CHAPTER 3 TRAFFIC SURVEY, ANALYSIS, AND FORECAST

3.1 Traffic Survey

3.1.1 Objectives of the Project

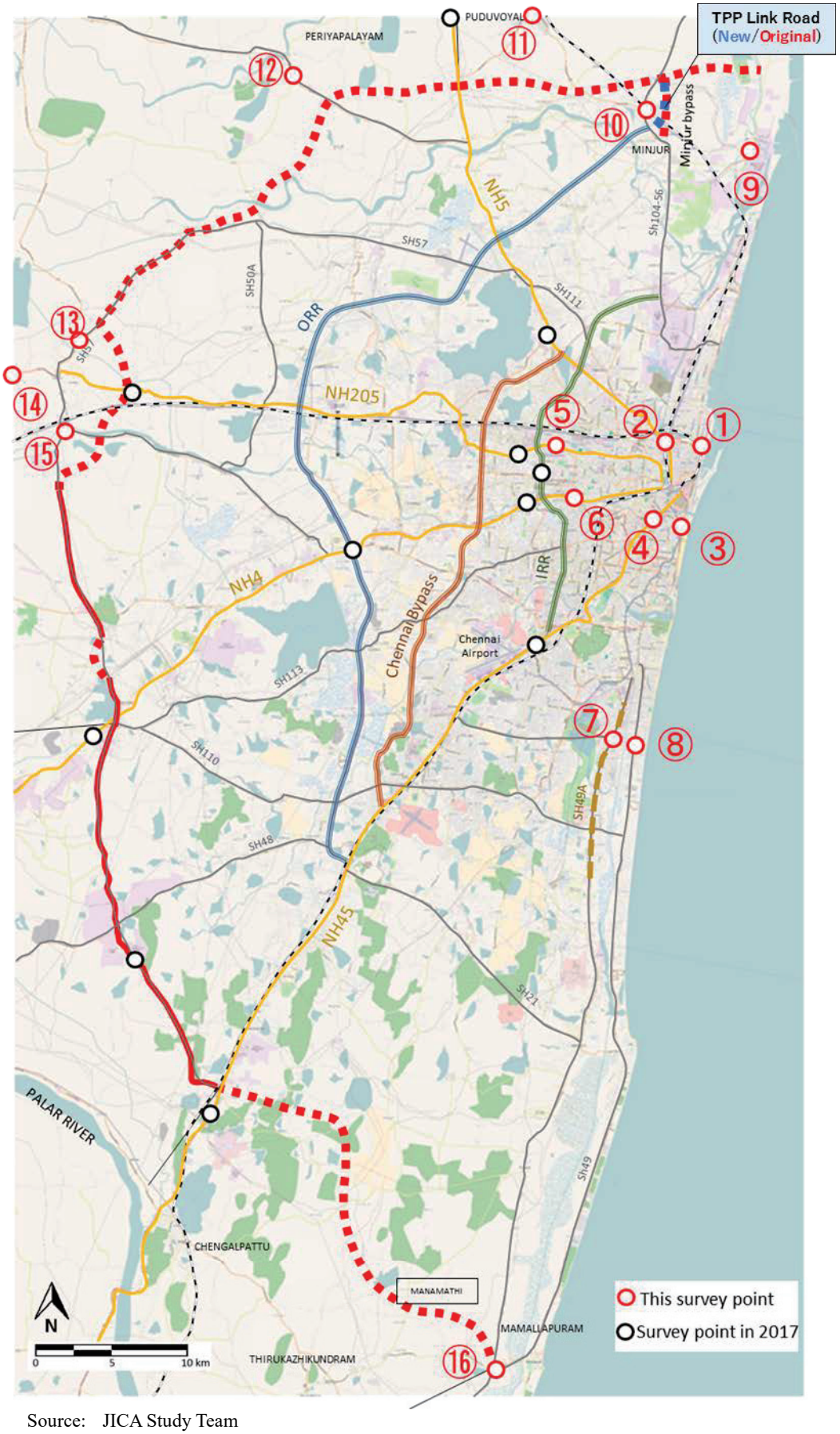
The target of the traffic survey is the central urban area which is the introduction area for the traffic signal control system and the Chennai Peripheral Ring Road (CPRR). In the central urban area, traffic survey was carried out inside the Inner Ring Road (IRR) and the information technology (IT) corridor, in which the number of IT companies increased remarkably. In the CPRR, traffic survey was carried out at the starting point and cross section of each section.

The outline of the traffic survey is shown in the table and figure below.

Table 3.1.1 Outline of Traffic Survey

Survey	Objectives	Contents
Intersection Traffic Volume Survey	Indicators for measuring the effect of introducing intelligent transport system (ITS)	Inside IRR × 6 places
	Check traffic distribution	Around the IT corridor × 2 places
	Update the Origin-Destination (OD) table	CPRR × 8 places

Source: JICA Study Team



Source: JICA Study Team

Figure 3.1.1 Traffic Survey Points

The JICA Study Team signed the entrustment contract with Expert Technologies, and the traffic volume survey was carried out with the following schedule. Prior to the survey, the JICA Study Team confirmed the work plan summarizing the survey spot, survey schedule, vehicle type classification, survey form, placement of investigators for each point, safety management, emergency contact list, etc.

During the survey, three members of the JICA Study Team confirmed whether the survey was properly implemented based on the work plan at the survey site. Table 3.1.2 and Figure 3.1.2 show the summary of the traffic volume survey and the survey site photos.

Upon inspection of the report, it was confirmed that the survey items and quantities in the specifications are being implemented, and the results are correctly counted.

Table 3.1.2 Outline of Traffic Survey

	Survey Points	Survey date
1	Clive Battery	30.Aug.2017(Wed)
2	Moolakothalam Basin Bridge	12.Sep.2017(Tue)
3	Ezhilagam/Madras University	29. Aug.2017(Tue)
4	Anna Statue/Mount Road	06. Sep.2017(Wed)
5	Villivakkam/New Avadi Road	30. Aug.2017(Wed)
6	Pachayappas College/New Avadi Road	05. Sep.2017(Tue)
7	OMR Thuraipakkam/Pallikaranai Radial Road	05. Sep.2017(Tue)
8	ECR (near VGP) Injambakkam	06. Sep.2017(Wed)
9	Ennore Kamarajar Port Trust	07. Sep.2017(Thu)
10	Minjur/Kattur Road	07. Sep.2017(Thu)
11	Ponneri/Thatchur/Pulicat Road	07. Sep.2017(Thu)
12	Periyapalayam/Thirunindravur Road	12. Sep.2017(Tue)
13	Ikkadu/Thiruvallur Road	06. Sep.2017(Wed)
14	Thiruvallur near Collectorate (3 road junctions)	06. Sep.2017(Wed)
15	Thiruvallur near Railway station (3 road junctions)	06. Sep.2017(Wed)
16	ECR/OMR/Chengalpattu/Mahabalipuram	07. Sep.2017(Thu)

Source: JICA Study Team

Source: JICA Study Team

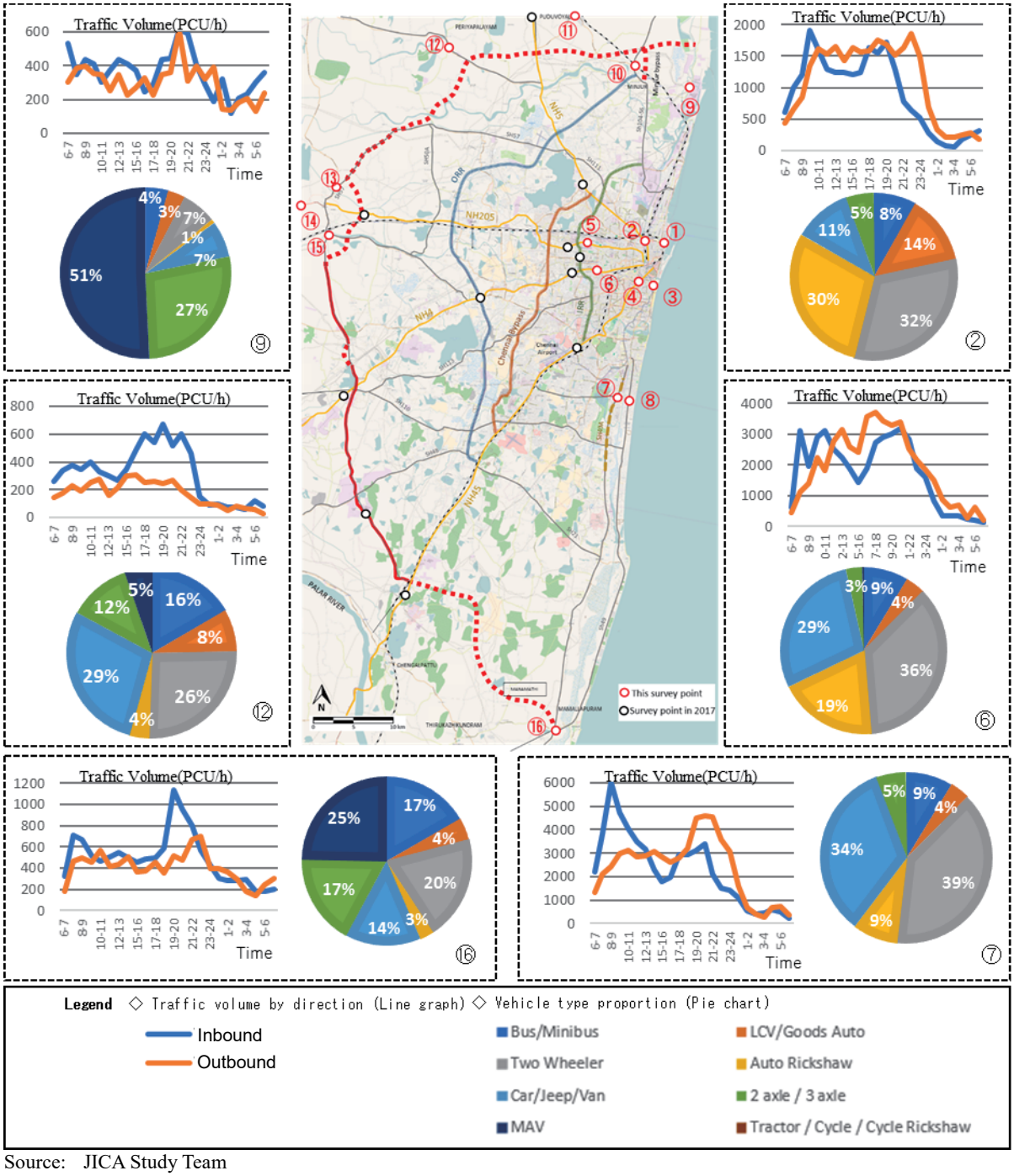
Figure 3.1.2 Traffic Survey

3.1.2 Results of the Traffic Survey

The outline and the summary of the results of the traffic volume survey are shown in the figure below. The survey was carried out for 24 hours at 16 points. The line graph shows the cross-sectional traffic volume of the main survey site. In the city, inbound traffic is high in the morning, and outbound traffic increases in the evening. On the other hand, traffic tends to increase in the suburbs from evening to midnight.

The pie chart shows the ratio by type of vehicle. Gray portions indicate the proportion of two-wheeled vehicles. There are many motorcycles in the center of the Chennai, such that two-wheeled vehicles account for 39% in SH49A. On the other hand, the proportion of large vehicles is relatively higher in the suburbs than in the city.

As such, the city road is used for commuting in the morning and evening, while the suburban road is used for large vehicles such as heavy trucks from evening to midnight.



Source: JICA Study Team

Figure 3.1.3 Outline of Traffic Volume Survey Results

3.2 Hearing Survey for Related Development Plans

3.2.1 Port Development Plans

Mr. Koyama and Mr. Suzuki of the Overseas Coastal Area Development Institute of Japan, who are implementing technical support for “Chennai Port Operation Management Improvement”, carried out a hearing survey on port development plan and future cargo volume.

The result of the hearing survey is shown in the table below.

Table 3.2.1 Results of the Hearing Survey

Item	Content
Date	2017/8/29 9:10-9:45
Location	Accord Hotel Business Center - Conference Room
Partner	The Overseas Coastal Area Development Institute - Executive Director: Koyama Akira - Second Survey Division Manager: Suzuki Hiroyasu
Content	- Port development plan and future handled cargo volume (Refer to the "Final Report for Sagarmala" (Vol. 1-6) which the Ministry of Shipping and the Indian Port Association entrusted to McKinsey in 2016.) - Competing ports in the Chennai Metropolitan Area (CMA) - Chennai Port (major port) - Ennore Port (major port) - Kattupalli Port (minor port) - Krishnapatnam Port (minor port, Andhra Pradesh State) - Statistic data on handled cargo volume Refer to the Indian Port Association site
Collected material	Chennai Port Operation Management Improvement

Source: JICA Study Team

3.2.2 Development Plans along the CPRR

A hearing survey to Mr. Haneda of Mahindra Industrial Park Chennai Limited was carried out. Mahindra Industrial Park Chennai is located along the CPRR (along NH5).

The result of the hearing survey is shown in the table below.

Table 3.2.2 Outline of Traffic Survey

Item	Content
Date	2017/9/13 14:30-15:30
Location	Mahindra Towers - Conference Room
Partner	Mahindra Industrial Park Chennai Limited - Head of Sales and Marketing: Toru Haneda
Content	- Mahindra Industrial Park Chennai area is 300ha. Currently, the sales of the first phase (100 ha) has started. It is possible to provide a physical distribution volume of the industrial park of the same scale in Southeast Asia. - It is considered that the companies of Mahindra Industrial Park Chennai mainly use Kattupalli Port (Adani). It is impossible to expect the expansion of Chennai Port in the future because there is a permanent urban area behind Chennai Port. Since there is no space to place the cargo, the import cargo must be carried to the surrounding container freight station (CFS) immediately. Also, to load the export cargo immediately, the container trailer must be assembled with the arrival of the vessel. On the other hand, it is possible to extend the container yard in Kattupalli Port, because there is nothing around there.
Collected material	Outline of Kattupalli Port (Adani)

Source: JICA Study Team

3.2.3 Results of Hearing Survey

(1) Access to the Port

1) Access to Ennore Port

There are two entrance and exit gates at Ennore Port, Gate 1 and Gate 2 (Figure 3.2.1). Gate 1 is used by bulk trucks, and Gate 2 is used by tank trucks.

It is accessible from the south and the north sides to Ennore Port as shown in the figure below. However, it is impossible for container trailer trucks to pass the north side because of the unpaved road as shown in the figure below. Therefore, access to Ennore Port is limited to the route shown below.

Source: JICA Study Team

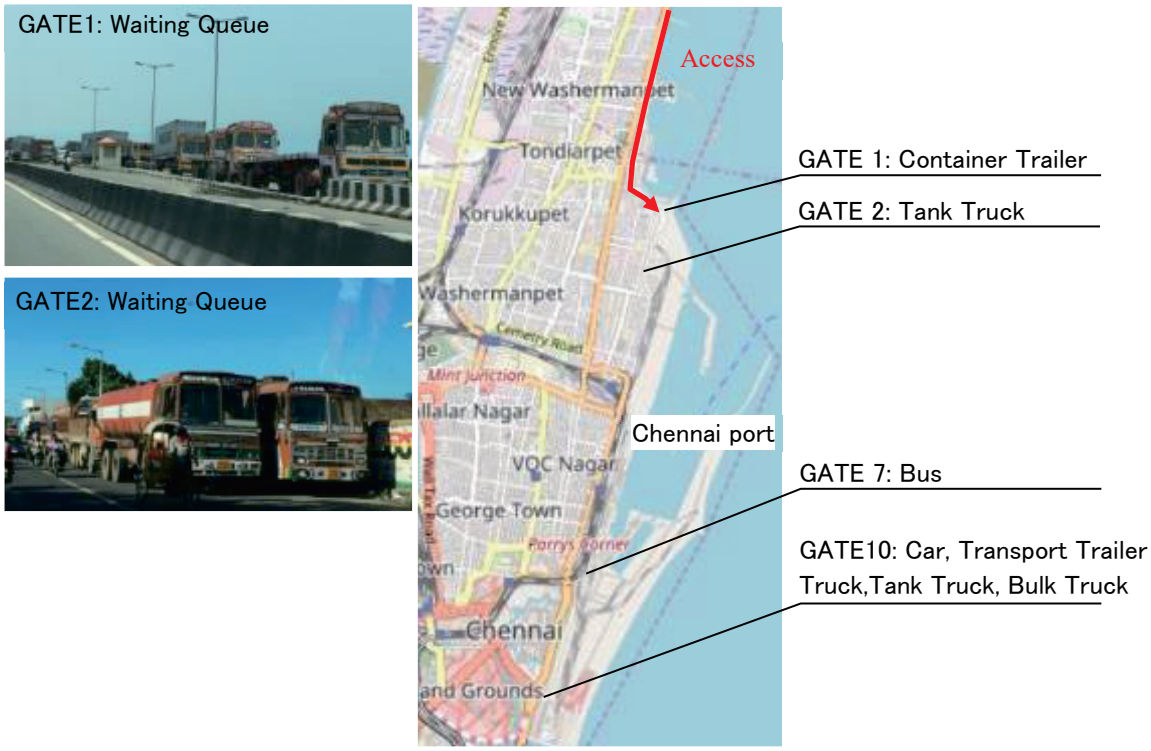
Figure 3.2.1 Access to Ennore Port

2) Access to Chennai Port

There are ten entrance and exit gates at Chennai Port, Gate 1 to Gate 10. However, there are only four available gates as shown in the figure below.

The problem is the waiting queue of container trailer of Gate 1. Many container trailer trucks are parked along the Ennore High Road (about 7.5 km) and Manali High Road (about 5 km).

Such a problem occurs because the container yard at Chennai Port is too narrow to fit a container, so export cargo is loaded by forming a queue of container trailer trucks.



Source: JICA Study Team

Figure 3.2.2 Access to Chennai Port

3) Access to Kattupalli Port

Access to Kattupalli Port uses the same route to Ennore Port because Kattupalli Port is located north of Ennore Port.

There are three entrance and three exit gates in Kattupalli Port. There is a lay bay (500 m*20 m) for the queue of the trailer trucks in front of the entrance gate. Therefore, a few trailer trucks are parked on the road around Kattupalli Port, which is not found in Chennai Port.

Source: JICA Study Team

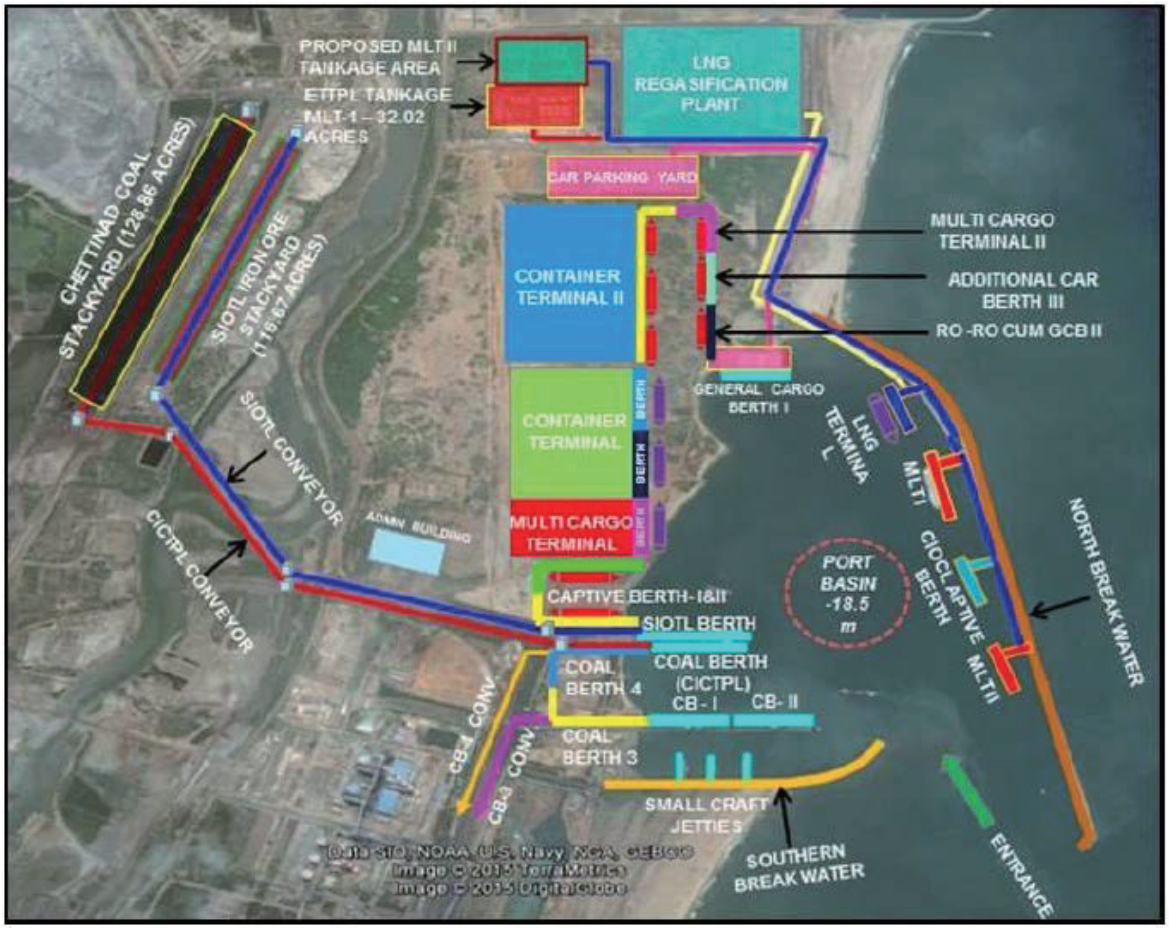
Figure 3.2.3 Vicinity of the Entrance and Exit Gates of Kattupalli Port

(2) Port Development Plan

1) Development Plan of Ennore Port

The development plan of Ennore Port follows its master plan.

The location of each project and the outline of ongoing projects, projects to be completed by 2020, and projects to be completed by 2035 are shown in the figure and table below.



Source: Final Report for Sagarmala (Vol. 4)

Figure 3.2.4 Projects to be Completed by Year 2035 (Ennore Port)

Table 3.2.3 Outline of the Project (Ennore Port)

No.	Project Name	Capacity Addition		Investment Required (INR in Crores)	Mode of Implementation	Remarks
		MTPA	MnTEU			
1	Development of LNG Terminal	5	-	5,151	PPP	Ongoing projects
2	TNEB Coal Berth CB 3	9	-	250	Port's funds	
3	TNEB Coal Berth CB 4	9	-	250	Port's funds	
4	Multi-Cargo Terminal	2	-	151	PPP	
5	Construction of Container Terminal Phase 1 Stage 1	15.4	0.8	800	PPP	
6	Development of Ro-Ro Terminal	1	-	150	Port's funds	
7	Capital Dredging Phase III	-	-	300	Port's funds	
	Subtotal	41.4	0.8	7,352		
1	IOC-POL Captive Jetty	3	-	465	PPP	Projects to be completed by Year 2020
2	Multi-User Liquid Terminal 2 (MLT 2)	3	-	393	PPP	
3	Construction of Container Terminal Phase 1 Stage 2	11.62	0.6	470	PPP	

No.	Project Name	Capacity Addition		Investment Required (INR in Crores)	Mode of Implementation	Remarks
		MTPA	MnTEU			
4	Modification of Existing Iron Ore Terminal to handle coal (SIOTL)	6	-	220	PPP	
5	Capital Dredging Phase-V for providing water depth of -16 m CD for the proposed Ro-Ro cum GCB 2, LNG, MLT 2 and IOCL Captive Jetty berths	-	-	250	Port's funds	
6	Development of Northern Port Access Road (4.35 km)	-	-	271	State Govt./ Stakeholders	
7	Development of Northern Rail Connectivity	-	-	244	Port's funds / IPRCL	
8	Upgrading the Southern Port Access Road	-	-	200	PPP	
9	FTWZ	-	-	850	Port's funds	
Subtotal		41.4	0.6	7,352		
1	Container Terminal Phase II	38.6	2.0	2,000	PPP	Projects to be completed by Year 2035
2	Coal Berths/Bulk Terminal (2 × 9 MTPA)	18	-	700	PPP	
3	Ro-Ro and General Cargo Berth	1	-	350	Port's funds	
4	Second Multi-Cargo Terminal	2	-	200	PPP	
Subtotal		41.4	2.0	7,352		
Projects Total		124.6	3.4	13,965		All projects

Source: Edited by the JICA Study Team based on the Final Report for Sagarmala (Vol. 4)

2) Development Plan of Chennai Port

The development plan of Chennai Port follows its master plan.

The outline of ongoing projects, projects to be completed by 2020, and projects to be completed by 2035 are shown in the table below.

Table 3.2.4 Outline of the Project (Chennai Port)

No.	Project Name	Capacity Addition (MTPA)	Investment Required (INR in Crores)	Mode of Implementation	Remarks
1	Development of Common Rail Yard inside the Port - 19 Port's Funds	-	19	Port's funds	Ongoing projects
Subtotal		-	19		
1	Development of Bunker Berth at Bharathi Dock	1	44	Port's funds	Projects to be completed by Year 2020
2	Development of Dry Dock at Timber Pond/Boat basin or Development of Marina	-	500	PPP	
3	Upgradation of JD East Berths and Paving of the Backup Area	1	90	Port's funds	
4	Development of Coastal Terminal	1.1	80	Port's funds	
Subtotal		3.1	714		
1	Conversion of JD East into Multi-Cargo Berth	1	110	PPP	Projects to be completed by

No.	Project Name	Capacity Addition (MTPA)	Investment Required (INR in Crores)	Mode of Implementation	Remarks
2	Development of BD II Back-up Area for Additional Container Storage or Developing BDII Berth and Back-up Space as Fully-Mechanized Fertilizer Terminal	2	100	PPP	Year 2025
3	SBM Terminal at Chennai	10	600	PPP	
	Subtotal	13	810		
	Projects Total	16.1	1,543		All projects

Source: Edited by the JICA Study Team based on the Final Report for Sagarmala (Vol. 4)

3) Development Plan of Kattupalli Port

The development plan of Kattupalli Port follows that of Adani Kattupalli Port.

Table 3.2.5 Outline of the Project (Kattuppalli Port)

Project Name	Details	Phase I
Quay Length	2 berths, 710 m	1 berth, 400 m
Capacity	1.2 million TEUs	0.8 million TEUs
Depth	16 m	16 m
Reefer Plugs	360 plugs, expandable	150
Ground Slots	5,120	4,000
Quay Cranes	6 post panamax cranes	4 units (22 across)
Rubber Tyre Gantry (RTG) Cranes	15 units for yard operations.	12 e-RTGs

Source: Edited by the JICA Study Team based on the Outline of Kattupalli Port (Adani)

(3) Amount of Future Cargo Handled at Ports

1) Amount of Cargo Handled of Ennore Port

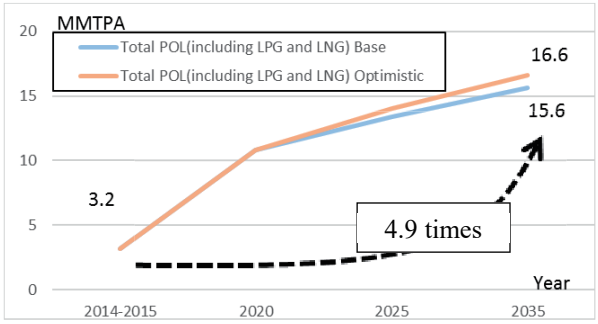
The amount future cargo handled of Ennore Port is shown in the figure below.

The amount of current liquid cargo handled is 3.2 million metric tonnes per annum (MMTPA), dry and break-bulk cargo is 24.32 MMTPA, and others is 2.7 MMTPA.

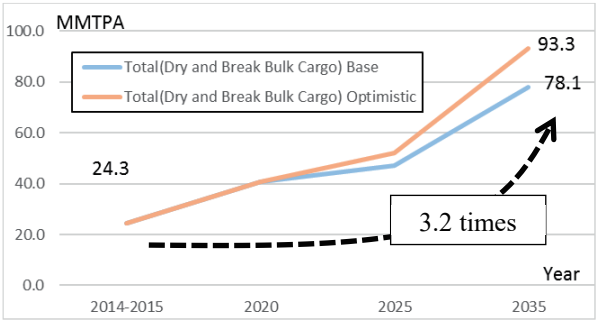
There are two scenarios for the amount of future cargo handled, basic scenario and optimistic scenario.

Regarding the basic scenario, it is predicted that handled cargo from 2014 to 2035 will increase by 4.9 times for liquid cargo, 3.2 times for bulk, and 3.4 times for others.

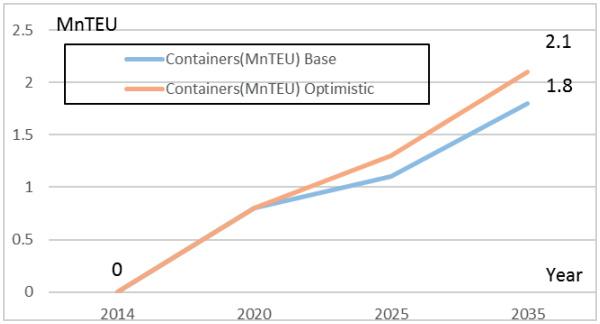
The container terminal of Ennore Port started operations in June 2017, but it has not been used as of the end of July 2017. However, the container handling volume in 2035 is estimated to be 1.8 million twenty-foot equivalent units (MnTEU). It is possible to handle 3.4 MnTEU containers until 2035, and future cargo handled is expected to reach half capacity.



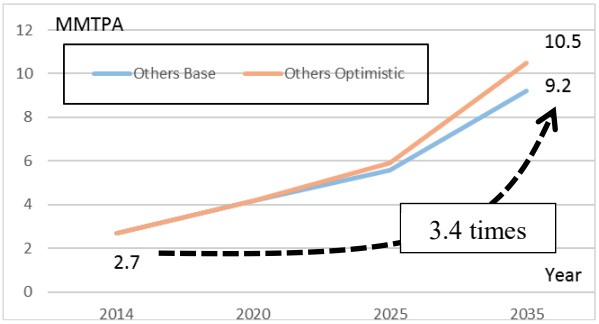
< Liquid Cargo >Photo①



< Dry and Break Bulk > Cargo



< Containers >



< Others >

Source: Edited by the JICA Study Team based on the Final Report for Sagarmala (Vol. 4)

Figure 3.2.5 Prediction of Cargo Handled by Year 2035 (Ennore Port)

Table 3.2.6 Prediction of Cargo Handled by Year 2035 (Ennore Port)

Ennore Port - Traffic Projections

Units: MMTPA (except Containers)

xx Base Scenario xx Optimistic Scenario

Commodity	2014-15	2020	2025		2035		Remarks
Liquid Cargo'							
POL product (EXIM and coastal)		6.3	6.6	7.0	8.1	8.8	• Shifting of POL product traffic from Chennai
LPG		1.5	1.8	2.0	2.5	2.8	
LNG		3.0	5.0	5.0	5.0	5.0	• 5 MTPA LNG terminal by IOCL
Total POL (including LPG and LNG)	3.2	10.8	13.4	14.0	15.6	16.6	
Dry and Break Bulk Cargo							
Thermal Coal (Loading)	0.0	0.0	0.0	0.0	0.0	0.0	
Thermal Coal (Unloading)	24.0	40.2	46.5	51.4	77.0	92.0	• Coastal increase, could also capture traffic from Cuddalore and Katupalli
Coking Coal	0.3	0.5	0.6	0.7	1.1	1.3	
Iron Ore	0.0	0.0	0.0	0.0	0.0	0.0	
Fertilizers	0.0	0.0	0.0	0.0	0.0	0.0	
Containers and other Cargo							
Containers (MnTEU)	0.0	0.8	1.1	1.3	1.8	2.1	
Others	2.7	4.2	5.6	5.9	9.2	10.5	• Vehicle Exports and Other commodities

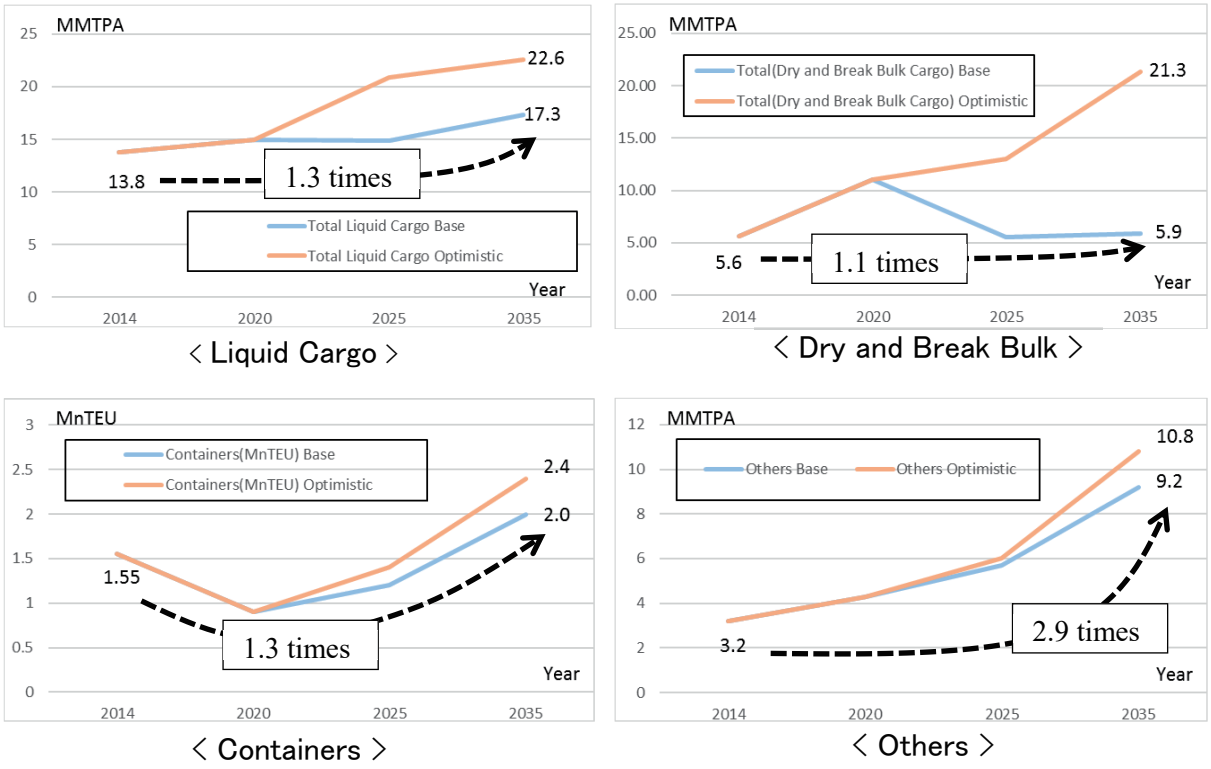
Source: Final Report for Sagarmala (Vol. 4)

2) Amount of Cargo Handled of Chennai Port

The amount of future cargo handled of Chennai Port is shown in the figure below.

