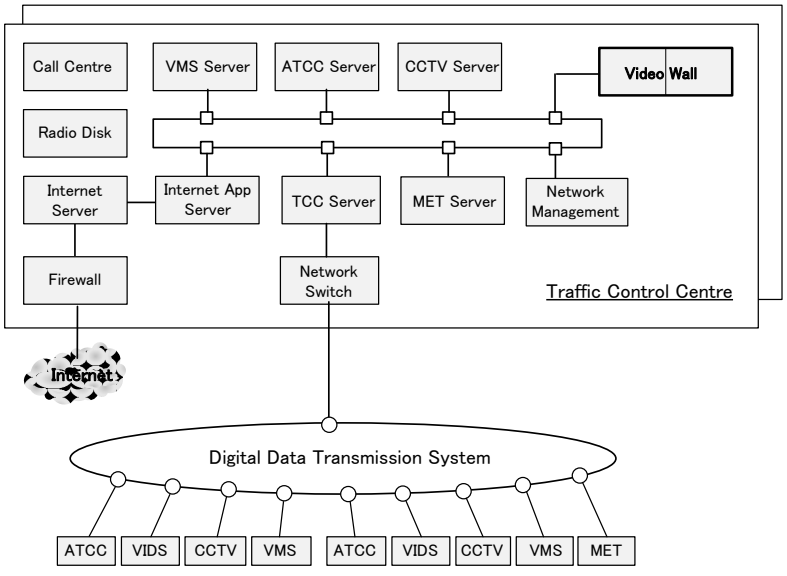
The figure below shows an image of Traffic Control Centre of Highway Traffic Management System.

(Source: Photography by JICA Study Team in East Nippon Expressway Co. Limited)

Figure 6.33 Image of Traffic Control Centre

The system will have a Traffic Control Centre at one of the interchanges of section-1 to oversee traffic for 24hours a day and 7days a week. The centre system will have duplex system configuration consisting of main and backup servers. In case of malfunction of main server, backup server takes over the operation so that the system operation is not interrupted.

The overall system configuration of the Highway Traffic Management System is shown in Figure 6.34.



(Source: JICA Study Team)

Figure 6.34 Overall Configuration of Highway Traffic Management System

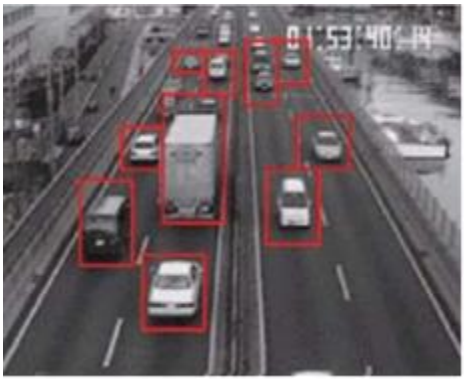
(3) Data / Information Collection

It is recommended that CCTV system, video incident detection system (VIDS), ATCC System, and meteorological monitoring system (MET) will be introduced for data/information collection.

CCTV system will be used to monitor traffic flow. VIDS system will be used to detect incidents such as standing object or object moving in opposite direction. In the case of big accident, or traffic events that need immediate measure, Traffic Control Centre requests to dispatch patrol car, traffic police, maintenance team or other related parties/agencies to site. The captured image will be stored for certain period.

ATCC counts the number of two types of vehicles: small and large sized vehicles. It also measures vehicle speed and occupancy. The vehicle speed measured by ATCC will be also used for supplement to probe system of Chennai Traffic Information Centre to generate congestion information. Therefore, the speed data collected by ATCC will be sent to Chennai Traffic Information Centre through Traffic Control Centre. The data will be stored for certain period.

The figure below shows a captured image of ATCC, identifying the vehicles.



(Source: Sumitomo Electric Industries, Ltd)

Figure 6.35 Captured Image of ATCC

The meteorological monitoring system (MET) measures weather conditions. It is necessary for providing adverse weather information to the users. Thus, the users can take appropriate action in adverse weather conditions. The system is proposed to be introduced in the Chennai Peripheral Ring Road with the following objectives:

- To measure weather conditions including rainfall, temperature, wind velocity/direction and visibility on the roads of Chennai Peripheral Ring Road.
- To utilise the measured meteorological data for taking appropriate countermeasures such as road closure, etc. in case that hazardous weather condition is detected.

- To provide the weather information to the road users through the information provision systems in order for them to take necessary cautious measures.
- To share the measured meteorological data of the hazardous weather condition with the relevant agencies such as road operators and traffic polices, etc.

It is considered that emergency call box is not required to be installed on Chennai Peripheral Ring Road because proliferation of mobile phone made it possible for drivers to contact the Traffic Control Centre or other relevant parties. A call centre will be established and special phone numbers be assigned.

(4) Data Processing and Monitoring

Traffic flow data collected by ATCC are processed at Traffic Control Centre and converted into the form suitable for statistical application. When malfunction of equipment is detected, a warning is issued to operator.

Image captured by CCTV camera and Video Incident Detection camera used for monitoring by the operator. The image is recorded by the digital video recorder. If any abnormality is detected by the Video Incident Detection system, a warning is also issued.

All calls made to the call centre will be automatically recorded for reviewing later.

(5) Information Dissemination

Traffic and related information will be disseminated to the road users through VMS. It is proposed that VMS will be installed on the main carriageway of Chennai Peripheral Ring Road and on the major access road such as national highways. The information to be provided will include the condition of road, traffic and weather in the downstream section so that drivers can take appropriate actions such as diverting to detour, being prepared for the incident, etc.

Two different types of VMS are recommended to be installed as shown below. VMS on the main carriageway of Chennai Peripheral Ring Road displays the information regarding Chennai Peripheral Ring Road with graphic and together with necessary messages. VMS on the access road displays the information regarding Chennai Peripheral Ring Road and other roads such as Outer Ring Road in the form of schematic image of road network with necessary messages. This enables the drivers to select the appropriate route.

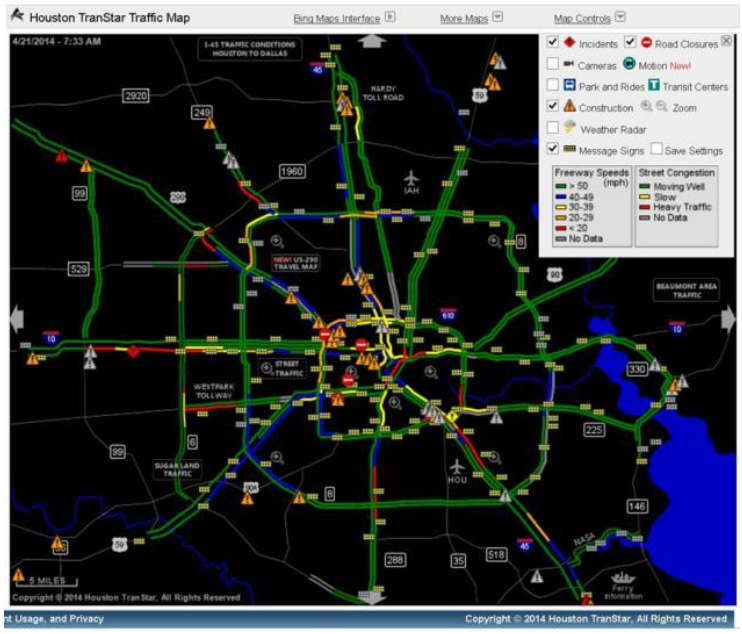
(Source: NAGOYA ELECTRIC WORKS CO.,LTD)

Figure 6.36 VMS for Main Carriageway of Chennai Peripheral Ring Road

(Source: Photography JICA Study Team)

Figure 6.37 VMS for Access Road

Traffic information is proposed to be disseminated through Internet as well. Congestion map showing the congested locations, incident locations, construction site, etc. is recommended to be prepared for road users. The figure below shows an example of traffic map on highways.



(Source: Houston: http://traffic.houstontranstar.org/layers/)

Figure 6.38 Example of Traffic Map

Traffic alert e-mail or SMS is also recommended to be prepared. In case of incident, construction work, road closure or other events that hampers the traffic, e-mail or short message will be sent to the registered users.

(6) Central Server System at Traffic Control Centre

Traffic Control Centre which accommodates Central Server System is proposed to be established at one of the interchanges, preferably at the same interchange of Toll Management Centre in the section-1.

The Central Server System at Traffic Control Centre will have the following major functions:

- Data collection from roadside equipment
- Monitoring and control of roadside equipment
- Data communication with roadside equipment
- Video Wall for monitoring traffic and roadside equipment
- Database Management
- Dissemination of information through VMS and Internet
- Human-machine interface

(7) Proposed Deployment Standard for Roadside Equipment of Chennai Peripheral Ring Road

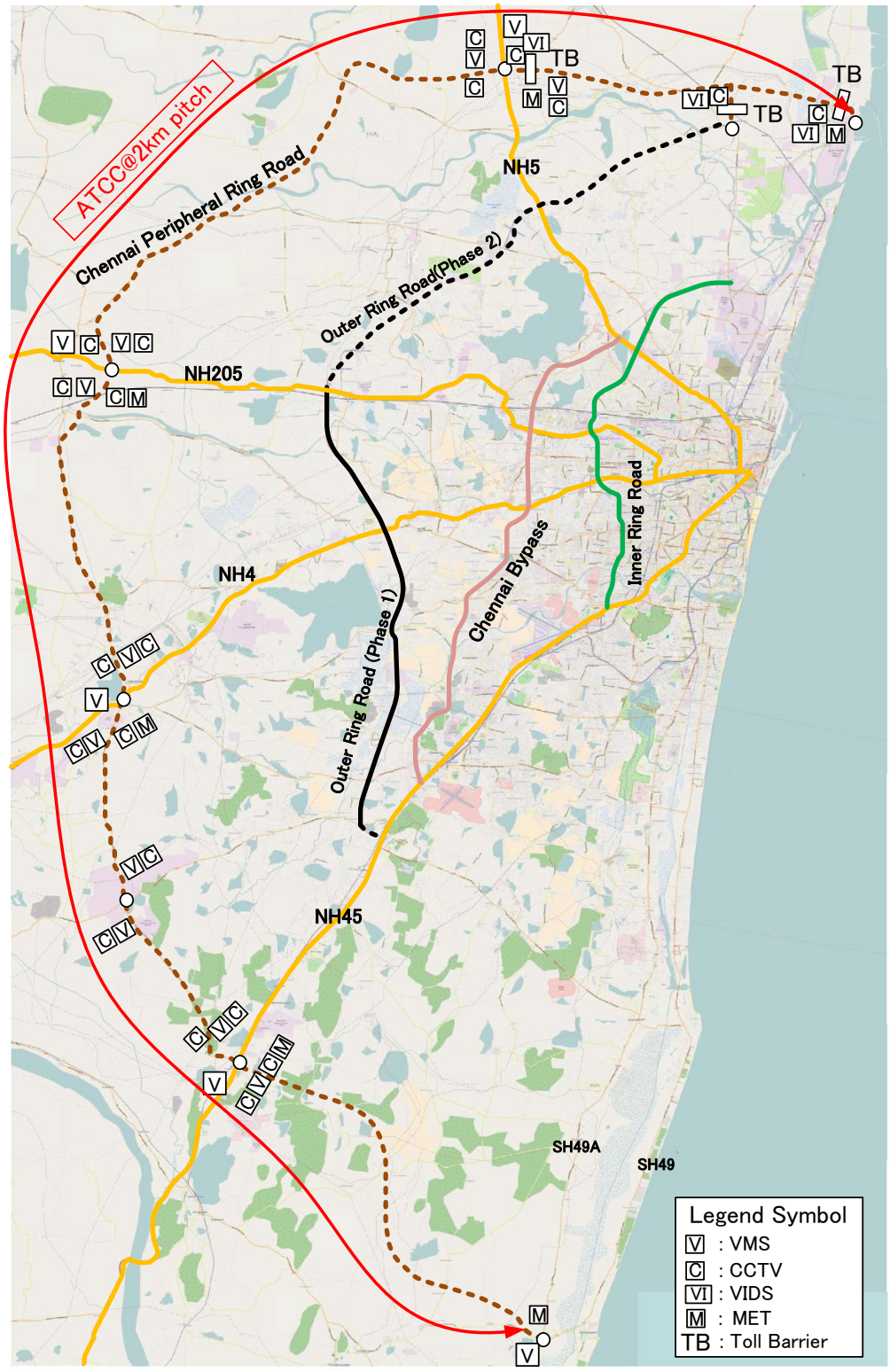
The following standard for deployment of roadside equipment of Chennai Peripheral Ring Road is recommended to be applied.

Table 6-9 Proposed Deployment Standard for Roadside Equipment of Chennai Peripheral Ring Road

Facility	Location			Purpose	Quantity
Variable message sign (VMS)	Main Carriageway of CPRR	Section-1	200m upstream of starting point of off-ramp	To provide information of CPRR	1
		Other Sections	200m upstream of junction		9
	Access Road to CPRR	Section-1	200m upstream of on-ramp in direction toward city	To provide information of CPRR and city road	1
		Other Sections	200m upstream of junction of major radial road in direction toward city		4
CCTV	Main Carriageway of CPRR	All Sections	200m upstream of diverting and merging point	To monitor traffic condition at site	20
Video Incident Detection System (VIDS)	Marin Carriageway of CPRR	Section 1	200m upstream of diverting and merging point	To detect abnormal traffic event	3
Automatic traffic counter cum (ATCC)	Main Carriageway of CPRR	All Sections	Every 2 km	To measure traffic volume To measure vehicle speed and occupancy (for C-TIC also)	134
Meteorological monitoring system (MET)	Main Carriageway of CPRR	All Sections	In the vicinity of interchange/ major junction	To measure weather condition	6

(Source: JICA Study Team)

Based on the proposed deployment standard, installation of the roadside equipment of Highway Traffic Management System of Chennai Peripheral Ring Road is proposed as shown in the figure below.



(Source: JICA Study Team)

Figure 6.39 Highway Traffic Management System Equipment Deployment Plan

6.4 ITS for Public Bus Transportation

Chennai has a number of industrial parks, schools and Information Technology corridors* such as SH49A in addition to port facilities. Accordingly, a large amount of people move about as commuters, students, etc. Hence, shifting the demand from private vehicles to public transport is very important. Currently, a part of metro network has been completed and extending work is going on. However, the major transportation mode for citizens is city buses, Metropolitan Transport Corporation because 3, 800 buses are running and they cover many bus stops and bus terminals in Chennai metropolitan area. Therefore, prompt introducing of ITS for city buses, thereby improving people's convenience will have an important impact.

* Information Technology Corridors : SH49 is called [Information Technology corridors] due to a lot of IT companies being located.

ITS of city bus consists of three major systems which are :

1) Bus Monitoring System
2) Passenger Information System
3) Electronic Ticket Management System

These systems contribute following items:

- Reduction of waiting time and planning of journey
- Increasing passenger convenience
- Increasing security of collected fare
- Reduction of leakage of fare collection
- Improving efficiency of bus management
- Utilisation of collected big data for future planning

6.4.1 Bus Monitoring System

(1) Purpose

The purpose of the Bus Monitoring System (BMS) is to enhance the city bus operation. The centre monitors each bus's operation status on realtime.

The major roles of the BMS are:

- To track the location of bus dynamically and continuously.
- To facilitate timely management of incidents/accidents.
- To reschedule buses based on data

- To make communication with bus driver and instruct diversion of bus in case of emergency or any unsafe incident.
- To effectively manage the fleet through a Decision Support system (software) by collecting, collating and storing information on realtime basis about the buses
- To utilize the cumulative data for route management, planning, etc.

The figure below shows an image of bus monitoring system.

(Source: Edited by JICA Study Team based on DHgate.com Website)

Figure 6.40 Bus Monitoring System Image

The bus monitoring system consists of the following major functions:

- Data Collection
- Data Storage, Processing and Analysis
- Monitoring and Management

(2) Data Collection

The system collects the bus location information dynamically through an on-board GPS device installed in each bus. The GPS device collects information such as longitude and latitude with time and sent to the central server at regular intervals. The communication between these on-board GPS devices and the central server is made through mobile communication network provided by service provider. The GPS device consists of processor, communication unit and power supply.

The figure below shows a typical GPS Device.