The amount of current liquid cargo handled is 13.8 MMTPA, dry and break-bulk cargo is 5.6 MMTPA, container is 2.0 MnTEU, and others is 3.2 MMTPA.

Regarding the basic scenario, it is predicted that handled cargo from 2014 to 2035 will increase by 1.3 times for liquid cargo, 1.1 times for dry and break bulk, 1.3 times for containers, and 2.9 times for others.



Source: Edited by the JICA Study Team based on the Final Report for Sagarmala (Vol. 4)

Figure 3.2.6 Prediction of Cargo Handled by Year 2035 (Chennai Port)

Table 3.2.7 Prediction of Cargo Handled by Year 2035 (Chennai Port)

Chennai Port - Traffic Projections

xx Base Scenario xx Optimistic Scenario

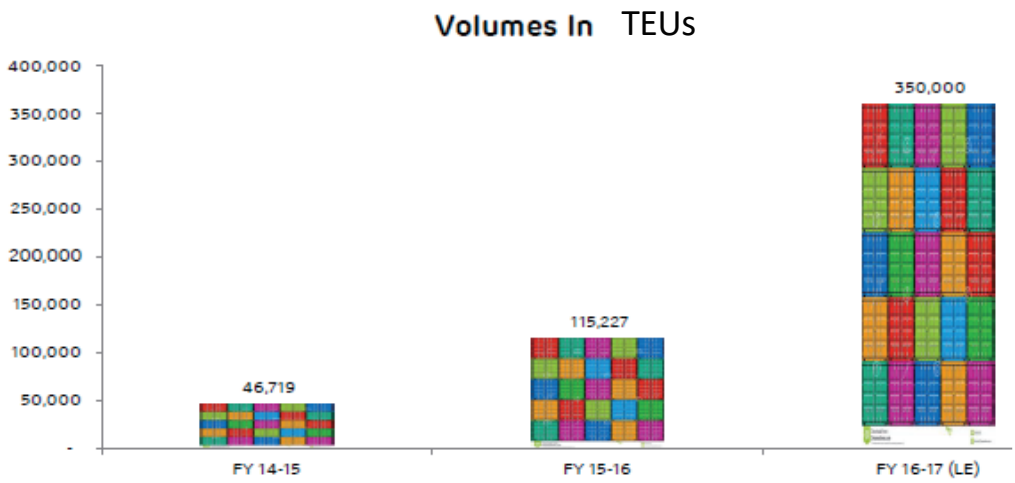
Commodity	2014-15	2020	2025		2035		Remarks
Liquid Cargo							
POL	12.7	13.3	13.1	18.8	14.3	19.2	▪ CPCL expansion considered in optimistic case
Vegetable Oil	1.1	1.7	1.8	2.1	3.0	3.4	
Dry and Break Bulk Cargo							
Thermal Coal (Loading)	0.0	0.0	0.0	0.0	0.0	0.0	
Thermal Coal (Unloading)*	0.0	6.1	0.0	7.0	0.0	12.5	▪ Traffic projections are contingent on permission to the port by Hon'ble SC to handle coal
Coking Coal	0.0	0.0	0.0	0.0	0.0	0.0	
Iron Ore	0.1	0.2	0.3	0.3	0.4	0.4	
Steel	1.4	1.9	2.5	2.9	3.0	5.5	
Limestone	2.6	1.5	1.4	1.4	1.2	1.2	
Dolomite	1.0	0.6	0.5	0.5	0.3	0.3	
Fertilizers	0.5	0.7	0.8	0.9	1.0	1.4	
Containers and other Cargo							
Containers (MnTEU)	1.55	0.9	1.2	1.4	2.0	2.4	▪ Traffic may further reduce by 2025 if Enayam comes up
Others	3.2	4.3	5.7	6.0	9.2	10.8	▪ Highly fragmented
Total (MMTPA)	52.5	47.7	49.3	66.9	71	101.0	

Source: Final Report for Sagarmala (Vol. 4)

3) Amount of Cargo Handled of Kattupalli Port

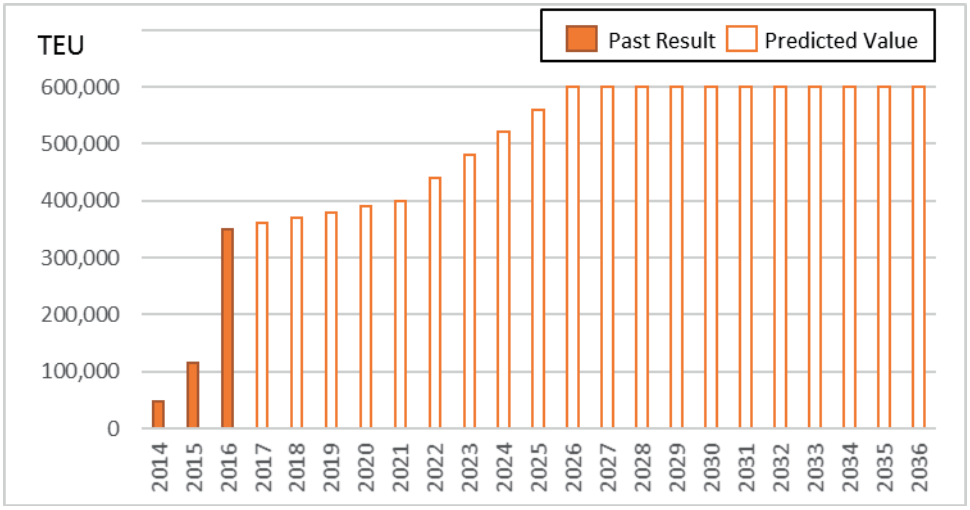
The amount of cargo handled from 2014 to 2016 in Kattupalli Port is shown in the figure below. It has increased dramatically each year.

There is no data on the future cargo handled in Kattupalli Port. Therefore, the amount of future cargo handled by Kattupalli Port is estimated as the capacity of cargo handled with reference to the estimates for Ennore Port.



Source: Outline of Kattupalli Port (Adani)

Figure 3.2.7 Cargo Handled from 2014 to 2016 (Kattupalli Port)



Source: Edited by the JICA Study Team based on the Outline of Kattupalli Port (Adani)

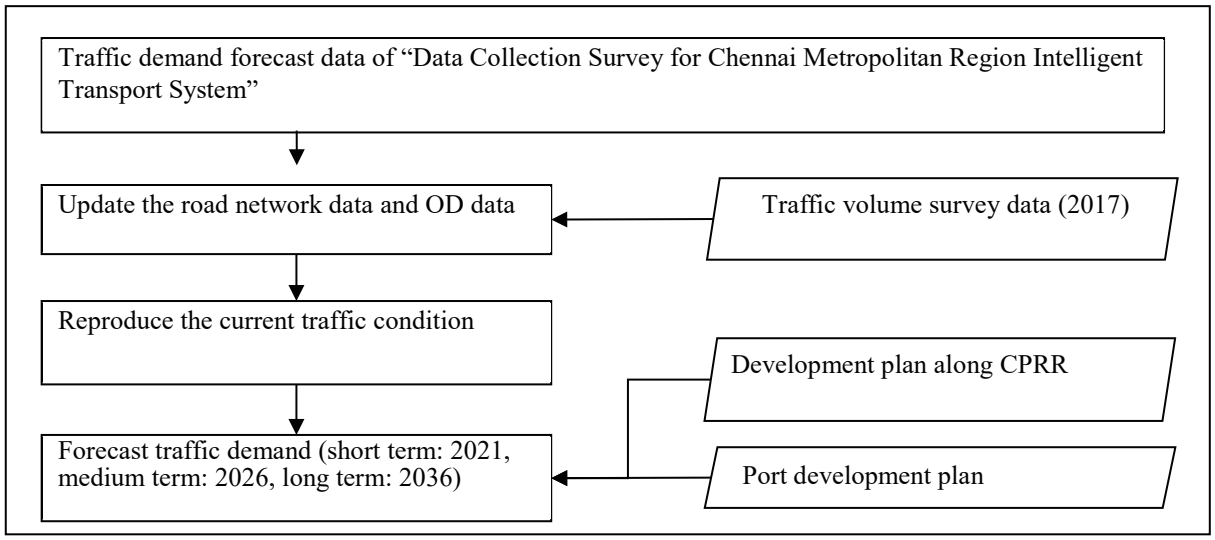
Figure 3.2.8 Estimation Result of Container Cargo Handled (Kattupalli Port)

3.3 Traffic Demand Forecast

In this survey, traffic demand forecast was reasonably carried out using network analysis of the "Data Collection Survey for Chennai Metropolitan Region Intelligent Transport System" in 2017. Specifically, the method and year of estimation of traffic demand forecast were set to be the same as that of the survey. The following points were also considered:

- Data update using the result of traffic volume survey.
- Future traffic demand considering the development plan along CPRR and port development plan.

The flow of traffic demand forecast is shown in the figure below.



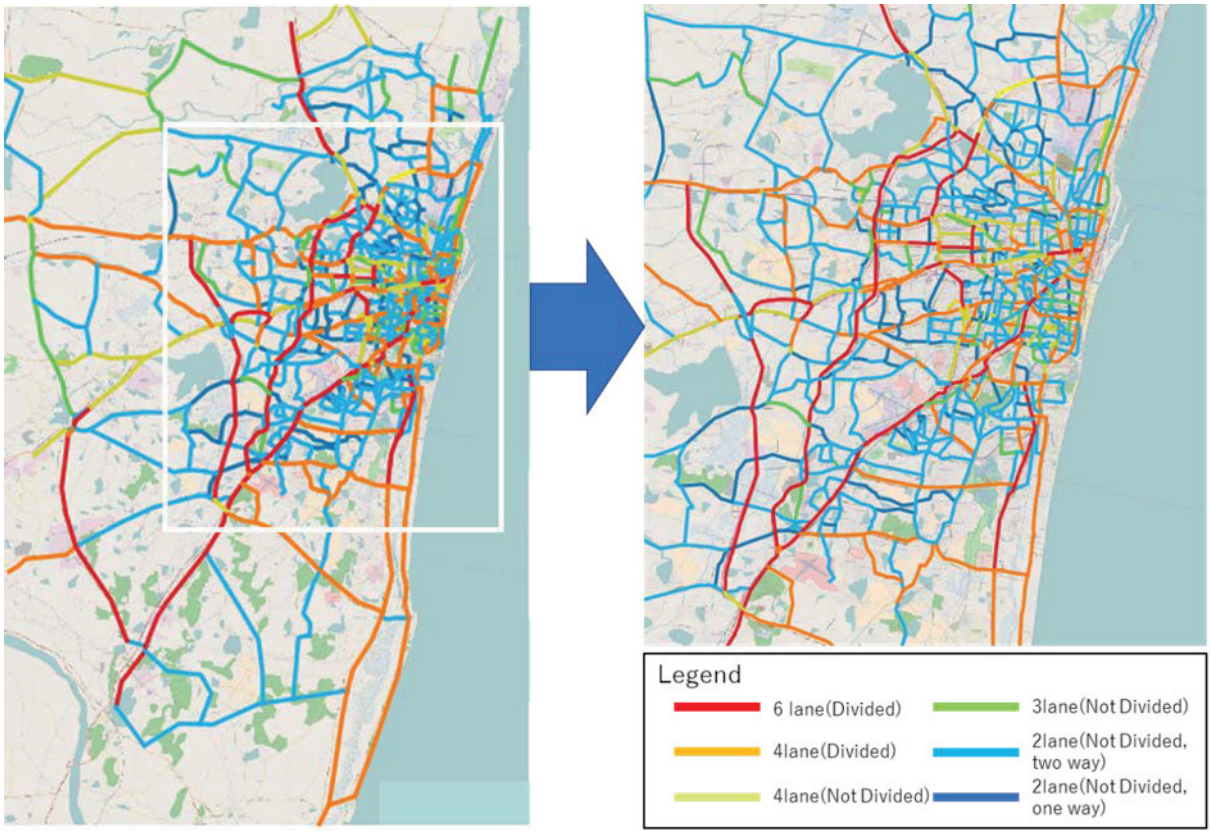
Source: JICA Study Team

Figure 3.3.1 Flow of Traffic Demand Estimate

3.3.1 Reproduction of Present Traffic Situation

(1) Update of Road Network

The road network of the "Data Collection Survey for Chennai Metropolitan Region Intelligent Transport System" was adopted with modifications such as the addition of new road links. The road network condition was set by referring to design service volume (passenger car units (PCUs) per hour) described in the "Guidelines for Capacity of Urban Roads in Plain Areas (IRC: 106-1990)". The daily capacity was calculated by dividing the design service volume per hour by the average peak rate of 8.7% in the traffic volume survey.



Source: JICA Study Team

Figure 3.3.2 Road Network Adopted in Traffic Analysis

Table 3.3.1 Recommended Design Service Volume

ID	No. of Lane	Divided /Not	Direction	Design Service Volume (PCU/hour)		
				Arterial*	Sub-arterial**	Collector***
1	2	undivided	one way	2,400	1,900	1,400
2	2	undivided	two ways	1,500	1,200	900
3	3	undivided	one way	3,600	2,900	2,200
4	4	undivided	two ways	3,000	2,400	1,800
5	4	divided	two ways	3,600	2,900	-
6	6	undivided	two ways	4,800	3,800	-
7	6	divided	two ways	5,400	4,300	-
8	8	divided	two ways	7,200	-	-

*: Roads with no frontage access, no standing vehicles, and very little cross traffic
**: Roads with frontage access but no standing vehicles and high capacity intersections.
***: Roads with free frontage access, parked vehicles, and heavy cross traffic
Source: Edited by the JICA Study Team based on IRC:106-1990

Table 3.3.2 Daily Capacity

ID	Line	Divided /Not	Direction	Daily Capacity Volume (PCU/day)		
				Arterial*	Sub-arterial**	Collector***
1	2	undivided	one way	27,600	21,900	16,100
2	2	undivided	two ways	17,300	13,800	10,400
3	3	undivided	one way	41,400	33,400	25,300
4	4	undivided	two ways	34,500	27,600	20,700
5	4	divided	two ways	41,400	33,400	-
6	6	undivided	two ways	55,200	43,700	-
7	6	divided	two ways	62,100	49,500	-
8	8	divided	two ways	82,800	-	-

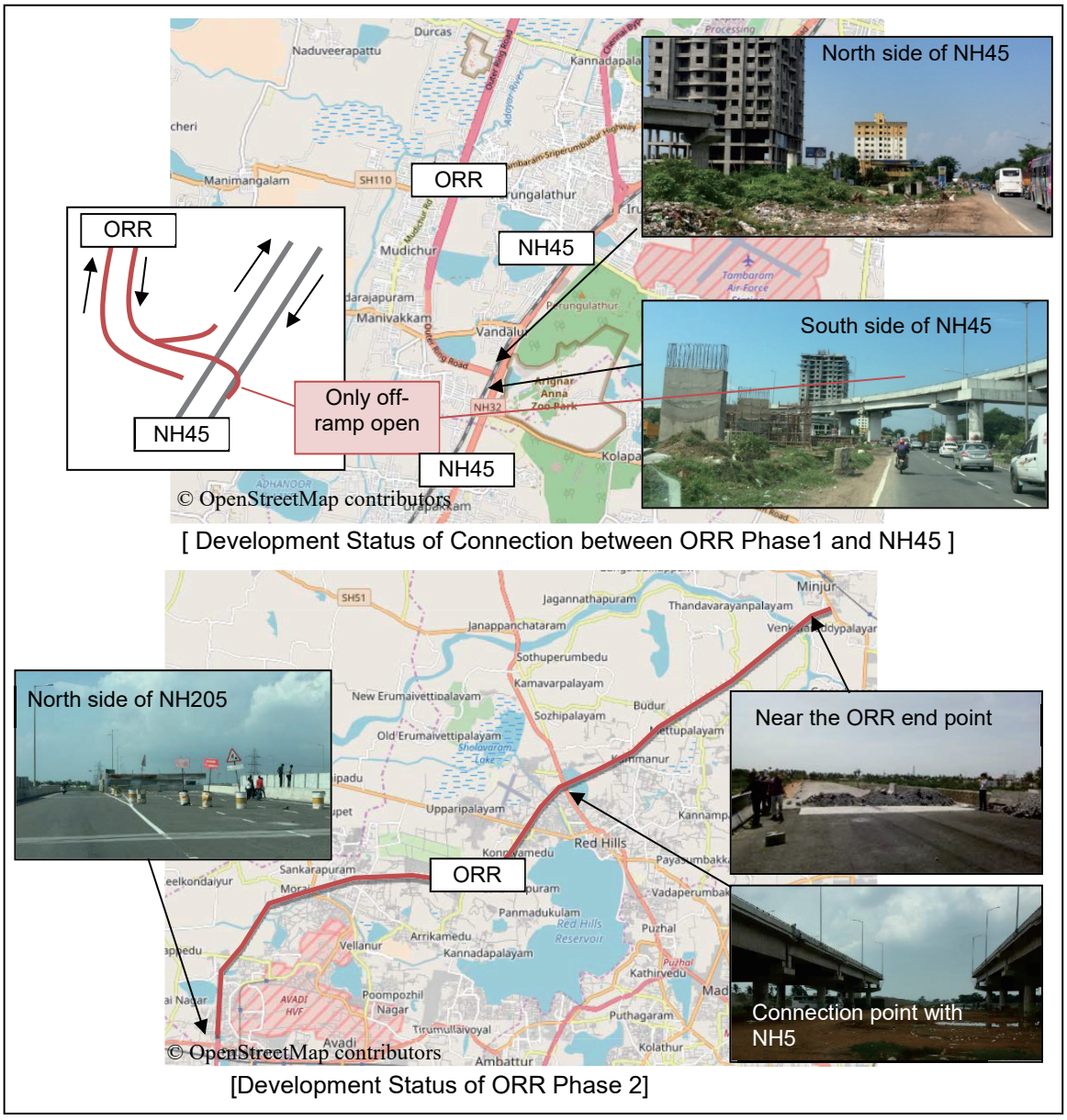
*: Roads with no frontage access, no standing vehicles, and very little cross traffic
**: Roads with frontage access but no standing vehicles and high capacity intersections.
***: Roads with free frontage access, parked vehicles, and heavy cross traffic
Source: JICA Study Team

The development status of ORR is shown in the figure below.

Connection between ORR Phase 1 and NH45: Only the off-ramp to the south side of NH45 was opened.

ORR phase 2: Although there is progress, the connection with the current road is not developed.

Thus, the off-ramp to the south side of NH45 was reflected in the current road network.



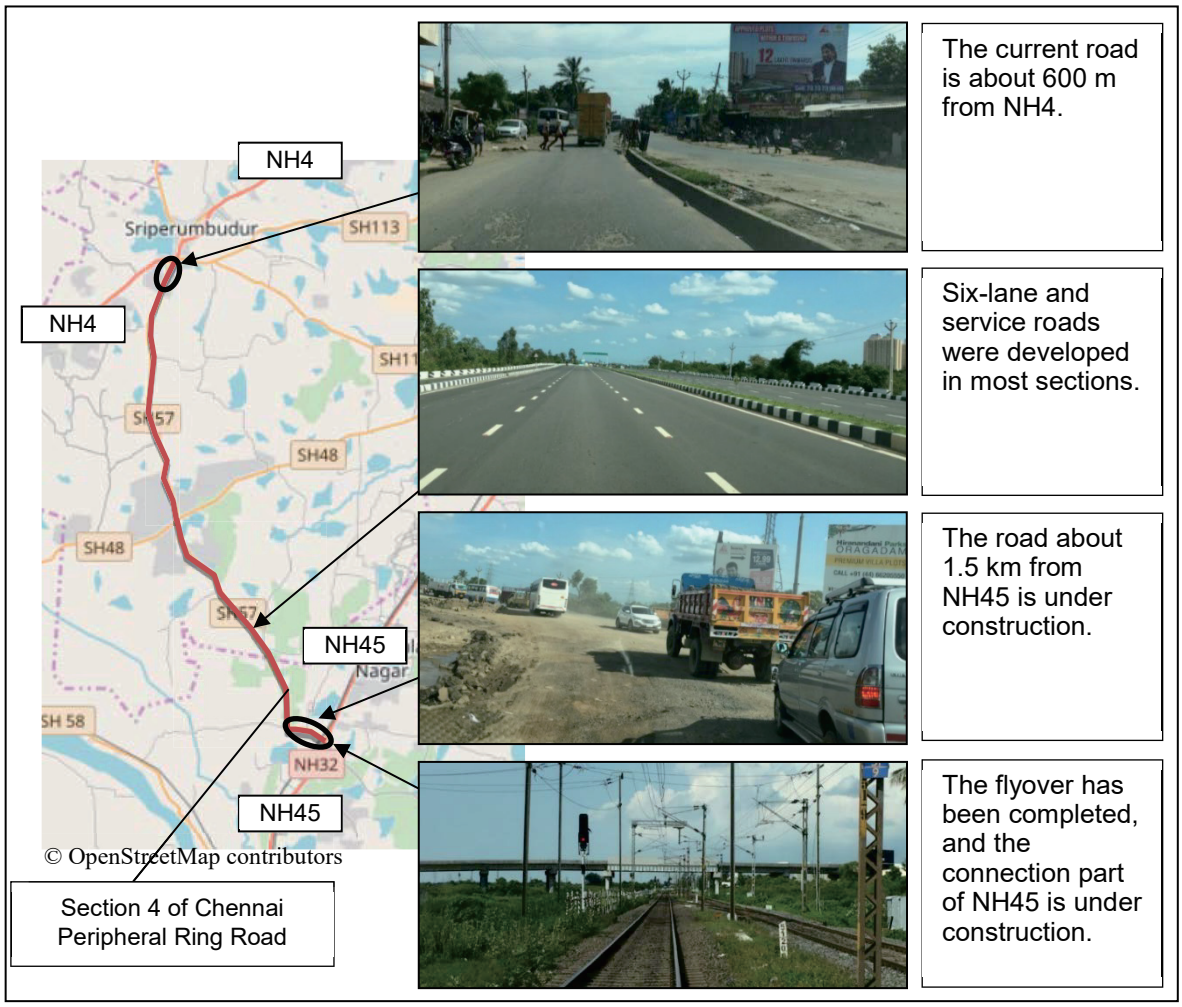
Source: JICA Study Team

Figure 3.3.3 Development Status of ORR

Connection between ORR Phase 1 and NH45: Only the off-ramp to the south side of NH45 was opened.

The development status of Section 4 of CPRR is shown in the figure below. Six-lane and service roads were developed in most sections. The connection point for NH4 and NH45 are under construction.

From the above, Section 4 of CPRR was reflected in the current road network.

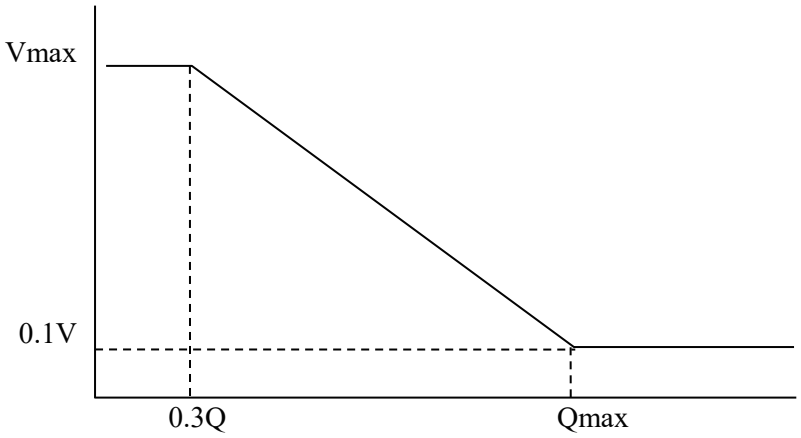


Source: JICA Study Team

Figure 3.3.4 Development Status of Sec. 4 of CPRR

(2) QV Conditions

QV conditions for the relationship of capacity and velocity were set as shown in Figure 3.3.5.

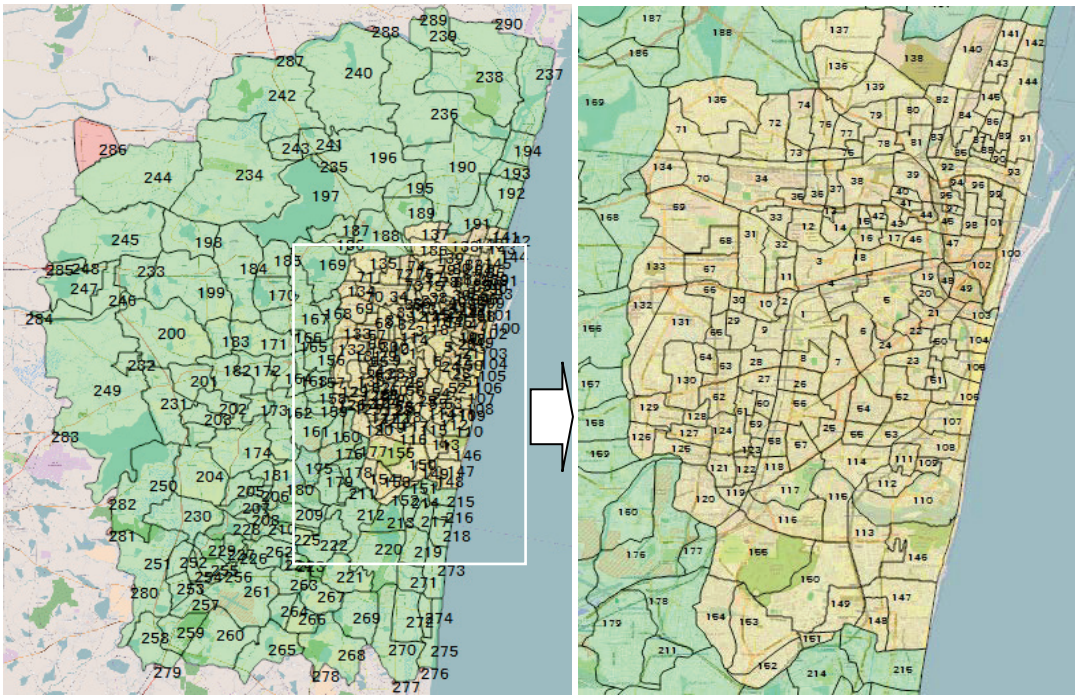


Source: JICA Study Team

Figure 3.3.5 QV Conditions

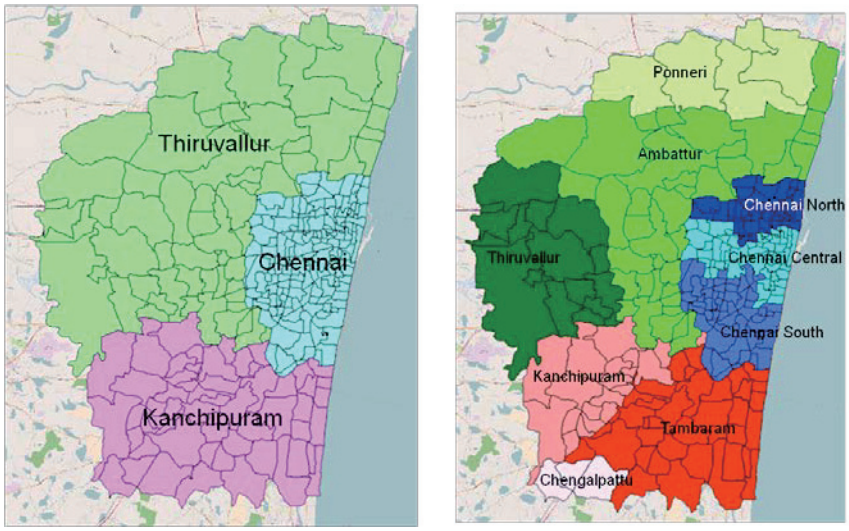
(3) Update of Origin-Destination (OD) Data

Zone divisions of OD matrix are set to be the same as those of the "Data Collection Survey for Chennai Metropolitan Region Intelligent Transport System". A total of 290 traffic analysis zones were divided into: 155 zones in the city area, 120 zones in the rest of the CMA, 15 external zones.



Source: JICA Study Team

Figure 3.3.6 Zone Divisions



Source: JICA Study Team

Figure 3.3.7 Zone Division Adopted in Traffic Analysis

Table 3.3.3 List of Zones (1)

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, DrAmbedkar 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
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, DrNatesan 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,
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)

Source: JICA Study Team

Table 3.3.4 List of Zones (2)

Zone	Large	Middle	Small
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, DrRadhakrishnan 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)

Source: JICA Study Team

Table 3.3.5 List of Zones (3)

Zone	Large	Middle	Small
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, Mouli pentankattalai, Thandalam, Kovur, Gerugambakkam, Peripanicheri,
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

Source: JICA Study Team

Table 3.3.6 List of Zones (4)

Zone	Large	Middle	Small
181	Kanchipuram	Kanchipuram	Polichalur
182	Thiruvallur	Thiruvallur	Chinnapanicheri, Paraniputhur, SennSirinivasapuram, Katturpakkam, Goparasanallur
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, Layon, Vadapurambakkam, Vadakarai, Layongrant, Naravarikuppam, Alinjivakkam
197	Thiruvallur	Ambattur	Puzhal Redhills, Tundalkalani
198	Thiruvallur	Ambattur	Kovilpadagai
199	Thiruvallur	Thiruvallur	Palaripattu, Sekkadu, Paruthipattu, Vilinjiambakkam
200	Thiruvallur	Thiruvallur	Thukkanampattu, Pidarithangal, Parivakkam, Veerar, Kolappancheri, Panavaduthottam
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
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, Melagaram, Malayambakkam, 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, Chinn Edayanchavadi, Vellivoyal, Thirunilai, Kodipallam, Periamullavoyal
237	Thiruvallur	Ambattur	Ennor
238	Thiruvallur	Ponneri	Vallur, Athipattu, Nandiyambakkam, Kollati, Ariyanvoyal

Source: JICA Study Team

Table 3.3.7 List of Zones (5)

Zone	Large	Middle	Small
239	Thiruvallur	Ponneri	Minjur
240	Thiruvallur	Ponneri	Sothupakkam, Perungavur, Pudur, Kummanur, Kandigai, Marambedu, Ankadu, Arumandai
241	Thiruvallur	Ambattur	Pdiyanallur, Thiruthakiriyampattu
242	Thiruvallur	Ponneri	Vijayanallur, Pannivakkam, Nallur, Siruniyam, Sembilivaram, Palayaermaivettipalaya
243	Thiruvallur	Ambattur	Attanthangal
244	Thiruvallur	Ambattur	Alathur, Velacheri, Pulikutti, Kadavur, Tenambakkam, 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
279-296	External Zone		

Source: JICA Study Team

The travel modes are set to be the same as those in the "Data Collection Survey for Chennai Metropolitan Region Intelligent Transport System". The passenger car unit (PCU) and the number of passengers per vehicle are shown in the table below.