(Source : Teltonika)

Figure 6.41 Typical GPS Device

(3) Data Storage, Processing and Analysis

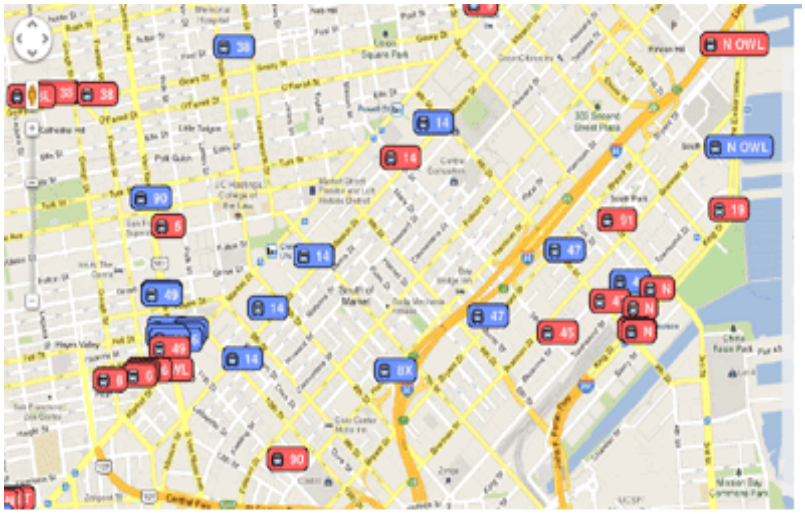
The centre server receives and processes the location data from GPS units and match with Geographic Information System map. -Server generates alerts, and reports as per the event or incident. Alerts are generated in such cases bus is deviating route, taking more time to reach a particular bus stop than planned, etc.

(4) Monitoring and Management

Operators in the control centre for bus monitor the location and time of each bus and communicate with bus drivers in the case of emergency. Bus drivers can be instructed to reschedule the bus if necessary.

The field officials can access the information from anywhere through smartphone or tablet such bus location, driver and other information. This information may help the field officials provide the required help in case of break down, flat tyre or any other situation.

The figure below shows and example of location buses of on a Geographic Information System maps



(Source: SF Live Bus Website)

Figure 6.42 Example of Location Buses on Geographic Information Map

The bus location matched with Geographic Information System map is shown in the video wall at the centre to share the information among officials and operators.-Bus picture is shown in different color codes to indicate the status of the bus. For example the color code can be as shown in the table below.

Table 6-10 Example of Colour by Bus Status

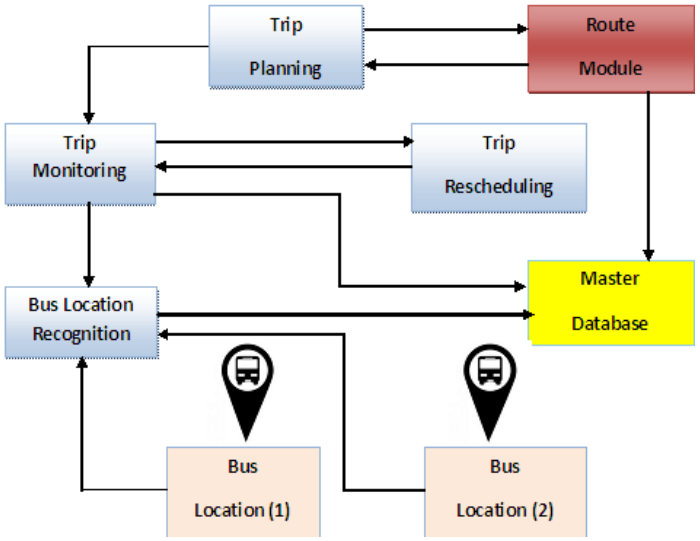
Colour	Bus Status
Green	On schedule
Red	Running late
Black	Breakdown

(Source: JICA Study Team)

Various graphics and functions are used to assist the operator to get the information as quickly as possible. For example, operator can know the detailed information such as route no, driver detail, etc. by placing cursor on the icon of bus. Interface also offers features such as altering the status of bus. For example if the driver of a bus reports a breakdown, then colour code of bus status will be changed to " breakdown " indicating in "black" colour.

(5) System Functions of Bus Monitoring System

The figure shows the functional architecture of Bus Monitoring System.



(Source: JICA Study Team)

Figure 6.43 Functional Architecture of Bus Monitoring System

a) **Function of Master Database**

Master database is used for asset management including information such as bus asset details, depot details, bus stop & terminal details, GPS device details etc., Bus asset details include bus ID number, chassis number, manufacturer, model, sitting capacity, year of registration, etc., depot details include information such as location, address, facilities available like workshop, fuel station, etc. Bus stop & terminal details include name, longitude, latitude, area/road, etc., GPS device details include device ID, model, date of purchase, etc.

b) **Function of Route Module**

The objective of the route module is to define the route in terms of origin, destination and the stops between origin and destination.

Route database will virtually have GPS fencing for all the routes operated by Metropolitan Transport Corporation. A geo fence is a virtual perimeter for a physical geographic area along the bus route or in the vicinity of bus stop.

For example, the geo fence generates provides notification when the bus approaches a particular bus stop or as soon as the bus deviates from the bus routes which it is supposed to run.

The figure below shows typical Geo fence.

(Source: Edited by JICA Study Team using Google map.)

Figure 6.44 Typical Geo-Fence for Bus Route

c) **Function of Trip Planning**

The objective is to optimize and rationalize the allocation of buses to different routes in the city. This module utilizes to consider passenger volume, direction movement of passenger, time of the day, working hours, route number, trip number, and start time, etc.

The bus routes, time of bus services, etc. are reviewed and modified using this function.

d) **Function of Trip Rescheduling**

The objective is to reschedule a trip. The rescheduling is made in such cases of bus break down, unexpected delay due to congestion, etc.

Trip rescheduling module will assist the operator to take appropriate actions by providing options as per rescheduling procedures. This module will coordinate with Trip planning and trip monitoring modules.

e) **Function of Trip monitoring**

The objective is to monitor movement of the buses and analyse as to whether the trip is completed the trip as planned. Trip monitoring module receives planned trip information as reference from trip planning module.

This module continuously matches the current position and planned location. If there is a deviation or not-planned behaviour, it generates alerts to the operators at the control room. This also communicate with trip rescheduling module for the continuous update.

f) **Function of Bus Location Recognition**

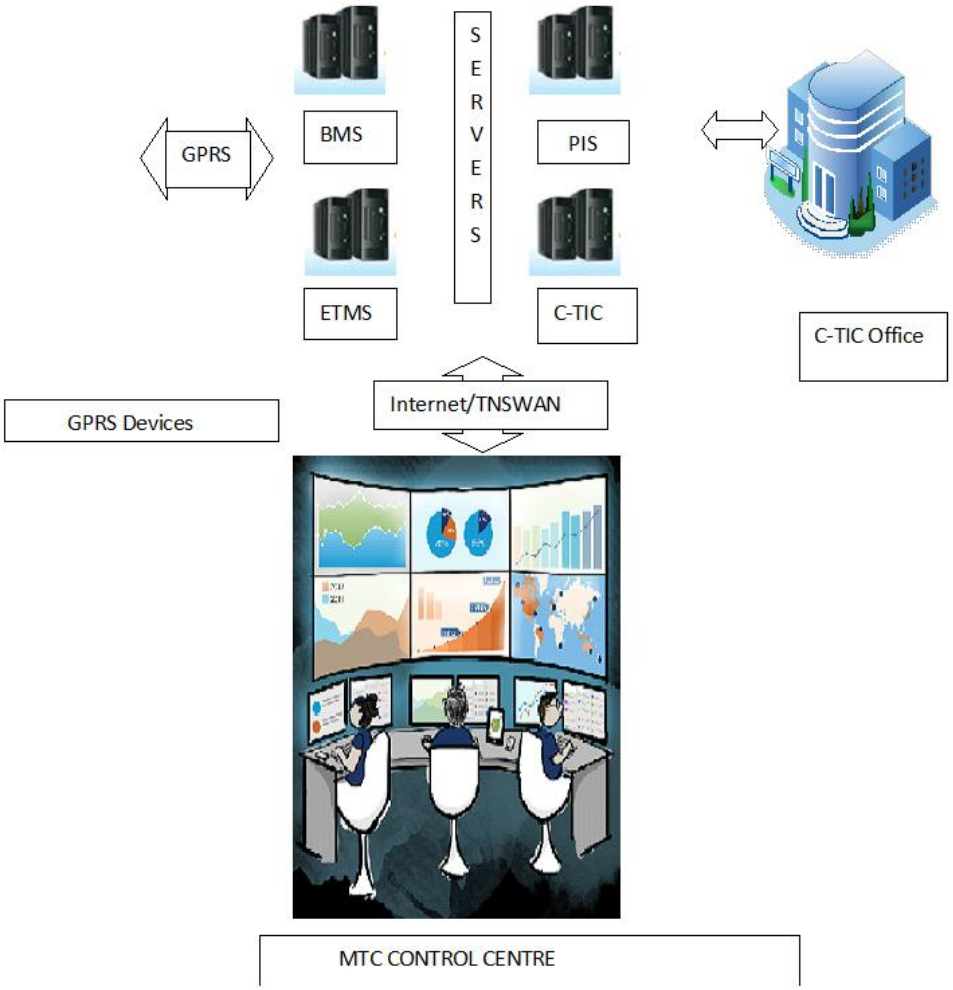
The objective of this module is to obtain the current location details of buses and pass this formation to trip monitoring module.

This module continuously obtains the bus location information from the GPS devices installed in the buses. Location information includes longitude, latitude and time.

(Note: this is only an illustrative description of the major modules of the bus monitoring system. More detail study is required for functional details).

(6) Development Plan

The figure below shows outline development plan.



(Source : Edited by JICA Study Team based on Materials on Compass icons Website and Pinterest Website)

Figure 6.45 Outline of Development Plan

a) **GPS Devices**

It is proposed that GPS devices will be installed on all the city buses, approximately. 3800

b) **BMS Server**

BMS server is proposed to be located at Tamil Nadu State Data Centre. The data security and saving maintenance cost can be assured by deploying the server at TNDC. BMS server will have an interface to share data and to receive data from Passenger Information System, Electronic Ticketing Machine System and Chennai Traffic Information Centre servers.

c) **Metropolitan Transport Corporation Command Control Centre**

The command control centre will be equipped with operator consoles, video wall, communication and network system and UPS for continuous operation. Communication with the BMS server will be connected through an Internet Service Provider (ISP) or Tamil Nadu State Wide Area Network.

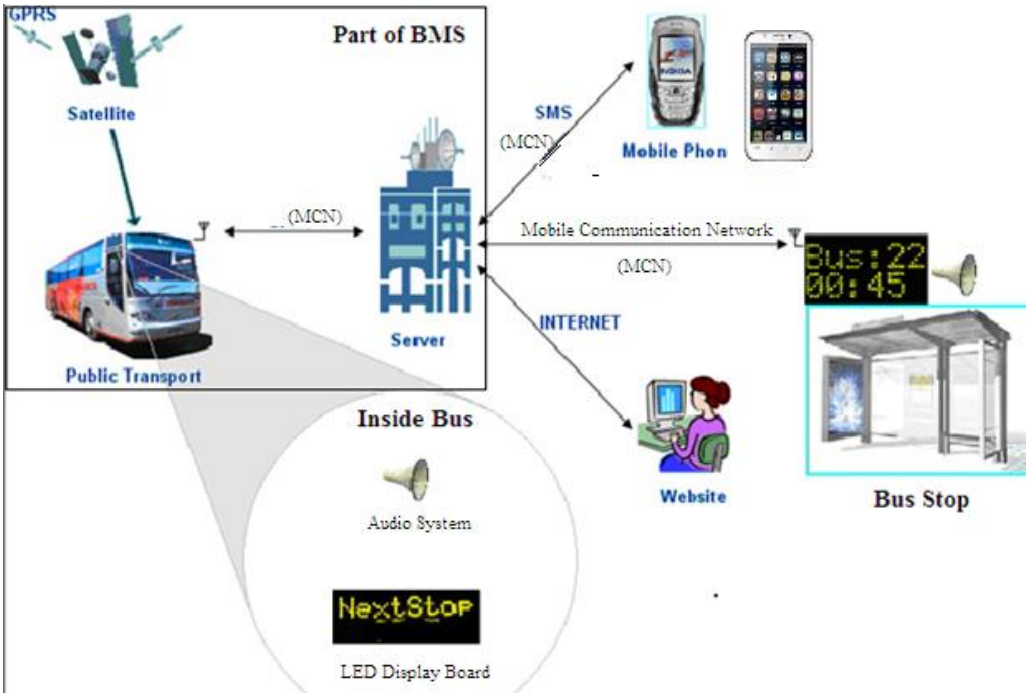
6.4.2 Passenger Information System

(1) Purpose

The objective of Passenger Information System(PIS) is to provide the information to the passengers about the bus routes, arrival and departure time of buses at the specific stop, etc. This information is shared with passengers with different modes or media viz. LED displays at bus stops & bus terminals, web and mobile application.

It is recommended that the setting place of Passenger Information System display board at the bus stops and bus terminals need to be placed where users can identify easily.

The figure below shows entire image of Passenger Information System:



(Source : Edited by JICA Study Team based on Materials on Compass Icons Website and Pinterest Website)

Figure 6.46 Image of Passenger Information System

(2) Function of Passenger Information System:

Passenger information system utilizes the data generated by the bus monitoring system and provide information to the passenger through different media as shown in the figure above.

Display board at the bus terminal/bus stops continuously provide bus no, expected time of arrival (ETA), expected time of departures (ETD), destination, etc.

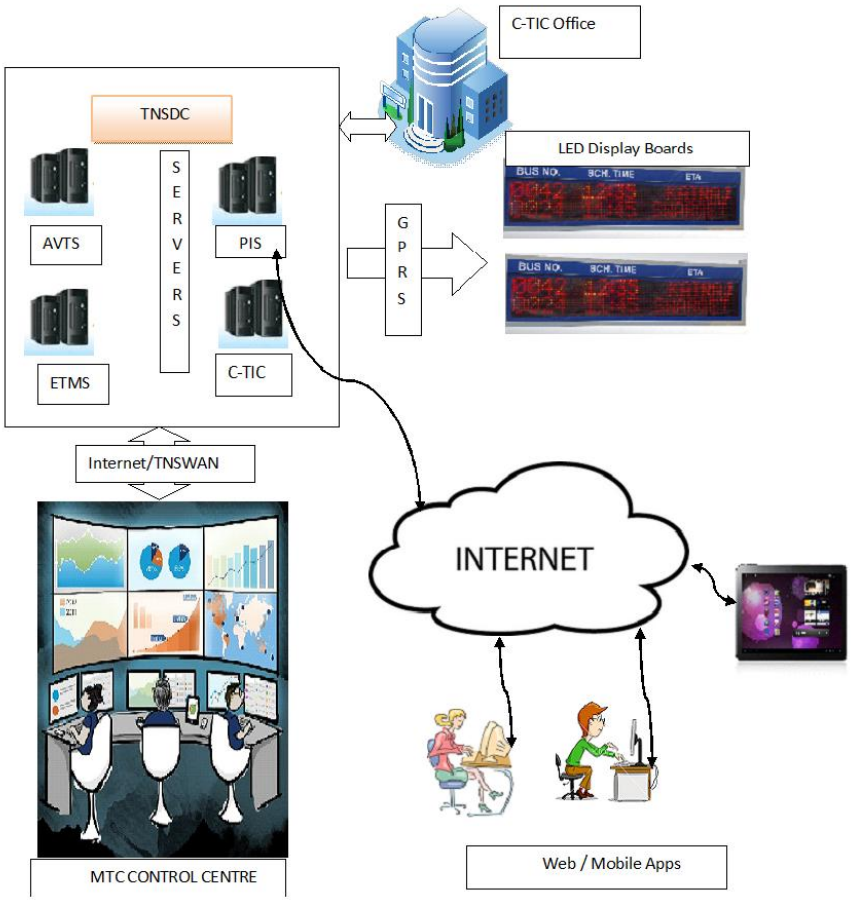
Web/mobile application provides more information such as:

- Bus routes availability between origin and destination, bus numbers, transit points, average travel time, fare, etc.
- ETA/ETD of buses at particular bus stop and bus terminal.
- Intermodal transit locations.

In, addition, LED display board installed in the bus displays the name of the next stop and audio system will announce the same just before arriving there.

(3) Deployment Plan:

The figure below shows outline development plan.



(Source : Edited by JICA Study Team based on Materials on Compass Icons Website and Pinterest Website)

Figure 6.47 Outline of Development Plan

a) **Passenger Information System Server**

Passenger Information System server will be hosted at the Tamil Nadu State Data Centre obtains data and information from BMS and generate the information which will be provided to the passengers through LED display board and web or mobile app.

b) **LED Display Boards**

LED display installed at the Bus Stops and Bus terminuses enable to use GPRS based communication and connected to the Passenger Information System server through GPRS. These LED display receive the content information from Passenger Information System sever at regular intervals and the same is displayed at the bus stops and terminus.