The travel modes are categorized as shown in the table below to create current OD data which matched the traffic survey using the Root Mean Square Error Minimizing Model.

Table 3.3.8 Trip Mode Categories, Passenger Car Unit, Number of Passengers per Vehicle

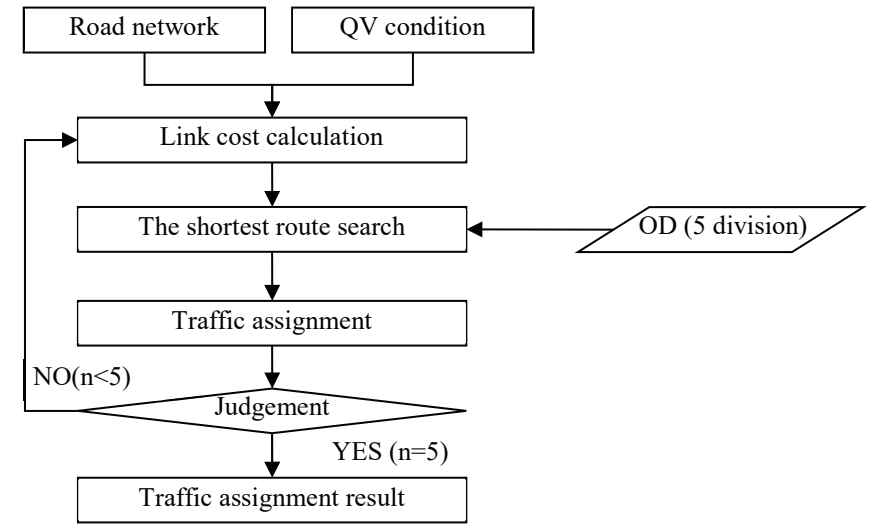
ID	Traffic Survey	ID	Traffic Demand Forecast	PCU *	Number of passengers per vehicle**	Average load tonnage
1	Two-wheeler	1	Two-wheeler	0.5	1.5	-
2	Car/Jeep	2	Car	1.0	2.6	-
3	Trip van/Maxi Cab/ Share Auto	3	Auto-Rickshaw	1.0	2.3	-
4	Auto-Rickshaw					
5	Bus	4	Bus	3.0	65	-
6	Mini Bus					
7	LCV*1	5	LCV	1.5	-	1.0 ***
8	Goods Auto					
9	2-axle	6	Truck	3.0	-	10.0 ****
10	3-axle					
11	MAV*2	7	MAV	4.5	-	29.0*****

*1: LCV (light commercial vehicle)
*2: MAV (multi-axle vehicle)
*source: Manual on Economic Evaluation of Highway Projects in India 2009
**source: Chennai Comprehensive Transportation Study
***source: Edited by JICA Study Team based on Network for Transport Measures
****source: Edited by JICA Study Team based on Northern Port Access Road FS NHAI 2008
*****source: Edited by JICA Study Team based on Northern Port Access Road FS NHAI 2008

(4) Reproduction of the Current Traffic Situation

The Incremental Traffic Assignment Method was used to divide the input OD traffic data into user-specified increments and to assign each increment to the minimum route where the generalized cost (i.e., the impedance calculated from travel time, distance, etc.) is the least.

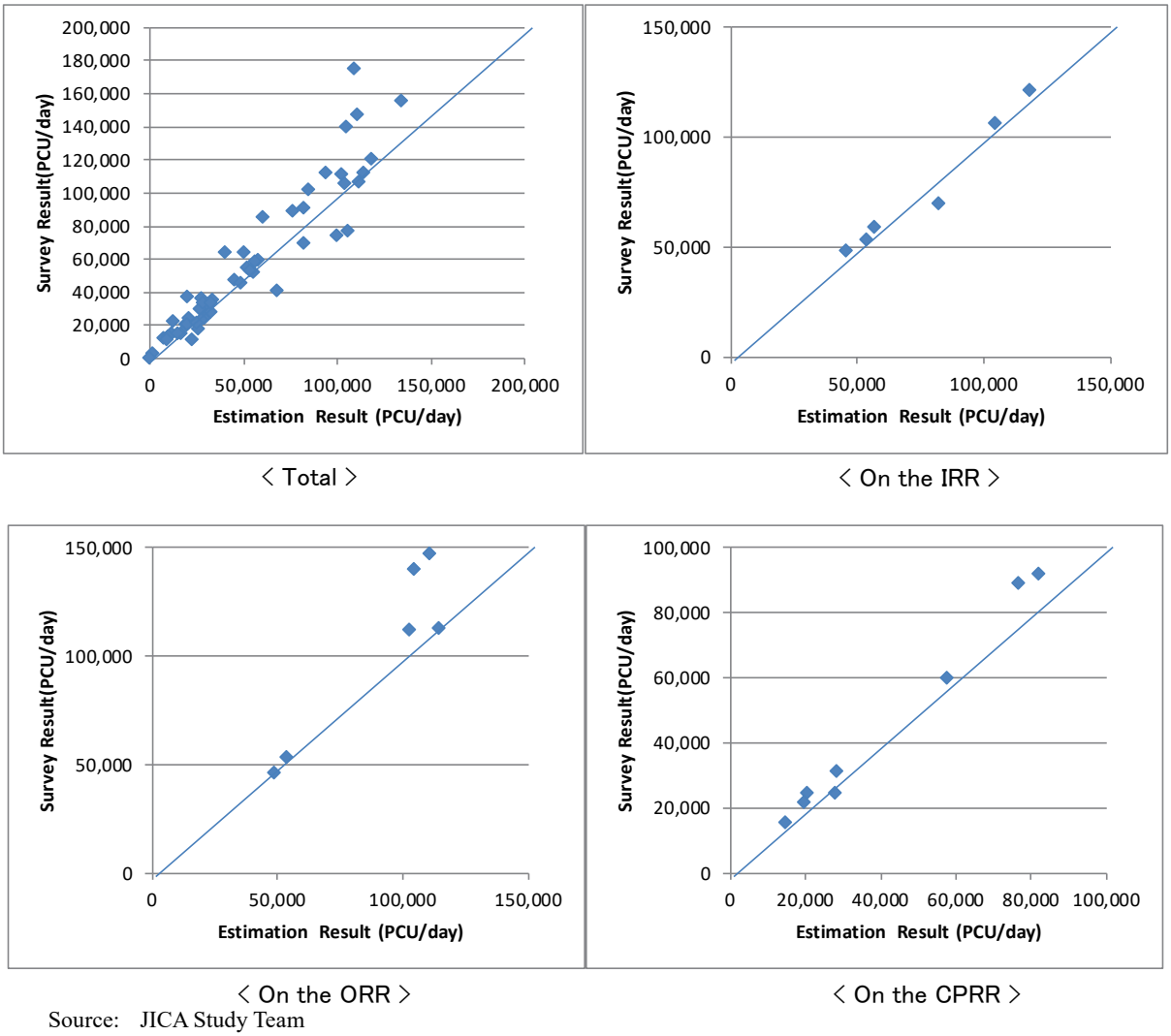
The origin-destination data has 5 divisions, distributing 20% for each. Road network, QV condition and origin-destination data show earlier were used as shown below.



Source: JICA Study Team

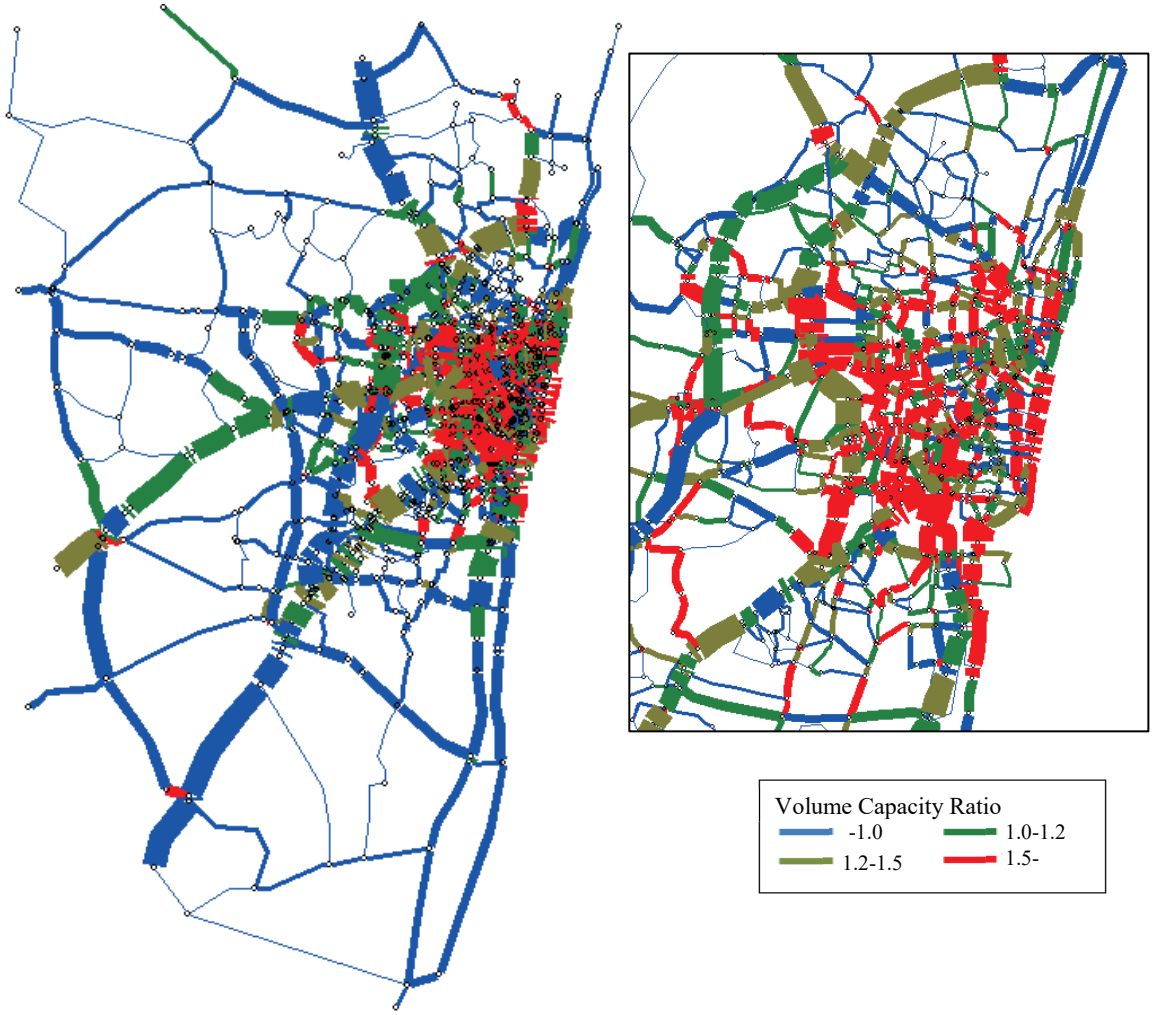
Figure 3.3.8 Traffic Assignment Flow

The result of the 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 is 0.929 in this correlation (on the IRR: 0.980, on the ORR: 0.933, on the CPRR: 0.994). Thus, it is judged that the reproducibility was mostly obtained.



Source: JICA Study Team

Figure 3.3.9 Survey Result and Estimation Result



Source: JICA Study Team

Figure 3.3.10 Traffic Assignment Result

3.3.2 Estimate of Developed Traffic Volume

(1) Future Traffic Demand

The growth rate of the future demand and the modal share are set to be the same as those of the "Data Collection Survey for Chennai Metropolitan Region Intelligent Transport System". The values are shown in the table below. Double counting of changes in freight vehicles due to changes in future cargo volumes to avoid trucks and multi-axle vehicles (MAVs) are not taken into consideration.

Table 3.3.9 Growth Rate of Future Traffic Demand for Target Years Estimated by this Study from Current Origin-Destination Data (2016)

Term	Year	Motor-cycle	Passenger Auto	Car/ Jeep	Bus	LCV*1	2&3Axle Trucks	MAV*2	All Type
Short	2021	1.394	1.219	1.383	1.222	1.580	1.300	1.251	1.361
Mid	2026	2.042	1.556	2.007	1.559	2.672	1.755	1.617	1.954
Long	2036	3.933	2.302	3.805	2.334	6.605	2.942	2.510	3.657

*1: LCV (light commercial vehicle)
*2: MAV (multi-axle vehicle)
Source: JICA Study Team edited based on the Detailed Project Report on CPRR

Table 3.3.10 Modal Share of Future Traffic Demand for Target Years

	Short	Mid	Long	Current	CCTS
	2021	2026	2036	2016	2026
Public Transport	62%	70%	70%	54.9%	70%
IPT	6%	8%	8%	4.6%	8%
Private Transport	32%	22%	22%	40.5%	22%

Source: CCTS, Chennai

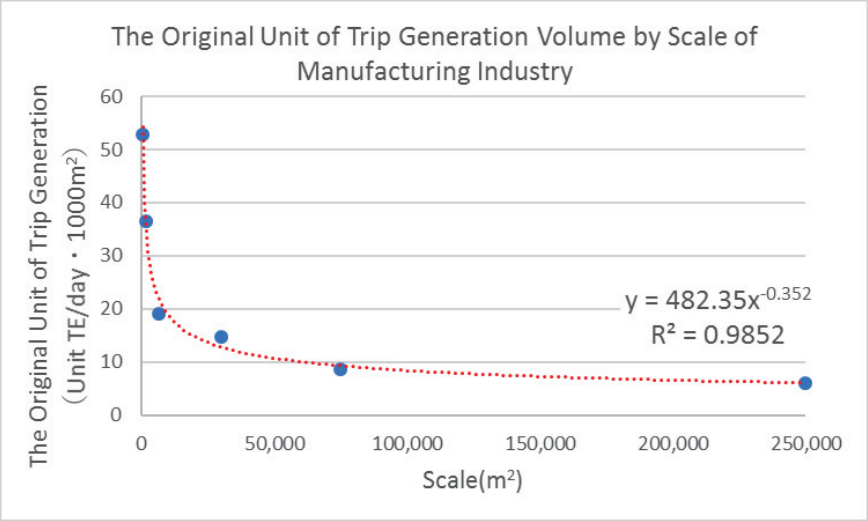
Note: The above table excludes non-motorized transport.

Note: Construction of Mass Rail Transit, Metro Rail, Mono Rail, Light Rail Transit, Bus Rapid Transit based on the plans is required, so that the public transport share rises to 70%. In addition, it is also important that parking lots, transfer stations, traffic information systems, 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 introducing the common card and securing regular schedule of trains are required. Most of city buses which are the 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%.

(2) Reflecting Traffic Volume in Consideration of the Development Plan

1) Mahindra Industrial Park Chennai

Mahindra Industrial Park Chennai is scheduled to develop 300 ha and has completed development and sales in the short term (2021). The original unit of trip generation volume from the Mahindra Industrial Park Chennai was set using the basic unit of manufacturing industry based on the scale below. The trip generation rate is multiplied by the mixing ratio of large vehicles, and the arrival and departure point of the large vehicles are set to Ennore Port. Since Mahindra Industrial Park Chennai is located along NH5, the mixing ratio of large vehicles is set to the value of NH5.



Source: Edited by the JICA Study Team based on the National Institute for Land and Infrastructure Management, Research Report No. 21

Figure 3.3.11 Original Unit of Trip Generation Volume by Scale of Manufacturing Industry

Table 3.3.11 Trip Generation Rate at Mahindra Industrial Park Chennai

Trip Generation Volume	Trip Generation Volume	Mixing Ratio of Large Vehicles	Number of Large Vehicles
2.5 unit TE/day・1000 m²	3,750 units/day	・Truck: 22.2% ・MAV: 9.6%	・Truck: 833 units/day ・MAV: 360 units/day

Source: JICA Study Team

(3) Cargo Vehicles Accompanying an Increase of Traffic Handled

1) Modal Split of Traffic Handled at the Port

The modal split of traffic handled at the Chennai Port in 2015 is assumed as shown in the table below. The same rates were applied to Ennore Port. It is assumed that only the road is used for Kattupalli Port. Future modal split was set to be the same as the current values.

Since the container does not use pipelines, it was set that 87% use the road and 13% use the railway.

Table 3.3.12 Modal Split of Traffic Handled

Year	Total Traffic Handled	Road		Rail		Pipeline	
		Tonnage	Ratio	Tonnage	Ratio	Tonnage	Ratio
2015	50.06	33.12	66%	4.2%	10%	12.09	24%

Source: Final Report for Sagarmala (Vol. 4)

2) Increase of Traffic Handled at the Port

The results of calculating the increment of future traffic handled from 2017 is shown in the table below.

Table 3.3.13 Increase of Traffic Handled per Year

	Commodity	Increase of Traffic Handled per Year		
		Chennai Port	Ennore Port	Kattupalli Port
Short (2021)	Liquid Cargo (MMTPA)	0.58	4.32	-
	Bulk Cargo (MMTPA)	1.60	9.48	-
	Container (MnTEU)	-0.27	0.46	0.04
	Other (MMTPA)	0.83	1.09	-
Mid (2026)	Liquid Cargo (MMTPA)	0.5	6.40	-
	Bulk Cargo (MMTPA)	-2.80	14.6	-
	Container (MnTEU)	-0.03	0.70	0.24
	Other (MMTPA)	1.95	2.45	-
Long (2036)	Liquid Cargo (MMTPA)	3.14	8.82	-
	Bulk Cargo (MMTPA)	-2.36	48.7	-
	Container (MnTEU)	0.86	1.47	0.24
	Other (MMTPA)	5.80	6.08	-

Source: JICA Study Team

The increase of traffic handled per day, where the number of working days is set to be 330 days per year, is shown in the table below.

Table 3.3.14 Increase of Traffic Handled per Day

	Commodity	Increase of Traffic Handled per Year		
		Chennai Port	Ennore Port	Kattupalli Port
Short (2021)	Liquid Cargo (MMTPA)	1,758	13,091	-
	Bulk Cargo (MMTPA)	4,848	28,727	-
	Container (MnTEU)	-803	1,394	121
	Other (MMTPA)	2,515	3,303	-
Mid (2026)	Liquid Cargo (MMTPA)	1,515	19,394	-
	Bulk Cargo (MMTPA)	-8,485	44,242	-
	Container (MnTEU)	-76	2,121	727
	Other (MMTPA)	5,909	7,424	-
Long (2036)	Liquid Cargo (MMTPA)	9,515	26,727	-
	Bulk Cargo (MMTPA)	-7,152	147,576	-
	Container (MnTEU)	2,591	4,455	727
	Other (MMTPA)	17,576	18,424	-

Source: JICA Study Team

3) Calculation of Increase of Number of Trucks

With reference to similar cases in India, load capacity by car type is set as shown in the table below.

Table 3.3.15 Load Capacity by Car Type

Commodity	Car type	Load Capacity
Liquid Cargo	Truck	10 tons/unit
Bulk Cargo	Truck	12 tons/unit
Container	Trailer	1.5 TEU/unit
Other	Truck	10 tons/unit

Source: Edited by the JICA Study Team based on the Northern Port Access Road FS NHAI 2008

The increase of traffic using the road was calculated based on the modal split of traffic handled.

Table 3.3.16 Increase of Traffic Handled using Road

	Commodity	Increase of Traffic Handled per Year		
		Chennai Port	Ennore Port	Kattupalli Port
Short (2021)	Liquid Cargo (MMTPA)	1,472	8,640	-
	Bulk Cargo (MMTPA)	4,062	18,960	-
	Container (MnTEU)	-887	1,213	154
	Other (MMTPA)	2,107	2,180	-
Mid (2026)	Liquid Cargo (MMTPA)	1,269	12,800	-
	Bulk Cargo (MMTPA)	-7,108	29,200	-
	Container (MnTEU)	-84	1,845	923
	Other (MMTPA)	4,950	4,900	-
Long (2036)	Liquid Cargo (MMTPA)	7,971	17,640	-
	Bulk Cargo (MMTPA)	-5,991	97,400	-
	Container (MnTEU)	2,861	3,875	923
	Other (MMTPA)	14,723	12,160	-

Source: JICA Study Team

The increase in the number of trucks that was calculated using load capacity by car type is shown in the table below. These trucks were allocated from each port to the CFS and the industrial park.

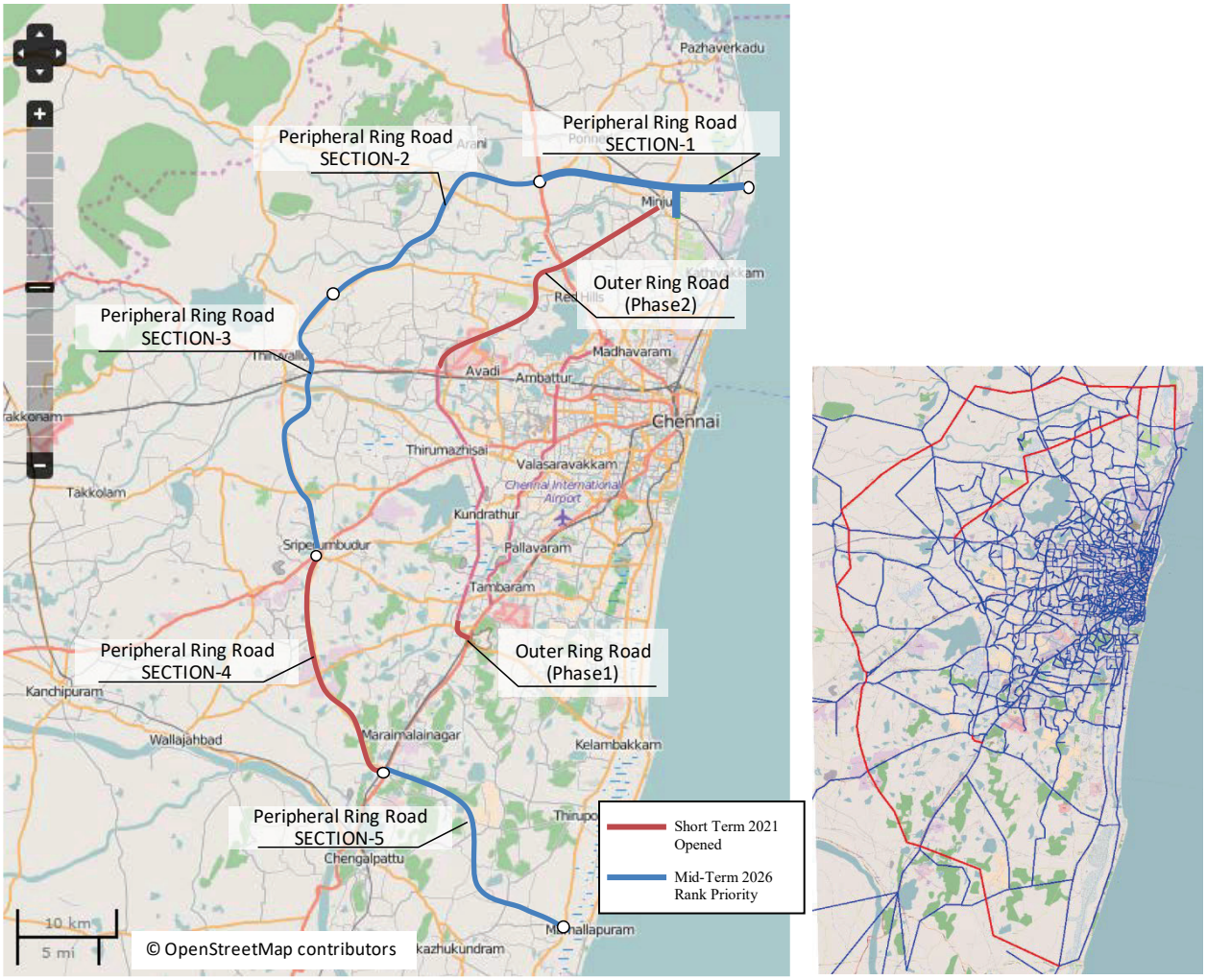
Table 3.3.17 Future Increase of Trucks at the Port

		Increase of Trucks		
		Chennai Port	Ennore Port	Kattupalli Port
Short (2021)	Trailer (unit/day)	-591	808	81
	Truck (unit/day)	764	2,978	-
Mid (2026)	Trailer (unit/day)	-56	1,230	485
	Truck (unit/day)	-89	4,690	-
Long (2036)	Trailer (unit/day)	1,907	2,584	485
	Truck (unit/day)	1,670	12,720	-

Source: JICA Study Team

(4) Preparation of Future Network Data

The planned major roads are the ORR (Phase 1 and Phase 2) and CPRR (from Section 1 to Section 5). These roads were added to the future network data. The opening year of each road is assumed as shown in the table below.



Source: JICA Study Team

Figure 3.3.12 Future Road Network

Table 3.3.18 Opening Year of Major Road

Term	Opening	Road
Short	2021	ORR (Phase 1, Phase 2), CPRR (Section 4)
Mid	2026	Review priority of CPRR (Sections 1 to 5)
Long	2036	CPRR (Sections 1 to 5)

Source: JICA Study Team

(5) Future Traffic Demand Forecast

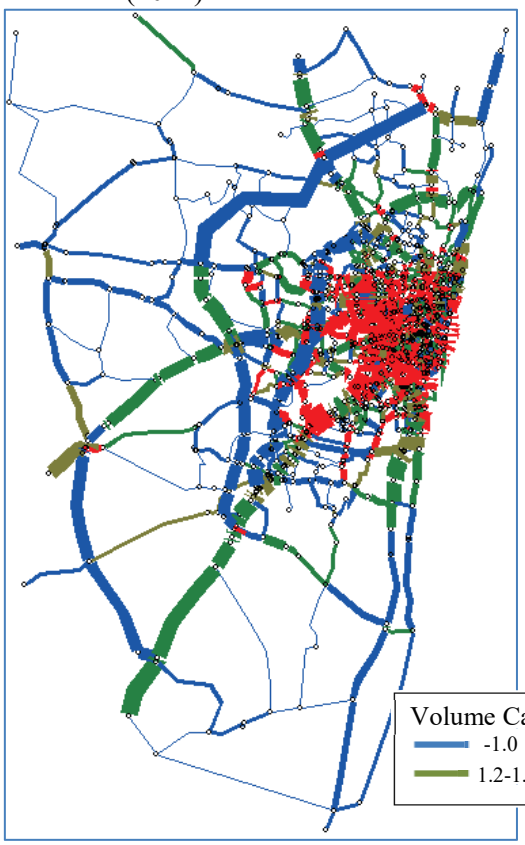
The results of the future traffic demand forecast for short term, mid-term and long term are shown in the figure below.

In the short term, the traffic capacity of the access road to the Ennore Port is expected to increase due to the increase in the cargo volume brought about by the improvement of the processing capacity at the Ennore Port. In addition, it is expected that there will be no problem in increasing the traffic volume of the ORR and the CPRR (Section 4), but it is expected that congestion will occur in the section from the ORR to the Ennore Port.

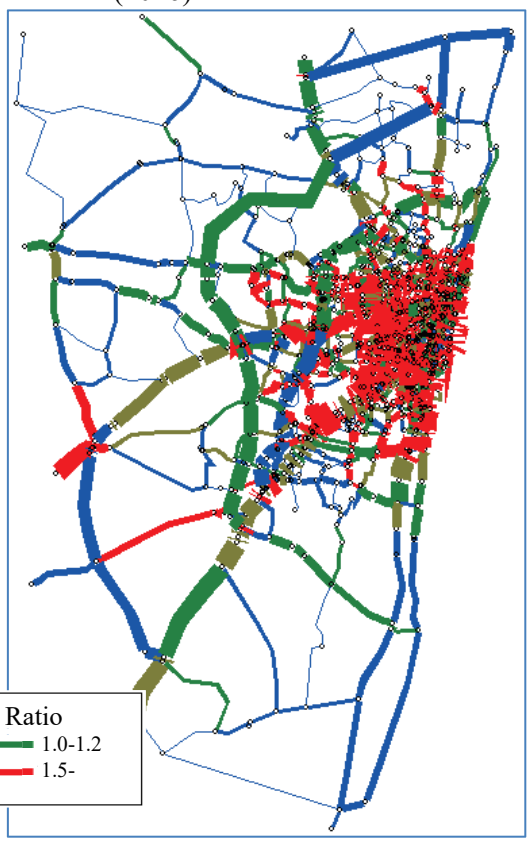
In the mid-term, it is expected that the congestion in the section from the ORR to the Ennore Port will be alleviated by constructing the CPRR (Section 1).

In the long term, traffic congestion occurrs in the city due to the increase in total traffic volume.

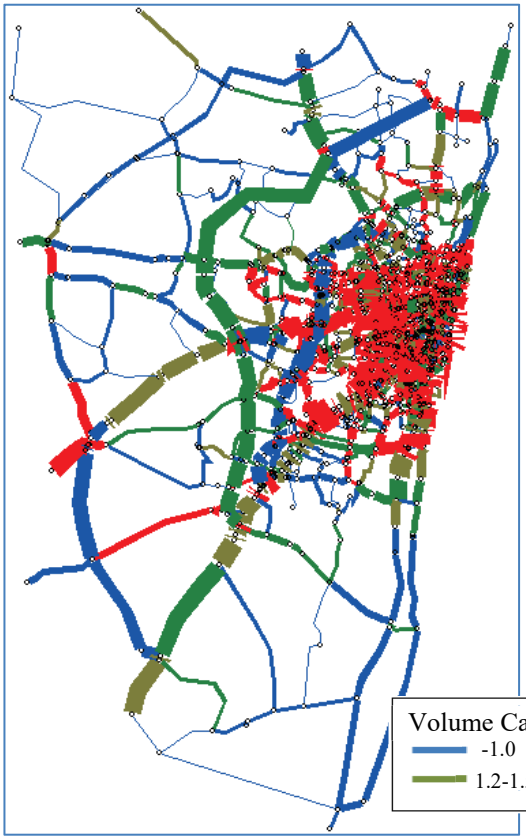
Short Term (2021) Sec. 4



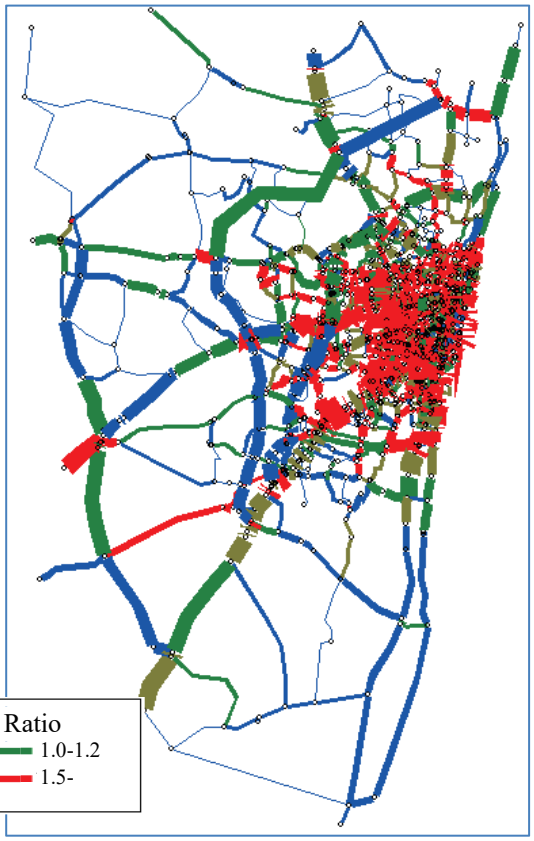
Mid Term (2026) Sec. 1 + Sec. 4



Mid Term (2026) Sec. 2 + Sec. 4



Mid Term (2026) Sec. 3 + Sec. 4



Source: JICA Study Team

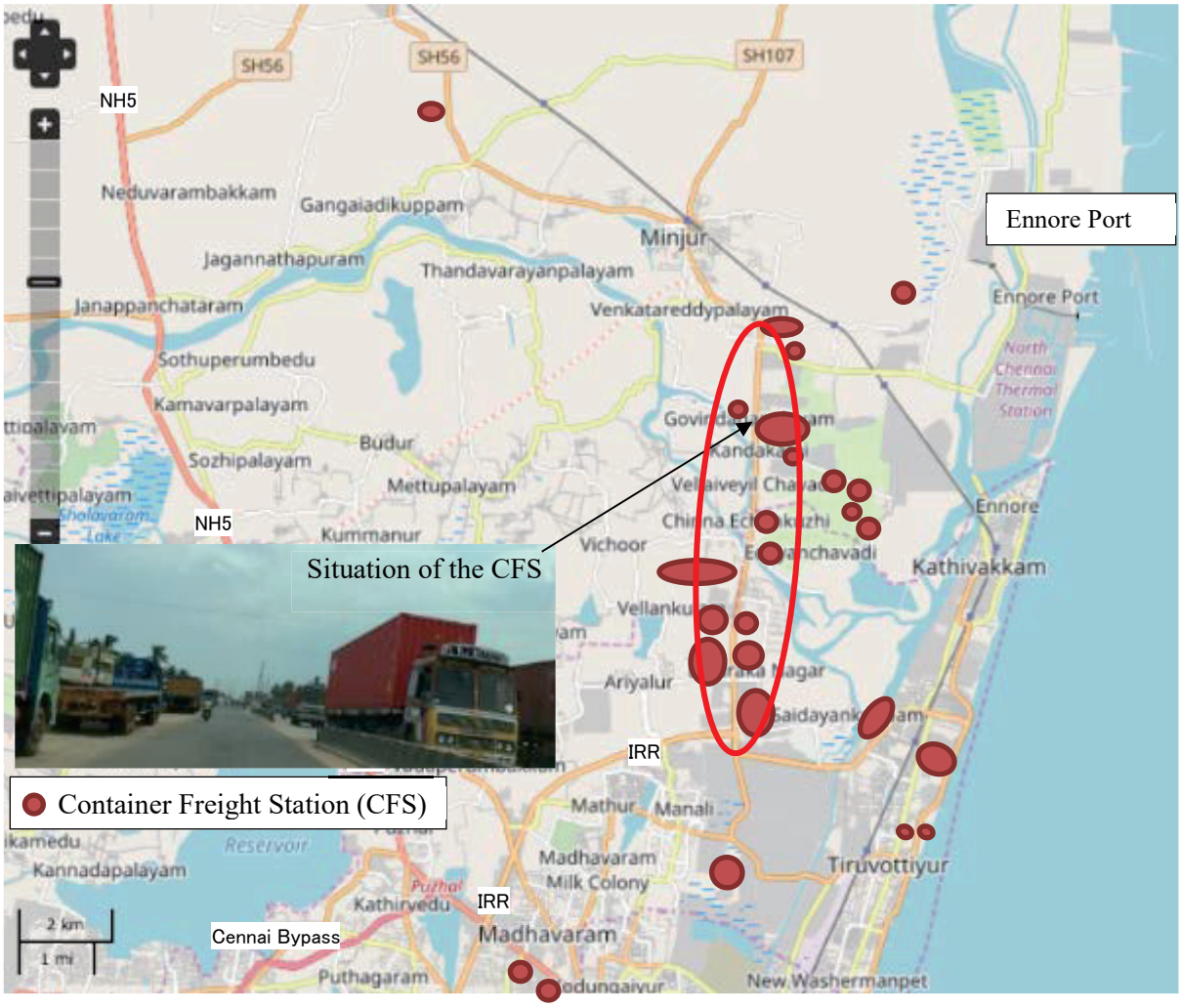
Figure 3.3.13 Traffic Assignment Result

(6) Road and Traffic Issues

1) Congestion around Container Freight Stations

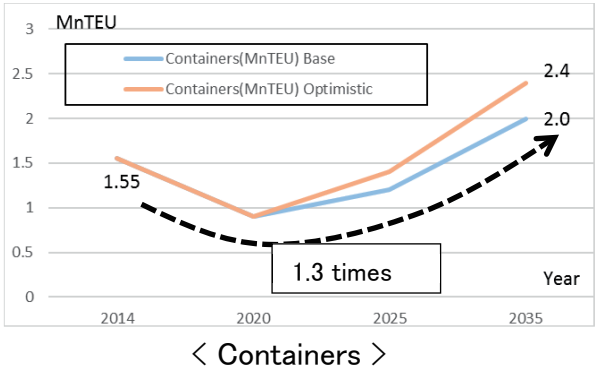
Several container freight stations are installed around the Chennai Port to compensate for the lack of capacity, as the yard is narrow and the capacity of Chennai Port is too small to accommodate containers . Congestion occurs around the Chennai Port by freight vehicles moving between Chennai Port and the CFS. In particular, the CFSs are concentrated in the area surrounded by the red frame in the figure below, and it is still crowded due to the influence of the large vehicles parked.