There are approximately 30,000 bus stops which are owned by Chennai City and 31 bus terminals owned by Metropolitan Transport Corporation in Chennai metropolitan area, according to the information provided by Metropolitan Transport Corporation. Several bus bays which are spaces for passengers to get on / off the buses are constructed in each bus terminal. Therefore, it is assumed that

at least 10 LED display boards at each bus terminal (310 LED display boards in total) which show arrival/departure information for each bus route and one large display board at each bus terminal (31 large display boards in total) which show arrival/departure information for each bus terminal will be required. Further, 3,800 LED display boards installed in each bus will be required. (The rough cost estimate which is shown in the later Chapter were made based on the number of equipment under the above assumption. It is noted that the number of LED display boards to be installed at bus stops owned by Chennai City are not included in the cost estimate due to the reason that many of these bus stops are not equipped with roof, electricity, communication cables and etc. More detail study is required to identify the required number of LED display board at bus stops. The number of LED display boards and large display boards at each bus terminal shall also be finalized by the detail study investigating such factors as appropriate location to be installed assuring visibility, availability of electricity and communication cables nearby, and etc.)

c) **Web or Mobile App**

Web or the Mobile application will provide the passenger information through the internet or an app down loadable to a mobile or tab.

d) **Operator for Passenger Information System at Metropolitan Transport Corporation Command Control Centre**

Operator for Passenger Information System console at the command control centre should be dedicated personnel. Operator will monitor the correctness of information displayed by LED display boards, soundness of LED display through diagnostic system at regular intervals, etc.

6.4.3 Electronic Ticket Management System

(1) Purpose

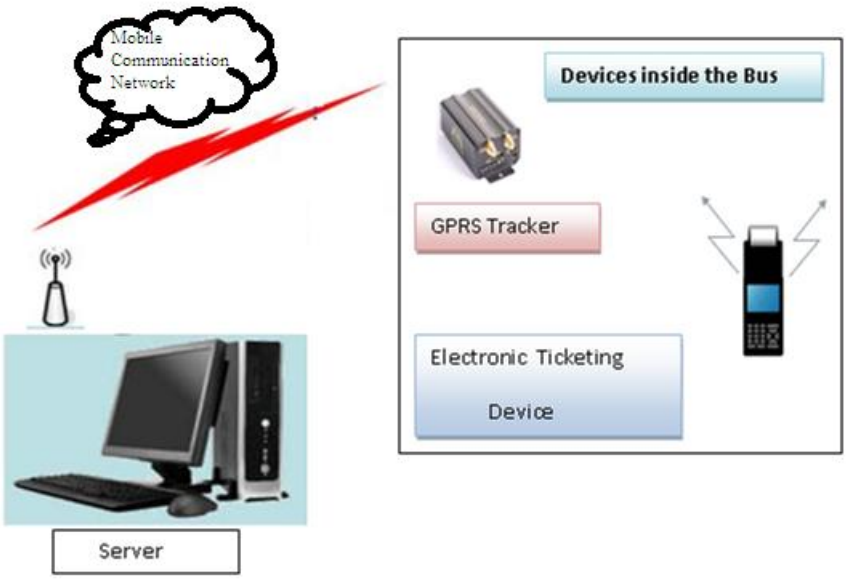
The objective of Electronic Ticketing Machine System is to enhance convenience of passengers and improve efficiency of bus fare collection management by automating the ticketing process. This reduces or eliminate work volume for manual ticketing work and improves management efficiency of conductor shifting, revenue, etc.

Introducing smartcard for Electronic Ticketing Machine System contributes to the following aspects as wel:;

- To minimize the use of cash
- To reduce paper-based ticket
- To improve convenience of transit to other transport modes (by introducing common mobility card)
- To introduce flexible discount service such as for student, senior citizens, etc.

- To realize plain distance-based fare payment system
- To improve bus route and bus service hours and optimise the number of bus by analysing passenger trip information as big data.

The figure below shows an image of electronic ticket management system



(Source : Edited by JICA Study Team based on Materials on Compass icons Website and Pinterest Website)

Figure 6.48 Image of Electronic Ticket Management System

Revenue collection details are transmitted to central Electronic Ticketing Machine System server at regular intervals or by batch mode (for example end of trip or shift). Data received at the server is processed, analyzed and reports generated as per the management requirement.

The figure below shows a typical electronic ticketing device.

(Source: Quantum Power Systems)

Figure 6.49 Typical Electronic Ticketing Device

This device consists of processing unit, touchpad, display, thermal printer and smart card reader. It can be easily carried by hand and it is operated by an internal chargeable battery. It also generates such reports as trip-wise revenue collection, shift-wise revenue collection, etc.

(2) Development Plan

a) **Electronic Ticketing Device**

Each bus conductor is equipped with Electronic ticketing Device (ETD) to issue tickets or validate the Smart card as the case may be.

Approximately 7600 numbers of ETD are proposed taking into consideration two conductors are assigned to one bus, working in different time schedule.

The revenue collection details are sent to the Electronic Ticketing Machine System server installed at the Tamil Nadu State Data Centre.

b) **Electronic Ticketing Machine System Server**

Electronic Ticketing Machine System server will be hosted at the Tamil Nadu State Data Centre and obtains data from BMS server.

c) **Operator for Electronic Ticketing Machine System at Metropolitan Transport Corporation Command Control Centre**

Operator for Electronic Ticketing Machine System console at the command control centre should be dedicated personnel. The operator for Electronic Ticketing Machine System manages and reports of revenue such as confirming the amount of revenue by hour, day, month, bus route, etc.

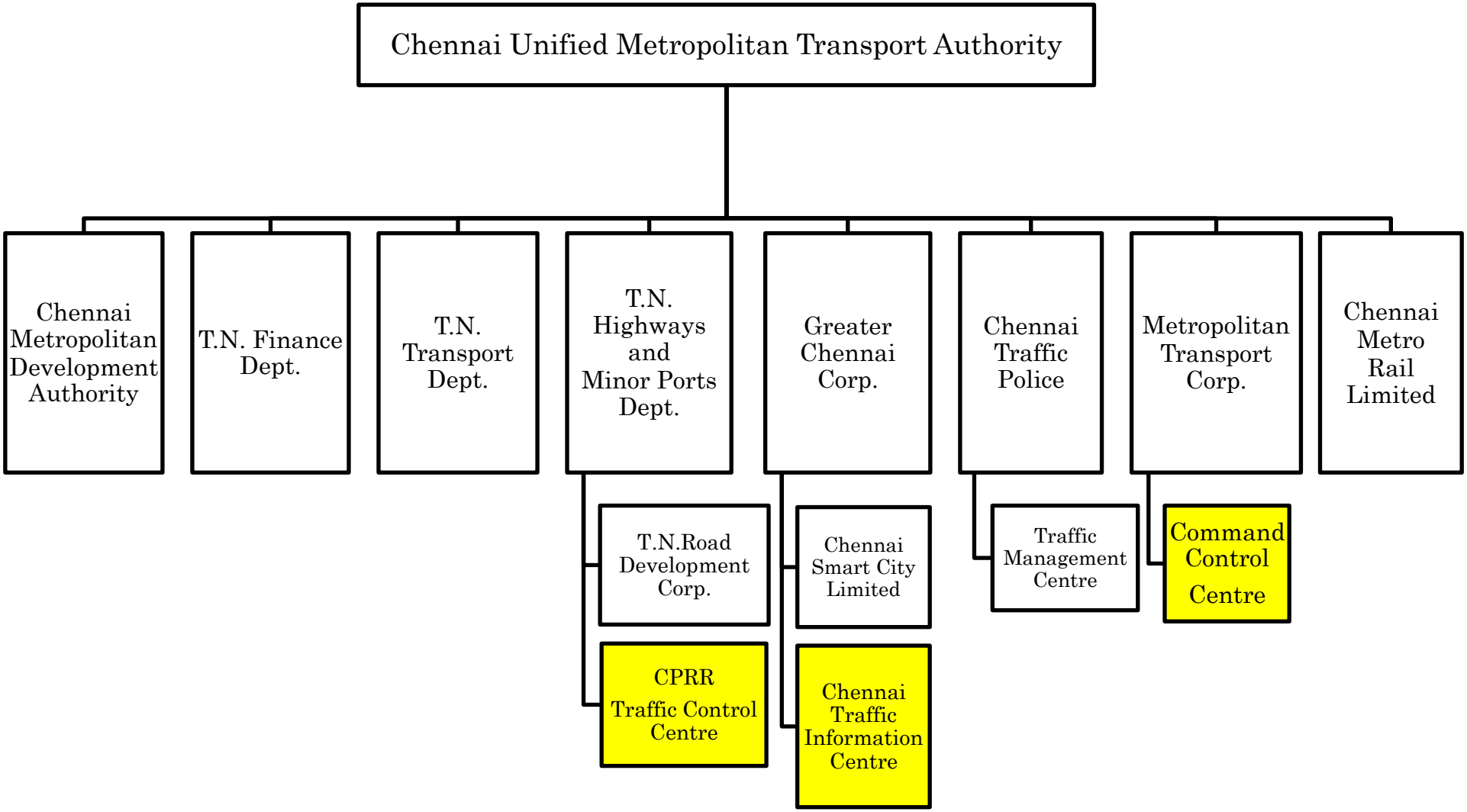
6.4.4 Current Status of ITS for Public Bus Transportation

Chennai Smart City Limited has planned to call tender regarding "Implementing ITS for Metropolitan Transport Corporation Buses" and they are preparing tender documents targeting February 2017 for announcement. The tender will be the single package and will include all systems described above (Bus Monitoring System (BMS), Passenger Information System, Electronic Ticket Management System).

7 Organization for ITS in Chennai

7.1 Proposed Organization Structure

Figure 7.1 shows an entire image of proposed organization structure for ITS in Chennai. The Study proposes to set up new centres for the selected ITS components, namely Chennai Traffic Information Centre, Traffic Control Centre for Chennai Peripheral Ring Road, and Command Control Centre for City Bus. As described in the previous chapter, Chennai Unified Metropolitan Transport Authority has been set up in Chennai for the purpose of decision making on urban transport issues and coordination amongst related agencies in the transport sector in Chennai. ITS requires to address cross-cutting issues for sustainable and proper operation, maintenance, planning and upgrading, and accordingly involvement and coordination of the related agencies are important. Therefore, the proposed new centres are recommended to be prepared under the individual responsible agencies under the framework of Chennai Unified Metropolitan Transport Authority as shown in the figure. It is also recommended to organize working group consisting of representatives of related organizations and convene regular meetings to discuss and exchange opinions of each organization. The participant members are recommended to include the departments under Chennai Unified Metropolitan Transport Authority, academic institutions such as Indian Institute of Technology- Madras and Anna University, NGOs, etc.



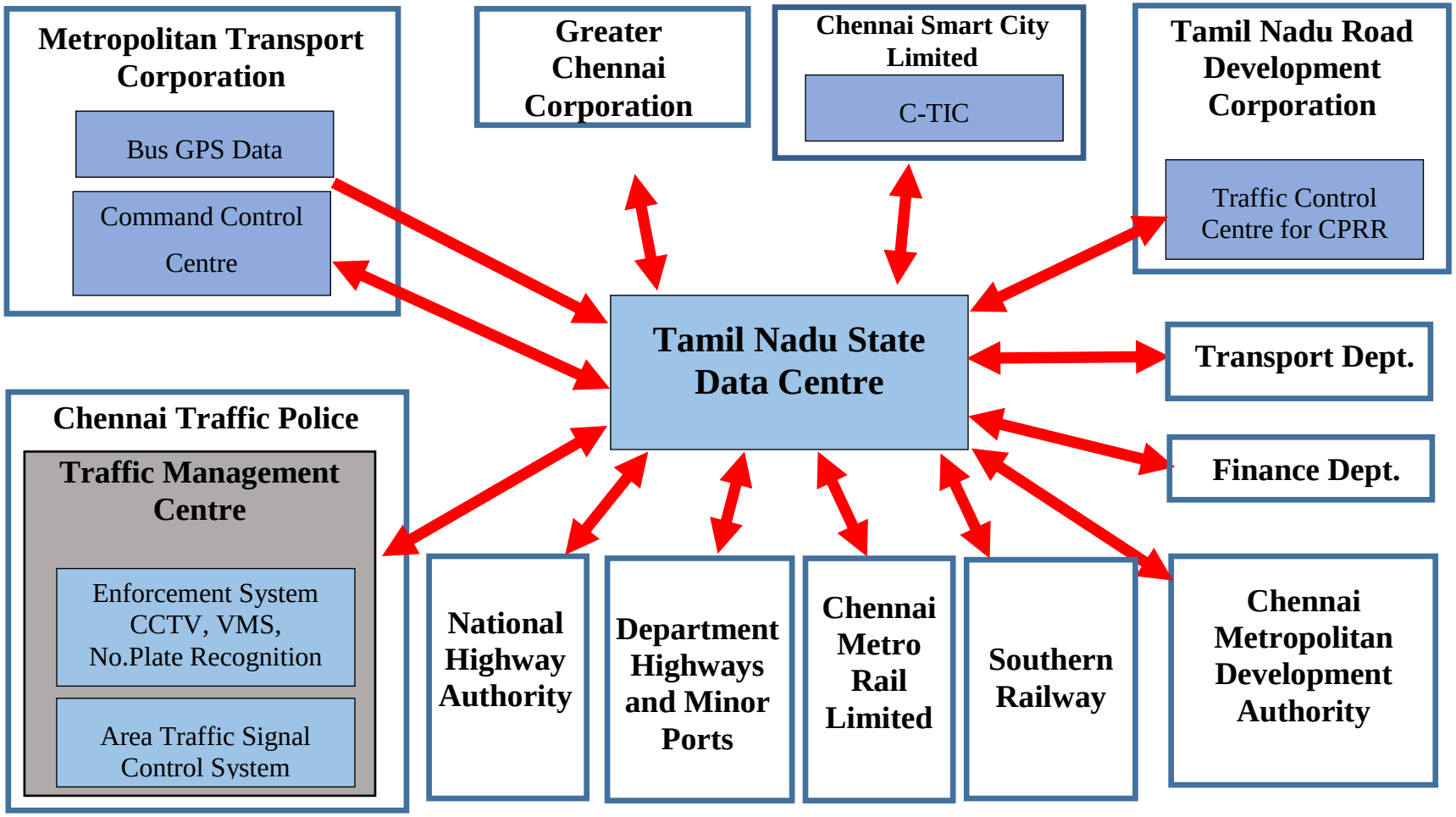
(Source: JICA Study Team)

Figure 7.1 Entire Image of Proposed Organization Structure for ITS in Chennai

7.2 **Involved Agencies and Data/Information Exchange**

Figure 7.2 shows the involved agencies and relation for information/data exchange. Centre servers of the new centres are recommended to install in Tamil Nadu State Data Centre, a data centre of Tamil Nadu State Government, because of good environment e.g. high security, favourable maintenance, etc. Data and information will be exchanged through the centre servers installed in Tamil Nadu State Data Centre with the relevant agencies as depicted in the figure.

The roles of each agency are explained in the following sections.



(Source: JICA Study Team)

Figure 7.2 Involved Agencies and Data/Information Exchange

7.3 Roles of Agencies for Selected ITS Component

7.3.1 Agencies for New Centres

(1) Chennai Smart City Limited

Chennai Smart City Limited is planned to establish as Special Purpose Vehicle by the Government of Tamil Nadu under Smart City Mission. The shareholder of Special Purpose Vehicle will be the Tamil Nadu Government and the Greater Chennai Corporation. One of the purposes of the Chennai Smart City Limited is to implement Intelligent Traffic Management System in the selected area for Smart City in Chennai.

It is proposed that the Chennai Smart City Limited will be the responsible agency of Chennai Traffic Information Centre for the following reasons.

- The purpose of the Chennai Smart City Limited is to carry out Intelligent Traffic Management System. On the other hand, the purposes of Chennai Traffic Information Centre are:
    - ✓ To disseminate the processed road/traffic information to users on a realtime basis
    - ✓ To utilise stored quantitative data for effective road and transport planning and operation
    - ✓ To share the road and transport information generated by Chennai Traffic Information Centre with related the related government agencies

  Since the purposes of both agencies match, it is best that Chennai Traffic Information Centre be set up under jurisdiction of the Chennai Smart City Limited.
- Chennai Traffic Information Centre collects the probe data from Metropolitan Transport Corporation buses and provides information on traffic congestion and time to destination to road users. The cumulated data and generated information will be also shared to government agencies Hence, the activities and coverage area of Chennai Traffic Information Centre extend across various government agencies as is the case with the Chennai Smart City Limited.

In order to achieve the objectives of the Chennai Smart City Limited, close coordination with the related government agencies and collection of traffic data are critical. Thus, the traffic data collected by Chennai Traffic Information Centre assists the activities of the Chennai Smart City Limited.

(2) Tamil Nadu Road Development Corporation

The Study recommends that Traffic Control Centre for Chennai Peripheral Ring Road will be developed for management of Chennai Peripheral Ring Road and providing traffic information to the Chennai Peripheral Ring Road users.

It is proposed that Tamil Nadu Road Development Company will be the responsible agency of Traffic Control Centre for Chennai Peripheral Ring Road because of the following reasons.

- Tamil Nadu Road Development Company will be the implementing agency for construction of Section-1 which is between Ennore port and NH5 (25.5 km) of Chennai Peripheral Ring Road. It is also the implementing agency for Outer Ring Road. The Outer Ring Road ends at Minjur town and the branch section of the Chennai Peripheral Ring Road also ends in the vicinity of Minjur town, and both trunk roads will be connected by bypass at this location. Tamil Nadu Road Development Company will be in charge of all these major roads including the sections toward Ennore port in the northern area of Chennai. Under the control of Tamil Nadu Road Development Company, the coordination such as traffic information exchange between Traffic Control Centre for Chennai Peripheral Ring Road and Outer Ring Road will be smooth.
- Tamil Nadu Road Development Company is the road administrator of major two toll roads in Chennai, which are SH49A and SH49. Therefore, Tamil Nadu Road Development Company has an experience of system operation and maintenance.

The following inputs are made for operation and maintenance of Traffic Control Centre for Chennai Peripheral Ring Road.

- Traffic Control Centre for Chennai Peripheral Ring Road collects various traffic data from roadside equipment installed along the Chennai Peripheral Ring Road. Close communication and coordination between Traffic Control Centre and maintenance team are required to maintain the equipment properly. It is recommended to locate the offices of Traffic Control Centre and maintenance team in the same building.

Traffic Control Centre for Chennai Peripheral Ring Road needs to provide the information such as road work, damage of pavement, slope failure, etc. Such information will be collected either by patrol cars for maintenance or road users.

(3) Metropolitan Transport Corporation

The Study recommends that City Bus Tracking System, City Bus Passenger Information System and Electronic Ticket Management System will be introduced. These systems will be developed for city bus and they will be introduced under Metropolitan Transport Corporation.

Metropolitan Transport Corporation is operating 3,800 city buses and bus network covers most of the major roads in Chennai metropolitan. There is a great potential that probe data obtained from GPS devices on the city buses can be utilised as a big data by Chennai Traffic Information Centre for analysis of traffic congestion on the road network in Chennai and generating dynamic congestion information, if GPS devices are introduced to all city buses.

In light of this, GPS devices on the city buses will be installed as one component of the City Bus Tracking System of Metropolitan Transport Corporation and Chennai Traffic Information Centre will utilise the probe data obtained from these GPS devices.

Metropolitan Transport Corporation will also utilise GPS positioning data for Bust Tracking System for management of city bus and City Bus Passenger Information System for convenience of passengers.

7.3.2 Other Agencies

(1) Tamil Nadu State Data Centre

Tamil Nadu State Data Centre is the data centre of Tamil Nadu State Government. They have a favourable environment such as sufficient redundancy power for continuous electric usage, adequate bandage of communication network, high data security, physical protection against intruders, etc. The servers of computer systems of the state government are installed here, and server operation and maintenance are being done by Tamil Nadu State Data Centre.

It is proposed that centre servers of the selected ITS components will be also installed here and server operation and maintenance be entrusted to Tamil Nadu State Data Centre. This greatly reduces burden of work load of the individual agency and a great amount of maintenance cost, and ensures data security. All data and information will be collected, exchanged and disseminated through Tamil Nadu State Data Centre.

(2) Chennai Traffic Police

The Study recommends that Area Traffic Signal Control System (ATSC) and VMS board will be introduced in Chennai. Operating traffic signal and providing traffic information come under jurisdiction of Traffic Police in view of controlling traffic in the city. Therefore, ATSC and VMS will be introduced under Chennai Traffic Police and they will be operated by them.

The congestion status on the road network in Chennai will be calculated from GPS probe data by Chennai Traffic Information Centre. The results of the calculation will be transmitted from Chennai Traffic Information Centre to Traffic Management Centre of Chennai Traffic Police. VMS installed on the roadside under Traffic Management Centre will automatically display the congestion status together with expected travel time to major landmark ahead as dynamic traffic information. Chennai Traffic Police manually input necessary messages such as accident as required at Traffic Management Centre and the messages will also be displayed by VMS.

(3) Department of Highways and Minor Ports

Department of Highways and Minor Ports is the road administrator of Inner Ring Road. Information on Inner Ring Road such as planned/completed road work, lane/road closure, etc. will be informed to Chennai Traffic Information Centre by Department of Highways and Minor Ports and Chennai Traffic Information Centre will incorporate such information into road traffic information to be provided to users. The compiled data sets of cumulated road traffic data such as monthly, yearly summary, results of analyses of traffic situation, etc. will be shared to Department of Highways and Minor Ports by Chennai Traffic Information Centre and they will be utilised for road planning, maintenance and evaluation of the project by Department of Highways and Minor Ports.

(4) National Highway Authority of India

National Highway Authority of India is the road administrator of the major trunk roads in Chennai which are NH5, NH205, NH4, NH45 and Chennai Bypass. Information on these roads such as planned/completed road work, lane/road closure, etc. will be informed to Chennai Traffic Information Centre by National Highway Authority of India and Chennai Traffic Information Centre will incorporate such information into road traffic information to be provided to users. The compiled data sets of cumulated road traffic data such as monthly, yearly summary, results of analyses of traffic situation, etc. will be shared to National Highway Authority of India by Chennai Traffic Information Centre and they will be utilised for road planning, maintenance and evaluation of the project by National Highway Authority of India.

(5) Chennai Metropolitan Development Authority, Transport Department, Finance Department and Chennai Metro Rail Limited

These agencies will utilise the data and information cumulated and generated by Chennai Traffic Information Centre for planning of road transport, carrying out transport studies, etc. Chennai Traffic Information Centre will share compiled data sets of cumulated road traffic data such as monthly, yearly summary, results of analyses of traffic situation, etc. This helps these agencies understand the traffic situation quantitatively and objectively such as transition of traffic volume of specific road, travel speed of peak hours and non-peak hours, changes of traffic flow before and after specific project, etc.

(6) Greater Corporation of Chennai

Greater Corporation of Chennai is the road administrator of city roads, many of which link the major trunk roads. Information on these roads such as planned/completed road work, lane/road closure, etc. will be informed to Chennai Traffic Information Centre by Greater Corporation of Chennai and Chennai Traffic Information Centre will incorporate such information into road traffic information to be provided to users. The compiled data sets of cumulated road traffic data such as monthly, yearly summary, results of analyses of traffic situation, etc. will be shared to Greater Corporation of Chennai by Chennai Traffic Information Centre and they will be utilised for road planning, maintenance and evaluation of the project by Greater Corporation of Chennai.

If the water height at underpass of the city roads reaches dangerous level on the occasion of heavy rain, Chennai Traffic Information Centre will inform Greater Corporation of Chennai.

Greater Corporation of Chennai is one of the shareholders of Chennai Smart City Limited which is a Special Purpose Vehicle and the chairperson of board meeting of Special Purpose vehicle is the commissioner of Greater Corporation of Chennai. It is highly expected that the Chennai Traffic Information Centre will be established under Special Purpose vehicle of Chennai Smart City Limit. Hence, decision making on the issues related to Chennai Traffic Information Centre and coordination with high level officials of the related agencies as required may be made upon request made by Chennai Traffic Information Centre.

Recommendation of Involvement of Academic Institute

Indian Institute of Technology- Madras and Anna University are actively conducting research and development activities on ITS together with Tamil Nadu government. It is recommended that the cumulated data on traffic in Chennai Traffic Information Centre be fully utilized sharing with these academic institutions upon their request to assist their research and development activities.

7.4 Roles of Chennai Traffic Information Centre and Involvement of Related Agencies

This section explains about the roles of Chennai Traffic Information Centre and how the related agencies are involved.

7.4.1 Role of Chennai Traffic Information Centre: Utilisation of Stored Data in Chennai Traffic Information Centre

The roles of Chennai Traffic Information Centre are: (i) providing dynamic traffic information to users on realtime basis and (ii) enabling related government agencies to utilise quantitative traffic data.

The quantitative data stored and cumulated in Chennai Traffic Information Centre will be utilised for road and transport planning, operation, maintenance and evaluation of the project. The processed data will be stored for certain period and the data will be shared in a compiled format with the related government agencies upon their request. The following items are major examples of utilisation of the stored data in Chennai Traffic Information Centre.

- Finding cause of bottleneck by identifying starting point of congestion.
- Finding alternative route by identifying peak hours and transition of queue length of road which is parallel to other route.
- Predicting the congestion status on arterial road to encourage users to use alternative route by notifying in advance.
- Understanding influence of road/lane closure of road work, adverse weather on traffic flow.
- Understanding correlation between contribution ratio of large sized vehicles and pavement damage.
- Compiling transition and tendency of congestion status by elapsed time.
- Compiling average travel speed and travel time by hour, day month and season to understand the tendency of changes on peak hours, weekday, holiday and festival season.
- Understanding the effectiveness of construction/extension of road, metro, flyover, etc. by comparing traffic status between before and after the project.
- Predicting the road which will be flooded/not flooded during heavy rain.

7.4.2 **Data/Information Sharing with Related Agencies**

For the above purposes, major examples of data/information sharing are:

- To share with traffic administrator (Chennai Traffic Police), road administrators (Greater Corporation of Chennai, Tamil Nadu Road Development Company, Highways and Minor Ports Dept. and National Highway Authority of India), planning agencies and other agencies to utilise for their purposes e.g. traffic/road management, infrastructure planning, project evaluation, etc.
- To share with Traffic Control Centre of Chennai Peripheral Ring Road in such case of occurrence of big accident which may affect each other (Chennai Peripheral Ring Road and roads in the city) such as secondary accident, road closure of Chennai Peripheral Ring Road, etc. (After Traffic Control Centre of Chennai Peripheral Ring Road is developed)
- To provide parking availability information of off-road public parking lot to users. (In future)

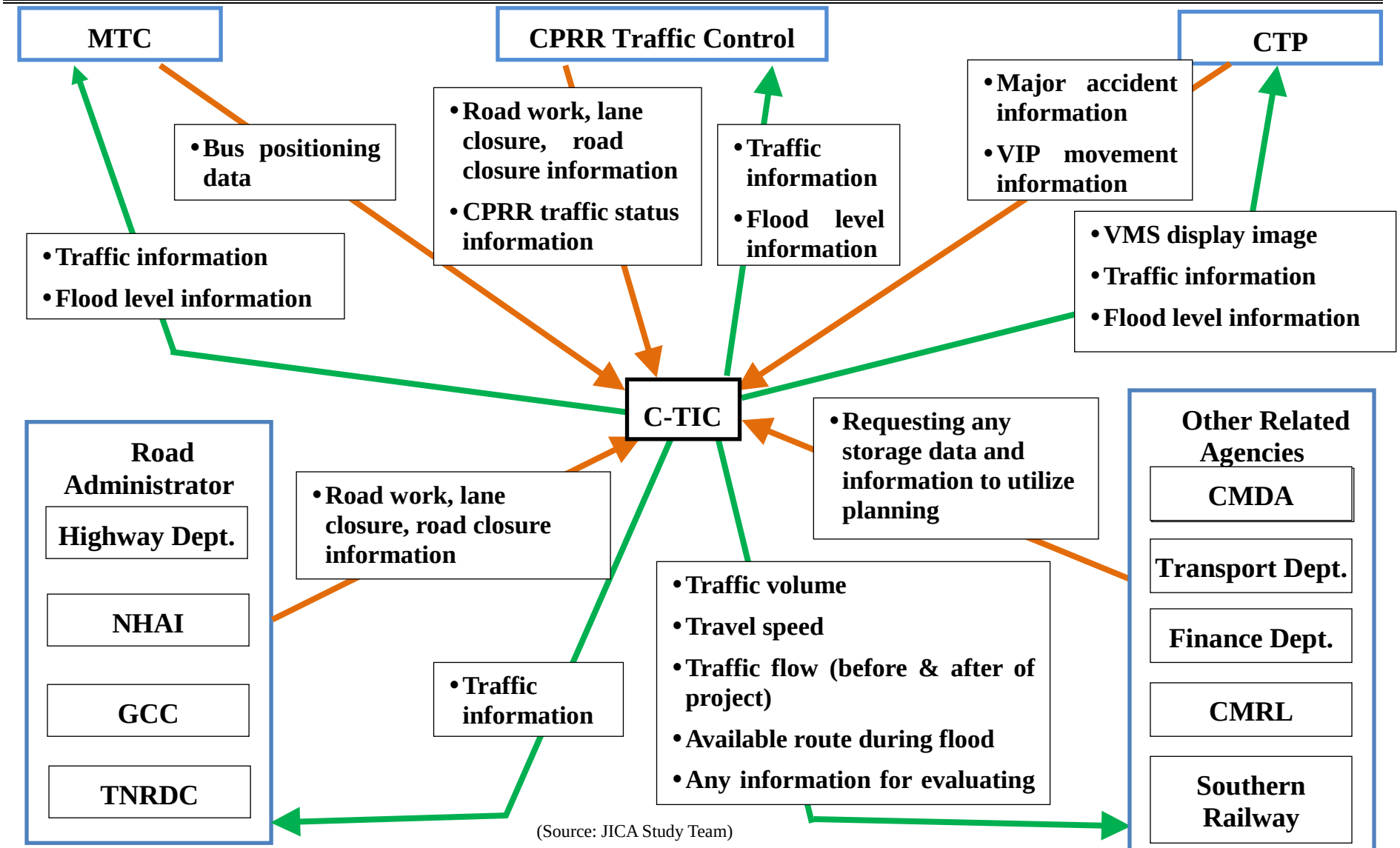
Following Table and Figure show information to be exchanged between Chennai Traffic Information Centre and each agency

Table 7-1 Information Exchange Between Chennai Traffic Information Centre and Agency

Name of Agencies	Roles of Agency	Information to Be Exchanged Between C-TIC and Agency	
		From C-TIC	To C-TIC
TNSDC	Managing C-TIC server without any stop	N/A	N/A
Smart City Limited	• Implementation of Smart City including ITS and management of C-TIC	• Traffic information of roads in selected area	• Any support for coordination of C-TIC's activities.
TNRDC	• Road administrator and planning/coordination of major highways in Chennai such as CPRR (Section-1), ORR, SH49A and SH49 • Traffic Control Centre of CPRR will be under jurisdiction of TNRDC	• Traffic Information of roads in city • Flood level information on the occasion of heavy rain.	• Information of road work, lane closure, road closure and other information of the roads under the jurisdiction of TNRDC
Traffic Control Centre for CPRR (Under TNRDC)	• Management of CPRR • Collection and processing the data collected from roadside equipment and provision of realtime traffic/road/weather information to users on CPRR • Maintenance of ITS roadside equipment and centre system	• Traffic Information of roads in city • Flood level information on the occasion of heavy rain.	• Information of road work, lane closure, road closure and major accident on the CPRR • Information of traffic volume and congestion status on CPRR
MTC	• City bus management • Collection and processing the data collected from GPS devices and provision of passenger information	• Traffic Information of roads in city • Flood level information on the occasion of heavy rain.	• Bus positioning data collected from GPS on city bus (C-TIC collects directly from the server at TNSDC)
Chennai Traffic Police	• Enforcement of vehicles violating traffic rule • Traffic administrator of ordinary roads in Chennai • Providing traffic status information to road users	• Calculation result of congestion status and expected travel time to major destination (to be displayed on VMS with schematic image of road map) • Traffic information of roads in	• Major accident information • VIP movement information

	• Maintenance of ITS roadside equipment and signals	city • Flood level information on the occasion of heavy rain	
Highway Dept.	• Road administrator and planning/coordination of State Highways in Chennai such as CPRR (Section 2 to Section 5)	• Traffic Information of roads in city • Flood level information on the occasion of heavy rain	• Information of road work, lane closure, road closure and other information of the roads under the jurisdiction of each agency
NHAI	• Road administrator and planning/coordination of National Highways in Chennai such as NH45, NH4, NH5 and NH205		
GCC	• Road administrator and planning/coordination of city roads and other infrastructures in Chennai		
CMDA	• Planning agency for Chennai metropolitan area such as Master Plan, New Town Development Plan, etc.	• Transition of traffic volume of specific road over time • Travel speed during non-peak hours and peak hours • Changes in traffic flow before and after project • Available route information on the occasion of flood • Other information useful for evaluating projects, carrying out studies, etc.	• Requesting stored data and information to utilise for planning and evaluation
Transport Dept.	• Management of vehicle registration • Management and issuing vehicle number plate and driver's license • Controlling vehicular emission		
Finance Dept.	• Facilitating infrastructure development projects • Preparing budget for projects • Preparing feasibility study report and DPR		
CMRL	• Construction and operation of Chennai metro		

(Source: JICA Study Team)



(Source: JICA Study Team)

Figure 7.3 Image of Information Exchange Between Chennai Traffic Information Centre and Each Agency

8 Rough Cost Estimate

Based on the studies so far, the rough cost of the ITS components is estimated as shown in following Table. The cost for the long-term is not calculated because of uncertainty of various aspects in the future.