Although the amount of containers handled by the Chennai Port in the future temporarily decreases, it is indicated in the Chennai Port Master Plan that the amount of containers will increase, which may cause further congestion.



Source: JICA Study Team

Figure 3.3.14 Location of the Container Freight Stations



Source: Edited by the JICA Study Team based on the Final Report for Sagarmala (Vol. 4)

Figure 3.3.15 Prediction of Cargo Handled by Year 2035 (Chennai Port)

2) Connection of ORR and CPRR

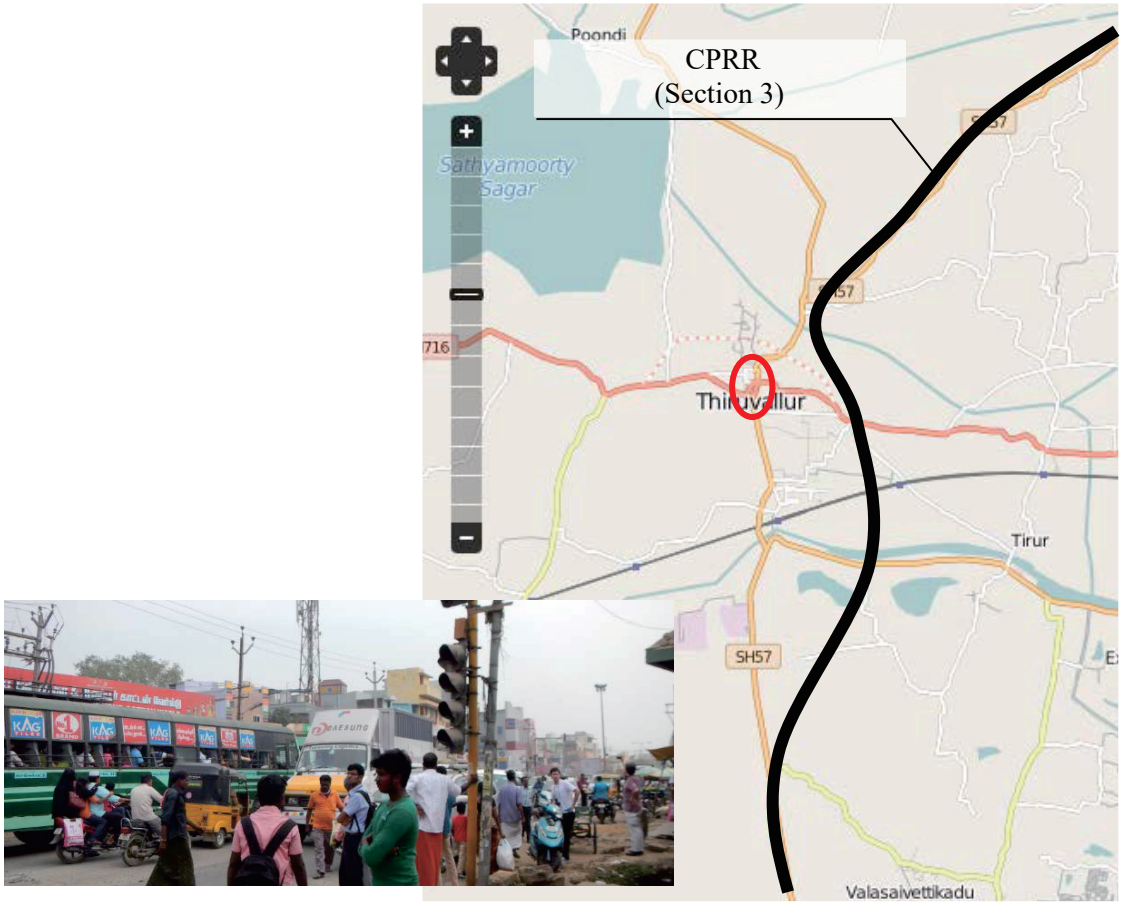
Currently, the ORR (Phase 2) and Section 1 of the CPRR are not planned to be connected. Both roads are planned to connect to the road in Minjur Village. This road in the village is a 2-lane road, and there are a number of houses and shops along the road, as shown in the photograph below. There is concern that this will be a bottleneck and traffic accidents may occur because there are many people on the roadside.

Source: JICA Study Team

Figure 3.3.16 Connection of ORR and CPRR

3) Intersection of NH205 and SH57

Section 3 of the CPRR is planned to bypass the intersection of NH205 and SH57 in Thiruvallur. This intersection is a four-lane section and is frequently used by a number of large vehicles, such as buses and trailer trucks, as shown in the photograph below. There are a number of houses and shops around the intersection. Thus, the traffic capacity has declined significantly. It is expected that this will be a bottleneck and may cause traffic accidents.



Source: JICA Study Team

Figure 3.3.17 Problems of Intersection of NH205 and SH57

(7) Sensitivity Analysis

1) Modal Share

As shown in the table below, the sensitivity analysis was carried out for the case that modal shift occurred from the current condition to the short – medium – long–term terget year.

Table 3.3.19 Modal Share of Future Traffic Demand for Target Years

	Current	Short	Mid	Long
	2016	2021	2026	2036
Public Transport	54.9%	58%	62%	70%
IPT	4.6%	5%	6%	8%
Private Transport	40.5%	37%	32%	22%

Source: JICA Study Team

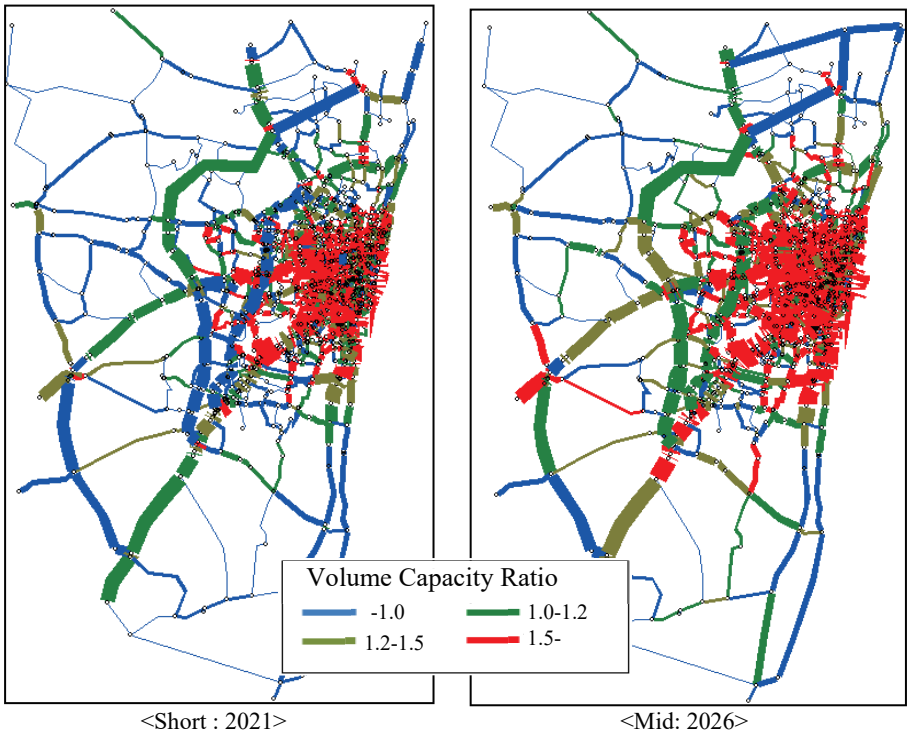
2) The Results of Sensitivity Analysis

The results of sensitivity analysis were compared using the total travel time for evaluating the efficiency of the road traffic in the survey area for the short and middle-term (CASE A: Sec.4 + Sec.1). As a result of comparing CCTS case and the case that the modal shift is carried out gradually toward the long-term (2036), the CCTS case, total travel time increased by 15% in the short term, 20% in the middle term.

Table 3.3.20 Total Travel Time of Each Analysis Case (unit: Vehicle Hour)

	Short 2021	Mid 2026
CCTS, Chennai [A]	3,226,956	4,377,730
Sensitivity Analysis [B]	3,712,172	5,314,043
[C] = [B] / [A]	1.15	1.21

Source: JICA Study Team



<Short : 2021> <Mid: 2026>

Source: JICA Study Team

Figure 3.3.18 The Result of Sensitivity Analysis

CHAPTER 4 PRIORITIZATION AND FORMULATION OF THE PROJECT FOR JICA LOAN SCHEME

4.1 Chennai Peripheral Ring Road (CPRR) Components

4.1.1 Approved Alignment and Sectioning of CPRR

According to the Detailed Project Report (DPR), the alignment for CPRR was approved by the Steering Committee and was finalized by the Principal Secretary of the Highways and Minor Ports Department (HMPD) on 9 July 2014. The CPRR starts at Ennore Port and ends at Poonjeri Junction (KM 56/800 of ECR) in Mahabalipuram. The alignment connects four national highways, namely NH5, NH205, NH4, and NH45, as well as eight state highways, namely SH51, SH50A, SH50, SH48, SH57, SH49B, SH49A (OMR), and SH49 (ECR). The length of the alignment is 133 km and is divided into five sections as follows:

- Sec. 1: Northern Port Access Road-Ennore Port to Thatchur on NH5, and
  CPRR (Ch.6+200) to Tiruvottiyur Ponneri Pancheti (TPP) Road via TPP Link Road
  (Connected point on TPP Road differs in original alignment and new alignment)
- Sec. 2: Thatchur on NH5 to the start of Thiruvallur Bypass
- Sec. 3: Start of Thiruvallur Bypass to Sriperumbudur on NH4
- Sec. 4: Sriperumbudur on NH4 to Singaperumalkoil on NH45
- Sec. 5: Singaperumalkoil on NH45 to Mahabalipuram

The outline of the sections is summarized in Table 4.1.1.

Table 4.1.1 Outline of Sections of CPRR

		Sec.1		Sec.2	Sec.3	Sec.4	Sec.5	TOTAL
		Main Road	TPP Link	Main Road	Main Road	Main Road	Main Road	
Section Length		21.51km	3.6km	25.61km	29.55km	24.85km	27.5km	132.62km
Scope of Work	New Construction	21.51km	3.6km (4.21km)	25.61km	19.95km	0km	25.5km	96.17km
	Improvement	0km	0km	0km	9.6km	24.85km	2km	36.45km
ROW		100m	45-60m	60m	60m	40-60m	60m	
Land Acquisition Area		255ha		188ha	208ha		163ha	814ha
Number of Lane	Main Line	2x2Lane	2x2Lane	2x3Lane	2x3Lane	2x3Lane	2x2Lane	
	Service Rd	2x2Lane	2x2Lane	2x2Lane	2x2Lane	2x2Lane	2x2Lane	
BP		Ch.0+000 /Ennore Port	TPP Link Ch.0+351 /CPRR (Ch.6+200)	Ch.21+506 /NH5 (29/000)	SH57 (50/500)	NH4 (42/100)	NH45 (47/400)	
EP		Ch.21+506 /NH5 (29/000)	TPP Link Ch.3+950 /TPP Rd	SH57 (50/500)	NH4 (42/100)	NH45 (47/400)	Ch.129+171 (Poonjeri)	
Structures	IC	0	0	1	2	0	1	4
	ROB	1	1	0	1	0	1	4
	MJB	1	0	2	1	0	1	5
	MNB	1	0	6	8	0	11	26
	VUP	6	0	5	6	9	6	32
	LVUP	6	0	4	2	4	7	23
	BC	39	0	0	1	0	7	47
	PC	8	0	204	107	0	132	451
	Entry/Exit Ramps	0	0	2	2	0	2	6

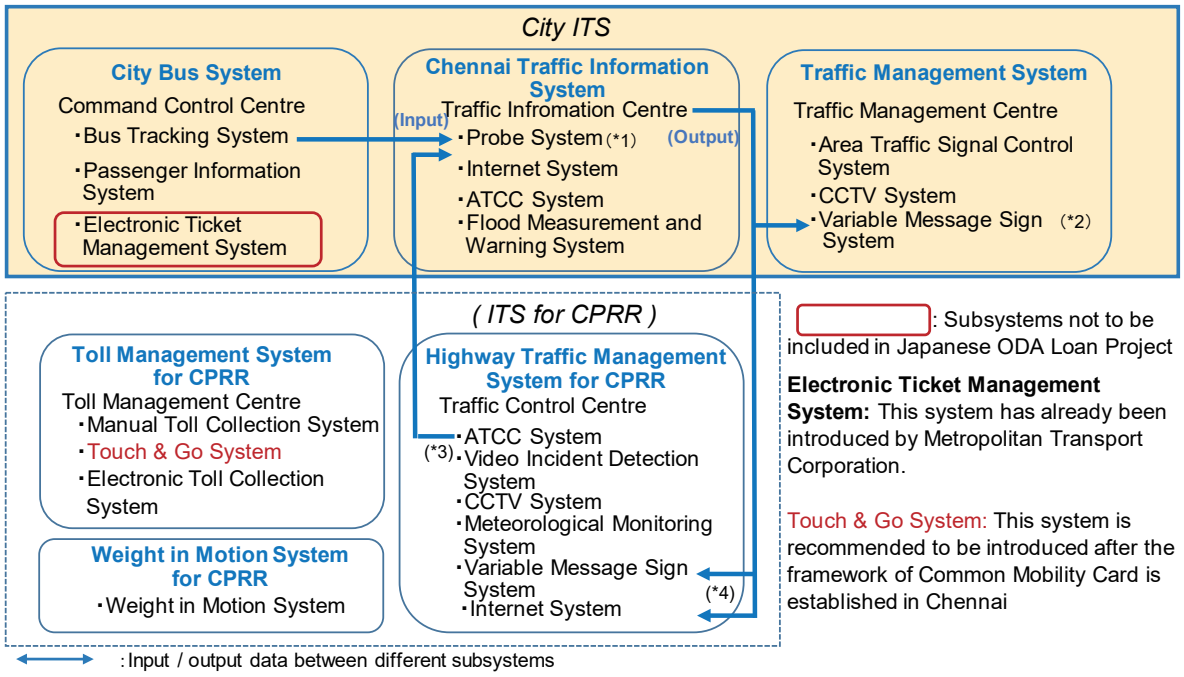
Source: Land Acquisition Area: STUP's Letter E/14518/149/NJW/GK/0132 dated 11 Aug 2017,
Chainage of BP/EP of each section: JICA Study Team estimates, Other Items: DPR Main Report, From P7-2 To P7-5
Note: 1) CPRR: Chennai Peripheral Ring Road, IC: Interchange, ROB: Railway Over Bridge, MJB: Major Bridge, MNB: Minor Bridge, VUP: Vehicular Underpass, LVUP: Light Vehicular Underpass, BC: Box Culvert, PC: Pipe Culvert
2) BC and PC are planned for irrigation and utility crossings.
3) MJB: Sec.1: Buckingham Canal, Sec.3: Kannigaipper Tank, Kosathalai River, Sec.4: Coovam River, Sec.5: Sengundram Tank
4) The alignment of TPP Link was modified and the section length was changed from 4.21km to 3.6km.

With respect to the TPP Link Road, HMPD conducted a survey on alternate alignments in May to June 2018, as the inhabitant's opposition were encountered on the original alignment. In early July, the state government decided that the new alignment would start from the TPP road around Minjur to the Northern Port Access Road (NPAR) (as a main line of Section 1), having a length of 3.6 km, Also, the new alignment connects to the Outer Ring Road (ORR) near Minjur.

4.2 ITS Components

4.2.1 Overall ITS Components

Figure 4.2.1 shows the overall Intelligent Transport System (ITS) components which are candidates for the Japanese ODA Loan Project. As described in 1.1 in this report, the ITS for CPRR was considered separately from the City ITS. The system linkage with the City ITS, as shown in Figure 4.2.1, will be established after introducing the ITS for CPRR.



*1: To generate congestion information on the road network based on the probe data obtained from Bus Tracking System

*2: To provide congestion information on the general roads under the authority of Traffic Police

*3: To complement the Probe System to generate congestion information after completion of CPRR

*4: To provide congetion information generated by Chennai Traffic Information System. Other information will be generated by Highway Traffic Management System for CPRR and provided.

Source: JICA Study Team

Figure 4.2.1 Overall ITS Components for Japanese ODA Loan Project

Regarding the Touch & Go System, the Japan International Cooperation Agency (JICA) Study Team recommended to adopt the common mobility card which can be used for other transport modes, e.g., Chennai Metro Rail, city buses, etc. In case the common mobility card does not exist yet in Chennai, the Touch & Go System should be introduced after the framework of the common mobility card is established in Chennai.

4.3 Prioritization of Components for Implementation

4.3.1 Prioritization of CPRR Components

In this Study, the priority of CPRR for the JICA Loan was examined from three viewpoints, mainly: (1) effect on improvement of traffic situation, (2) magnitude of environmental and social impact, and (3) economic rationality.

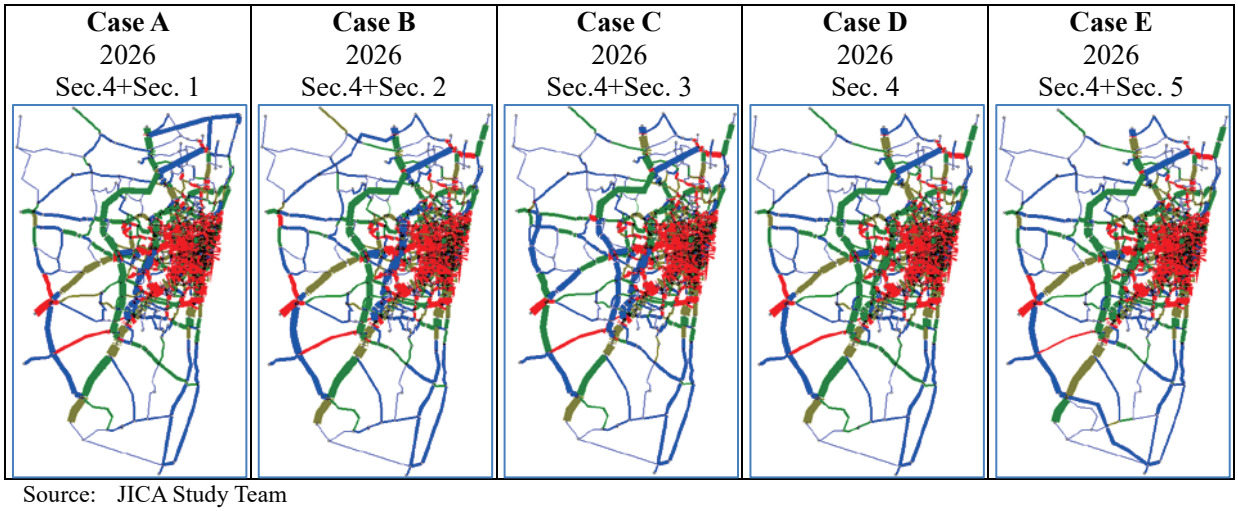
(1) Effect on the Improvement of Traffic Situation

Roads in Chennai City are suffering from severe traffic congestion. Thus, alleviation of traffic congestion on major roads is the main objective of the Project. With this in mind, particular attention shall be paid to the effect of the improvement on the traffic situation. The effect is evaluated in this Study through two indicators, 1) traffic volume in the focused section and 2) reduction of total travel time on the road network.

1) Traffic Volume

A simple reference index which indicates the effect of the Project is the traffic volume in the focused section. Traffic volumes are estimated in the traffic analysis assuming the situation in which only one focused section of the CPRR exists while other sections do not exist. The conditions of traffic simulation including the target year, the socio-economic framework, and the road network other than CPRR should be the same for fair comparison.

Figure 4.3.1 presents the results of the traffic simulation (Case A to E) that was made for the comparison of sections (see Figure 3.3.13 for details). It is considered that Case D is the "Without Project" case since widening of Section 4 is substantially completed.



Source: JICA Study Team

Figure 4.3.1 Results of Traffic Simulation for the Comparison of Sections

Cross-sectional traffic volumes of every section are summarized in Table 4.3.1.

Table 4.3.1 Traffic Volume of Every Section for Each Case

Case	A	B	C	D	E
Section	**Sec. 1**	**Sec. 2**	**Sec. 3**	**Sec. 4**	**Sec. 5**
Traffic Volume (pcu/day)	58,324	31,184	89,528	73,196	43,282
Sec. 4 (pcu/day)	75,091	72,402	69,714	73,196	74,940

Source: JICA Study Team

Section 3, with 89,528 passenger car units (pcu)/day, recorded the highest volume, followed by Section 4 with 73,196 pcu/day, while Section 2 with 31,184 pcu/day recorded the lowest volume.

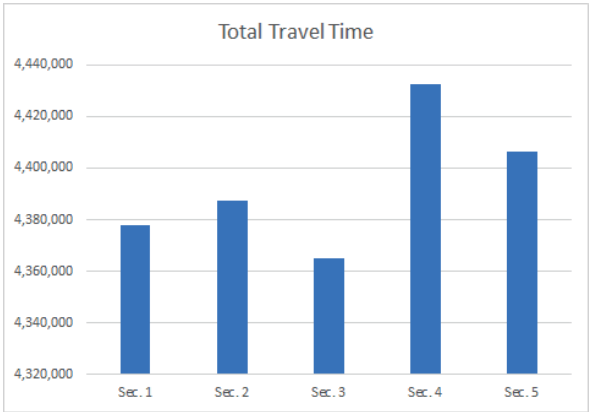
2) Reduction of Total Travel Time of the Road Network

Another index of the effect of the Project is the impact on the total travel time of the road network in Chennai Metropolitan Area (CMA). In this Study, it was considered that the degree of reduction in total travel time induced by the construction of a section represents the scale of contribution made by the section to the CMA road network.

The reduction in total travel time of every section are shown in Figure 4.3.2 and Table 4.3.2.

Case C (Sec. 3 + Sec. 4), with 67,494 vehicle hours, marked the largest impact followed by Case A (Sec. 1 + Sec. 4) with 54,871 vehicle hours, while Case E (Sec. 5 + Sec. 4), with 26,239 vehicle hours, marked the smallest impact.

Unit: Vehicle Hour



Source: JICA Study Team

Figure 4.3.2 Reduction in Total Travel Time Made by Every Section for Each Case

Table 4.3.2 Reduction in Total Travel Time Made by Every Section for Each Case

Case		A	B	C	D	E
Total Travel Time (vehicle hour)	Total	4,377,730	4,387,409	4,365,107	4,432,601	4,406,362
	Inside of CPRR	4,214,124	4,240,501	4,195,454	4,267,919	4,282,490
	Inside of ORR	2,196,586	2,229,587	2,196,052	2,245,832	2,261,239
	Inside of IRR	579,334	590,500	578,146	588,820	608,981
Difference from Case D (vehicle hour)	Total	54,871	45,192	67,494	-	26,239
	Inside of CPRR	53,795	27,418	72,465	-	-14,571
	Inside of ORR	49,246	16,245	49,780	-	-15,407
	Inside of IRR	9,486	-1,680	10,674	-	-20,161

Source: JICA Study Team

3) Large Vehicle Rate

In the existing road network, especially in the vicinity of the proposed alignment of CPRR, it was observed that a considerable number of large vehicles are travelling even on community roads as stated in Section 2.2.2 of this report. Such large vehicles running through small towns and villages severely affect the traffic environment in the community. Therefore, it is expected that CPRR shall cater to the industrial traffic of large vehicles and shall alleviate the traffic load from the community roads. In this sense, the large vehicle rate is considered in the prioritization of the project.

Table 4.3.3 Large Vehicle Rate of Every Section for Each Case

Case	A	B	C	D	E
Section	**1**	**2**	**3**	**4**	**5**
Large Vehicle Rate (%)	76%	13%	25%	27%	27%
Sec. 4	27%	26%	27%	27%	25%

Source: JICA Study Team

Case A (Sec. 1 + Sec. 4), with a percentage of 76%, marked the largest by a wide margin compared to the other cases.

(2) Magnitude of Environmental and Social Impact

Negative environmental and social impacts of the Project may constitute serious obstacles to the implementation of the Project, although every effort is made to mitigate those impacts through the Project phase of planning, design, construction, and operation. Therefore, the magnitude of environmental and social impacts shall be considered in the evaluation of the project prioritization. In this Study, 1) impact on Reserved Forest (RF) and Coastal Regulation Zone (CRZ) is taken as an index for the Project to assess the environmental condition, while the 2) area of land to be acquired is used as a barometer of the social impact of the Project.

1) Impact on Reserved Forest (RF) and Coastal Regulation Zone (CRZ)

a) Reserved Forest (RF)

The alignment of Section 3 passes through the Mannur RF with a length of 0.2 km, while Section 5 passes through the Thirutteri RF and Sengunram RF with lengths of 0.5 km and 1.26 km, respectively.

In accordance with the Forest (Conservation) Act of 1980, the diversion of forest land is required for the affected RF. The areas of land where diversions are required are shown in Table 4.3.4.

Table 4.3.4 Area of Forest Land to be Diverted

Section	1	2	3	4	5
Area of Forest Land to be Diverted (ha)	0	0	0.28	0	9.95 (2.56 + 7.39)

Source: HMPD's Letter 362/2014/JD01 dated 30 May 2016

b) Coastal Regulation Zone (CRZ)

The alignment of Section 1 passes through a CRZ Category III as explained in Chapter 11 of this report.

The CRZ Notification (2011) defines Category III as follows:

CRZ-III: areas that are relatively undisturbed and those that do not belong to either a CRZ-I or II, which include coastal zones in the rural areas (developed and undeveloped) and also areas within municipal limits or in other legally designated urban areas not substantially built up.

Since the development in the CRZ is controlled and monitored by the Environment and Forests Department, a CRZ Clearance shall be obtained before the project is initiated.

Table 4.3.5 Impact on CRZ

Section	1	2	3	4	5
Impact on CRZ	Category III	None	None	None	None

Source: HMPD's Letter 362/2014/JD01 dated 30 May 2016

2) Area of Land to be Acquired

The DPR consultant summarized the area of land to be acquired by section based on the Land Plan Schedule (LPS) as shown in Table 4.3.6.

Table 4.3.6 Area of Land to be Acquired

Section	1	2	3	4	5
Area of Land to be Acquired (ha)	255	188	208	0	163

Source: Land Acquisition Area: STUP's Letter E/14518/149/NJW/GK/0132 dated 11 Aug 2017

Section 1 requires the largest land of 255 ha since it is proposed to be a new road with a right of way (ROW) of 100 m, followed by Section 3 which requires 208 ha and where two interchanges are planned to be developed. No new land acquisition is required in Section 4 as it has already been widened to six-lane highway.

(3) Economic Rationality

It is a common practice for governments to evaluate projects with economic indicators to help in the decision-making process for implementation. In this report, the Economic Internal Rate of Return (EIRR) of each project (of each section of the CPRR) is preliminarily calculated to examine the economic rationality of the projects for prioritization.

The EIRR is an indicator that represents cost-effectiveness of the projects and thus it is widely used to evaluate projects of a different scale. The EIRR is defined as the interest rate at which the economic cost and benefit of a project discounted over its lifetime are equal.

Conditions for the calculation of the EIRR are as follows:

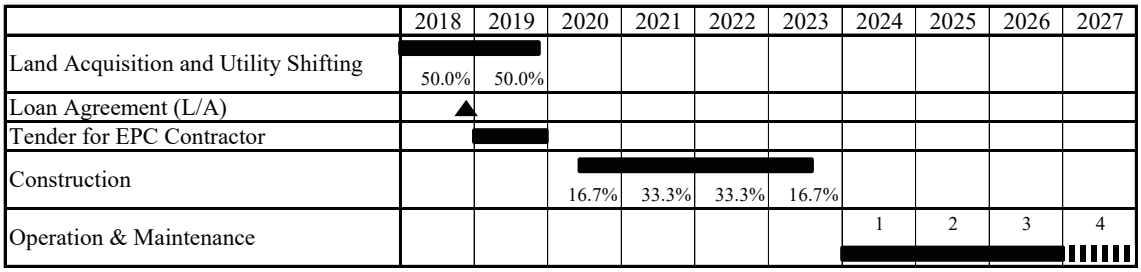
Cost: Project costs estimated in the DPR are converted to economic costs by multiplying with a factor of 0.90. Project costs estimated in the DPR are shown in Table 4.3.7.

It is assumed that the ratio of O&M costs to construction costs are 0.1% (recurrent) and 0.4% (periodic).

This part is intentionally left blank

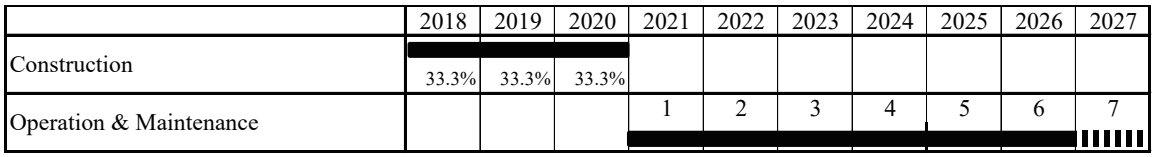
Benefit: Traffic volumes by vehicle type and average travel speed of each link in the road network model are estimated in the traffic simulation, while the determined unit rates of vehicle operation cost and travel time cost are referred from the Indian Road Congress (IRC) documents and from past practices in India.

Project Implementation Schedule: In this evaluation, the project implementation schedule shown in Figure 4.3.3 is considered for all sections, except for Section 4 which has already been substantially widened to a six-lane highway. It is assumed that the remaining works for Section 4 is to be completed as per the assumed schedule shown in Figure 4.3.4.