Table 8-1 Rough Cost Estimate

Unit=INR crore

ITS Component		Equipment Cost	O&M Cost(Annual)	Equipment Cost	O&M Cost(Annual)	Equipment Cost	O&M Cost(Annual)
		Short Term (stage-1)		Short Term (stage-2)		Mid Term	
Chennai Traffic Information System (C-TIC)	Centre System (including Probe System, Internet System)	43.5	**7.3**		**7.3**	1.4	**7.4**
	Automatic Traffic Counters-cum-classifier (ATCC) System	22.6					
	Flood Measurement and Warning System	7.0					
Subtotal		**73.1**				**1.4**	
City Bus System (MTC)	Bus monitoring System	14.6	**13.0**		**13.0**		**13.0**
	Passenger Information System	38.7					
	Electronic Ticket ManagementSystem	76.6					
Subtotal		**129.9**					
Traffic Management System (Chennai Traffic Police)	Traffic Management Centre	8.7	**18.2**	0.6	**40.5 (18.2+22.3)**		**40.5**
	Area Traffic Signal Control System	146.6		222.6			
	CCTV Traffic Monitoring System	4.7					
	Variable Message Sign (VMS) System	21.9					
Subtotal		**181.9**		**223.2**			
ITS for Chennai Peripheral Ring Road (CPRR)	Highway Traffic Management Sytem (HTMS)					150.1	15.0
	Toll Management System (TMS)					30.6	3.1
Subtotal						**180.7**	
Grand Total		**384.9**	**38.5**	**223.2**	**60.8**	**182.1**	**79.0**

Total (Equipment)	**790.2**

※The above cost includes contingency at 10%.

※The cost for minimal civil work for improvement of intersection is included in Advanced Traffic Signal System

※The cost for operation and maintenance is calculated at 10% of the equipment cost

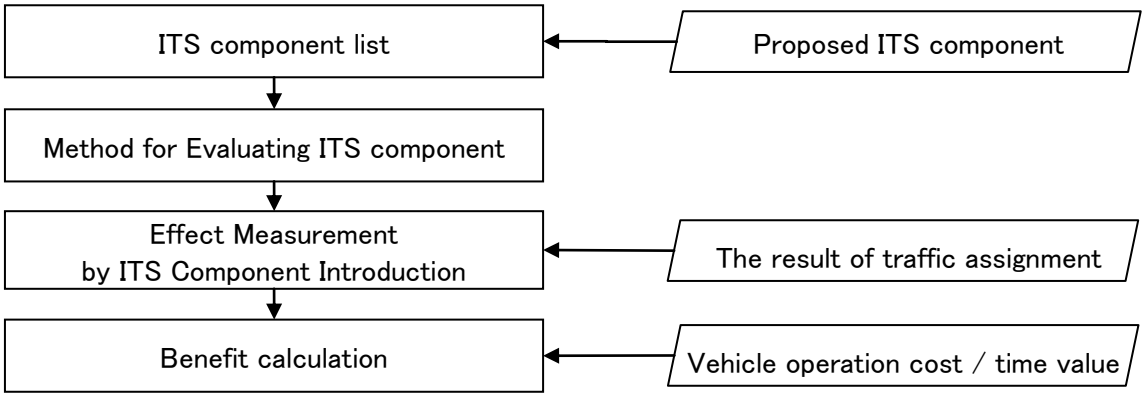
(Source: JICA Study Team)

9 ITS Evaluation

9.1 Objective and Procedure

The effectiveness of ITS component is evaluated in this section. The flow of evaluation of ITS component is shown in the figure below.

It is necessary to measure the ITS effect by the traffic assignment. The results of the traffic assignment before and after ITS introduction are compared and to measure the ITS effect. Therefore, evaluable ITS component is limited to the components that directly affect the traffic flow. Because the provision of traffic information and traffic signal control largely contribute to traffic flow, it is targeted for the evaluation. The reduction of travel time and vehicle operation cost by the ITS effect is calculated in terms of monetary value as benefit.



(Source: JICA Study Team)

Figure 9.1 Flow of Evauation of ITS Introduction

9.2 ITS Component for Evaluation

The ITS components to be evaluated are listed in Table 9-1.

ITS components of traffic information system and area traffic signal control system were evaluated. There are several ITS components of the traffic information system for each stage of process, i.e. data collection, data processing and information provision. These ITS components were included in the evaluation of the traffic information system as shown in Table 9-1.

ITS components which do not directly affect the traffic flow were excluded from the evaluation.

Toll Management System relieves the queue at the tollgate by automating the toll collection and it reduces the travel time. But, Toll Management System is road ancillary equipment of Chennai Peripheral Ring Road. Therefore, the effect of construction of Chennai Peripheral Ring Road and Toll

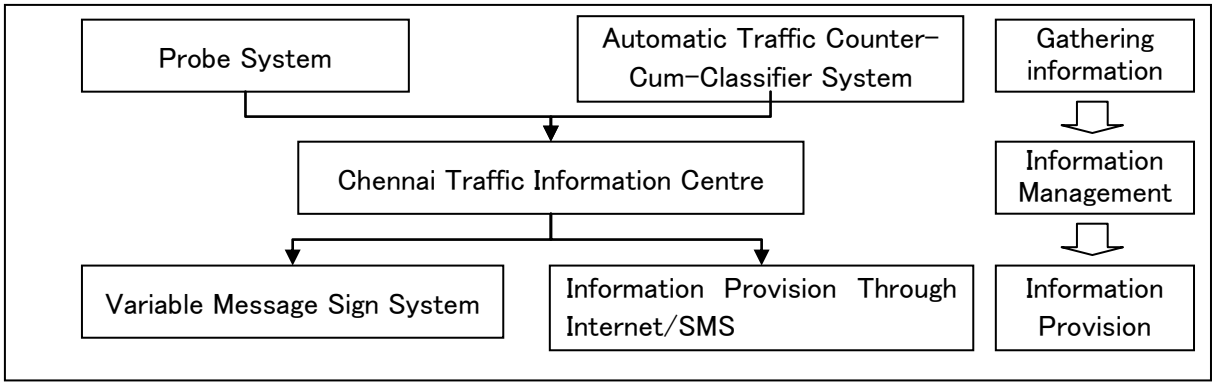
Management System should be evaluated together with. However, the project cost for the construction is not clear yet. Thus, the evaluation of Toll Management was excluded.

Various effects are expected to be brought by city bus systems. For example, a reliable bus service will be realized by introduction of Command Control Centre and Bus Monitoring System which monitor bus drivers that sometimes take wrong routes. The time required for the passengers to wait bus will be reduced and anxiety of the passengers who do not know when their buses come will be relieved by providing expected arrival time through Bus Passenger Information System. The waiting queue of the passengers for bus fare payment will be relieved and the stopping time of the bus at the bus stop will be reduced, consequently resulting in reduction of travel time by Electronic Ticket Management System. Such improvements of the bus services are expected to contribute to increase in the number of bus users. However, various factors other than introduction of the city bus systems have been considered for modal shift to public transport in this study. Therefore, the ITS components of the city bus systems were excluded from the evaluation.

Table 9-1 List of ITS Component for Evaluation

	ITS Component	Evaluation
1)	Chennai Traffic Information Centre	Effect measurement by the information service
2)	Traffic Management Centre for Traffic Police	It is excluded because it does not directly affect the traffic flow.
3)	Highway Traffic Management System for CPRR	It is excluded because it does not directly affect the traffic flow.
4)	Probe System	Effect measurement by the information service
5)	Automatic Traffic Counter-Cum-Classifier System	Effect measurement by the information service
6)	CCTV Traffic Monitoring System	It is excluded because it does not directly affect the traffic flow.
7)	CCTV Enforcement System for Violated Vehicle	It is excluded because it does not directly affect the traffic flow.
8)	No. Plate Recognition System	It is excluded because it does not directly affect the traffic flow.
9)	Flood Measurement and Warning System	It is excluded because it effect only at the time of disaster.
10)	Variable Message Sign System	Effect measurement by the information service
11)	Toll Management System	It is excluded because it is a expressway ancillary equipment.
12)	Information Provision Through Internet/SMS	Effect measurement by the information service
13)	Area Traffic Signal Control System	Effect measurement by the signal control
14)	Weigh in Motion System for CPRR	It is excluded because it does not directly affect the traffic flow.
15)	Road Accident Data Management System	It is excluded because it does not directly affect the traffic flow.
16)	Command Control Centre for City Bus	It is excluded because it does not directly affect the traffic flow.
17)	Bus Monitoring System	It is excluded because it does not directly affect the traffic flow.
18)	Passenger Information System(PIS)	It is excluded because it does not directly affect the traffic flow.
19)	Electronic Ticket Management System(ETM)	It is excluded because it does not directly affect the traffic flow.
20)	Clearinghouse and Common Smart Card	It is excluded because it does not directly affect the traffic flow.
21)	Parking Management System	It is excluded because it does not directly affect the traffic flow.
22)	Road Inventory Database	It is excluded because it does not directly affect the traffic flow.
23)	Footpath/Bicycle Way Information Provision System	It is excluded because it does not directly affect the traffic flow.
24)	Bicycle Sharing System	It is excluded because it does not directly affect the traffic flow.
25)	Commercial Vehicle Tracking System	It is excluded because it does not directly affect the traffic flow.

(Source: JICA Study Team)



(Source: JICA Study Team)

Figure 9.2 ITS Components of Traffic Information System at Each Processing Stage

9.3 Method for Evaluation of Introduction of ITS

9.3.1 Case for Evaluation

The combination of Traffic Information System and Area Traffic Signal Control System was evaluated.

Table 9-2 Case for Evaluation

Case	ITS Component
1	Area Traffic Signal Control System and Traffic Information System

(Source: JICA Study Team)

9.3.2 Method of Effect Measurement of Introduction of ITS Component

Method of effect measurement by ITS component introduction is shown in Table 9-3.

As for the effect of the introduction of Area Traffic Signal Control System, reduction of the delay time at the intersection is expressed by increase in link capacity and velocity. As for the effect of introduction of Traffic Information System, optimized traffic flow is expressed by increasing the number of traffic distribution, applying incremental assignment method (*).

(*) Incremental Assignment: Origin-Destination (OD) traffic volume is divided and distributed to the shortest route and this is repeated by the divided number. By increasing the divided numbers and distributing OD traffic volume accordingly, the route is progressively selected avoiding the congested routes. This reproduces the situation in which the traffic information is provided and the congested route is avoided.

Table 9-3 Method of Effect Measurement by ITS Component Introduction

ITS Component	Method of Effect Measurement by ITS Component Introduction	
Area Traffic Signal Control System	Without Case	Adopting a similar link capacity of current situation.
	With Case	Increasing 10% in the link capacity of intersection with the traffic signal system in terms of traffic volume and velocity
Traffic Information System	Without Case	Adopting Incremental Assignment: five times (All vehicles)
	With Case	Adopting Incremental Assignment: ten times: The vehicle to pass the Variable Message Sign position in Without Case. five times: Other Vehicles

(Source: JICA Study Team)

The conditions of increasing in link capacity in terms of traffic volume and velocity to be realized by introduction of Area Traffic Signal Control System were set, referring to the following survey results.

<Link Capacity in terms of Traffic Volume>

It was set targeting to improve the traffic situation on weekday to the level on holiday. Table 9-4 shows the result of existing traffic survey carried out in Chennai in 2013. Table 9-5 shows the aggregated result by weekdays and holidays. This shows that the traffic volume increases 11% on weekdays compared to holidays. This means that the capacity of intersection (link capacity) needs to be increased approximately 10% to realize the traffic situation which is almost identical to holiday. Therefore, increasing 10% in link capacity in terms of traffic volume was set.

<Link Capacity in terms of Velocity>

It was set referring to the case in Japan which improved the travel speed after introduction of Area Traffic Signal Control System. Table 9-6 shows the result of travel speed improved by Area Traffic Signal Control System in Japan. It shows 13% increase in the travel speed. Taking into consideration the difference of various factors between the traffic situations in Japan and India, increasing 10% in link capacity in terms of velocity (travel speed) was set.

Table 9-4 The Result of Traffic Volume Survey in Chennai in 2013

Daily variation of traffic (PCU)	TVC-1	TVC-2	TVC-3	TVC-4	TVC-5	TVC-6	TVC-7	TVC-8	TVC-9	TVC-10	TVC-11	TVC-12	TVC-13	TVC-14	TVC-15
	ECR	SH49	NH45	SH57	SH57	NH4	SH57	SH50	NH205	SH57	SH50	SH51	NH5	SH104	Minjur
Satruday	13,857	3,942	88,681	9,028	17,018	63,074	12,906	13,220	11,817	5,946	10,926	13,393	50,188	6,036	2,992
Sunday	13,815	4,096	80,613	5,553	25,114	50,714	10,003	15,637	10,354	5,311	10,962	13,940	40,092	5,556	3,149
Monday	12,850	3,948	95,155	10,586	26,815	64,086	13,161	14,689	12,627	6,357	10,393	13,840	53,718	6,056	3,149
Tuesday	11,862	4,176	95,028	10,492	26,269	62,232	13,640	13,628	12,079	6,359	11,470	14,139	55,421	5,728	3,077
Wednesday	13,276	4,491	94,941	10,609	25,936	64,456	13,773	14,337	10,614	5,448	12,394	15,177	44,941	5,714	3,223
Thursday	14,176	3,999	96,897	10,679	23,667	69,890	13,724	15,003	12,444	6,245	10,822	13,483	52,862	5,228	3,065
Friday	15,079	4,254	100,754	9,563	18,702	68,093	13,400	15,453	12,230	6,431	10,825	16,408	51,636	5,374	2,738

(Source: Summarized by JICA Study Team based on 'DPR on CPRR')

Table 9-5 Aggregated Result of Traffic Volume Survey by Weekdays and Holidays in Chennai in 2013

	Average Traffic Volume (PPV)	Difference (Weekday-Holiday)	Increased Ratio
Holidays	20,598	2,542	11%
Weekdays	23,140		

(Source: Summarized by JICA Study Team based on 'DPR on CPRR')

Table 9-6 Result of Improved Travel Speed in Japan

	Before Signal Introduction	After Signal Introduction	Difference	Improved Ratio
	a	b	c=a-b	d=c/a*100
Travel speed (average) (km/hour)	23.35	26.45	3.1	13%

(Source: Summarized by JICA Study Team based on 'Report on the Effectiveness of Traffic Safety Facilities')

9.3.3 Setting Vehicle Operation Cost

Vehicle Operation Cost per unit distance is estimated by type of vehicle as shown in Table 9-7. It is composed of a) fuel cost, b) oil cost, c) tire cost, d) spare parts cost, e) maintenance cost, f) depreciation cost, g) crew cost, and h) other fix cost.

The unit price of Vehicle Operation Cost is set by the velocity according to the vehicle model. The unit price of Vehicle Operation Cost in India is defined by 'Comprehensive Transportation Study for Mumbai Metropolitan Region'. The unit price of Vehicle Operation Cost in 2005 (Table 9-7) was converted to the 2016 unit price using Yearly Wholesale Price Index (WPI) (Table 9-8). WPIs have been published until 2015. Yearly growth rate in 2016 was assumed to be 6.0% because the growth rate in 2014 and 2015 were 6%. The converted unit price of Vehicle Operation Cost unit price in 2016 is shown in Table 9-9.

Table 9-7 Unit Price of Vehicle Operation Cost in 2005

(Unit: INR /Vehicle-km)

Vehicle type (km/h)	Motorcycle	Car	Bus	LCV	Truck / MAV
10	2.49	6.11	26.06	18.30	25.41
20	1.89	4.11	17.92	12.31	17.67
30	1.74	3.29	16.40	10.00	15.04
40	1.55	2.88	14.63	8.78	13.65
50	1.57	2.82	13.58	8.08	12.25
60	1.63	3.05	15.47	8.20	12.57

（Source: Mumbai Metropolitan Region Development Authority）

Table 9-8 Yearly Wholesale Price Index : All Commodities

Year	Index	Growth Rate	Remark
2005	100	-	
2006	104.47	4.5%	
2007	111.35	6.6%	
2008	116.63	4.7%	
2009	126.02	8.1%	
2010	130.81	3.8%	
2011	143.32	9.6%	
2012	156.13	8.9%	
2013	167.62	7.4%	
2014	177.64	6.0%	
2015	181.19	6.0%	
2016	199.60	6.0%	Yearly growth rate in 2016 was used 6.0%

（Source: JICA Study Team created on the basis of 'Office of the Economic Adviser, Government of India, Ministry of Commerce & Industry, Department of Industrial Policy &Promotion'）

Table 9-9 Unit Price of Vehicle Operation Cost in 2016

(Unit: INR /Vehicle-km)

Vehicle type (km/h)	Motorcycle	Car	Bus	LCV	Truck / MAV
10	4.97	12.20	52.02	36.53	50.72
20	3.77	8.20	35.77	24.57	35.27
30	3.47	6.57	32.73	19.96	30.02
40	3.09	5.75	29.20	17.52	27.25
50	3.13	5.63	27.11	16.13	24.45
60	3.25	6.09	30.88	16.37	25.09

(Source: JICA Study Team)

9.3.4 Setting Travel Time Cost

Value of Time for Passenger Car (2009) is shown in Table 9-10. Value of Time for Cargo Vehicle (2009) is shown in Table 9-11.

The unit price of Travel Time Cost in 2009 is described on 'Manual on Economic Evaluation of Highway Projects in India'. As for cargo vehicle, daily commodity holding cost is converted into value of time.

The unit price of Travel Time Cost in 2009 (Table 9-10 and Table 9-11) was converted to the 2016 unit price using Yearly Wholesale Price Index (WPI) (Table 9-8). The unit price of Travel Time Cost in 2016 is shown in Table 9-12.

Table 9-10 Value of Time for Passenger Car in2009

Vehicle Type	Value of Time (INR per passenger-hour)	Average Occupancy (passenger/vehicle)	TCC (INR per vehicle-hour)
Motorcycle	32	1.5	48
Car	62.5	4.8	300
Bus	43.5	43	1870.5

(Source: Manual on Economic Evaluation of Highway Projects in India 2009)

Table 9-11 Value of Time for Cargo Vehicle in 2009

Vehicle Type	Commodity Holding Cost (INR per vehicle-day)	Time Conversion Coefficient	Travel Time Cost (INR per vehicle-hour)
LCV	58.10	1/12	4.8
Truck / MAV	333.0	1/12	27.8

(Source: Manual on Economic Evaluation of Highway Projects in India 2009)

Table 9-12 Travel Time Cost in 2016

Vehicle Type	Travel Time Cost (INR per vehicle-hour)
Motorcycle	76.0
Car	475.2
Bus	2,963.1
LCV	7.6
Truck / MAV	44.0

(Source: JICA Study Team)

9.4 Effect Measurement of Introduction of ITS Component

The effect by ITS component introduction was measured in short-term (2021), mid-term (2026) and long-term (2036). The effect was measured by liner interpolation between short-term, mid-term and long-term. The result of effect by ITS component introduction is shown in Table 9-13.

Table 9-13 Result of Effect of Introduction of ITS Component

	Year	Discount Rate	TTC(Unit = INR crore)									VOC(Unit = INR crore)									Σ (Unit=INR crore)	
	Base Year 2016		TW	Car	Auto Ricksha	Bus	LCV	Truck	MAV	Undiscount Σ	Discount Σ	TW	Car	Auto Ricksha	Bus	LCV	Truck	MAV	Undiscount Σ	Discount Σ	Undiscount Σ	Discount Σ
Operation	2021	0.5674	3.5	11.7	13.6	62.6	0.04	0.2	0.1	91.7	52.0	1.6	2.8	3.1	9.2	1.7	1.7	0.7	20.8	11.8	113	64
1	2022	0.5066	3.7	12.3	14.5	73.9	0.04	0.4	0.2	104.9	53.1	1.7	2.9	3.3	11.1	1.9	5.8	2.3	29.2	14.8	134	68
2	2023	0.4523	3.9	12.8	15.4	85.1	0.05	0.6	0.2	118.1	53.4	1.9	3.1	3.6	13.0	2.2	9.9	4.0	37.6	17.0	156	70
3	2024	0.4039	4.1	13.4	16.2	96.4	0.06	0.8	0.3	131.3	53.0	2.1	3.2	3.8	14.9	2.5	14.0	5.6	46.0	18.6	177	72
4	2025	0.3606	4.3	14.0	17.1	107.7	0.06	1.0	0.4	144.5	52.1	2.2	3.3	4.1	16.8	2.8	18.1	7.2	54.4	19.6	199	72
5	2026	0.3220	4.6	14.5	18.0	119.0	0.07	1.2	0.5	157.7	50.8	2.4	3.4	4.3	18.6	3.0	22.2	8.8	62.8	20.2	221	71
6	2027	0.2875	4.7	14.8	18.2	120.5	0.07	1.2	0.5	160.0	46.0	2.5	3.5	4.4	18.6	3.1	22.1	9.9	64.0	18.4	224	64
7	2028	0.2567	4.8	15.1	18.5	122.0	0.07	1.2	0.6	162.2	41.6	2.5	3.6	4.4	18.6	3.1	22.0	11.0	65.3	16.8	227	58
8	2029	0.2292	4.9	15.3	18.7	123.5	0.08	1.2	0.6	164.4	37.7	2.6	3.7	4.5	18.6	3.2	21.9	12.1	66.5	15.2	231	53
9	2030	0.2046	5.1	15.6	19.0	125.0	0.08	1.2	0.7	166.6	34.1	2.7	3.7	4.5	18.6	3.2	21.9	13.1	67.8	13.9	234	48
10	2031	0.1827	5.2	15.9	19.2	126.5	0.08	1.2	0.7	168.8	30.8	2.7	3.8	4.6	18.6	3.3	21.8	14.2	69.0	12.6	238	43
11	2032	0.1631	5.3	16.1	19.5	128.0	0.08	1.3	0.7	171.1	27.9	2.8	3.9	4.6	18.6	3.4	21.7	15.3	70.2	11.5	241	39
12	2033	0.1456	5.4	16.4	19.7	129.5	0.08	1.3	0.8	173.3	25.2	2.9	3.9	4.7	18.6	3.4	21.6	16.4	71.5	10.4	245	36
13	2034	0.1300	5.6	16.7	20.0	131.0	0.09	1.3	0.8	175.5	22.8	2.9	4.0	4.7	18.6	3.5	21.6	17.5	72.7	9.5	248	32
14	2035	0.1161	5.7	17.0	20.3	132.5	0.09	1.3	0.9	177.7	20.6	3.0	4.1	4.8	18.5	3.5	21.5	18.5	74.0	8.6	252	29
15	2036	0.1037	5.8	17.2	20.5	134.0	0.09	1.3	0.9	179.9	18.7	3.1	4.2	4.8	18.5	3.6	21.4	19.6	75.2	7.8	255	26
Σ (2021～2036)			76.6	238.7	288.4	1,817.4	1.13	16.6	8.9	2,447.8	620.0	39.5	57.0	68.2	269.5	47.4	289.2	176.2	947.0	226.6	3,395	847

(Source: JICA Study Team)

9.5 Cost for ITS Component

The cost for ITS component is shown in Table 9-14.

As for Traffic Information System, a half amount of initial investment was allocated every five years after introduction as update cost. The cost for expansion was also allocated according to the implementation schedule shown in Chapter 5. However, the update cost for the expanded system was not allocated due to the reason that surrounding environment and related factors such as technologies and traffic situation may change in the future.

As for Area Traffic Signal Control System, a half amount of initial investment was allocated nine years after introduction as update cost. The allocated amount is further distributed into three years before and after nine years i.e. eight, nine and ten years after introduction, considering required construction period.

Table 9-14 Cost for ITS Component

	Year	Discount Rate	Undiscount(Unit=INR crore)				Discount(Unit=INR crore)				Σ (Unit=INR crore)			
			Chennai Traffic Information System		Traffic Management System		Chennai Traffic Information System		Traffic Management System		Undiscount		Discount	
	Base Year 2016		Equipment	O&M	Equipment	O&M	Equipment	O&M	Equipment	O&M	Equipment	O&M	Equipment	O&M
	2017	0.8929					0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	2018	0.7972	24.4		60.6		19.4	0.0	48.3	0.0	85.0	0.0	67.8	0.0
	2019	0.7118	24.4		135.0		17.3	0.0	96.1	0.0	159.4	0.0	113.5	0.0
	2020	0.6355	24.4		135.0		15.5	0.0	85.8	0.0	159.4	0.0	101.3	0.0
Operation Start	2021	0.5674		7.3	74.4	18.2	0.0	4.1	42.2	10.3	74.4	25.5	42.2	14.5
1	2022	0.5066		7.3		58.7	0.0	3.7	0.0	29.7	0.0	66.0	0.0	33.4
2	2023	0.4523		7.3		58.7	0.0	3.3	0.0	26.6	0.0	66.0	0.0	29.9
3	2024	0.4039	0.5	7.3		58.7	0.2	3.0	0.0	23.7	0.5	66.0	0.2	26.7
4	2025	0.3606	37.0	7.3		58.7	13.3	2.6	0.0	21.2	37.0	66.0	13.3	23.8
5	2026	0.3220	0.5	7.3		58.7	0.1	2.4	0.0	18.9	0.5	66.0	0.1	21.3
6	2027	0.2875		7.4		58.7	0.0	2.1	0.0	16.9	0.0	66.2	0.0	19.0
7	2028	0.2567		7.4		58.7	0.0	1.9	0.0	15.1	0.0	66.2	0.0	17.0
8	2029	0.2292		7.4	61.5	58.7	0.0	1.7	14.1	13.5	61.5	66.2	14.1	15.2
9	2030	0.2046	36.6	7.4	61.5	58.7	7.5	1.5	12.6	12.0	98.1	66.2	20.1	13.5
10	2031	0.1827		7.4	61.5	58.7	0.0	1.4	11.2	10.7	61.5	66.2	11.2	12.1
11	2032	0.1631		7.4		58.7	0.0	1.2	0.0	9.6	0.0	66.2	0.0	10.8
12	2033	0.1456		7.4		58.7	0.0	1.1	0.0	8.6	0.0	66.2	0.0	9.6
13	2034	0.1300		7.4		58.7	0.0	1.0	0.0	7.6	0.0	66.2	0.0	8.6
14	2035	0.1161	36.6	7.4		58.7	4.2	0.9	0.0	6.8	36.6	66.2	4.2	7.7
15	2036	0.1037		7.4		58.7	0.0	0.8	0.0	6.1	0.0	66.2	0.0	6.9
Σ (2016～2036)			184.1	118.4	589.8	898.8	77.7	32.7	310.5	237.2	773.9	1,017.2	388.1	269.9

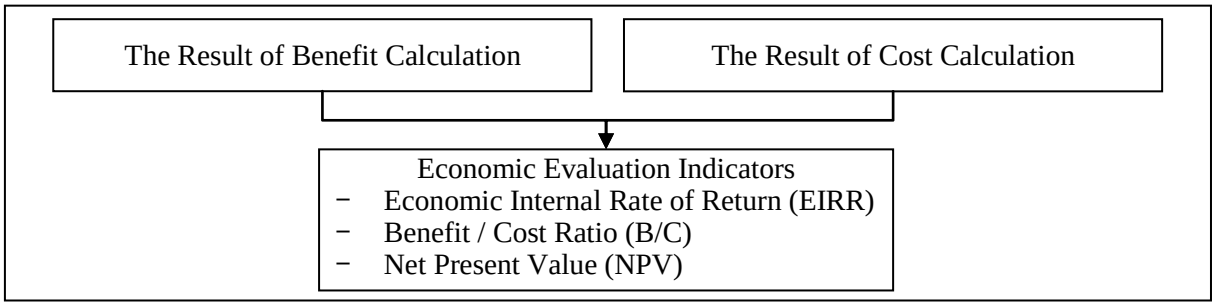
(Source: JICA Study Team)

10 Economic Analysis

10.1 Objective and Procedure

ITS, such as providing information and signal control, play an important role in the smoother transportation and traffic safety. The smoother transportation is directly linked to a reduction in logistic cost in the trade city like a Chennai. Therefore, the profits of the company and tax revenue increase, and the economy of the city is greatly promoted.

However, it is necessary to confirm about the economic validity of ITS. The economic validity of the project is expressed by Economic Internal Rate of Return(EIRR), Benefit, Cost Ratio (B/C) and Net Present Value (NPV) at the social discount rate of 12%. The value of economic validity should be more than 12% for EIRR, more than 1.0 for B/C and positive value for NPV.



(Source: JICA Study Team)

Figure 10.1 Flow of Economic Evaluation of ITS Component

10.2 **Economic Evaluation Indicators**

The economic costs and benefits throughout the project life periods are shown by a discounted cash flow analysis. Three indicators, i.e. Economic Internal Rate of Return (EIRR), Benefit / Cost Ratio (B/C) and Net Present Value (NPV) are calculated as shown in Table 10-1 .

12% discount rate is adopted because this is widely used in India as a social discount rate. The useful life of ITS system is about 10 years after introduction. Therefore, project evaluation period was set for the period up to 2036. (The year 2036 includes 10 years after expansion of Chennai Traffic Information Centre in 2027) Economic Evaluation Indicators are shown in Table 10-1.

Table 10-1 Economic Evaluation Indicators

No.	Indicator	Calculation Formula or Value
1	Discount Rate	12% as a social discount rate generally used in India
2	EIRR	$\sum \frac{B_n}{(1+r)^n} = \sum \frac{C_n}{(1+r)^n}$ B:Benefit, C:Cost, r:satisfying
3	B/C	$\sum \frac{B_n}{(1+DR)^n} \div \sum \frac{C_n}{(1+DR)_n}$ DR: Discount Rate
4	NPV	$\sum \frac{B_n - C_n}{(1+DR)^n}$
5	Project Evaluation Period	Period for 2016 -2036 (20years)

(Source: JICA Study Team)

10.3 **Result of Economic Evaluation**

The result of economic evaluation is shown in Table 10-2.

All cases were greater than value of the economic validity, i.e. Economic Internal Rate of Return(EIRR) > 12%, Benefit~(B/C) > 1.0, Net Present Value(NPV) > 0).

Table 10-2 Result of Economic Evaluation

Cost-Benefit Stream

EIRR= 19.26% NPV= 188.7 B/C= 1.287

	Year	Discount Rate	Undiscount(Unit=INR crore)							Discount(Unit=INR crore)						
			Cost			Benefit			Benefit − Cost	Cost			Benefit			Benefit − Cost
	Base Year 2016		Equipment	O&M	Total	VOC	TTC	Total		Equipment	O&M	Total	VOC	TTC	Total	
	2017	0.8929	0.0	0.0	0.0			0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	2018	0.7972	85.0	0.0	85.0			0.0	−85.0	67.8	0.0	67.8	0.0	0.0	0.0	−67.8
	2019	0.7118	159.4	0.0	159.4			0.0	−159.4	113.5	0.0	113.5	0.0	0.0	0.0	−113.5
	2020	0.6355	159.4	0.0	159.4			0.0	−159.4	101.3	0.0	101.3	0.0	0.0	0.0	−101.3
Operation	2021	0.5674	74.4	25.5	99.9	91.7	20.8	112.5	12.6	42.2	14.5	56.7	52.0	11.8	63.8	7.1
1	2022	0.5066	0.0	66.0	66.0	104.9	29.2	134.1	68.1	0.0	33.4	33.4	53.1	14.8	67.9	34.5
2	2023	0.4523	0.0	66.0	66.0	118.1	37.6	155.7	89.7	0.0	29.9	29.9	53.4	17.0	70.4	40.6
3	2024	0.4039	0.5	66.0	66.5	131.3	46.0	177.3	110.8	0.2	26.7	26.9	53.0	18.6	71.6	44.8
4	2025	0.3606	37.0	66.0	103.0	144.5	54.4	198.9	95.9	13.3	23.8	37.2	52.1	19.6	71.7	34.6
5	2026	0.3220	0.5	66.0	66.5	157.7	62.8	220.5	154.0	0.1	21.3	21.4	50.8	20.2	71.0	49.6
6	2027	0.2875	0.0	66.2	66.2	160.0	64.0	224.0	157.8	0.0	19.0	19.0	46.0	18.4	64.4	45.4
7	2028	0.2567	0.0	66.2	66.2	162.2	65.3	227.5	161.3	0.0	17.0	17.0	41.6	16.8	58.4	41.4
8	2029	0.2292	61.5	66.2	127.7	164.4	66.5	230.9	103.2	14.1	15.2	29.3	37.7	15.2	52.9	23.7
9	2030	0.2046	98.1	66.2	164.3	166.6	67.8	234.4	70.1	20.1	13.5	33.6	34.1	13.9	48.0	14.3
10	2031	0.1827	61.5	66.2	127.7	168.8	69.0	237.8	110.1	11.2	12.1	23.3	30.8	12.6	43.5	20.1
11	2032	0.1631	0.0	66.2	66.2	171.1	70.2	241.3	175.1	0.0	10.8	10.8	27.9	11.5	39.4	28.6
12	2033	0.1456	0.0	66.2	66.2	173.3	71.5	244.8	178.6	0.0	9.6	9.6	25.2	10.4	35.6	26.0
13	2034	0.1300	0.0	66.2	66.2	175.5	72.7	248.2	182.1	0.0	8.6	8.6	22.8	9.5	32.3	23.7
14	2035	0.1161	36.6	66.2	102.7	177.7	74.0	251.7	149.0	4.2	7.7	11.9	20.6	8.6	29.2	17.3
15	2036	0.1037	0.0	66.2	66.2	179.9	75.2	255.2	189.0	0.0	6.9	6.9	18.7	7.8	26.5	19.6
Σ（2021～2036）			773.9	1,017.2	1,791.1	2,447.8	947.0	3,394.8	1,603.7	388.1	269.9	658.0	620.0	226.6	846.6	188.7

(Source: JICA Study Team)

10.4 **Sensitivity Analysis**

Sensitivity analyses for the cases of Cost +10%, Cost +20%, Benefit -10%, Benefit -20%, Cost +10% and Benefit -10% were carried out. The results are shown in Table 10-3.