Source: JICA Study Team

Figure 4.3.3 Assumed Project Implementation Schedule for Sections 1, 2, 3, and 5



Source: JICA Study Team

Figure 4.3.4 Assumed Project Implementation Schedule for Section 4

From the above premise, calculations of the EIRR for each case is shown in Table 4.3.8. (Cash flow is explained in Section 12.3.)

Table 4.3.8 EIRR for Each Case

Case No.	Case	EIRR
1	Section 4 and 1 are constructed.	18.1%
2	Section 4 and 2 are constructed.	19.7%
3	Section 4 and 3 are constructed.	20.2%
4	Section 4 and 5 are constructed.	12.8%

Source: JICA Study Team

(4) Prioritization of CPRR Components

In this Study, the prioritization is made by setting out the evaluation criteria shown in Table 4.3.9.

As a result, it is recommended that the 1st priority be given to Section 1, the 2nd priority to Sections 2 and 3, and the 3rd priority to Section 5 considering that Sections 2 and 3 shall be developed simultaneously since they will form a united road section from the viewpoint of completeness of the CPRR.

Table 4.3.9 Evaluation Criteria for Prioritization

Criteria		Indicator	Evaluation (Score)		
			High	Middle	Low
1	Effect on Improvement of Traffic Situation	Traffic Volume (pcu/day)	**10:** 100,001- **9:** 75,001-10,000 **8:** 50,001-75,000	**7:** 40,001-50,000 **6:** 30,001-40,000 **5:** 20,001-30,000 **4:** 10,001-20,000	**3:** 7,501-10,000 **2:** 5,001-7,500 **1:** 2,501-5,000 **0:** -2,500
		Reduction in Total Travel Time (vehicle hour)	**10:** 100,001- **9:** 75,001-10,000 **8:** 50,001-75,000	**7:** 40,001-50,000 **6:** 30,001-40,000 **5:** 20,001-30,000 **4:** 10,001-20,000	**3:** 7,501-10,000 **2:** 5,001-7,500 **1:** 2,501-5,000 **0:** -2,500
		Large Vehicle Rate (%)	**10:** 41- **9:** 36-40 **8:** 31-35	**7:** 26-30 **6:** 21-25 **5:** 16-20 **4:** 10-15	**3:** 8.0-9.9 **2:** 6.0-7.9 **1:** 4.0-5.9 **0:** -3.9
2	Magnitude of Environmental and Social Impact	Impact on Reserved Forest and Coastal Regulation Zone	**5:** RF: - **5:** CRZ: -	**2:** RF: 0-4ha **2:** CRZ: III	**0:** RF: 5ha- **0:** CRZ: I, II
		Area of Land to be Acquired (ha)	**10:** -50 **9:** 51-100 **8:** 101-150	**7:** 151-200 **6:** 201-250 **5:** 251-350 **4:** 351-400	**3:** 401-600 **2:** 601-800 **1:** 801-1,000 **0:** 1,001-
3	Economic Rationality	EIRR (%)	**10:** 28.0- **9:** 24.0-27.9 **8:** 21.0-23.9	**7:** 18.0-20.9 **6:** 15.0-17.9 **5:**12.0-14.9 **4:** 9.0-11.9	**3:** 8.0-8.9 **2:** 7.0-7.9 **1:** 6.0-6.9 **0:** -5.9

Source: JICA Study Team

Table 4.3.10 Evaluation Results for Prioritization

Criteria		Indicator		Sec.1	Sec.2	Sec.3	Sec.5
1	Effect on Improvement of Traffic Situation	Traffic Volume (pcu/day)		58,324	31,184	89,528	43,282
			SCORE	**8**	**6**	**9**	**7**
		Reduction in Total Travel Time (vehicle hour)		54,871	45,192	67,494	26,239
			SCORE	**8**	**7**	**8**	**5**
		Large Vehicle Rate (%)		76	13	25	27
			SCORE	**10**	**4**	**6**	**7**
2	Magnitude of Environmental and Social Impact	Impact on Reserved Forest and Coastal Regulation Zone		RF: - CRZ: Cat..III	RF: - CRZ: -	RF: 0.28 CRZ: -	RF: 9.95 CRZ: -
			SCORE	**7**	**10**	**7**	**5**
		Area of Land to be Acquired (ha)		255	188	208	163
			SCORE	**5**	**7**	**6**	**7**
3	Economic Rationality	EIRR (%)		18.1	19.7	20.2	12.8
			SCORE	**7**	**7**	**7**	**5**
TOTAL SCORE				45	41	43	36
PRIORITY				**1**	**3**	**2**	**4**

Source: Land Acquisition Area: STUP's Letter E/14518/149/NJW/GK/0132 dated 11 Aug 2017,
Project Cost: Construction Cost shown in DPR Main Report, P9-3

1st **2nd** **3rd**

During the consultation with inhabitants around the site of the TPP Link Road (Original Alignment), it was found that it is very important to obtain social consensus for the road construction. As an alternative solution to minimize the social impact, the south end of the TPP Link Road is to be shifted approximately 1.5 km west of the original alignment. This new alternative alignment has a total length of 3.6 km from the connecting point with Northern Port Access Road to the southern end. The length of 1.65 km in the northern part is the same as the original alignment, and the remaining 1.95 km in the southern part is different from the original alignment.

4.4 Consulting Services for the Prioritized Project

4.4.1 CPRR

(1) Mode of Contract Scheme

A model of the Engineering, Procurement, and Construction (EPC) contract mode has been published by the Planning Commission for highway projects in India based on past experiences in infrastructure development, where the conventional item-rate contract is said to be generally prone to time and cost overruns. This is particularly evident in the national highway sector, resulting in enhanced cost to the financing institutions, and also considerable delay in the completion of projects.

Most of the EPC contracts in India, except for the projects financed by the multilateral development banks World Bank and Asian Development Bank awarded since 2014, seem to have been affected by Local Competitive Bidding (LCB) in accordance with the procedures used in India. EPC has also been introduced in state highway projects, and applications of the EPC for CPRR is one of options according to HMPD.

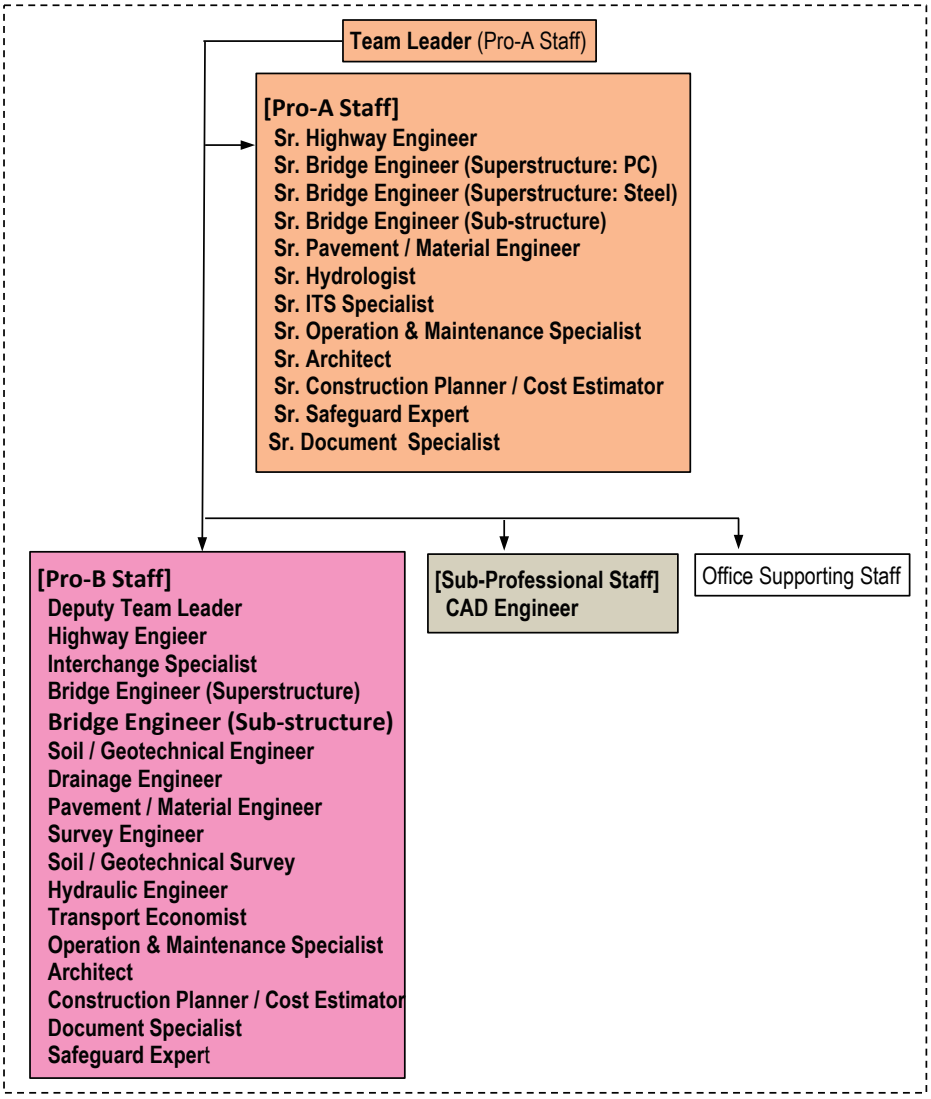
(2) Tender Method of Consultant Procurement

A supervising consultant selected by the executing agency through International Competitive Bidding (ICB) will discharge the functions and duties of an Authority's Engineer (AE) as per the Terms and Conditions of the EPC Agreement.

With the intention of maintaining high quality in the works executed by the contractor, the JICA Study Team recommends applying 'Procurement of Works' of the 'JICA Standard Bidding Documents Under Japanese ODA Loans (Works)' which follows the general conditions of the Federation International des Ingenious-Conseils (FIDIC MDB) Harmonized Edition. Review of detailed design is also recommended to identify shortage of design and suggest design update for bidding by the JICA SBD.

(3) Proposed Organization of the Detailed Design (D/D) Review Consultant

The proposed organization of the D/D Review Consultant for CPRR is shown in Figure 4.4.1.

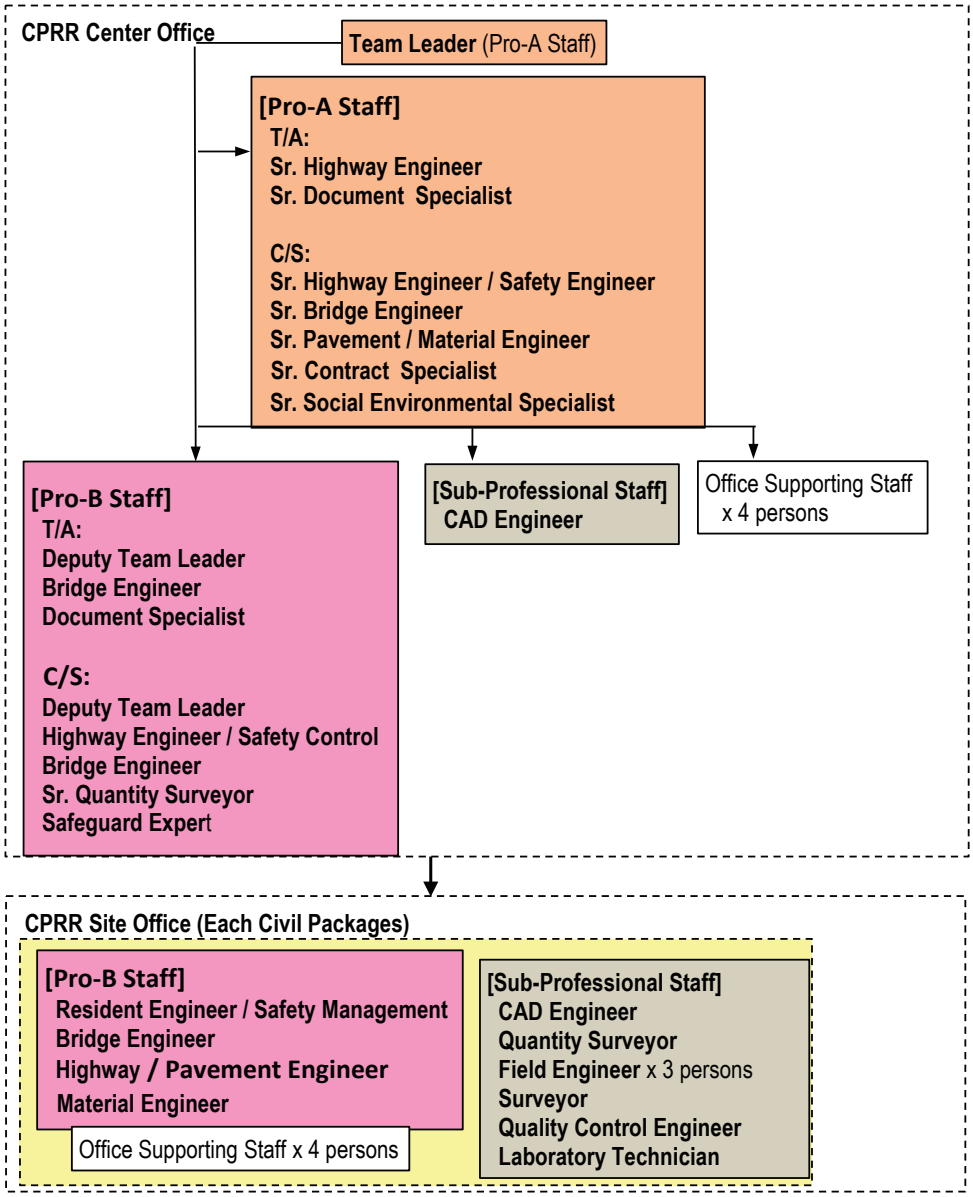


Source: JICA Study Team

Figure 4.4.1 Proposed Organization Structure of D/D Review Consultant

(4) Proposed Organization of the Construction Supervision (C/S) Consultant

The proposed organization of the C/S Consultant for CPRR is shown in Figure 4.4.2. The organization of Tender Assistance (T/A) is also provisionally proposed. A site office shall be provided to each section of the CPRR, with proposed staff as shown in Figure 4.4.2.



Source: JICA Study Team

Figure 4.4.2 Proposed Organization Structure of C/S Consultant

4.4.2 CPRR ITS

(1) Mode of Contract Scheme

The 'Design Build' scheme, i.e., design, supply, and installation, wherein the employer prescribes the requirement of the systems and performance and the contractor carries out the detailed design, is best suited because ITS is a project which is mainly composed of systems and equipment.

The 'Design Build' scheme was also adopted to other public projects of ITS in India. Some major examples are the MITRA Project of the City Bus Monitoring and Passenger Information System in Mysore in Karnataka State (World Bank), the KSRTC Project of the Inter-City Bus Monitoring and Passenger Information System in Karnataka State (state budget), and the B-TRAC Project of the Traffic Management System of Bengaluru traffic police in Karnataka State (state budget).

The 'Procurement of Electrical and Mechanical Pant, and for Building and Engineering Works, Designed by the Contractor' from the 'JICA Standard Bidding Documents Under Japanese ODA Loans (SBD, Design Build)' which is based on FIDIC is recommended to be used for this Japanese ODA Loan Project. This SBD

has been used in the ITS project under the Japanese ODA Loan Project in other city in India.

(2) Tender Method of Consultant Procurement

It is very important that the requirements are clearly defined/prescribed so that bidders can properly reflect the requirement on their proposals, particularly because the ITS project utilizes advanced technology. This is a different method from 'Turn Key Project' or EPC, where the contractor takes almost the entire responsibility regarding the design and construction. In particular, the Indian local contractors do not have sufficient experience on ITS projects yet. As such, ensuring the quality throughout the project, particularly the upper stage (basic design and contractor procurement), is very important because the quality of the upper stage will affect the entire project including the stages of implementation, operation, and maintenance. Therefore, procuring the Consultant through ICB, including the stages of basic design and contractor procurement, is recommended.

(3) Selection Method of Contractor Procurement: Quality and Cost Based Selection (QCBS)

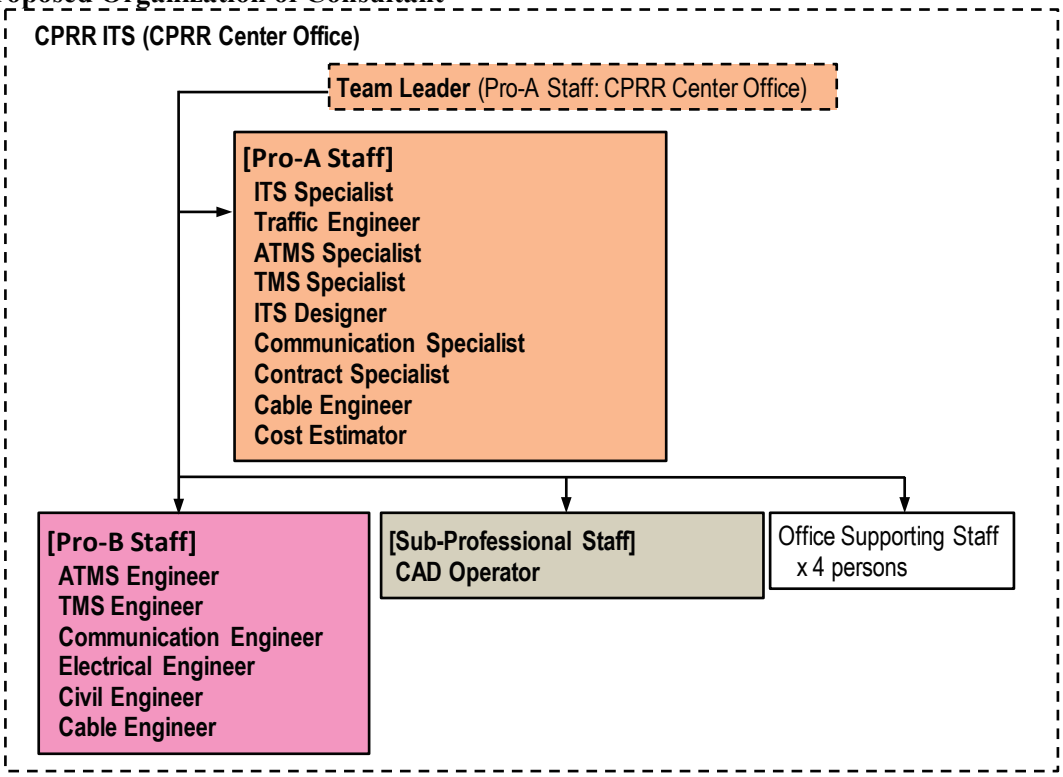
ITS facilities such as an emergency call box, traffic counter, CCTV, weather monitoring facility, VMS, and center system are all obligated to be installed on national highways under the jurisdiction of NHAI, where a certain level of traffic volume is expected (i.e., more than 40,000 daily traffic volume). However, there is currently no road where these facilities have been installed correctly, and no information is actually provided. As for the City ITS in India, Ahmadabad in Gujarat State is the only city where the dynamic traffic information has been provided in real time by an installed traffic information system. The system was introduced by a Japanese company under a support scheme of the Japanese small and medium enterprise overseas business developments by JICA.

It is considered that the above situation of ITS in India is caused by the fact that the contractors who have sufficient technical capabilities for developing and handling the advanced system are not selected, and the selection method of the contractor procurement is considered one of the predominant factors behind this. ITS consists of several subsystems wherein technical aspects are vitally important, such as software processing methods, interface between subsystems or external systems, and integration of systems. Therefore, selecting a contractor with enough technical capabilities determines the success of a project. To properly evaluate the technical capabilities of bidders and to select an appropriate contractor, adopting QCBS as an evaluation point of technical evaluation as reflected in addition to the financial evaluation is strongly recommended.

The Smart City Mission, which will develop 100 smart cities, is the case in India that drove the selection method from the conventional Cost Based Selection to QCBS. The first several cities such as Mumbai and Surat adopted Cost Based Selection for cost savings, but later on fell into a situation wherein the integration of the system could not be achieved because the contractor did not possess enough technical capabilities for it. In line with this, it was decided to adopt a QCBS method for the Smart City Mission. For example, the ratio of technical evaluation and financial evaluation for QCBS is 8:2 in Agra and 7:3 in Jabalpur and Lucknow.

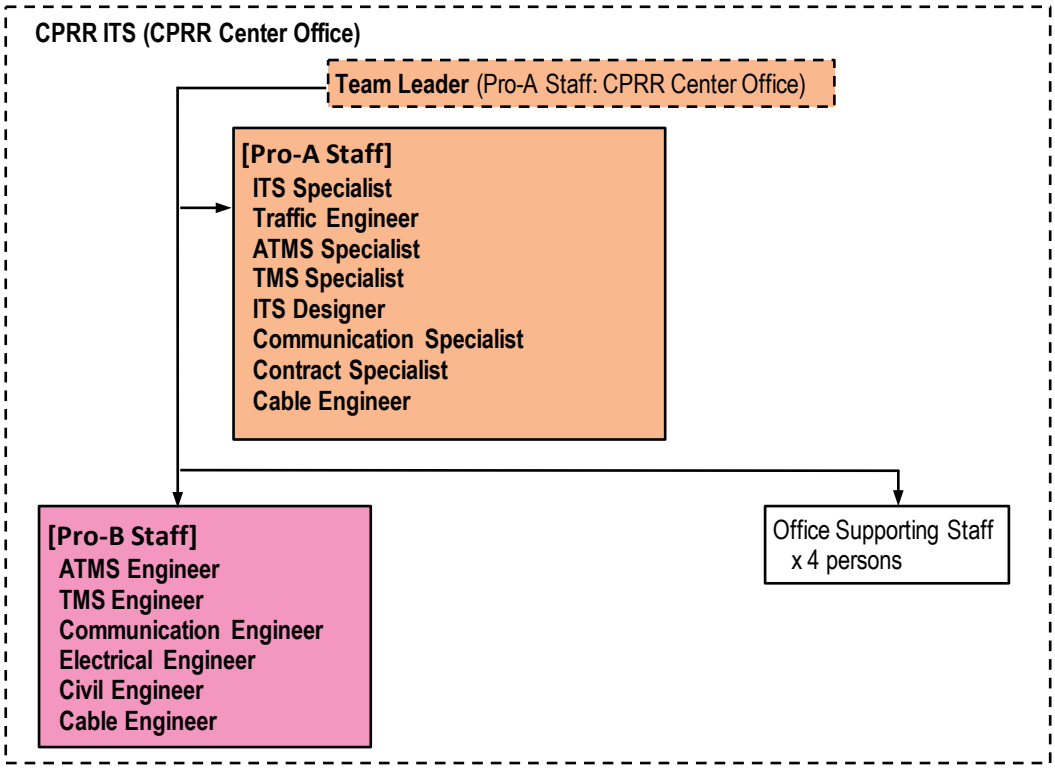
Furthermore, QCBS was used for a City Bus System project in Mysore, Karnataka State and was financed by the World Bank to select a contractor. The ratio of technical evaluation and financial evaluation was 6:4. The system has already been in operation, and the project earned a high reputation as one of the successful ITS projects in India.

(4) Proposed Organization of Consultant



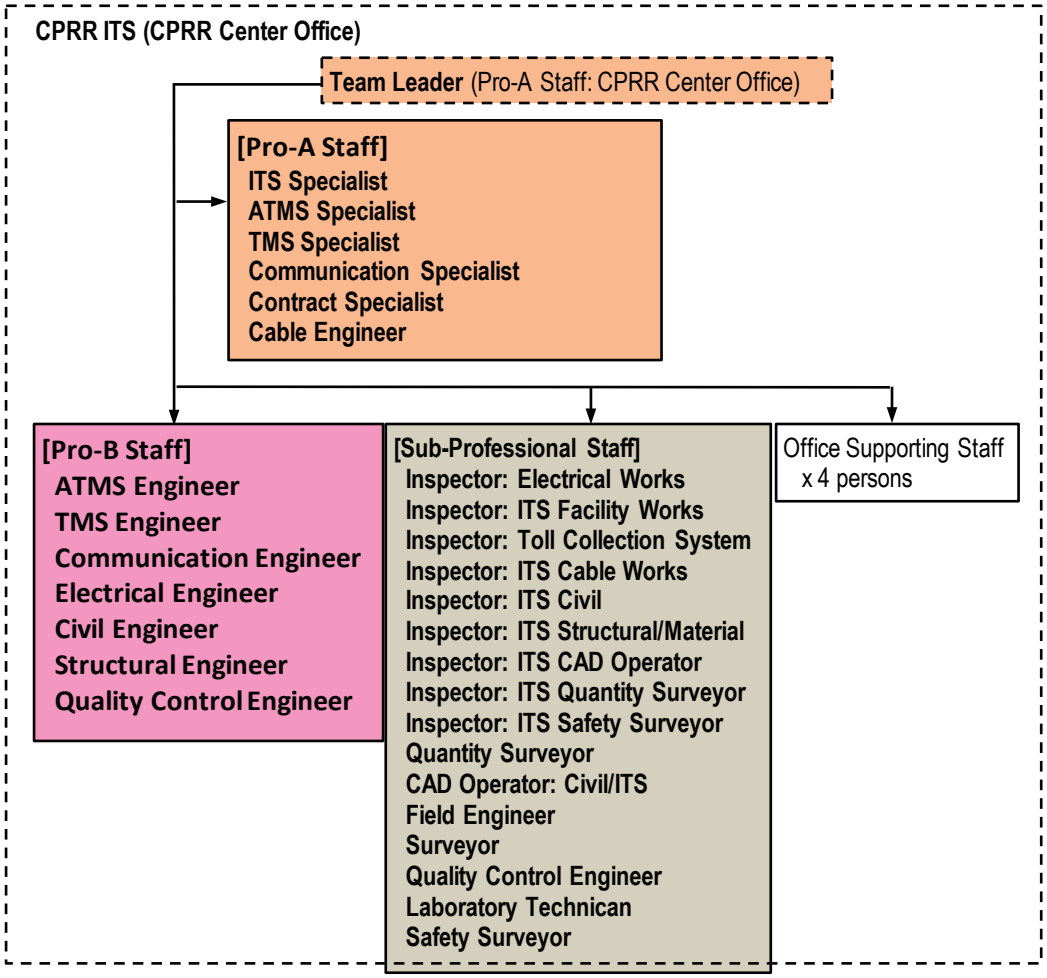
Source: JICA Study Team

Figure 4.4.3 Proposed Organization Structure of ITS Consultant (CPRR: B/D)



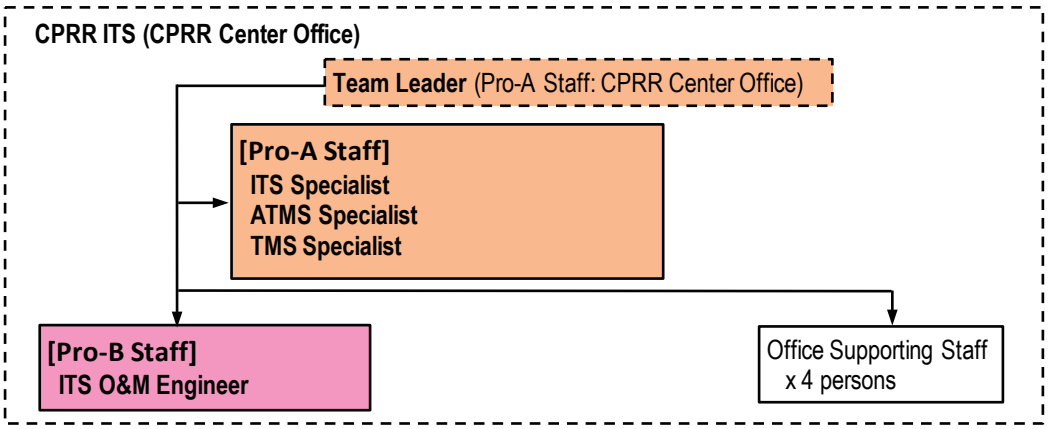
Source: JICA Study Team

Figure 4.4.4 Proposed Organization Structure of ITS Consultant (CPRR ITS: T/A)



Source: JICA Study Team

Figure 4.4.5 Proposed Organization Structure of ITS Consultant (CPRR ITS: C/S)



Source: JICA Study Team

Figure 4.4.6 Proposed Organization Structure of ITS Consultant (CPRR ITS: O/M)

CHAPTER 5 HIGHWAY OPERATION AND MAINTENANCE (O&M) STRUCTURE

5.1 Outline of Roads in Tamil Nadu

5.1.1 National Highways (NHs)

NHs compose the road network connecting state capitals, major cities, major ports, large industrial areas, and important tourist centers, and are noted by the Ministry of Road Transport and Highways (MORTH), Government of India. NHs form the economic backbone of the country enhancing quick movement of people and materials to their requisite destinations on time and facilitate rapid development along their routes.

The 4,994-km long national highways run through the Tamil Nadu State. Out of this, 1,985 km are maintained by the State National Highways Wing, and the balance of 3,009 km are maintained by the National Highways Authority of India (NHAI). Although NH are developed with funds from the MORTH, some of them are also funded through a Public Private Partnership (PPP) model.

5.1.2 State Highways (SHs)

SHs connect the district headquarters with NHs and with neighboring states. SHs get maximum importance because most have heavy traffic. The total length of SHs in Tamil Nadu State is 12,095 km.

5.1.3 Major District Roads (MDRs)

MDRs connect towns and municipal areas with district headquarters. These roads connect the production and marketing centers with NHs and SHs. In Tamil Nadu State, the total length of MDRs is 11,628 km.

5.1.4 Other District Roads (ODRs)

ODRs are the backbone of the rural economy and day to day activities of the public, connecting villages with marketing, educational, and health care centers, taluk headquarters, and other nearby important roads. Based on the traffic intensity, ODRs are maintained as single-lane or intermediate-lane roads.

Sugarcane development roads are also under the ODR category, which connect the sugarcane cultivating areas with sugar mills and nearby marketing centers. There are 33,751 km of ODRs, including 1,676 km of sugarcane development roads in Tamil Nadu State.

The details of the road network in Tamil Nadu State are given in Table 5.1.1.

Table 5.1.1 Details of Road Network in Tamil Nadu (as of 2016)

No.	Road Kind	Length (km)	Maintained by
1	National Highway (NH)	1,985	NH Wing
		3,009	NHAI
2	State Highway (SH)	12,095	C&M Wing
3	Major District Roads (MDRs)	11,628	
4	Other District Roads (ODRs)	33,751	
	Total	62,468	

Source: JICA Study Team based on Highway and Minor Ports Department, Policy Note 2016-2017

5.2 Highways and Minor Ports Department (HMPD), Tamil Nadu

5.2.1 Organization of HMPD

Tamil Nadu State traditionally has a strong industrial base which contributes substantially to the industrial production of the country. Roads and bridges along with ports play a vital role in the development of key sectors of the economy like industry, technology, and agriculture. HMPD administers the road infrastructure and the minor ports in Tamil Nadu State.

Tamil Nadu State is the forerunner in bringing out standard specifications for the roads and bridges in 1954. The department is also in-charge of the improvement and maintenance of NH in the state. Minor ports were later brought under the purview of this department. Subsequently, this department was renamed as the HMPD. The Highways Department aims to develop and maintain the highway network in the state, ensuring road safety and hassle-free traffic.

HMPD is made up of the following five substructures:

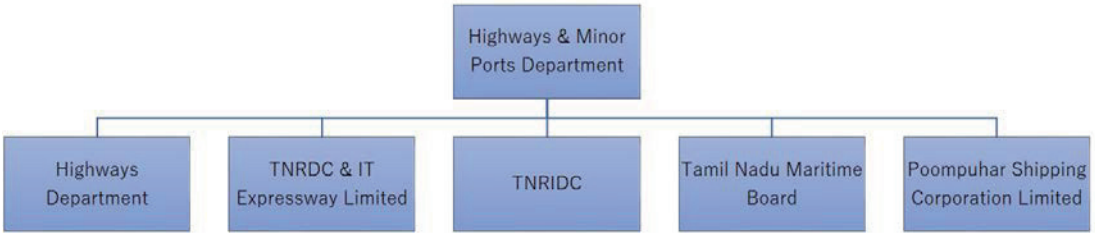
a) Highways Department

b) Tamil Nadu Road Development Company (TNRDC) and IT Expressway Limited (special purpose vehicle: subsidiary company owned by TNRDC)

c) Tamil Nadu Road Infrastructure Development Corporation (TNRIDC)

d) Tamil Nadu Maritime Board

e) Poompuhar Shipping Corporation Limited



Source: JICA Study Team base on the website of Highway Department
＜http://www.tnhighways.net/pdf/Organisation_Chart.pdf＞(Final access 20 July 2017)

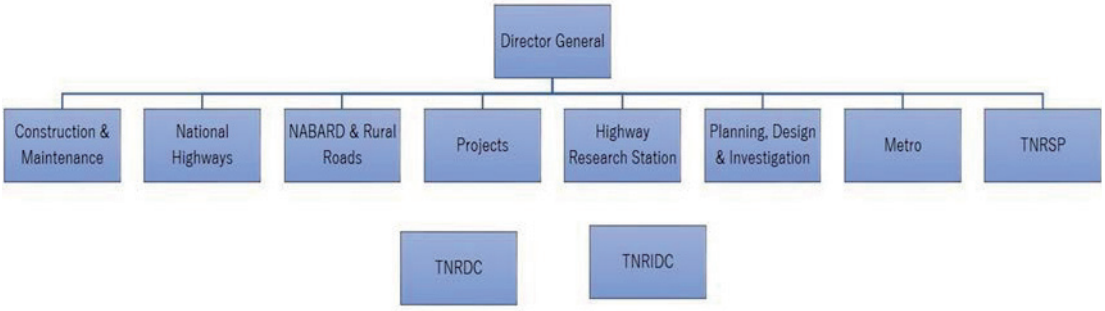
Figure 5.2.1 Organizational Structure of HMPD

5.2.2 Highways Department

(1) Organization of the Highways Department

The Highways Department of the Government of Tamil Nadu was established in 1946. Currently, the Highways Department maintains 62,468 km of road network spread across the entire length and the breadth of the state. The department has a clear-cut mandate of creating, augmenting, and maintaining the road infrastructure of the state with the vision to “increase the capacity, connectivity, efficiency, and safety” of the highway system.

The organization is strengthened by the coordination of eight wings under the control of the Director General. The research works are being done by the Highways Research Station Wing. The designs and the required field investigations are being done by the Designs and Investigation Wing. The two mentioned wings are non-execution wings, and the remaining six wings are for execution of works of the department. There are two road corporations that oversee special projects.



Source: JICA Study Team base on the website of the Highways Department
＜http://www.tnhighways.net/pdf/Organisation_Chart.pdf＞(Final access 20 July 2017)

Figure 5.2.2 Organizational Structure of the Highways Department

(2) Recent Activities of Highways Department

The Highways Department has come up with integrated e-PATHAI system which helps to maintain the road network at the desired service level by fixing performance indicators based on the roughness index, traffic density, and surface conditions for effective, efficient, and transparent functioning of the department.

In addition, the e-PATHAI system helps to identify the black spots on the road network. The department has taken up a massive project to rectify the black spots all over the state with the latest standard engineering practices to reduce accidents and fatalities using more budgetary allocation to enhance road safety.

Lots of innovative methods and latest technological inputs are being progressively adopted for all highway projects. The implementation of major projects are increasingly being undertaken through Engineering, Procurement, and Construction (EPC) modes of contract, which enables the department to shift the risks onto the contractor and avoids cost and time overrun thereby reducing burden on governments exchequer.

The maintenance of roads is being done in selected districts employing innovative Performance Based Maintenance Contracts (PBMC) and Output and Performance Based Road Contracts (OPRC), which considerably reduces the overall expenditure of this department. Investments are being attracted through PPP projects, engaging prospective investors to provide good transport infrastructure for the development of society, thus contributing to nation building.

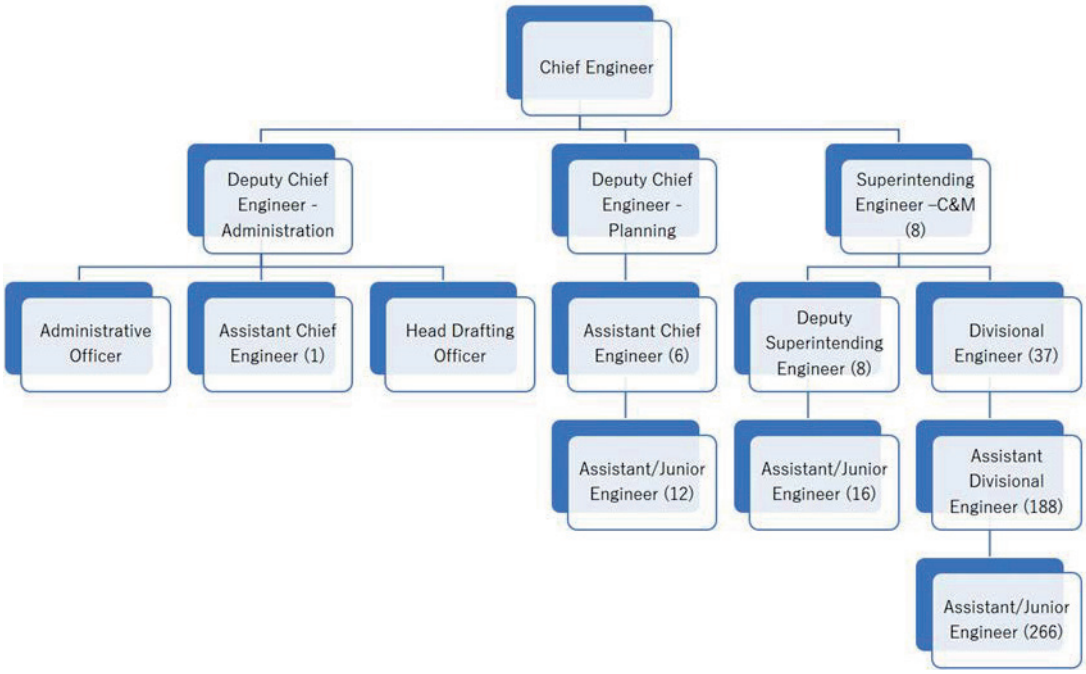
5.2.3 Construction and Maintenance Wing

(1) Organization of Construction and Maintenance Wing

The Construction and Maintenance Wing of the Highways Department maintains a total length of 57,466 km of roads categorized as SHs, MDRs, and ODRs. This wing undertakes major infrastructure projects involved in the widening, strengthening, and improvement of roads, including the construction of bridges/grade separators, and culverts, as well as the formation of bypasses and road safety works among others.

Maintenance work is assigned to private contractors. Although the contracts have been on a single fiscal year basis, the contracts are being replaced with five-year long PBMC contracts.

To execute these works, eight circles and 41 divisions function under the Chief Engineer. The details of various categories of work and schemes undertaken by this wing are as follows:



Source: JICA Study Team base on the website of the Highways Department
＜http://www.tnhighways.net/pdf/Organisation_Chart.pdf＞(Final access 20 July 2017)

Figure 5.2.3 Organizational Structure of Construction & Maintenance Wing

(2) Works of Construction and Maintenance Wing

1) Comprehensive Road Infrastructure Development Program (CRIDP)

CRIDP was formulated in 2004 to 2005 for the economic and industrial development of Tamil Nadu State. Infrastructure development like widening and improvement of roads; construction of bridges, culverts, protective works, center medians, crash barriers, and drains; road safety works; and formation of bypasses are undertaken in CRIDP. Sanction has been accorded for an amount of INR 15,205 crore in the last five years.

It has been announced that all SHs will be widened to double lanes and all MDRs will be widened to an intermediate lane. Accordingly, large-scale widening was undertaken in the CRIDP. In the last five years, a total length of 913 km of SHs has been widened to double lanes, and a total length of 3,041 km of MDRs has been widened to intermediate lanes.

2) PART-II Scheme

The Part-II scheme is carried out to improve the working environment for employees. It includes the construction/purchase of offices, traveler bungalows, office equipment, laboratory equipment, and software for conducting research. During 2015 to 2016, spill over works of 13 buildings were undertaken for construction. New works have been sanctioned for construction of the office buildings for five divisions, 20 quality control subdivisions, and one traveler's bungalow at a cost of INR 7.50 crore. These works are in progress. During 2015 to 2016, 19 buildings have been completed at a cost of INR 5.78 crore. The revised budget provision of INR 4.00 crore has been allotted for 2016 to 2017.

3) New Works in Chennai Extended Corporation Area

In the Chennai Extended Corporation area, 250 km of roads are taken up under this scheme in the Thiruvallur District and the Kancheepuram District. Works will be taken up for INR 1,033.00 crore. As an initiating step, the government has sanctioned INR 250.00 crore for seven works in SHs, three works in MDRs, and four works in ODRs, and all the works are in progress. In the 2nd phase, INR 150.00 crore has been sanctioned for 2015 to 2016. There are 22 works covering a length of 60.10 km that have been taken up and are in progress. During 2016 to 2017, three works totalling a length of 91.26 km have been completed at a cost of INR 152.72 crore. The revised budget provision of INR 60.86 crore has been allotted for 2017 to 2018.

4) Formation of Bypasses

Bypasses help in reducing traffic congestion in major towns and create a diversion for thorough traffic. There are 13 bypasses that have been completed in the last five years. The present status of bypass works being carried out by this wing are as follows: 13 complete, five in progress, 19 loan agreements (LA) in progress, four Detailed Project Reports (DPRs) in progress, and two under consideration.

5) Railway Over Bridge (ROB) at Railway Level Crossing

Construction of an ROB in Thiruvallur District at a cost of INR 23.30 crore is in progress under the Railway Works Programme (RWP). In Nagapattinam District, the construction of an ROB was completed by the Railway Authorities, and the construction of approaches to ROB was taken up through state funds. This work has been taken up at a cost of INR 12.00 crore and is nearing completion. The construction of ROB in Coimbatore District, under the CRIDP scheme at a cost of INR 20.00 crore, was completed and opened for traffic.

6) Performance Based Maintenance Contract (PBMC)

The PBMC for roads is designed to increase the efficiency and effectiveness of road asset management. PBMC ensures the good condition of the roads, fulfilling the adequate needs of road users throughout the entire period of the contract. This scheme includes initial rectification, periodic renewal, minor improvements, ordinary maintenance, and emergency works.

In the Pollachi Highways Division, PBMC is being implemented in 191.40 km of SHs and 185.98 km of MDRs for a period of five years at a cost of INR 233.93 crore. Initial rectification works for 152.59 km have been completed, periodic renewal works for 81.15 km have been completed, and balance works are in progress.

Subsequently, in the Krishnagiri Highways Division, the maintenance of 307 km SHs and 274 km MDRs are also undertaken through PBMC. A sanction of INR 450 crore was accorded. Initial rectification works for 151.40 km have been completed, and balance works are in progress.

In the Ramanathapuram Highways Division, sanction was accorded for INR 460 crore for the maintenance of 229 km of SHs and 340 km of MDRs under PBMC. Out of the total 196.67 km for initial rectification works, 185.37 km has been completed, and balance works are in progress.

In the Thiruvallur Highways Division sanction was accorded for INR 630.38 crore for the maintenance of 498 km of SHs and 278 km of MDRs under this scheme. Out of the total 211.19 km for initial rectification works, 79.60 km has been completed, and balance works are in progress.

Now, the PBMC scheme will be extended to the Virudhunagar Highways Division in the current financial year.

7) CPRR Development Plan

The Government of Tamil Nadu is in the process of identifying and implementing infrastructure projects. One of the major projects included in Vision 2023 is the CPRR, which was conceptualized to provide better connectivity around the city, catering future traffic requirements and providing efficient commercial transportation by enhancing port connectivity. This road will facilitate container movement from southern districts to Ennore Port.

This road starts at Ennore Port and ends at Poonjeri Junction near Mamallapuram, having a total length of 133 km which is split into five sections as follows:

a) Section-I: Northern Port Access Road – Ennore Port to Thatchur on NH5 (25.11 km)

   Northern Port Access Road-Ennore Port to Thatchur on NH5, 21.51 km, and

   TPP Link Road (original alignment) 4.21 km (new alignment) 3.6 km

b) Section-II: Thatchur on NH5 to start of Thiruvallur Bypass (25.61 km)

c) Section-III: Start of Thiruvallur Bypass to Sriperumbudur on NH4 (29.55 km)

d) Section-IV: Sriperumbudur on NH4 to Singaperumalkoil on NH45 (24.85 km)

e) Section-V: Singaperumalkoil on NH45 to Mamallapuram (27.50 km)

The government has sanctioned INR 10 crore for the preparation of the DPR for this work, which has already been completed. The project cost, including land acquisition, has been worked out to INR 12,301 crore. The proposal for external funding for civil works (85% of construction cost) through JICA has been sent to the central government and is under consideration. Currently, utility mapping on the proposed corridor is being carried out.

8) Formation of Road Grids along Chennai Outer Ring Road (CORR)

The CORR is a major orbital corridor for the Chennai Metro region. Traffic originating from this corridor will have to be provided with an effective dispersal system to link with the radial corridors. Thus, a grid system of roads with radial and orbital linkages have been proposed. Macro grid linkages at 18 locations have been identified, and all these are to be developed in accordance with the stipulations stated in the Second Master Plan of Chennai Metropolitan Development Authority (CMDA).

Out of 18 macro linkages, 15 grids are taken up by the Construction and Maintenance Wing. The government has proposed to create road grids for effective dispersal of traffic originating from the CORR and has sanctioned INR 5.22 crore for the preparation of the DPR. The preparation of the DPR has been completed for 15 road grids.

9) Road Safety Works

A comprehensive proposal to improve the black spots in government roads has been prepared at an estimated cost of INR 1,130 crore. The proposal includes the following engineering measures:

a) widening of narrow culvert (where the width of the culvert is less than the carriage way),
b) widening of narrow culvert (where the width of the culvert is narrow as per the Indian Road Congress (IRC)),
c) realignment of 'S' curve (radius of the curve is less than 90 m),
d) realignment of 'S' curve (radius of the curve is more than 90 m),
e) construction of safety wall/crash barrier around the road side open well/tank bunds,
f) construction of safety wall/crash barrier along high embankment,
g) construction of safety wall/crash barrier in ghats roads,
h) construction of center median,
i) provision for road furniture (gantry boards, studs, delineators, and center line marking), and
j) junction improvements.

The above road safety works are being implemented in a phased manner. During 2015 to 2016, 2,113 works have been completed at an expense of INR 99.57 crore. During 2016 to 2017, INR 150 crore under the CRIDP scheme for road safety works and INR 100 crore under the road safety fund was proposed.

10) Non-Plan Maintenance Works

During 2016 to 2017, an allocation of INR 859.27 crore has been made for the maintenance of roads and bridges, and 2,862 km of roads has been completed at an expense of INR 805.57 crore. Budget provision of INR 897.24 crore has been made for 2017 to 2018.

5.2.4 Tamil Nadu Road Development Company Ltd (TNRDC)

(1) Outline of TNRDC

TNRDC was established in 1998 as a 50:50 joint venture between government-owned Tamil Nadu Industrial Development Corporation Ltd (TIDCO) and private Infrastructure Leasing and Financial Service Ltd (IL&FS). Later in 2009, government-owned TIDEL Park Ltd (TIDEL) acquired the entire equity held by IL&FS, making it a completely government-owned entity.

The mandate of TNRDC is to develop initiatives in the road sector by catalyzing private sector resources and investments under the PPP framework. TNRDC's activities span the entire project from project conceptualization to implementation, operations, and maintenance. The core strength of TNRDC is in formulating appropriate implementation and financing strategies for infrastructure projects so that they are

implemented in an efficient and time bound manner while adhering to the costs and quality.

IT Expressway Ltd (ITEL) was incorporated by TNRDC in the year 2004 as its wholly government-owned subsidiary for the implementation of the IT Corridor Project, with a shareholding pattern of 77% by TNRDC and balance 23% by TIDCO.

TNRDC is managed by the board comprising the nominees of the government, TIDCO, TIDEL, and an independent director. ITEL, being a government-owned investment vehicle, and TNRDC as its managing associate is responsible for project implementation, operations, and maintenance of the IT Corridor.

(2) Works of TNRDC

The company is responsible for the implementation of projects that are viable on a standalone basis or of projects that are marginally viable as a principal project sponsor. For projects that are socially and economically relevant but cannot be implemented under a commercial format, the company provides a range of services to the respective project sponsors on a on-fee basis.

1) Chennai Outer Ring Road (CORR)

The Government of Tamil Nadu has decided to provide a major connectivity corridor on the western side to ease congestion and to allow for free and quick flow of traffic. Administrative sanctions have been accorded for the development of the CORR Project Phase-1 as a green field project with the formation of dual three lanes with service roads for a length of 29.65 km from Vandalur in NH45 to Nemilichery in NH205 via Nazarathpet in NH4 at a cost of INR 1,081.40 crore. Land acquisition for this greenfield project has been done by the CMDA.

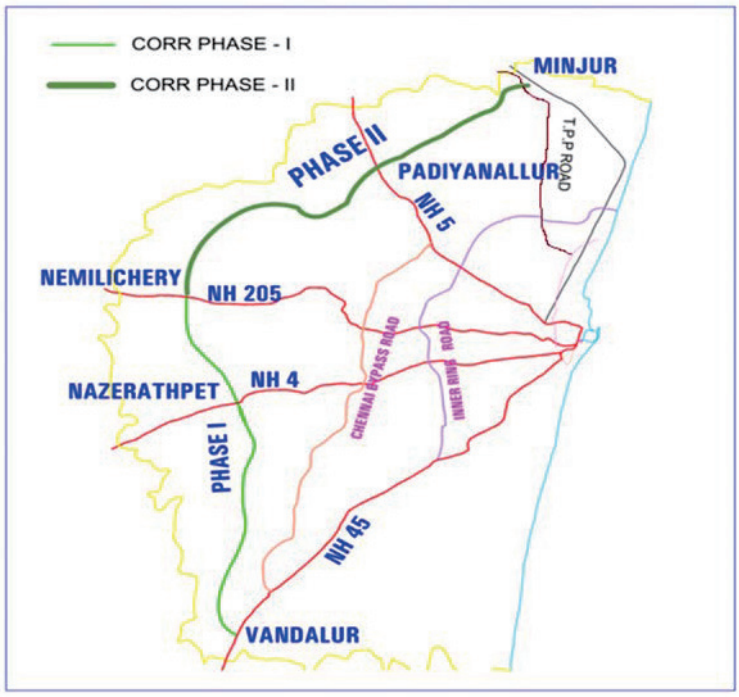
The implementation of this project was awarded to M/s GMR Outer Ring Road Pvt. Ltd (a consortium of M/s GMR Infrastructure Ltd, M/s GMR Energy Ltd, and M/s NAPC Ltd), on a Design-Build-Finance-Operation-Transfer (DBFOT) semi-annuity basis, through an ICB process. The concession period will be 20 years, consisting of two and a half years of construction period and 17½ years of operations and maintenance period.

The completed portion of the project, with a total length of 27.00 km from Mannivakkam to Nemilichery, was inaugurated on 28 August 2014 and was opened to public. At present, 97% of works have been completed. The land acquisition process was expected to be completed by September 2016, and the remaining 3% of works were targeted to be completed by September 2017.

The government has sanctioned the CORR Phase-II, a major six-lane road connectivity project, to a length of 30.50 km from Nemilicheri in NH205 to Minjur in TPP Road via Padiyanallur in NH5 at a cost of INR 1,075 crore under the Design-Build-Finance-Operate-Transfer (DBFOT) mode with semi-annual annuity payment in the same model as that of Phase-I. Phase-II of the project started on 28 August 2014.

The work has been awarded to M/s GVR Ashoka Chennai Outer Ring Road Ltd, with the concession period of 20 years comprising of two and a half years of construction period and 17½ years of operations and maintenance period.

At present, 82% of works have been completed, and the remaining works are in progress. The project should be completed by September 2016 as per the concession agreement, but due to heavy rainfall in November and December 2015 resulting in heavy floods, the project is likely to be extended.



Source: JICA Study Team base on the website of Highway Department
＜http://www.tnhighways.net/pdf/Organisation_Chart.pdf＞(Final access 20 July 2017)

Figure 5.2.4 Location Map of Chennai Outer Ring Road (CORR)

2) Ennore Manali Road Improvement/Chennai Ennore Port Road Connectivity

The Project envisages the improvement of about 30 km of road network in North Chennai with the objective of establishing seamless and efficient road connectivity from Chennai Port and Ennore Port to the NH network. The roads that are being improved include the Ennore Expressway, the Manali Oil Refinery Road, the northern part of IRR, and the TPP Road.

NHAI, the project lead sponsor, has engaged TNRDC as its managing associate and subsequently as its supervision consultant. As of late, 93% of works have been completed, and the remaining works will be completed soon.

3) Improvement of North Chennai Thermal Power Station Road and Ennore Port Road

Toshiba, a Japanese concern-JSW Turbine and Generator Pvt. Ltd., (JV) has set up a manufacturing plant on the TPP Road. Shipments from this manufacturing unit should be transported by a special heavy transport vehicle (525 MT) which needs to travel 7.35 km on the TPP Road, 4.8 km on North Chennai Thermal Power Station (NCTPS) Road, and 2.4 km on the Ennore Port Road to reach the Ennore Port. Among these three roads, the TPP Road which is part of the Ennore Manali Road Improvement Project (EMRIP), is being improved in the project.

TNRDC is the managing associate for the project in the other two roads (i.e., North Chennai Thermal Power Station Road and Ennore Port Road).

This is a unique project wherein the roads and bridges are designed to sustain 525 MT, especially over-designed shipment for the first time in Tamil Nadu State. The railway bridge also faces massive technical challenges because of the difficult terrain and because its location is near the sea. All these challenges were overcome successfully, and all the bridges have been completed and tested successfully.

All works have been completed and were inaugurated on 14 February 2016. Toshiba successfully transported the manufactured equipment from its plant by a special transport vehicle carrying over-dimensional cargo through the project roads and bridges to the Ennore Port on 11 April 2016.

4) Northern Port Access Road (NPAR) (CPRR Phase-I)

The proposed the NPAR is an important link to the fast growing Ennore Port and Kattupalli Port, which handle major cargo movements. The proposed new road will connect the northern gate of Ennore Port and Thatchur on NH5 with an additional spur road linking the TPP Road.

This will also cater to the needs of the recently developed Kattupalli Port by L&T. The total length of this road connecting the Ennore Port to Thatchur is about 21.15 km, and length of the TPP link Road is 4.35 km. Two phases are proposed. Phase-I totals 10.550 km and consists of the construction of the road from the Ennore Port entrance to Neidavoyal Village, from Neidavoyal Village to the Vallur link road (km 4.350); and Phase-II consists of the construction of the remaining 14.95 km from Neidavoyal to Thatchur in NH5.

On 19 February 2016, HMPD accorded an administrative sanction for the NPAR for a sum of INR 951 crore towards land acquisition in 15 villages of Ponneri Taluk in Thiruvallur District. Land acquisition is ongoing.

5) Improvement and Widening of East Coast Road into a Four-Lane Road

The East Coast Road from Akkarai to Koonimedu on the outskirts of the Puducherry State limit was initially improved to a two-lane carriageway with hard shoulders and was maintained by TNRDC as a toll road on 24 March 2002. The increasing traffic intensity is the cause of increased accident rates in the absence of a center median. Besides, the insufficient carriageway necessitated the widening of this road to four lanes with divided carriageway from Akkarai to Mamallapuram as Phase I, including the geometric improvements to curves and junctions between the border of Mamallapuram and Puducherry.

Accordingly, an administrative sanction was accorded by the government for INR 272.10 crore. Out of this, a sum of INR 108.84 crore was set by the government as the Viability Gap Fund (VGF), which is 40% of project cost to TNRDC. The balance should have been mobilized by TNRDC.

Works commenced on 28 February 2014, and 77% have been completed and further works are in progress. Out of the 13-curve improvement works, seven works have been completed, and out of seven junction improvement works, three are completed. The balance works are held up owing to the order of the Honorable National Green Tribunal (southern zone).

5.2.5 Tamil Nadu Road Infrastructure Development Corporation (TNRIDC)

(1) Outline of TNRIDC

TNRIDC was established in 2005 as a non-profitable organization to implement, upgrade, and maintain road infrastructure in the Tamil Nadu State. The Oragadam Industrial Corridor project and the four-laning project of the Madurai Ring Road are being implemented by the TNRIDC.

(2) Works of TNRIDC

1) Oragadam Industrial Corridor Project

Oragadam and Sriperumbudur are the largest and most developed industrial areas in Kancheepuram District. The four State Industries Promotion Corporation of Tamil Nadu Ltd (SIPCOT) units, having several prominent Indian and multinational companies, six global car manufacturing companies, and the National Automotive Testing Research Infrastructure Project (NATRIP) are situated in and around Oragadam and Sriperumbudur.

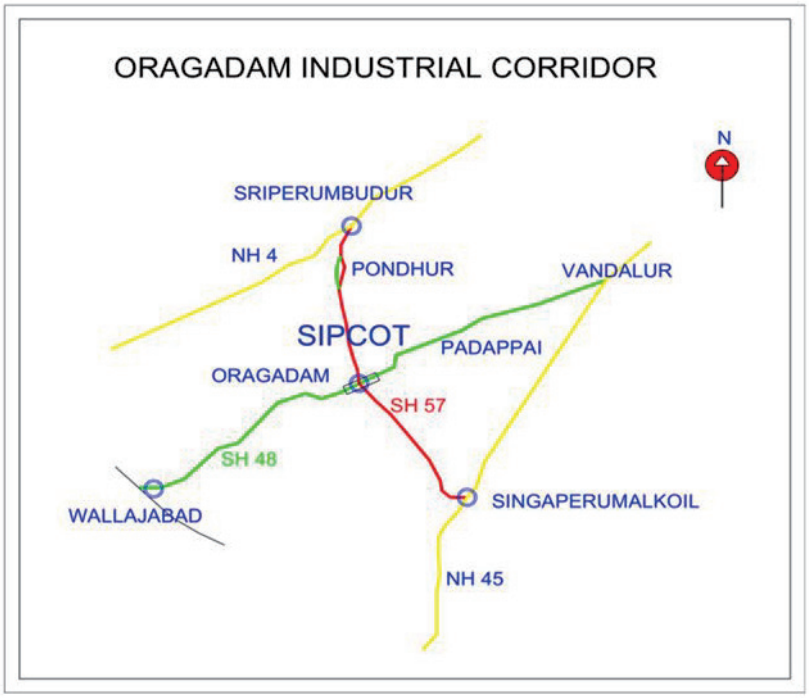
Considering the speedy development of industries in and around Sriperumbudur in Kancheepuram District, it was decided to improve the road infrastructure facilities for the Oragadam Industrial Park.

Out of the 57.40 km length of the Oragadam Industrial Corridor Project, 55.10 km had been completed in the Phase-I work. The remaining 2.30 km will be completed after finishing land acquisition. The construction of a grade separator at the Oragadam junction has been completed and is in public use. The total expenditure incurred in Phase-I is INR 463.00 crore, which includes an expenditure of INR 184.62 crore for the land acquisition.

In Phase-II, out of 12.00 km, 11.20 km (excluding the Sriperumbudur and Mathur LA stretches) has been completed in March 2016, and the remaining 0.80 km will be done after the completion of land acquisition. An expenditure of INR 96.41 crore has been incurred so far.

Phase-III works will be completed during this financial year. Out of 16.60 km in the Phase-IV, a 4.20-km

work is in progress in various stages. Phase-IV works will be completed in the next financial year.



Source: JICA Study Team base on the website of the Highways Department
＜http://www.tnhighways.net/pdf/Organisation_Chart.pdf＞(Final access 20 July 2017)

Figure 5.2.5 Location Map of Oragadam Industrial Corridor

2) Four-Laning of Madurai Ring Road

The Madurai Ring Road, having a total length of 27.20 km, is the main arterial road with two lanes and caters to the Madurai City traffic. There is heavy traffic flow in this road due to the connectivity provided by the Rameswaram Road (NH49), Tuticorin Road (NH45B), Tirunelveli Road (NH7), and Thondi Road (NH230).

The four-laning work of the Madurai Ring Road is implemented through TNRIDC under BOT (toll) scheme at a cost of INR 213.69 crore during the fiscal year 2015 to 2016. The existing two-lane road is proposed to be transformed to a four-lane road by widening both sides to have a 9.0-m carriageway on either side with a center median of 1.20 m. Furthermore, it involves the widening of two railway-over-bridges and one river bridge. The project is to be executed under the BOT basis with suitable VGF.

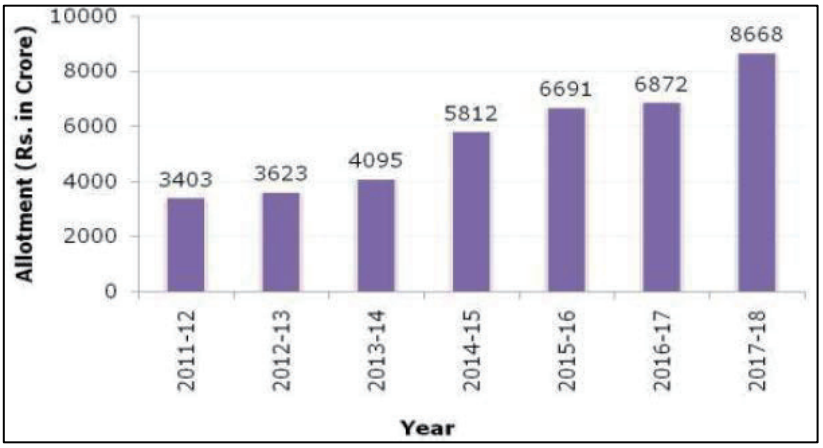
For this work, an agreement has been executed, and preliminary activities are in progress. The concessionaire is in the process of finalizing the financing arrangements. After which, construction work will commence.

5.3 Financial Situation of the Highways Department

5.3.1 Changes in Annual Financial Allotment

The figure below shows the growth of financial allotment to the road sector of the Tamil Nadu State. The financial allotment has significantly increased during the past ten years, i.e., multipliedd three times. This increase has contributed to the overall improvement of the state road network. The increased allocation has aided in achieving the policy of the state government to upgrade all SHs into two-lane roads at least. This has resulted in improved road safety conditions. The latest statistics (Road Accidents in India 2015 by MORTH) reveals that the severity of accidents (the number of fatalities per 100 accidents) in Tamil Nadu State is 22.7, which is lower than the national average of 29.1. Further, while at the national level, fatal accidents have generally increased by 5.7% comparing the 2012 and 2015 data, whereas in Tamil Nadu State,

it has reduced by 3.3%.

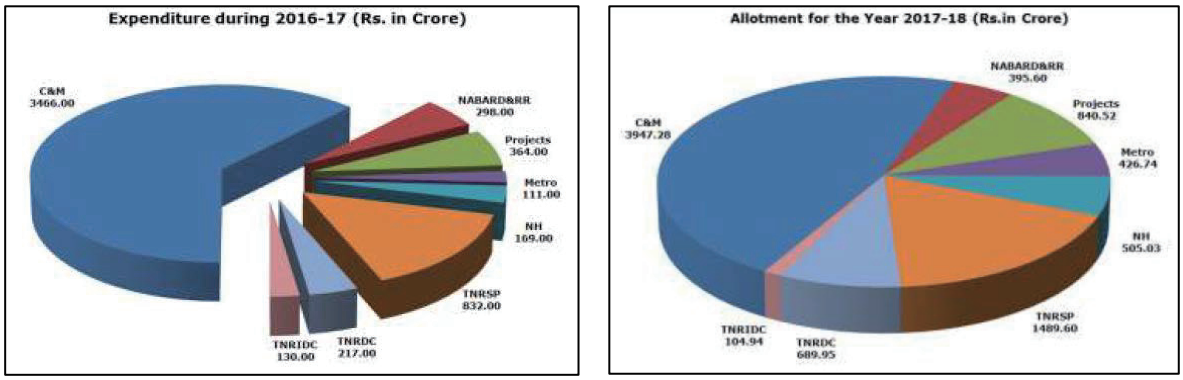


Source: Policy Note 2017-2018, HMPD

Figure 5.3.1 Changes in Annual Financial Allotment to the Highways Department

5.3.2 Breakdown of Annual Financial Allotment

The Highways Department constructs and maintains roads in various schemes, utilizing funds from the state, and central and external funding agencies. For 2016 to 2017, INR 6,875.40 crore has originally been allotted to the Highways Department for implementation of planned works. Later, in the revised budget estimate, the allocation has been reduced to INR 6,255.67 crore, of which an expenditure of INR 5,588.09 crore have been incurred (89%). A total of INR 6,871.87 crore was allotted in the Revised Budget Estimate to the Highways Department for 2017 to 2018.