Table 10-3 Result of Sensitivity Analysis

	EIRR (Unit=INR crore)	**NPV**	**B/C**
Base Case	19.26%	188.7	1.287
Cost +10%	16.51%	122.9	1.170
Cost +20%	14.01%	57.1	1.072
Benefit －10%	16.22%	104.0	1.158
Benefit－20%	12.83%	19.3	1.029
Cost +10%, Benefit－10%	13.48%	38.2	1.053

(Source: JICA Study Team)

11 Referential Information for ITS Implementation

11.1 Electronic Road Pricing System (ERP)

The following sections are given for Indian authorities in Chennai as reference information of important general idea to consider Electronic Road Pricing in the future, describing key points that need to be kept in mind.

11.1.1 What is Electronic Road Pricing (ERP)

To handle growing road traffic congestion, most cities strive to provide many supply measures such as improved road capacity and more available public transport. A worldwide trend in transport sector realised that it is impossible to tackle the congestion by measures only on supply side. Thus, most transport measures include Transportation Demand Management nowadays.

One of the major focuses of Traffic Demand Management is to discourage usage of private transport. There are a variety of measures such as providing more efficient modes of travel, restricting the provision of car parks in central area of the city to discourage entry, allowing only high occupancy vehicle to pass during certain period of a day, increasing petro tax or vehicle tax, etc. A congestion pricing comes under the umbrella of Traffic Demand Management. The motorists are imposed to pay for the use of the roads at times and places. The roads within a congestion priced areas can only be accessed on payment of charge which varies by time of day according to the traffic situation. The automated congestion pricing by system is called 'Electronic Road Pricing (ERP)'

The concept of the congestion pricing is not same as road tolling. The toll road aims that more motorists use the road, in many cases, diverting the traffic from certain area or route. Accordingly, the toll roads want more road usage to maximise the revenue. On the other hand, the congestion pricing intends that fewer motorists use the charged area or roads thereby urging them to use more efficient modes such as public transport or to change their travel behaviour such as commuting at different time. Therefore, the main consideration is not the revenue but controlling the demand.

11.1.2 Area Pricing and Line Pricing

There are mainly two methods of congestion charge, area pricing and line pricing both of which are to control transportation demand. The motorists are charged to enter a certain area in the case of area pricing. The area to be charged to enter is a place that is mostly congested in the city and required to alleviate the congestion. It is generally in many cases around Central Business District because it attracts a lot of vehicle due to its activities. The area pricing has been implemented in Singapore, London and Stockholm. In the general case of line pricing, different toll fees are charged on the roads to control the traffic flow or demand. For example, lower fee is charged for truck on route-A which

runs in the suburbs than route-B which passes through residential area to encourage to use the route-A. The area pricing method is usually referred as congestion charge, and therefore the following sections mainly discuss the area pricing.

11.1.3 How to Decide Whether Congestion Charging Is Implemented

It is important to note that the congestion pricing by itself will not solve the transportation issues. It is one of urban transport measures such as improvement of public transport, road network, proper traffic management, etc. Assurance should then be given that the government will not depend solely on congestion pricing for solving traffic problems. Further, the congestion pricing is generally unpopular measure for public because the motorists are now asked to pay for the roads that they could use for free. People are already heavily taxed and they may see it as a ploy of government to collect more tax. Hence, implementing the congestion pricing will be carefully considered and at least the following questions, but not necessarily limited to these, need to be strictly asked before deciding on going for it;

- Why do we need the congestion pricing?
- In which area does the congestion need to be improved and why is it in that area?
- How bad is the congestion? The government may face difficulties in persuading the public under the situation where the average travel speed is 20 to 30 km/hour during peak hours. Anything below 10 km/hour could be persuasive.
- Aren't really there any alternative measures remained to improve the congestion, other than pricing?
- Is public transport fairly available for public including trunk line, last mile connectivity and transfer facilities? – Many of those affected may switch to public transport.
- Are there reasonable alternative routes for those affected to detour the priced area?
- Is government ready to compensate the residents who will be affected in the priced area and how?
- How good is traffic manners and how effective is traffic enforcement? – These are necessary for the system to properly function and for enforcement of the congestion pricing.
- Are vehicle number plates standardised? – Same as above.
- Is a good database which links the vehicle number plate with the details of the latest vehicle owner available? – This is necessary for enforcement of the congestion pricing, sending out notices for fines for violating vehicles, etc.
- How will the revenue gained from the congestion pricing be used? Will it be used only for urban transport measures or for others as well?

Aren't there necessities of amending relevant acts to allow collecting the congestion charge?

11.1.4 Selection of Area for Charging

To consider defining pricing area, locations with land use which attract traffic are to be included. This will be the area with offices, commercial activities and with sufficient parking facilities which are used by motorists visiting these buildings. Such areas are usually defined as Central Business District or Regional Centres. On the other hand, it should exclude as far as possible residential area, schools, religious places/facilities, etc. to minimise the impact on daily activities of residents. If the area selected for congestion pricing is too large, it will require many entrances that have to be controlled and there will be greater possibility of inclusion of residential area. But too small an area results in less effective. Thus demarcating the boundary is a sensitive issue and it needs to be considered to maximise the effect as well.

The evaluation criteria are recommended to set out for defining the area. They generally comprise such items as

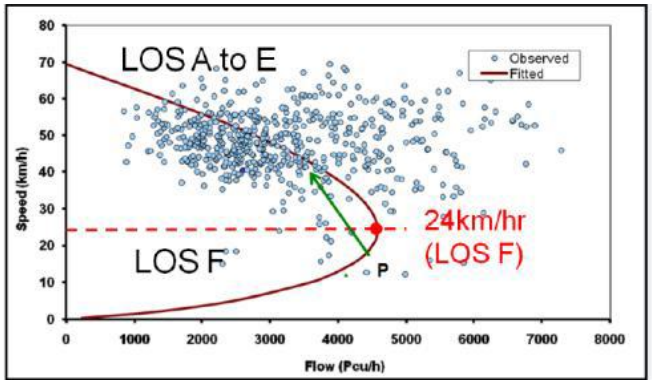
- Approx. peak hour travel speed on the roads inside and around the target area,
- Expected effect on before/after pricing time in terms of traffic volume
- Percentage (or number) of commercial/administration/industry land use of total land use in the area,
- Number of residents, schools, religious places/facilities, etc. in the area,
- Availability of proper public transport e.g. metro stations and bus services, and alternative routes around the area, and

Other conditions such as existence of escape routes around the area, number of entry point, etc.

11.1.5 Level of Service

A quantitative method to define congestion is to consult the speed-flow curves derived for different types of roads in the city. The speed-flow curve derived for a three-lane per direction of major arterial road in Chennai was provided by the Indian Institute of Technology, which is shown in Figure below.

The speed-flow is a standard method of working out traffic levels of service. The traffic flow is categorised from Level of Service A (very free flowing) to Level of Service F (very slow traffic of stop-go conditions). The traffic flow breaks down at the bullet nose of the curve which is at a speed of 24 km/hr. So the speeds below 24 km/hr, called the critical speed, occur on arterial roads in Chennai before it gets into the undesirable Level of Service F. The trigger point of congestion pricing can be when the average speed along the roads in the area falls below the critical speed. The congestion pricing is intended to improve to a better Level of Service i.e. A to E by reducing the inbound traffic into the area.



(Source: Edited by JICA Study Team based on Speed Flow Curve shared by IIT Chennai)

Figure 11.1 Speed Flow Curve

11.1.6 Pricing Concept

The congestion pricing usually charges only during time that experiences congestion, generally peak hours. The charges can vary for different time of the day. In a typical case, the vehicles that enter the pricing area are charged when they cross the imaginary cordon which encircles the area. Other options are to charge vehicles moving in the area or to charge by distance travelled within the area. The latter cases become technically and operationally more complicated in general.

Setting price is important. Different class of vehicles can be charged differently according to the effect they have on traffic flow. If it is set too high, many motorists may avoid the area resulting in deserting the roads. If it is set too low, the number of vehicles avoiding the area will be small resulting in insufficient improvement of congestion. A sense of fairness as to being imposed the price is also important factor for the public. A proper way would be to assign charges proportionately to the vehicles of different class according to Passenger Car Unit which describes dynamic effect of different types of vehicles to traffic stream. If a passenger car is 1, then motorcycle is 0.5, light goods vehicle 1.4, heavy goods vehicle 2.2, etc. It is preferable that emergency vehicles be exempted from the charge.

11.1.7 Technologies for Electronic Road Pricing (ERP) and Practices in the World

Congestion pricing has been implemented in Singapore since 1975, London since 2003 and Stockholm since 2006. Only these three (3) cities have so far realised genuine area pricing in the world. There have been a series of discussion on introducing the area pricing in Japan; however, it has never been implemented yet due to many difficulties.

Major technologies for EPR are:

(1) Dedicated Short Range Communication Method

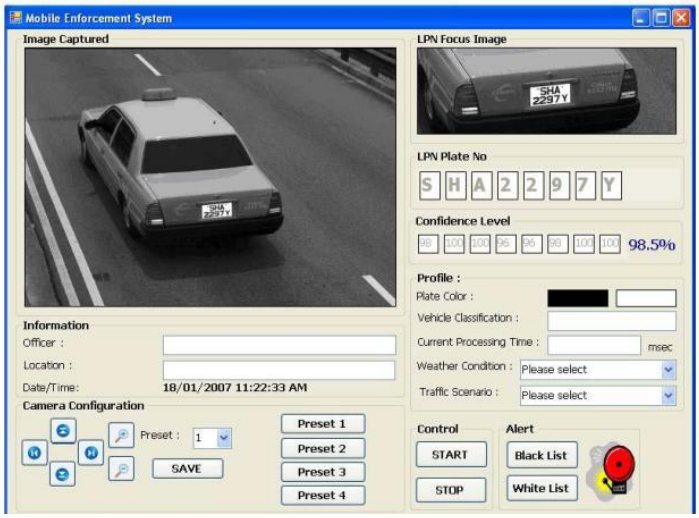
Dedicated Short Range Communications using pre-paid card with powered On-board Unit has an internal power source, a battery, and communicates with the antenna mounted on the overhead gantry. Electronic Road Pricing(ERP) charge is debited from the pre-paid card inserted into the On-Board Unit on a realtime basis when the vehicle passes under the overhead gantry at the control point. Singapore uses Dedicated Short Range Communication method for Electronic Road Pricing(ERP) using 2.45 GHz microwave.

(Source: MSI Global)

Figure 11.2 On-Board Unit and Roadside Equipment on Gantry in Singapore

(2) Automatic Number Plate Recognition Method

Motorists register as user in advance and create their personal account on the system or register their bank account. License plates of vehicles passing under Electronic Road Pricing(ERP) gantry or moving around inside the pricing area are captured by cameras and sent to central server. Electronic Road Pricing(ERP) charges are deducted from their registered account. If the balance in the account is insufficient or becomes below or close to threshold amount, warnings are sent to the drivers. The system architecture is simpler than Dedicated Short Range Communication method but such factors as difficulty in properly capturing the license plate of all vehicles by camera, requirement of robust communication network, heavy back-end system, etc. are challenging issues. Automatic Number Plate Recognition method for congestion pricing is adopted in London and Stockholm. Automatic Number Plate Recognition technology is used for enforcement on violating vehicles of congestion pricing in Singapore.

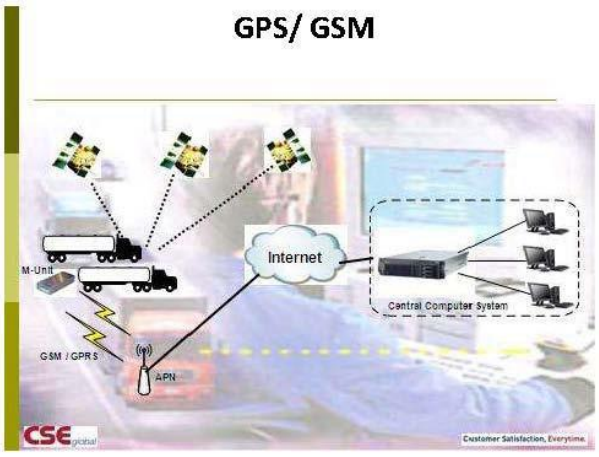


(Source: MSI Global)

Figure 11.3 Automatic Number Plate Recognition in London

(3) Global Navigational Satellite System/Cellular Network Method

This is a GPS based tracking system. Locations of vehicles are recorded by Global Navigational Satellite System receiver installed on the vehicle. The location data in terms of longitude/latitude is sent from Global Navigational Satellite System receiver to centre server through mobile communication network. Running mileages are calculated at centre and accordingly required amount is paid by users. This system does not require overhead Electronic Road Pricing(ERP) gantries. However, accuracy of recording locations using GPS in the places surrounded by high-rise buildings is an issue. Therefore, Global Navigational Satellite System / Cellular Network is used for tolling of commercial vehicle on highways in suburbs in Germany, not for Electronic Road Pricing(ERP) in metropolitan area.



(Source: MSI Global)

Figure 11.4 Global Navigational Satellite System / Cellular Network in Germany

(4) RFID Method

Motorists register as user in advance and create their personal account on the system or register their bank account. Unique ID which is linked to vehicle and owner information is registered on RFID tag and tags are issued to individual vehicles. Communication between antenna mounted on gantry and RFID tag pasted on windshield of the vehicle is made when the vehicle passes under the gantry and unique ID is read from RFID tag. The read information is sent to central server and then Electronic Road Pricing(ERP) charge is deducted from the account. RFID method for Electronic Road Pricing(ERP) has never been implemented anywhere in the world yet. However, under the situation where RFID method for toll collection on National Highways in India is increasingly adopted, this method could be one of candidate technologies for Electronic Road Pricing(ERP) in India. Technical trials are required.

(Source: JICA Study Team)

Figure 11.5 RFID Tag Pasted on Windshield and Headlight (for Toll Road Usage) in India

11.1.8 Other Important Aspects

(1) Alternative Route

Motorists who don't have their final destinations in the pricing area are not likely to pay just to go through the area. They will need some fair alternatives. Whilst the congestion pricing improves traffic flow in the area, the congestion will transfer to outside the area or other routes. Therefore, these routes have to have sufficient capacity to cater such traffic. Motorists should also be given information on the alternative routes to avoid the pricing area.

(2) Adequate Public Transport

Changing the mode of travel to public transport is a desired option. It is essential that those who divert to public transport as a result of congestion pricing find places in the buses/metro to get to their destination. Completion of Chennai metro network of Phase-1 and Phase-2 is highly desired. Improvement of quality of bus services is also strongly recommended.

(3) Public Feedback

Congestion pricing is a sensitive topic. Motorists are not getting anything new but they are now being asked to pay for the use of existing roads. It is likely that the government will get adverse feedback from public. All feedback has to be carefully taken care of and dealt with a satisfactory manner. For this, assistance of public relation firms is recommended.

(4) Regular Monitoring on Effect of Congestion Pricing

The effect of congestion pricing needs to be regularly monitored and charging price be accordingly adjusted. In Singapore, the monitoring is done every 3 month and appropriate rate of charging is adjusted. The interval could be longer in Chennai, but such items as traffic volume, travel speeds, conditions on adjacent roads, violations, system errors, revenue/costs, etc. need to be regularly monitored.

(5) High Level Steering Committee and Technical Committee

Planning and implementing congestion charging, and operating and maintaining the systems require involvement of a number of relevant parties in urban transport sector in Chennai. A high-level steering committee consisting of senior officials of these organizations needs to be set up. A technical committee to work on technical consideration is also recommended to set up.

(6) Legislation

Legislation for congestion pricing may be required. Enacting legislation is a lengthy process. Hence, it is necessary to embark on this vital activity from very early stage.

(7) Organization Setup

Setting up implementing and operating groups is suggested. Required number of staff to operate the congestion pricing system depends on the design of the system; hence finalising the number of required staff can only be done after the design.

(8) Dialogue with Stakeholders and Public

Congestion pricing can only be accepted reluctantly by public. Motorists are not used to the concept of paying for usage of general road. Thus it is better to start dialogue with all interested parties and public at early stage once implementation of congestion pricing is decided. The interested parties may

include motorists' organization, motor traders' organizations, chambers of commerce, trade unions, grass root organizations, etc. This helps to imprint the concept of congestion pricing into the minds of public.

11.2 Common Mobility Card

Tamil Nadu Government is planning to introduce inter-modal fare payment system using smartcard, common mobility card, which can be used across different transport modes such as Chennai metro, city bus, MRT, monorail, toll roads, etc. A working group named 'Integration of Public Transport Modes' under Chennai Unified Metropolitan Transport Authority was recently established.

Planning and designing the common mobility card requires considerable amount of work. The following sections are made for Indian authorities as reference information of important general idea to plan common mobility card.

11.2.1 Rational of Introducing Common Mobility Card in Chennai

The public transport network in Chennai is better planned and constructed in terms of inter-modal connectivity compared with other cities in India. For example, many metro stations are connected to MRT bus terminals (city bus terminal) and these connecting stations are shown on the map in the train and stations. Large terminals of city bus and inter-city bus are constructed adjacent to metro station. Monorail which is under tender process will be also connected to metro stations. The common mobility card is a card using smartcard which can be commonly used for different transport such as metro, bus, monorail, Touch & Go for toll road, etc. There exist a great potential that users' convenience can be enhanced, thereby assisting to shift transport demand to public transport, under such good physical connectivity in Chennai.

11.2.2 Feature of Common Mobility Card

Paper ticket and magnetic card used to be used for fare payment of public transport. Nowadays a worldwide trend is that Integrated Circuit card, generally called smartcard, is increasingly used for the public transport fare payment because of a number of advantages comparing with these conventional methods. One of the major advantages of smartcard is that it can be used commonly across different transport modes. Such card is called 'Common Mobility Card'.

Major technical features of smartcards are:

- High security
  - ✓ Designed for secured Near Field Communication
  - ✓ Protected against duplication/disruption of data stored on the chip
- High durability

- ✓ Long life up to approx. 500,000 times of read and write

- Fast processing for a large volume of transaction
- Large memory size to store travel and payment record data

The following items become possible by introducing common mobility card using smartcard:

- Fast payment at entry/exit gate of public transport e.g. metro, monorail, bus, etc.
- Utilising inter-modal travel records saved in memory for the purposes such as person trip analysis
- Flexible payment services such as applying discount, altering zoning or fixed fare system to distance-based fare system, etc.
- Enabling passengers to avoid waiting in queue to purchase ticket and carrying small coins
- Enabling public transport operators to avoid preparing small coins for change at station and reduce amount of work for handling cash
- Minimising leakage of fare collection

11.2.3 Parties in Common Mobility Card Scheme

There are mainly three parties in the common mobility card scheme: Transport Operator, Card Issuer and Value Issuer.

(1) Transport Operator

Interoperability of common mobility card amongst different transport operators needs to be ensured. Rules such as tariff system, specification/standard of card system, etc. need to be established and agreed amongst the transport operators in order to ensure the interoperability. The transport operators that agree and accept these rules will be a member of the scheme of the common mobility card. If the cards are intended to be used for shopping, the parties such as kiosk, retail shop, etc. also need to be included as members.

(2) Card Issuer

The party that issues smartcard to card users is called 'Card Issuer'. The card issuer is usually the transport operator or bank. In the case of Chennai metro, Chennai Metro Rail Limited is the card issuer.

(3) Value Issuer

Amount charged on the card (e-money) is called 'value'. The party that adds the value and manages the balance of the value on the card is called 'Value Issuer'. In many cases, the card issuer and value issuer are same party. In the case of Chennai metro, Chennai Metro Rail Limited is also the value issuer.

The transport operator, card issuer and value issuer are called 'Alliance Members' of common mobility card scheme.

11.2.4 Settlement Methods and Clearinghouse

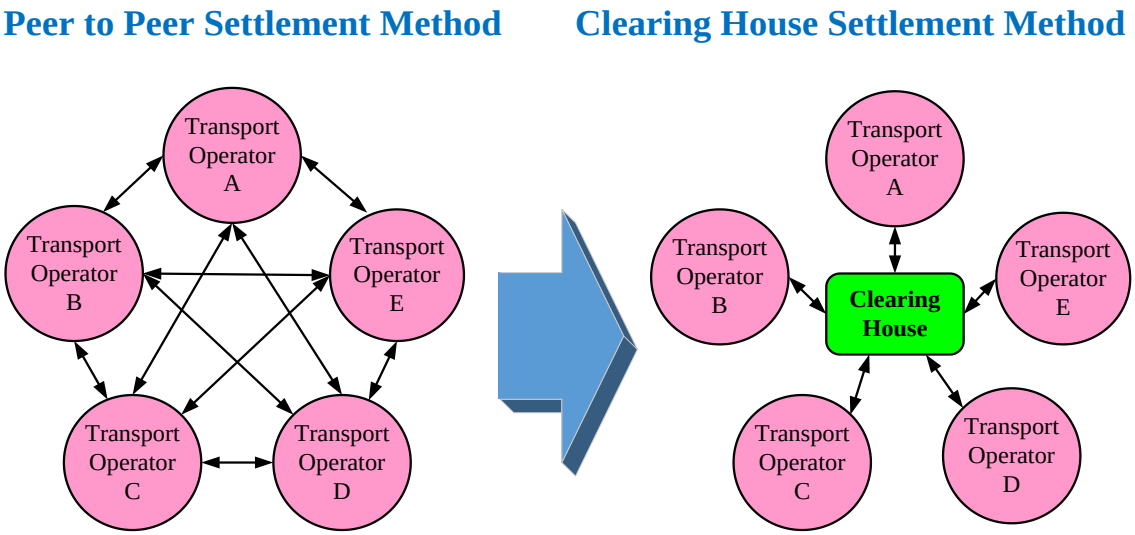
The amount used for different transport modes by a single common mobility card needs to be settled. There are basically two kinds of settlement methods.

(1) Peer to Peer Settlement Method

In principle, the amount is settled between two operators. They have peer relation and data for settlement is transferred each other. The advantage of this method is that it is relatively easy to initiate because the system is simple. But the data flow and settlement procedures become complicated if the participants such as additional transport operators increase.

(2) Clearinghouse Settlement Method

This method is better suited for the scheme of multiple participants of alliance members. A clearinghouse is established for settlement and it settles the amount spent for different transport modes by a single common mobility card. All data for settlement is sent to the clearinghouse and settlement process is done by the clearinghouse. The data flow and settlement procedures remain simple even if the participants increase. However, common rules such as settlement procedure, tariff system, data format, technical standard, etc. need to be established, agreed and followed by all participants.



(Source: JICA Study Team)

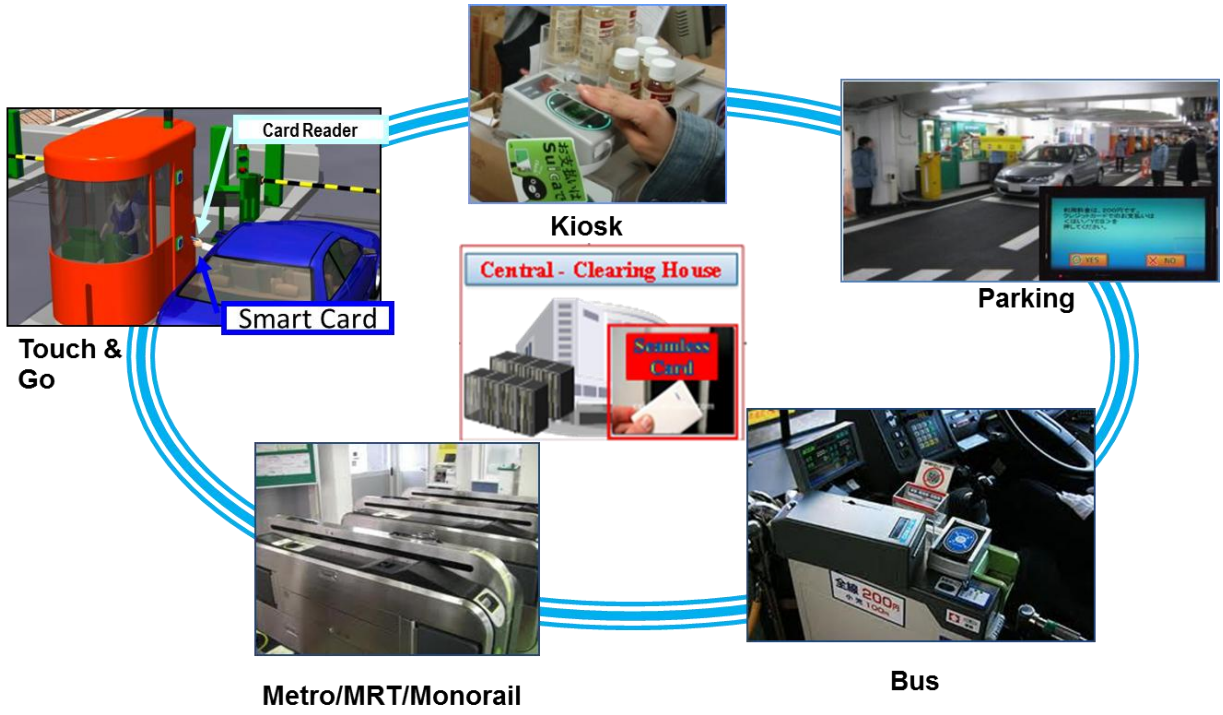
Figure 11.6 Peer to Peer and Clearinghouse Settlement Methods

(3) Clearinghouse

The clearinghouse executes the work necessary for settlement and gains commission fee for settlement work from alliance members. The major tasks of the clearinghouse are:

- To collect data on usage record of the common mobility card from transport operators. The usage record includes the data such as recharged amount, recharged terminal, spent amount of fare payment and its transport mode.
- To calculate the amount which needs to be paid to each alliance member; i.e. transport operator, value issuer and card issuer.
- To send the result of calculation to the alliance members for physical distribution of money
- To receive commission fee for settlement work from transport operators, card issuers and value issuers.

The figure below shows an overview of the clearinghouse and participants.



(Source: JICA Study Team)

Figure 11.7 Clearinghouse and Participants

11.2.5 Management Committee

Realising the common mobility card and sustainably operating/maintaining the system are not easy task. The policy and strategy will be set out and a number of rules need to be determined, agreed and followed by all involved parties in the common mobility card scheme. The involved parties are not only alliance members but also include other relevant organizations such as financial department/planning department of state government, retail unions, etc. The initial step towards introducing the common mobility card is to form a 'Management Committee' constituted by these involved parties.

It functions as a decision making body for important issues such as formulating policy, setting out strategies and deciding rules. For example, the Management Committee determines the following items:

- Technical standard to be adopted and information security policy
- Settlement procedure
- Contents and format of data for transaction
- Test acceptance criteria

- Rules for assurance of confidentiality
- Rules and procedures for acceptance of new alliance members

12 Conclusions and Recommendations

(1) Strong Initiative of Government of Tamil Nadu for Implementing ITS

Government of Tamil Nadu held stakeholder meetings which were chaired by Additional Secretary during this study. During these meetings, the leaders of the government acknowledged the importance of introduction of the proposed ITS and showed strong willingness to tackle the issues which hinder prompt realisation of ITS.

A strong commitment of the policy makers and relevant authorities is important for implementation of ITS. The implementation of ITS requires close coordination and collaboration amongst stakeholders. The strong initiatives of the government make it possible.

(2) Further Study for ITS

The basic policy of ITS development was proposed and the conceptual designs were made by this study as per the purposes of the study. However, the design work is required for the ITS components of which the conceptual designs were made. Further, such ITS components as parking system require infrastructure development plans such as parking master plan. Therefore, further studies towards implementation were strongly recommended to be carried out.

(3) Development and Improvement of Transport Infrastructure Together with ITS

ITS is one of soft measures to alleviate traffic congestion. The road and transport infrastructure need to be sufficiently and properly developed in order for ITS to exert effectiveness. As described in this report, there are a number of issues of infrastructures in Chennai. They include, for example, improvement of intersection/junction, transfer facilities, parking spaces, pedestrian foot paths, etc. Therefore, it is important that the development and improvement of road transport infrastructures be carried out together with ITS.

(4) Adopting New Technologies

Innovation and advancement of information and communication technology are rapidly progressing. The development policy was proposed based on currently available technologies. However, it is most likely that the new technologies which do not exist today will become available in a few years later. Therefore, it is important that attention always be paid to explore the latest technologies to apply.

(5) Continuous Promotion of ITS

ITS is not 'one-time implementation'. Once it is deployed, it needs to be sustainably operated and maintained. It will then be reviewed, evaluated, planned and upgraded in accordance with advancement of technology and changes of traffic conditions as time goes on. Therefore, ITS needs to be continuously maintained and promoted.

(6) Capacity Development

Capacity building is one of the most important factors to assure sustainable operation, maintenance, reviewing, planning and upgrading of ITS over a long period. The involved personnel and officials will be equipped with adequate skills and competencies of ITS technologies and operations. Thus, it is important to draw up plans for training and carry out them to enable continuous improvement of their skills. The training programs which contain lectures provided by instructors who have sufficient knowledge and experiences and actual practice such as simulation are recommended to be planned. Another effective way to foster experts for ITS is to dispatch the involved personnel to the developed countries where the state-of-the-art-ITS are operated on daily basis and study the required knowledge as ITS expert through actual experiences.

(7) Establishment of Strong Central Body

Establishing a central body for continuous initiatives is important. The measures for urban transport needs to be taken together with ITS. The required measures involve issues which extend across different stakeholders/agencies. Participation of the related agencies such as Tamil Nadu Infrastructure Development Board, Chennai Metropolitan Development Authority, Metropolitan Transport Corporation, Greater Corporation of Chennai, Traffic Police, Chennai Metro Rail Limited, etc. is important. In Chennai, there is already Chennai Unified Metropolitan Transport Authority, decision making and coordination body participated by the related organizations in the urban transport sector. Such committees as 'Integration of Public Transport' and 'Smart City', etc. are already established under Chennai Unified Metropolitan Transport Authority. Therefore, establishing new committee under Chennai Unified Metropolitan Transport Authority is recommended.

(8) Strengthening Driver/Pedestrian Education and Enforcement of Traffic Rules and Regulations

One of the most serious issues of urban transport in Chennai is traffic manners. The traffic conditions cannot be improved only by developing infrastructure and applying ITS. The education of

drivers/pedestrians and enforcement of traffic rules and regulations need to be strengthened to attain the full effect of introduction of ITS.

(9) Standardising Motor Vehicle Number Plate and Improvement of Vehicle Registration

Standardised number plates and properly registered motor vehicle information are indispensable factors for ITS. Proper enforcement by ITS cannot be realised without these. The Government of India mandated standardisation of number plate in 2005. However few states have accomplished it in India and state of Tamil Nadu has not implemented yet. The tender process for supplier of the standardised number plate has been in progress. It is expected to take long time to replace the existing non-standardised number plates in Chennai. The authorities are also facing difficulties in identifying second-hand vehicles for enforcement due to insufficient vehicle registration. Therefore, the standardisation of the number plate and improving vehicle registration need to be accelerated.

(10) Improvement of Chronic Congestion Caused by Chennai Port

In northern region of Chennai, there is chronic traffic congestion caused by a large number of container cargos waiting to enter the Chennai port. The long queue of heavy trucks occupies the road space and causes traffic accidents. Chennai port is the second largest container port in India and handling volume of container is expected to continuously increase. Such situation cannot be solved by ITS based measures. The container facilities at Ennore Port are under introduction. Such improvements should be further implemented. It is also important that the handling capability of container at Chennai port be improved so that the required time for container processing is shortened.