Source: Policy Note 2017-2018, HMPD

Figure 5.3.2 Breakdown of Annual Financial Allotment to the Highways Department

The acronyms in Figure 5.3.2 stand for respectively as follows:

C&M	: Construction and Maintenance
TNRDC	: Tamil Nadu Road Development Company
TNRIDC	: Tamil Nadu Road Infrastructure Development Corporation
NABARD	: Execution of bridges and roads with loan assistance from the National Bank for Agriculture and Rural Development (NABARD)
PROJECTS	: Road over and under bridges at railway level crossings and major bridges
METRO	: Execution of Chennai Metropolitan Development Plan (CMDP) works
NH	: National Highway

TNRSP : Road upgradation works with World Bank assistance

HRS : Highway Research Station

5.3.3 Non-Plan Maintenance Works

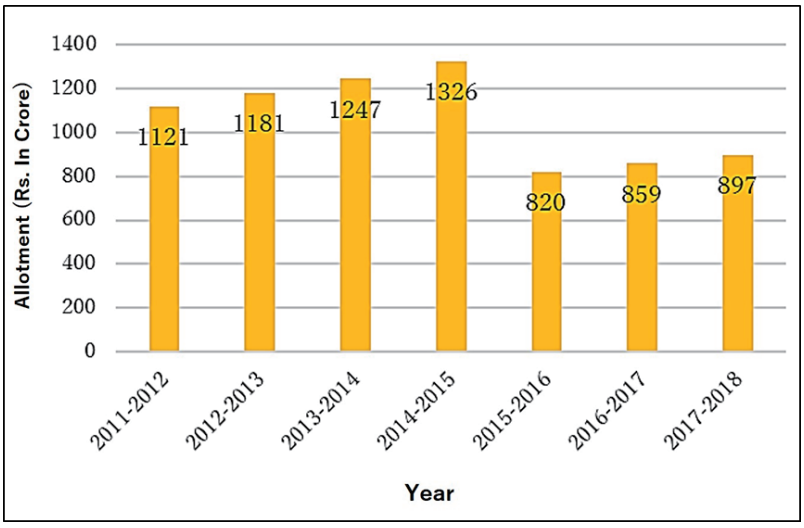
During 2016 to 2017, an allocation of INR 859.27 crore has been made for the maintenance of roads and bridges and for the renewal of 2,862 km of roads.

The financial performance indicating the details of expenditure incurred during 2016 to 2017 under various heads of non-plan maintenance works and the allocation for 2017 to 2018 is given in Table 5.3.1.

Table 5.3.1 Non-Plan Financial Allocation and Expenditure (Rs. in Lakhs)

No.	Name of Scheme	2015-2016		2016-2017 Revised Budget Estimate
		Budget Estimate	Expenditure	
1	NH (Urban)	234.52	234.52	234.52
2	Certain important roads in Chennai City taken from the Corporation of Chennai	2,110.64	2,100.00	2,110.64
3	SH	15,984.22	16,406.31	16,667.10
4	MDR	14,439.01	13,965.34	15,197.74
5	ODR	51,219.67	46,213.11	53,571.73
6	Sugarcane Roads	1,849.79	1,549.93	1,849.79
7	Improvements to Nigiris Ghat Roads	90.00	87.96	92.35
	Total	85,927.85	80,557.17	89,723.87

Source: Performance Budget 2016-2017, Highways Department



Note: Since the central government grant for rural road maintenance ended, the allotment in and after 2015-2016 has decreased.
Source: JICA Study Team

Figure 5.3.3 Changes in Annual Financial Allotment to the Highways Department for Non-Plan Maintenance

5.4 Recent Model Contracts for Operations and Maintenance in India

5.4.1 Performance Based Maintenance Contract (PBMC)

(1) Features of the PBMC Contract

The Tamil Nadu State Highway Department used to contract out road maintenance works to private contractors on a single fiscal year basis. The contracts, however, are currently being replaced with the PBMC model.

PBMCs are not new to the transport sector, with many variations used in different countries for the past two decades. International lending institutions, such as the World Bank, have played a significant role in pushing PBMCs into developing nations as part of loan assistance packages.

The contractor in a road PBMC is paid on an output basis (i.e., maintaining the road at a specified service standard) rather than on an input basis as in traditional maintenance contracts.

PBMCs have several benefits over traditional input-based contracts. By paying contractors based on the level of service they deliver, output based contracts provide a clear financial incentive for contractors to meet performance standards. Private contractors are also incentivized to improve their efficiency and minimize cost because they are paid at a set level for performance, not based on the value of the inputs used.

Durations of PBMCs are usually longer than traditional maintenance contracts, which incentivize private contractors to take measures that improve the road conditions for the duration of the contract rather than on ad hoc repairs. Longer maintenance contracts also commit governments to fund maintenance for several years, reducing the risk of delaying maintenance for budget reasons. Tamil Nadu State has adopted five years.

The Public-Private Infrastructure Advisory Facility (PPIAF)[1] has addressed five key lessons learned in designing and implementing road PBMCs as follows:

a) Successful performance-based contracts require sufficient dedicated fiscal resources and realistic performance expectations.

b) Private operators may need training and capacity building to bid for and implement performance-based contracts.

c) Clear baseline data is needed to establish and monitor performance indicators and standards.

d) Simple performance indicators and user monitoring can improve contract performance.

e) Vehicle overloading is a major challenge to implementing effective output-based maintenance contracts.

According to the pre-qualification document of the "Performance Based Maintenance Contract for Five Years for State Highways and Major District Roads in Pollachi (H) C&M Division", bidders must demonstrate that they own or have assured ownership for the key equipment. It is only the minimum level of suggested major equipment, however, notwithstanding the above, wherein the contractor shall be required to provide all necessary items and equipment, as well as plants and materials to carry out the prescribed works within the required timeframes.

Table 5.4.1 Minimum Mandatory Requirement of Plant and Equipment

No.	Equipment Type and Characteristics	Minimum Number Required
1	10-ton Tipper Truck	15
2	Loader/Back Hoe (0.5 m^3 bucket)	3
3	Excavator (0.75 m^3 bucket)	3
4	Asphalt Plant (60 ton/hr capacity)	3
5	Mechanical/Sensor Asphalt Paver (3.5 m)	3
6	Bitumen Distributor (2,000 liter)	3

[1] The Public-Private Infrastructure Advisory Facility (PPIAF) is a multi-donor technical assistance facility that is financed by 11 multilateral and bilateral donors. It was established in 1999 as a joint initiative of the Governments of Japan and the United Kingdom, working closely with and housed inside the World Bank Group.

No.	Equipment Type and Characteristics	Minimum Number Required
7	Motorized Grader (min. 120 hp.)	3
8	Water Bowser	3
9	8-10-ton Vibratory Steel Drum Roller	3
10	12-ton Pneumatic Tired Roller	3
11	Vibrating Plate/Rammer	3
12	Emulsion Sprayer	3
13	Tractor or Rubber Tired Dozer with Adjustable Back Blade	3
14	Mini Vibrating Roller	3
15	Tandem Roller	6
16	Power-broom or Tractor Mounted Compressor	3
17	6-ton Truck for Patrol Maintenance Unit	2
18	Concrete Mixer Machine with Bucket Loader	4

Source: Performance Based Maintenance Contract for Five Years for State Highways and Major District Roads in Pollachi (H) C&M Division

(2) Issues in India

Currently, four road sections in Tamil Nadu, namely Pollachi (SH 191.40 km and MDR 185.98 km), Krishnagiri (SH 307 km and MDR 274 km), Ramanathapuram (SH 229 km and MDR 340 km), and Thiruvallur (SH 498 km and MDR 278 km), totaling SH 1,225.4 km and MDR 1,077.98 km, are being maintained under PBMCs and are getting assistance from the World Bank. The contracts include the following five components:

a) Ordinary (or routine) maintenance: paid as a lump sum evenly divided into 60 monthly payments (five years)

b) Initial Rectification Works: to be completed within the first six months to bring the road to below intervention standards; initial rectification works is a firm lump sum that will be measured and paid on the actual works output

c) Periodic Maintenance: paid based on a schedule when work is completed

d) Minor Improvement Works: paid based on a schedule when work is completed

e) Emergency Works (day works): paid on a unit rate basis for time/quantity used when ordered

The first PBMC came into the road sections in Pollachi in 2014, and it is still early to evaluate the contract effectiveness. The conventional single-year maintenance contract, however, requires about three months (April to June) to prepare tendering, and the actual maintenance work starts only after July. Regarding the practicability of continuous maintenance work over several years, the Construction and Maintenance Wing, which oversees the maintenance of SH and MDRs, highly appreciate the new contract.

As addressed by PPIAF, it is a prerequisite to clearly indicate expected performances and corresponding prices for a successful PBM contract. Expected performances are often called as Key Performance Indicators (KPIs). These indicators, however, vary with road categories, importance of locations, and local economic activity situations and are required to have a baseline for performances and costs. Then, by monitoring actual performances, it is possible to determine the appropriate KPIs. It is necessary to carefully monitor current PBMC performances together with corresponding prices for the coming years to establish PBMCs in India.

5.4.2 Operation-Maintenance-Transfer (OMT) Contract

(1) Features of the OMT Contract

Regarding road projects awarded on a PPP contract, completed road stretches are operated and maintained on a long-term basis by the concessionaires. Whereas for road stretches constructed through public-funded projects, the central and state road authorities undertake operations and maintenance (O&M) through item-rate-based short-term contracts, which entailed excessive monitoring burden on road authorities. Besides, in the past, repair and maintenance of roads have not received the fair attention it requires primarily due to the lack of funds available for O&M. Furthermore, there are separate contracts for O&M and tolling, often leading to multiplicity of contracts and huge monitoring requirements.

In 2009, authorities introduced a new contract concept, the OMT contract, combining a tolling contract and a contract for O&M and drastically reducing the number of contracts by integrating multiple road section contracts together. Under the OMT Contract, the primary objective is to outsource the O&M of the road to a private entity for a definite concession period. OMT contracts include each construction work of toll plazas, toll collection, and O&M. The concession period is basically nine years considering the renewal period of road facilities. After which, the concessionaire must transfer the project stretch back to the government authorities.

The selection of the concessionaires is based on competitive bidding where selected bidders specify the concession fee they offer to the authority, or in some cases the O&M support required if their operational expenditures exceed the toll revenues expected.

The response from the private sector to OMT contracts has been very strong. Between 2009 and 2014, NHAI awarded a total of around 2,400 km of NH (12 projects) to be maintained on an OMT basis. State authorities that followed the suite include Maharashtra State Road Development Corporation, Madhya Pradesh State Road Development Corporation, Karnataka Road Development Corporation, and Bihar State Road Development Corporation.

(2) Issues in India

The central government has taken the lead in promoting the OMT contract. In 2012, the OMT policy was approved and a model concession agreement (MCA) for OMT contracts was drafted. The tolling policy for NH was also revised along with finalization of the standardized technology. New policies and many projects at the national and state levels have been providing a wide range of business opportunities for OMT contractors, equipment manufacturers, and material suppliers.

The OMT contract has gained momentum in the roads sector. Governments at both central and state levels have emphasized on outsourcing OMT to private service providers. Many OMT projects have been identified and awarded at both central and state levels.

However, some key issues need to be resolved to sustain growth. Some identified issues include risk allocations between highway authorities and OMT players, lack of expertise in tolling and O&M, delay in handing over the project road to OMT players, lack of coordination between related agencies, incomplete sections of project road, mismatch in delivery timelines between EPC and OMT contracts, lower traffic growth on some project stretches, and the short concession period of nine years.

5.4.3 Toll-Operate-Transfer (TOT) Contract

(1) Features of the TOT Contract

The Cabinet Committee on Economic Affairs (CCEA) approved the Toll-Operate-Transfer (TOT) Contract in August 2016. Then, CCEA has authorized NHAI to monetize 75 public funded NHs that are operational and that have been generating toll revenues for at least two years. According to the rating agency ICRA Ltd, these 75 projects with a road length of 4,376 km can yield around INR 35,600 crore.

The TOT Contract is also aimed at overcoming some limitations of the OMT model, which include a relatively short concession period of nine years in principle depending on when the major period maintenance is due, the restriction of participation only to contractors and developers, and a high level of toll exemptions.

The TOT Contract is designed to monetize public-funded operational toll-based roads on the condition that the roads have been generating revenues for a minimum of two years after the commercial operation

date. In the bidding of the TOT Contract, concession fees for the O&M and the tolling of NH will be auctioned to domestic and international players. This way, the TOT model helps secure future cash inflows and utilize those for creation of new road assets. The model produces one-time monetization of the concession fee of tolls with an established traffic for the coming 30-year concession term.

The TOT model also offers new business opportunities to new investors in partnership with developers specializing in O&M of highways. It will open doors to various categories of investors such as institutional investors, insurance funds willing to invest in low-risk assets, and the like. Although these investors do not want to take road construction risks, they are ready to make long-term investments in completed toll roads that are producing revenue.

The first bunch of toll roads to be monetized on a TOT Contract comprises nine roads spanning 680 km across the states of Andhra Pradesh and Gujarat and will be bid out for a tenure of 30 years. According to the bid document, the concession period of 30 years could be reduced by more than five years or be increased by more than ten years based on a mutual consent of both concessionaire and NHAI.

Under the TOT contract, the rights of collection of toll fees on selected NH are proposed to be auctioned and assigned to a concessionaire for a period of 30-years against an upfront payment of a lump-sum amount to the government. The concessionaire is responsible for the O&M and tolling of the NH during the tenure.

According to MORTH, the project has drawn interest from several international investors including Abu Dhabi Investment Authority (ADIA), Singapore's Sovereign Wealth Fund GIC Pte. Ltd, Singapore's state-run investment firm Temasek Holdings Pte. Ltd, Hastings Funds Management Ltd, Keppel Infrastructure Fund Management Pte. Ltd, Mizuho Asia Infra Capital, Macquarie Group Ltd, Morgan Stanley Infrastructure Inc., Equirus Capital Pte. Ltd, I Squared Capital Advisors LLC, JP Morgan Asset Management Inc., and Infrastructure Leasing & Financial Services Ltd.

(2) Issues in India

The TOT Contract has already been tested internationally including the Chicago Skyway, the Indiana Toll Road, the Puerto Rico Highway PR-22, and the Malaysian Penang Bridge with concession periods ranging between 40 and 99 years. The responsibility of O&M of the road lies with the TOT concessionaire. Though the TOT model is yet to be practically introduced to India, it is important to ensure sound implementation by making contract procedures transparent to all stakeholders.

Issues that need to be tackled during the implementation of the TOT model should include duration of concession periods, minimum portfolio size, contract termination payment clause, and capacity augmentation after project awarding. It is also required to address prevailing issues in the Indian road sector such as the lack of trained manpower, ambiguous certification process, neglect of safety parameters, high rate of toll exemptions and leakages, and unstable regulatory environment. It is also advisable for TOT players to enhance their technical capacity by positively introducing efficient intelligent transport system (ITS) and effective O&M methodology practiced internationally.

5.4.4 Engineering-Procurement-Construction (EPC) Contract (Maintenance Clause)

(1) Features of the EPC Contract

The Government of India has decided to build NH primarily under PPP since 2005 and has been using the BOT model for the procurement contracts. However, the Government of India has been facing problems such as the following:

a) frequent cost and time overrun because of aggressive bidding,

b) stretched financial position of road developers, and

c) decelerating global and domestic economic growth.

These problems adversely affect the further development of the NH projects, and the Government of India has frequently had unsuccessful biddings as well as contractual defaults one after another. These situations have led to a review of the contract models. MORTH has decided to shift from the PPP models, which use the financial procurement by road developers, to road construction using government funds.

Since the 1980's, the Government of India ceased the use of the conventional contract model of design-bid-build (DBB), which is generally accepted around the world. Instead, the government conducted research to develop new models. As a result, the "Standard Agreement for Road & Bridge Works on Engineering-

Procurement-Construction (EPC) Model" was developed in 2012, referring to the "Conditions of Contract for EPC/Turnkey Projects (1/1999)" by FIDIC. The rate of the application of the Indian version of the EPC for national highway projects in the country has gradually been increasing since 2012.

The EPC contract obligates the contractor to maintain the Project Highway for a period of four years, commencing from the date of the provisional certificate[2]. For the performance of its maintenance obligations, the contractor shall be paid 0.5% of the contract price for the first year and 1%, 1.5%, 2% for the second, third, and fourth year, respectively. In case of a standalone project like a bridge, the rates of the payment are 0.25%, 0.5%, 0.5%, and 0.5%.

The contractor shall be responsible for all defects and deficiencies until the expiry of the 4-year period commencing from the date of the provisional certificate. The defects and liability period shall in no case be less than 42 months from the date of the completion certificate. The defects and liability correlate with the maintenance obligations, and the period is also four years.

Regarding the maintenance of the project road, the contractor will be responsible for four years after completion of the construction. The contractor will be obliged to prepare (in consultation with the independent engineer) a maintenance program, ten days prior to the month in which the O&M will commence. The contractor will also be obliged to conduct a road inspection together with the independent engineer. The required maintenance level shall be based on the Schedule-E maintenance requirement of the contract. The contractor's obligation based on the contract will include the following items during the period of the maintenance:

a) permitting safe, smooth, and uninterrupted flow of traffic on the project highway;

b) undertaking routine maintenance including prompt repairs of potholes, cracks, joints, drains, embankments, structures, pavement markings, lighting, road signs and other traffic control devices;

c) undertaking repairs to structures;

d) informing the authority of any unauthorized use of the project highway;

e) informing the authority of any encroachments on the project highway; and

f) operations and maintenance of all communication, patrolling, and administrative systems necessary for the efficient maintenance of the project highway in accordance with the provisions of the contract

The contractor shall ensure and procure that, during the maintenance period, the project highway conforms to the maintenance requirements set forth in Schedule-E (the "Maintenance Requirements").

(2) Issues in India

The EPC Contract was introduced in 2012, and there exists only a few experiences of O&M under the contract. Issues should be identified while accumulating experience. The following are some issues that should be addressed to smoothly implement O&M under the EPC contract model successfully in the future.

The major part of the EPC contract is road construction. The part of O&M is only 3%, totaling four years after completion of the construction. The major concerns of the contractor, therefore, centers on the construction part, and the contractor is not necessarily well-versed in O&M. Moreover, the duration of O&M is as short as four years, and the contractor may have difficulty in planning O&M equipment and manpower from the long-term viewpoint.

The four-year term of O&M and liabilities for defects and deficiencies is longer than international practices and should be shortened by half. The road will be transferred to the road administrator after the completion of the term, then the road administrator will decide whether they will maintain the road directly or outsource the O&M to private entities. There is a marked tendency to outsource road O&M to private companies in India, and the Tamil Nadu State has been positively introducing Performance Based Maintenance (PBM) contracts.

Other outsourcing methods of road O&M include the OMT Contract and the TOT Contract, which are

[2] MORTH. 2017. Article 14.1 Maintenance obligation of the Contractor: *EPC (Engineering Procurement and Construction) Agreement for Construction of Two-Lane National Highway Works*. New Delhi

about to accumulate experience in India and are expected to be effective O&M contracts in the future.

5.4.5 Public-Private-Partnership (PPP) Contract (Maintenance Clause)

(1) Features of PPP Contract

The scope of a PPP Contract includes O&M of the project road during the concession period in accordance with the provision of Article 17 "Operation and Maintenance". The details are stated as follows:

> 17.1 O&M Obligations of the Concessionaire
>
> 17.1.1 During the Operation Period, the Concessionaire shall operate and maintain the Project in accordance with this Agreement either by itself, or through the O&M Contractor and if required, modify, repair or otherwise make improvements to the Project to comply with the provisions of this Agreement, Applicable laws and Applicable Permits, and conform to Specifications and Standards and Good Industry Practice. The obligations of the Concessionaire hereunder shall include:

a) Procuring and ensuring safe, smooth, and uninterrupted use of the Project, including prevention of loss or damage thereto, during normal operating conditions

b) Minimizing disruption in the event of accidents or other incidents affecting the safety and use of the Project by providing a rapid and effective response and maintaining liaison with emergency services of the Sate

c) Carrying out periodic preventive maintenance of the Project

d) Undertaking routine maintenance including prompt repairs of potholes, cracks, joints, drains, embankments, structures, markings, lighting, signage, and other control devices

e) Undertaking major maintenance such as resurfacing, repairs to structures, and repairs and refurbishment of system and equipment

f) Preventing, with the assistance of concerned law enforcement agencies, any unauthorized use of the Project

g) Preventing, with the assistance of the concerned law enforcement agencies, encroachments on or unauthorized entry to the Project

h) Protection of the environment and provision of equipment and materials thereof

i) Operations and maintenance of all communication, control, and administrative systems necessary for the efficient operation of the project and for providing safe, smooth, and uninterrupted use of the Project

j) Maintaining a public relations unit to interface with and attend to suggestions from the users, government agencies, media, and other agencies

k) Complying with safety requirements in accordance with Article 18

The concessionaire shall procure that at all times during the operation period, the Project conforms to the maintenance requirements set forth in Schedule-K (the "Maintenance Requirements).

(2) Issues in India

Long concession periods under PPP contracts may affect the O&M of the projects. O&M under a PPP Contract entails the work during the entire contract period, which are usually long, ranging from 15 to 30 years. It is difficult to accurately predict some important factors for a long period such as economic fluctuation, traffic volume increase rate, change in road users' response to toll, change in government policy on toll roads, etc. In the past, India saw some cases of PPP Contract termination due to various reasons. Some examples include the following: the actual traffic volume was much lower than expected; the contractor was unable to solve prevailing long queues in front of the toll plaza; and the road users started a strong and large campaign against tolling.

When the actual traffic volume is lower than expected, the effect on O&M can be severe. If toll revenue decreases, a loan repayment receives preferential treatment from the toll revenue, and allotment to O&M gets smaller resulting in lower quality of O&M.

Inefficient O&M also affects the quality of O&M in great deal. Efficient O&M involves such practices as effective measures against overloaded vehicles and accidents, effective measures against natural disaster using preventive management, efficient O&M with an asset management system, efficient O&M with application of ITS, etc. The lack of efficient O&M results in higher cost and lower quality in O&M.

Appropriate supervision of concessionaires by road administrators influences the quality of O&M as well. Since the present maintenance requirements carries item-wise repairs on identified defects, it involves long-time and laborious work for road administrators to oversee concessionaires, whether or not concessionaires are conforming to the maintenance requirements. It is needed to simplify the work for the road administrators to oversee the PPP concessionaires.

5.4.6 Maintenance Requirements (Schedule-K in PPP and Schedule-E in EPC)

(1) Maintenance Requirements

The Concessionaire shall, always maintain the project highway in accordance with the provisions of the agreement, applicable laws and applicable permits. The concessionaire shall, always during the operation period, conform to the maintenance requirements set forth in the schedule (the "Maintenance Requirements").

The Concessionaire shall repair or rectify any defect or deficiency set forth in Paragraph 2 of the Schedule-K within the time limit specified therein and any failure in this behalf shall constitute a breach of the agreement. Upon occurrence of any breach hereunder, the Authority shall be entitled to recover damages as set forth in Clause 17.8 of the agreement, without prejudice to the rights of the Authority under this agreement, including termination thereof.

(2) Repair/Rectification of Defects and Deficiencies

The obligations of the Concessionaire with respect to the maintenance requirements shall include repair and rectification of the defects and deficiencies specified in Annex-I of Schedule-K within the time limit set forth therein.

(3) Other Defects and Deficiencies

With respect to any defect or deficiency not specified in Annex-I of Schedule-K, the Concessionaire shall undertake repair or rectification in accordance with good industry practice and within the time limit specified by the Independent Engineer.

With respect to any defect or deficiency not specified in Annex-I of Schedule-K, the Independent Engineer may, in conformity with good industry practice, specify the permissible limit of deviation or deterioration with reference to the specifications and standards, and any deviation or deterioration beyond the permissible limit shall be repaired or rectified by the Concessionaire within the time limit specified by the Independent Engineer.

(4) Extension of Time Limit

Notwithstanding anything to the contrary specified in Schedule-E, if the nature and extent of any defect or deficiency justifies more time for its repair or rectification than the time specified herein, the Concessionaire shall be entitled to additional time in conformity with good industry practice. Such additional time shall be determined by the Independent Engineer and conveyed to the Concessionaire and the Authority with reasons thereof.

(5) Emergency Repairs/Restoration

Notwithstanding anything to the contrary contained in Schedule-K, if any defect, deficiency, or deterioration in the project highway poses danger to the life or property of the users thereof, the Concessionaire shall promptly take all reasonable measures for eliminating or minimizing such danger.

(6) Daily Inspection by the Concessionaire

The Concessionaire shall, through its engineer, undertake a daily visual inspection of the project highway and maintain a record thereof in a register to be kept in such form and manner as the Independent Engineer may specify. Such record shall be kept in safe custody of the Concessionaire and shall be open to inspection by the Authority and the Independent Engineer at any time during office hours.

(7) Pre-Monsoon Inspection/Post-Monsoon Inspection

All defects and deficiencies specified in Schedule-K shall be repaired and rectified by the Concessionaire so that the project highway conforms to the maintenance requirements on the transfer date.

(8) Display of Schedule-K

The Concessionaire shall display a copy of Schedule-K at the toll plaza(s) along with the Complaint Register stipulated in Article 46.

(9) Repair/Rectification of Defects and Deficiencies

The Contractor shall repair and rectify the defects and deficiencies specified in Annex-I of Schedule-K within the time limit set forth in the table below.

Table 5.4.2 Repair/Rectification of Defects and Deficiencies (Annex-I)

Roads	Nature of Defect or Deficiency	Time Limit for Repair/Rectification
(a)	**Carriageway and paved shoulders**	
(i)	Breach or blockade Temporary restoration Permanent restoration	 24 hours 15 days
(ii)	Roughness value exceeding 2,500 mm in a stretch of 1 km (as measured by a calibrated bump integrator)	180 days
(iii)	Pot holes	48 hours
(iv)	Cracking in more than 5% of road surface in a stretch of 1km	30 days
(v)	Rutting exceeding 10 mm in more than 2% of road surface in a stretch of 1 km (measured with 3 m straight edge)	30 days
(vi)	Bleeding/skidding	7 days
(vii)	Raveling/stripping of bitumen surface exceeding 10 sqm	15 days
(viii)	Damage to pavement edges exceeding 100 mm	15 days
(ix)	Removal of debris	6 hours
(b)	**Hard/earth shoulders, side slopes, drains, and culverts**	
(i)	Variation by more than 2% in the prescribed slope of camber/cross fall	30 days
(ii)	Edge drop at shoulders exceeding 40 mm	7 days
(iii)	Variation by more than 15% in the prescribed side (embankment) slopes	30 days
(iv)	Rain cuts/gullies in slope	7 days
(v)	Damage to or silting of culverts and side drains during and immediately preceding the rainy season	7 days
(vi)	Desilting of drains in urban/semi-urban areas	48 hours
(c)	**Road side furniture including road signs and pavement marking**	
(i)	Damage to shape or position; poor visibility or loss of retro-reflectivity	48 hours
(d)	**Street lighting and telecom (ATMS)**	
(i)	Any major failure of the system	24 hours
(ii)	Faults and minor failures	8 hours
(e)	**Trees and plantation**	
(i)	Obstruction in a minimum head-room of 5 m above carriageway or obstruction in visibility of road signs	24 hours
(ii)	Deterioration in health of trees and bushes	Timely watering and treatment
(iii)	Replacement of trees and bushes	90 days
(iv)	Removal of vegetation affecting sight line and road structures	15 days
(f)	**Rest areas**	
(i)	Cleaning of toilets	Every 4 hours
(ii)	Defects in electrical, water, and sanitary installations	24 hours
(g)	**Toll plaza**	
(i)	Failure of toll collection	8 hours
(ii)	Damage to toll plaza	7 days

Roads	Nature of Defect or Deficiency	Time Limit for Repair/Rectification
(h)	**Other project facilities and approach roads**	
(i)	Damage or deterioration in approach roads, (pedestrian facilities, truck lay-bys, bus-bays, bus-shelters, cattle crossings, traffic aid posts, medical aid posts, and other works	15 days
Bridges	**Nature of Defect or Deficiency**	**Time Limit for Repair/Rectification**
(a)	**Superstructure of bridges**	
(i)	Cracks Temporary measures Permanent measures	 48 hours 45 days
(ii)	Spalling/scaling	15 days
(b)	**Foundations of bridges**	
(i)	Scouring and/or cavitation	15 days
(c)	**Piers, abutments, return walls, and wing walls of bridges**	
(i)	Cracks and damages including settlement and tilting	30 days
(d)	**Bearings (metallic) of bridges**	
(i)	Deformation	15 days
(e)	**Joints in bridges**	
(i)	Loosening and malfunctioning of joints	15 days
(f)	**Other items relating to bridges**	
(i)	Deforming of pads in elastomeric bearings	7 days
(ii)	Gathering of dirt in bearings and joints; or clogging of spouts, weep holes, and vent-holes	3 days
(iii)	Damage or deterioration in parapets and handrails	3 days
(iv)	Rain-cuts or erosion of banks of the side slopes of approaches	15 days
(v)	Damage to wearing coat	15 days
(vi)	Damage or deterioration in approach slabs, pitching, apron, toes, floor, or guide bunds	30 days
(vii)	Growth of vegetation affecting the structure or obstructing the waterway	15 days

Source: Schedule-K in MCA for PPP

5.5 Operations and Maintenance (O&M) of Chennai Outer Ring Road (CORR)

5.5.1 O&M Requirements

The CORR runs in parallel with the CPRR on the east side. It was opened to traffic in 2013. Since both roads are similar in road configurations, CORR offers the reference in preparation of the O&M for CPRR.

CORR is a project based on a Design-Build-Finance-Operate-Transfer (DBFOT) annuity contract. Its O&M manual was prepared by the concessionaire, GMR Chennai Outer Ring Road Private Limited, and sets out the methodology of carrying out the O&M for CORR. The JICA Study Team has studied, interpreted, and summarized the content of the O&M manual in the succeeding paragraphs.

As per clause 17 of the concession agreement of CORR, the concessionaire shall operate and maintain the project highway either by itself or through O&M contractors, and if required, modify, repair, or otherwise make improvements to the project highway to comply with provisions of concession agreement, applicable laws, and permits, and confirm to specifications, standards, and other requirements and manufacturer's guidelines and instructions with respect to the toll system.

CORR

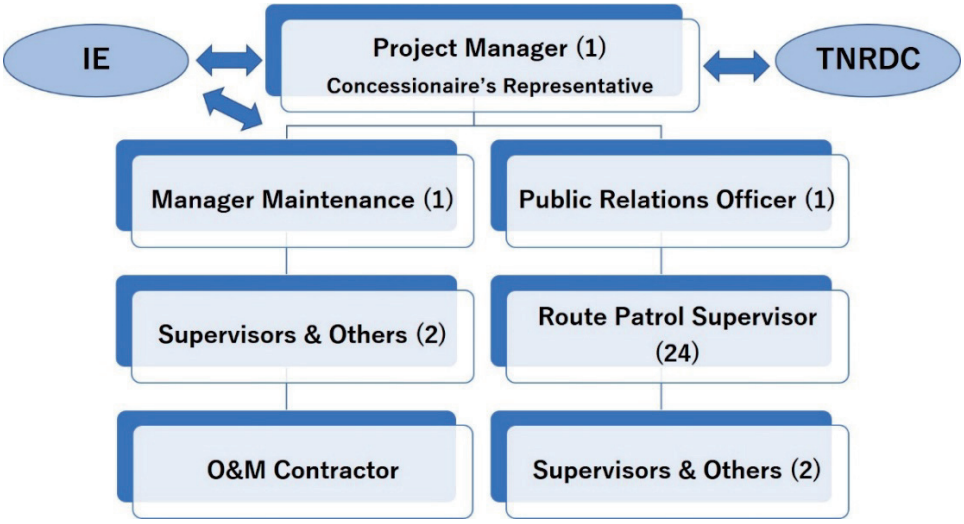
O&M Field Office

Source: JICA Study Team

Figure 5.5.1 CORR and O&M Field Office

5.5.2 O&M Team

The structure of the O&M team of the concessionaire of CORR to carry out the obligations and responsibilities during the O&M period is shown in Figure 5.5.2. Although it outsources part of maintenance works to an O&M contractor, the concessionaire carrys out all the other parts on their own.



Source: JICA Study Team based on O&M Manual of CORR

Figure 5.5.2 Organizational Chart of O&M Team

5.5.3 Traffic Management

(1) Highway Patrol

Highway patrolling shall be done to ensure safe, uninterrupted, and smooth traffic flow so that:

a) Vehicles should not be allowed to park on the carriageway or on the shoulder, and parked vehicles should be removed with the help of traffic aid police.

b) Immediate assistance is provided to accident victims and their rescuers.

c) Minor debris and stalled vehicles are removed from carriageways within reasonable time after clearance from concerned authorities.

d) In the event of traffic congestion, adequate measures shall be taken to mitigate further congestion with the help of the police from traffic aid posts, and approaching traffic is duly cautioned about it.

(2) Initial Response to Safety, Vehicle Breakdowns, and Accidents

a) In case of unsafe conditions, vehicle breakdowns, and accidents, the concessionaire shall follow the

relevant operating procedures, which shall include the setting up of temporary traffic cones and lights, as well as the removal of obstruction and debris expeditiously.

b) The concessionaire shall ensure that any diversion or interruption of traffic is remedied without delay, and liaison with police is done. Their cooperation is sought to overcome any difficulty.

(3) Control Room Operator (CRO)

The CRO shall prepare a Management Information System (MIS) to provide all functions stated below:

a) to provide rapid and effective response to incidents,

b) to provide static and real-time transportation information to users,

c) to attend to emergency calls and, accordingly, public safety dispatch and emergency operations,

d) to provide incident information to route patrol (RP),

e) to communicate via Radio Mobile System (RMS),

Control Room

Ambulance

Source: JICA Study Team

Figure 5.5.3 Control Room and Ambulance

(4) Emergency Operations

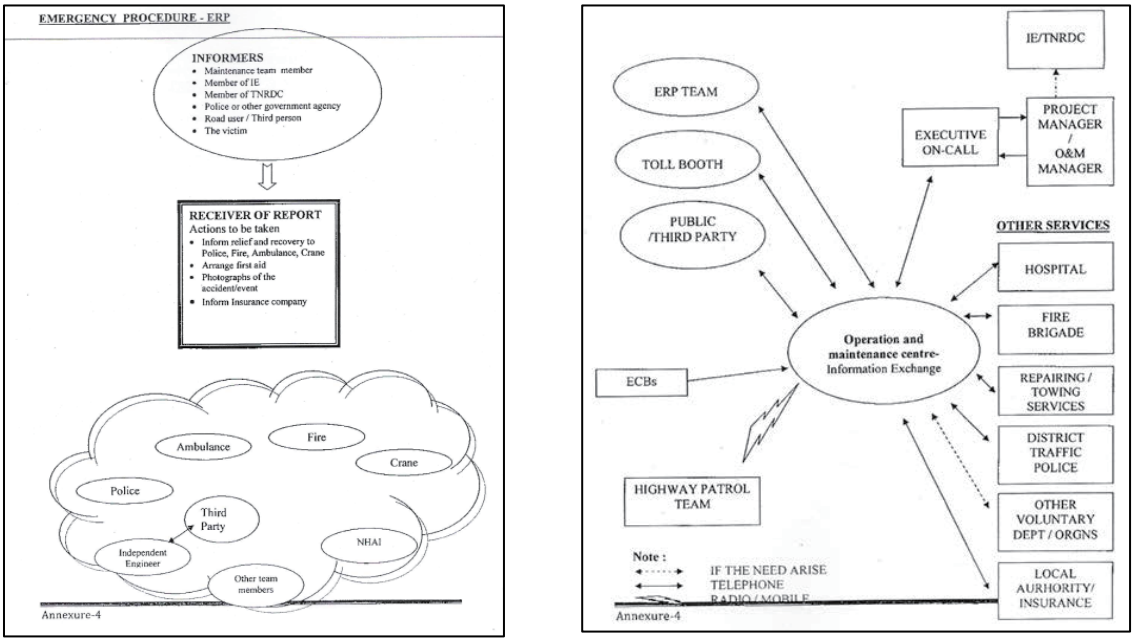
Highway patrolling/control room operator teams are continuously monitoring the project highway and respond and try to reach the site to extend assistance within a maximum of 10 minutes, subject to traffic bottlenecks. Emergency operations are done to minimize disruption to traffic in the event of accidents and/or incidents affecting the safety and use of the project highway by providing a rapid and effective response and maintaining liaison procedures as indicated in the figure below, with emergency services using the following setups:

a) Ambulance will be stationed at middle of the stretch and will be made available for accident victims. If required, more ambulance services will be made available to road users through the local hospitals.

b) Tow-truck/cranes of adequate capacity shall have all requisite arrangement of pulling and shifting accident/breakdown vehicles and will also be available on call.

c) Fire tender services from fire stations available along the project highway will be extended to the project by the local authorities.

d) The concessionaire will display all emergency service information at salient points for the benefit of road users.



Source: O&M Manual of CORR

Figure 5.5.4 Emergency Service Procedure

(5) Traffic Control for Work Zone Safety

It is important to limit/minimize the closure of roads and to ensure that traffic is delayed as little as possible by repair operations. A traffic control zone can be defined as an area of the project highway which involves conflict on the right of use between road users and the authority responsible for maintenance/improvement of the project highway. From a traffic safety point of view, a repair work zone comprises four zones as described herein and shown in the left side of Figure 5.5.5. The length of all zones shall be basically governed by the speed of approaching vehicles and shall be referred from the table below, as stipulated in IRC:SP:55-2001 Guidelines on Safety in Road Construction Zones:

a) Advanced Warning Zone

b) Approach Transition Zone

c) Working Zone

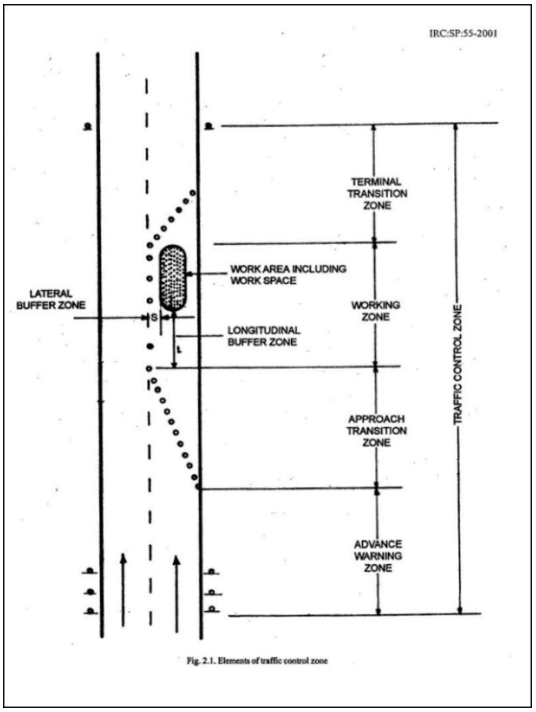
d) Terminal Transition Zone

Table 5.5.1 Recommended Length of Traffic Control Zones

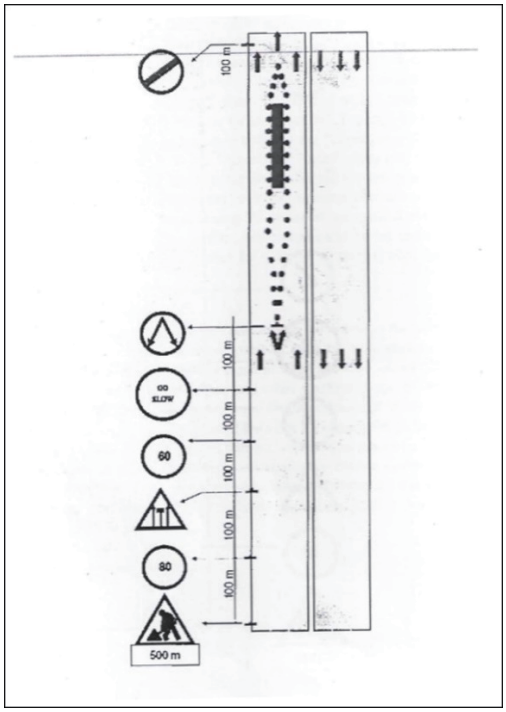
Average Speed (km/h)	Advance Warning Zone (m)	Approach Transition (m)	Working Zone (m)
50	100	50	Varies
51-80	100-300	50-100	
81-100	300-500	100-200	
Over 100	1000	200-300	

Source: IRC:SP55-2001

When the work to be done in the middle of the carriageway is of small magnitude, such as minor repairs of potholes, cracks, and patches, then traffic control measures shall mainly consist of providing cautionary signs of "Men at Work" about 500 m before the work zone for the approaching vehicles, and other cautionary signs of "Road narrows" shall be placed 100 m ahead of the work area. Regulatory signs of "Keep Left/Right" shall be placed at the commencement point of the work zone and next to the barriers for the approaching vehicles. Movable types of barriers shall also be placed on both sides of the work area. Cones or drums shall be placed at a suitable interval to demarcate the work area as indicated in the right side of Figure 5.5.5.



Source: IRC:SP55-2001



Source: O&M Manual of CORR

Figure 5.5.5 Traffic Control for Work Zone Safety

(6) Traffic Control for Work Zone Safety

The objectives of the rescue and medical aid services are to save the lives of road users from accidental death by attending to the victim within the "Golden Hour". For that purpose, the medical aid post with round-the-clock ambulance services shall be established. The function of the rescue and medical aid services are as follows:

a) to rush to the accident spot after receiving emergency messages from the control room operator,

b) to provide first aid service to accident victims, then transfer the victims to the nearest hospital for further treatment,

c) to rescue road users from any kind of accident/incident/breakdown on the project highway,

d) to coordinate with emergency and rescue services like police, hospital, fire, crane, etc., and

e) to provide actual information of the incident/accident to the police/authorities.

5.5.4 Highway Maintenance

(1) Types of Maintenance

Road maintenance can be divided into four basic types:

a) Routine Maintenance: a group of recurrent activities, which relates to the repair of faults and to the attention to road structure and facilities within the entire right of way (ROW) in the required condition, to ensure the preservation of the asset and the convenience and safety of traffic

b) Preventive Maintenance: an organized, systematic process for applying a series of preventive treatments over the life of the pavement to minimize life cycle costs

c) Periodic Maintenance: a group of activities which can normally be predicted and planned for by nature, location, and extent, and can be carried out periodically with a view to safeguard the pavement crust and improve riding quality

d) Special Repairs: a group of activities performed to restore the roadway following damage due to natural calamities such as heavy floods, sand storms, hurricanes, cyclones, earthquakes, or landslides

which are unpredictable

(2) Plant, Machinery, and Laboratory Equipment

The concessionaire will provide the following equipment for routine maintenance as and when required:

a) Patrolling vehicle

b) Maintenance vehicle

c) Water tankers

d) Debris trucks

e) Sweeping machine

f) Tractor with trolley

g) Hydra crane (as and when required on call basis)

For periodic maintenance activities, the plant, machinery, and equipment will either be outsourced or established by the concessionaire. For emergency activities, the patrolling vehicles as described are available. Other services of rescue activities will be outsourced.

Road Cleaner

Mobile Crane

Source: JICA Study Team

Figure 5.5.6 Examples of Maintenance Equipment

(3) Highway Inspection

Highway inspection is conducted to ensure the safety of the road and to identify any necessary actions to keep the soundness of the road.

a) Daily Inspection: Checking is conducted visually from the patrol vehicle travelling at a slow speed (<30 kph) with stops and foot inspections if necessary. Patrols are to be timed to ensure that all parts of the road are visited at peak and off-peak periods and both in daylight and in the dark.

b) Close Inspection: Monthly/bi-monthly inspection of all junctions, urban lengths, road crossing, toll plaza, amenity areas, barriers, fences, structures, bridges, and other significant roadside features and installations.

c) Through Inspection: Done before the preparation of maintenance programs and at least annually on lightly trafficked lengths, or six-monthly on heavily trafficked lengths, detailed inspections, if necessary, complete relevant checks and assessment including checking of drains, culverts, access covers, road marking, signs, lighting, and all other roads.

d) Additional Inspection: Done during, for instance, heavy rain, flooding risk, and exceptional congestion (festivals), and if necessary at other occasions, in addition to the management of accidents, other incidents, and routine maintenance activities.

Table 5.5.2 Frequency of Inspection

Object	Item	Daily	Monthly	Quarterly	Before/After Rains
Riding Surface	Pavement	V	C		T
	Expansion Joints	V	C		T
Median	Kerb	V	C		T
Side Slopes	Shape	V		C	T
	Turfing		V		T
	Pitching and Masonry		V		T
	Retaining Wall		C		T
Drainage	Side/Toe Drain	R	C		
	Gullies and Catch Pits	R	C		
Bridges	Superstructure			C	T
	Substructure			C	T
	Head Wing Walls and Aprons			C	T
	Painting				T
	Hand Rail		C	T	
Culverts/Underpass					T
Safety Barrier		R		C	T
Traffic Operation Facilities	Signs		T*		T
	Marking	R	C*	C	T
	Delineator	R	C*	C	T
	Lighting	R	C*	C	T
Other Facilities	Vegetation/Landscaping	R	C	T	
	Toll Plaza	R	C	T	
	Truck Lay Bay/Wayside Amenities	R	C	T	
Traffic Conditions		R	T	C	
Encroachments		R	T		

Legend
V: Visual Inspection C: Close Inspection T: Thorough Inspection R: Visual Inspection (during rainy season only) *: at night also

Source: O&M Manual of CORR

(4) Performance Criteria/Standards

Operational performance criteria/standards and acceptable limits shall be maintained throughout the concession period as per Table 5.5.3. Time limits for repair/rectification of defects and deficiencies are set forth in Table 5.4.2. The performance criteria/standards of the O&M Manual of CORR are slightly higher than those stipulated in IRC: SP:95-2011 “Model Contract Document for Maintenance of Highways”.

Table 5.5.3 Maintenance Standards of O&M Manual for CORR

No.	Service Factor	Level 1 (Acceptable)
1	Roughness by bump integrator (maximum permissibility)	2,200 mm/km for main carriageway and 2,500 mm/km for service road
2	Potholes per km (max) i) less than 75 mm deep ii) more than 75 mm deep	 2 sizes of <5 sqm nil
3	Percent cracking	<5% of pavements in any 1 km section
4	Rutting	Not exceeding 10 mm in more than 2% of road surface in a stretch of 1 km
5	Raveling/stripping of bitumen	Not exceeding 10 sqm
6	Earthen shoulder, side slope, drains, and culverts	Earthen shoulder variation not exceeding 2% of camber, edge drop at shoulders not exceeding 40 mm, embankment slope variation not more than 15%
7	Sign boards and pavement marking	Good reflectivity

Source: O&M Manual of CORR

(5) Horticultural Maintenance

Visual inspections regarding horticulture shall be performed bi-annually. During routine and periodic maintenance operations, the concessionaire shall carry out visual inspections. Any noticeable problems or any item which represents immediate or imminent hazard will be treated with the same priority as immediate defects. The schedule of operations including watering is given in the table below.

Table 5.5.4 Frequency of Operations for Horticultural Maintenance

No.	Operations	Frequency
1	Making of plant basin for holding water	3 months
2	Cleaning of plant basin for holding water	1 month
3	Hoeing and weeding	1 month
4	Training, trimming, and pruning of plants	3 months
5	Watering of plants	2 days
6	Cutting of grass	As required
7	Cleaning of medians	1 month
8	Removal of weeds	1 month
9	Control of monsoon growth	After monsoon
10	Dressing and levelling median ground	After monsoon
11	Sprinkling of water in median	1 month

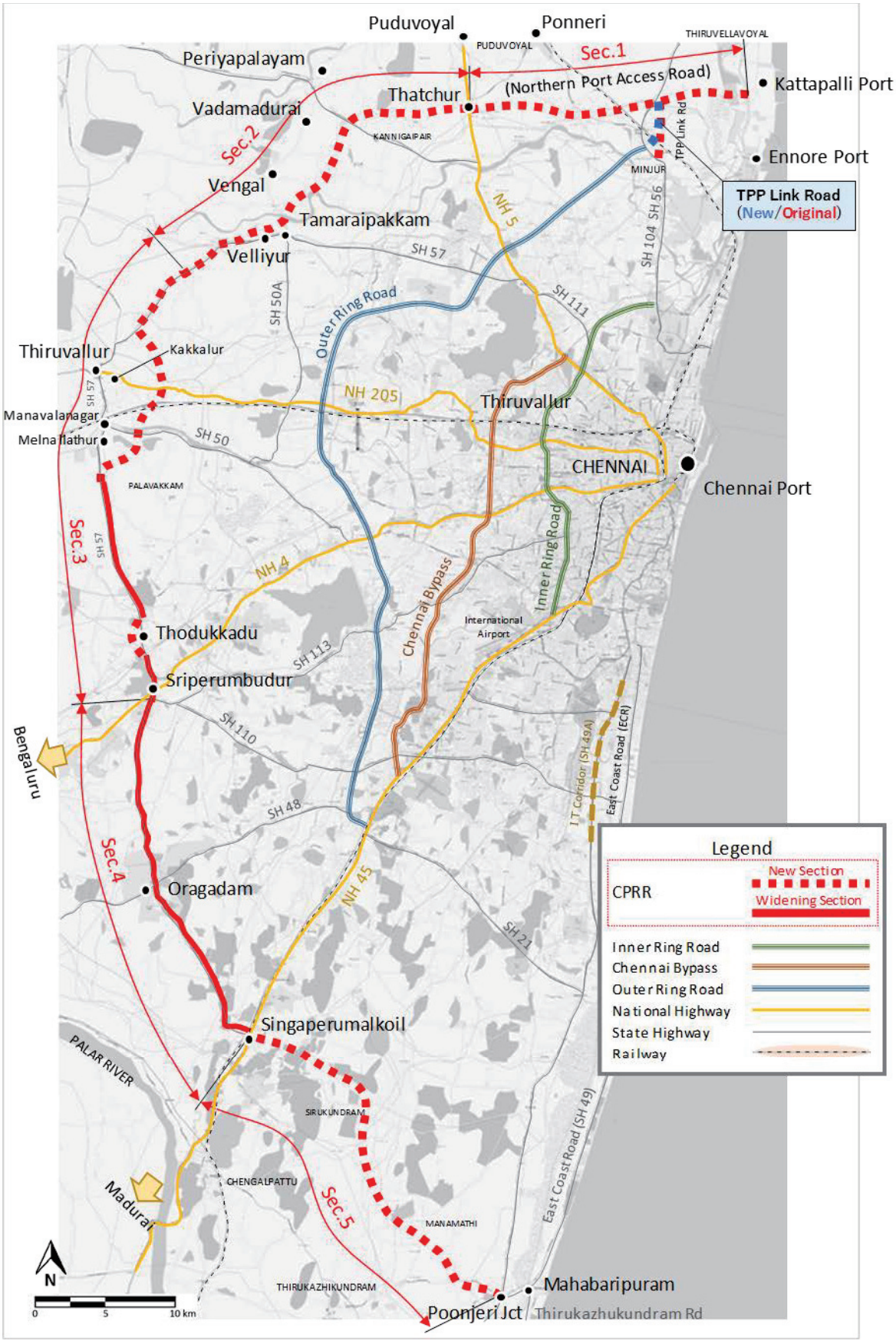
Source: O&M Manual of CORR

5.6 Recommendations on the O&M Plan

5.6.1 Basic Data of CPRR for O&M

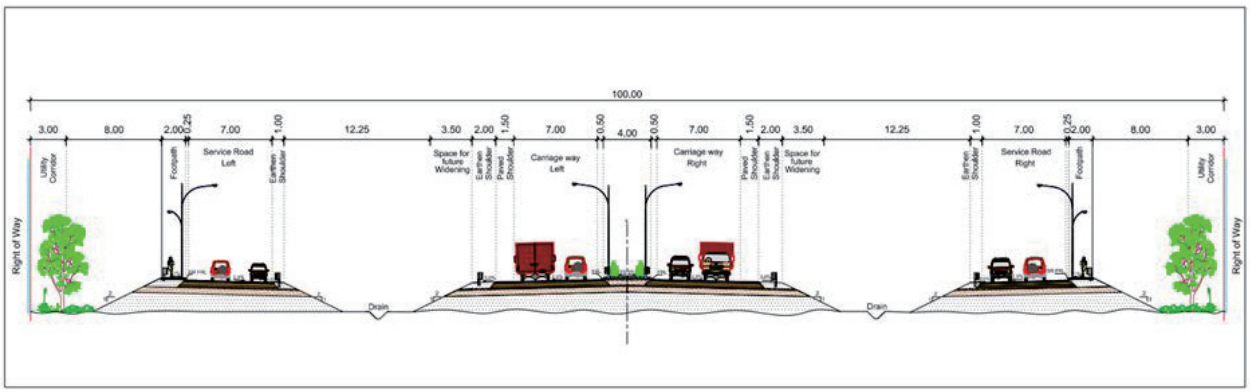
(1) Locations of Roads and Typical Cross Sections required for O&M

It is indispensable for the O&M to prepare figures and tables that carry basic data of the project road. A description of the CPRR is stated as, “starts at Ennore Port and ends at Poonjeri Junction (East Coast Road) in Mamallapuram. CPRR connects four National Highways, namely NH5, NH205, NH4 and, NH45, and eight State Highways, namely SH51, SH50A, SH50, SH48, SH57, SH49B, SH49A (OMR), and SH49 (ECR). The total length of CPRR is 133 km, which is split into five road sections.” The locations of each section and crossing roads are indicated in Figure 5.6.1. The typical cross sections of each road section are shown in Figure 5.6.2.

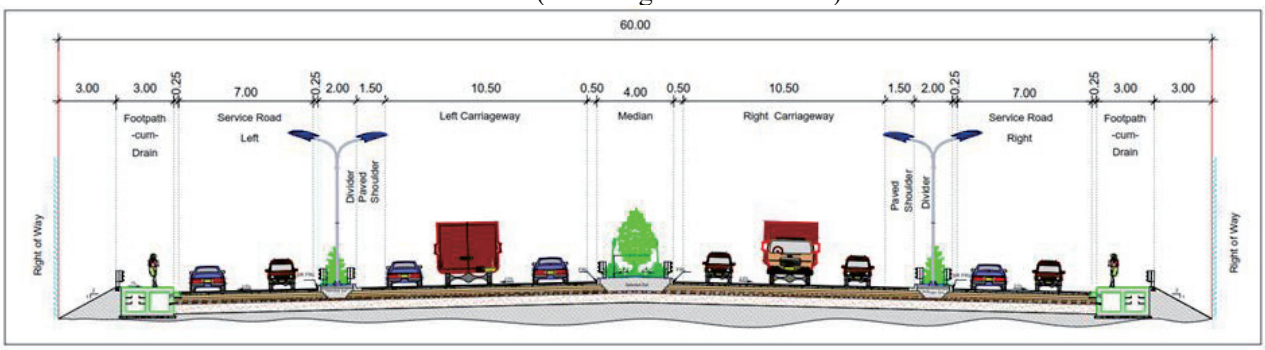


Source: JICA Study Team

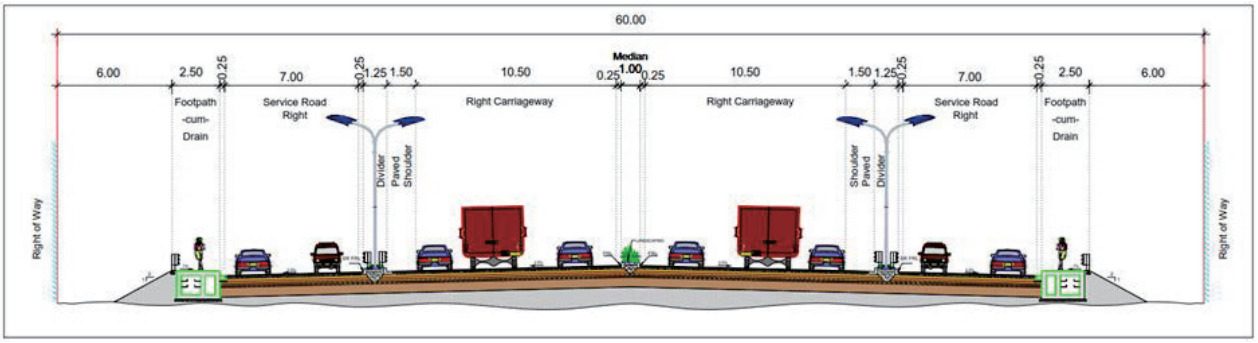
Figure 5.6.1 Location of Project Road and Crossing Roads



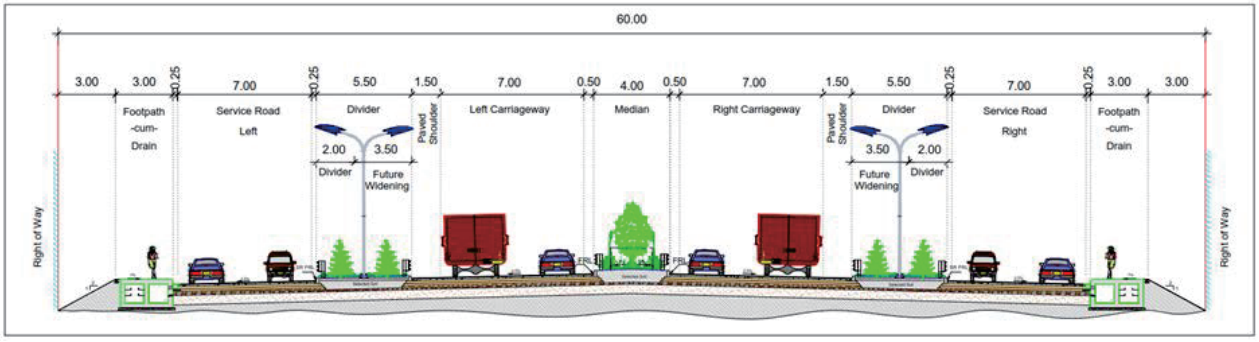
Section 1 (Including TPP Link Road)



Section 2 and Section 3



Section 4



Section 5

Source: JICA Study Team based on DPR

Figure 5.6.2 Typical Cross Sections of Each Road Section

(2) Road Details Required for O&M

The details of each section are shown in Table 5.6.1.

Table 5.6.1 Details of Each Road Section (New Construction Portion Only)

		Total	Section 1		Section 2	Section 3	Section 4	Section 5
Road Name		Chennai Peripheral Ring Road (CPRR)						
Features of Road Structure		The scope of the project consists of the main road and the service road, with footpaths cum drain on both sides. The main road is access-controlled and connects national highways with interchanges. The service roads connect all crossing roads with at-level intersections. There are dividers between the main road and the service roads with several entry/exit ramps.						
Start/End Points		Ennore Port/ Mamallapura	Ennore Port/ Thatchur	TPP Link (Original Alignment)	Thatchur/ Thiruvallur Bypass	Thiruvallur Bypass/ Sriperumbudur	Sriperumbudur/ Singaperumalkoil	Singaperumalkoil/ Mamallapuram
Length (km)		133.23	21.51	4.21	25.61	29.55	24.85	27.50
Construction Type		-	New alignment	New alignment	New/widening	New/widening	Widening	New/widening
No. of Lanes		Main Road	Road 4, Bridge 6	Road 4, Bridge 6	Road 6, Bridge 6	Road 6, Bridge 6	Road 6, Bridge 6	Road 4, Bridge 6
		Service Road	2 x 2	2 x 2	2 x 2	2 x 2	2 x 2	2 x 2
Width of ROW (m)		-	100	100	60	60	60, 40 (Main Road)	60
Thickness of Pavement (Bituminous)		Main Road	615 mm	615 mm	615 mm	615 mm	635 mm	610 mm
		Service Road	590 mm	590 mm	590 mm	590 mm	590 mm	590 mm
Design Speed (km/h)		Main Road	100, 65 (Start)	100, 80 (End)	100	100, 80 (Partial)	100/80 (Mainly)	100
		Service Road	40	40	40	40	40	40
Interchange		4	0	0	1	2	0	1
At-level Intersection		5	2	2	0	2	0	1
No. of Bridges	IC	4	1	0	0	2	0	1
	Railway	3	1	1	0	1	0	0
	River	5	1	0	2	1	0	1
	Road	19	1	1	5	1	0	11
No. of Cross Structures	L Vehicle	31	5	0	5	6	9	6
	S Vehicle	17	1	2	3	1	3	7
No. of Cross Culverts	Box	113	47	6	13	20	0	27
	Pipe	216	11	2	84	61	0	58
No. of Truck Parking		10	2	1	2	2	0	3
No. of Bus Bay		17	2	1	1	4	0	9
ITS	Toll Plaza	3	2	1	0	0	0	0
	Weigh-in-Motion	3	2	1	0	0	0	0
	VMS*	15	2	0	3	3	5	2
	CCTV*	20	3	1	4	4	6	2
	VIDS*	3	2	1	0	0	0	0
	ATCC*	134	21	5	26	30	25	27
	MET*	6	2	0	0	1	1	2

Note*: Variable Message Sign (VMS), Video Incident Detection System (VIDS), Automatic Traffic Counter cum Classifier (ATCC), Meteorological Monitoring System (MET)
Source: JICA Study Team

5.6.2 Proposal on O&M Plan

(1) Proposal on O&M Contracting

The Highways and Minor Ports Department (HMPD) of the Government of Tamil Nadu will oversee the construction and O&M of the CPRR. Most probably, the Project Wing of the Highways Department will take charge of the construction of CPRR, and the Construction and Maintenance Wing will take charge of the O&M.

During the meeting held in February 2018 between HMPD and JICA, HMPD agreed in principle to apply the Standard Bidding Documents (SBD) issued by JICA for the contract for Section 1, although HMPD and JICA are discussing which particular SBD is to be applied in the project. The JICA mission stated that the SBD for "Procurement of Works" is generally mandatory in similar types of Japanese ODA Loan Projects.

When the construction of CPRR is completed, the supervision of O&M will be shifted from the Project Wing to the Construction and Maintenance Wing.

After the completion of construction, most probably a PBMC will be used for the O&M works. Currently, the Highways Department has been switching one-by-one to PBMC from the conventional single-year maintenance contract. It is being introduced successively to one of the highway divisions in eight circles in the state, and up to date, four highway divisions are using PBMC, namely Pollachi, Krishnagiri, Ramanathapuram, and Thiruvallur. Now the PBMC scheme will be extended to the Virudhunagar Highways Division in the current financial year.

Section 1, Section 2, and a part of Section 3 of CPRR fall under the jurisdiction of the Thiruvallur Highways Division, where PBMC was introduced on 24 February 2016. The O&M of SHs and MDRs with a total length of 498 km is being carried out with the contract worth INR 630.38 crore.

The remaining Section 3, Section 4, and Section 5 of CPRR fall under the jurisdiction of the neighboring Chengalpattu Highway Division. This division has not yet introduced PBMC. It is assumed, however, that it will be introduced by the time the CPRR is completed.

PBMC includes ordinary maintenance, initial rectification works, minor improvement works, periodic maintenance works, and emergency works. The amount as stated in a contract is a provisional estimate excluding emergency works. Ordinary maintenance will be payable as a proportionate monthly lumpsum over the 60-month period of the contract. Other works will be measured and paid based on the actual work output. The project scope and the duration of the PBMC for Pollachi[3] is described below:

Project Scope and Duration of Performance Based Maintenance Contracts (PBMC) for Pollachi

To undertake Ordinary Maintenance, Initial Rectification Works, Periodic Maintenance Work, Minor Improvement Works and Emergency Works on select roads totaling approximately 377.388 Kilometers. The maintenance work will also include cross drainage works, minor work on bridges, and roadside maintenance within the select road limits. Ordinary Maintenance will be payable as a proportionate monthly Lump Sum over the 5-year period of the Contract on issuance of certificate by the Engineer in the reach where the black top by the contractor under this contract for the items listed in the specification and it will be item wise for the actual output in the reaches where the block top was not renewed under this contract. Initial Rectification, Minor Improvements and Periodic Maintenance will be paid on measured quantity to the quoted rate. Emergency work has to be carried out as identified by the Contractor and with the approval of the Engineer for the provisional rate quoted. There is a requirement for specialized maintenance equipment and the contract obligation is for continuous input over a period of five years.

(2) Proposal on O&M Structure and Cost Estimate

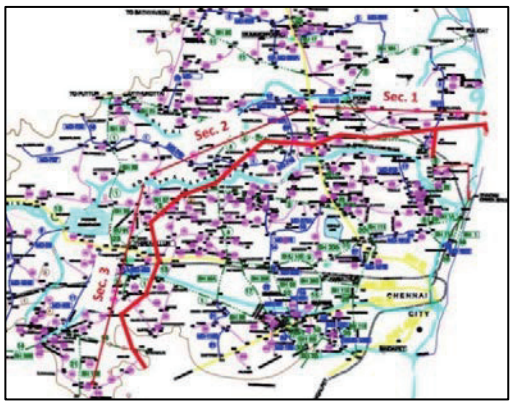
1) O&M Structure

Regarding the O&M for Section 1 of CPRR, it is assumed that the execution entity TNRDC will be in

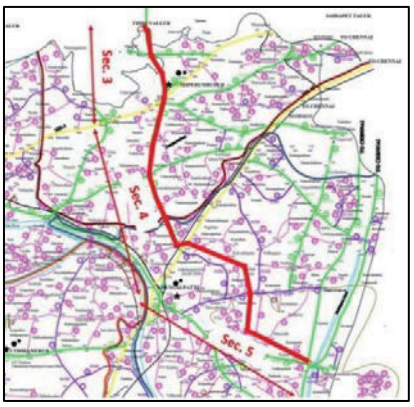
[3] Government of Tamil Nadu Highways Department. 2013. *Performance Based Maintenance Contract (PBMC) Volume - 1 Pre-Qualification Document. Performance Based Maintenance contract for 5 years for State Highways and Major District roads in Pollachi (H) C&M, Division*

charge. The maintenance work will be contracted out to private companies.

Section 2 and a part of Section 3 of the CPRR will fall under the jurisdiction of the Thiruvallur Highways Division. Regarding the remaining sections, Section 3, Section 4, and Section 5 will fall under the jurisdiction of the neighboring Chengalpattu Highways Division. The Thiruvallur Highways Division has been contracting out to private O&M contractors with PBMC and will incorporate newly completed sections into the contract. It is assumed that the PBMC will be introduced to the Chengalpattu Highways Division by the time the CPRR is completed. If the introduction is delayed, a single-year maintenance contract will be used.



Thiruvallur Highways Division

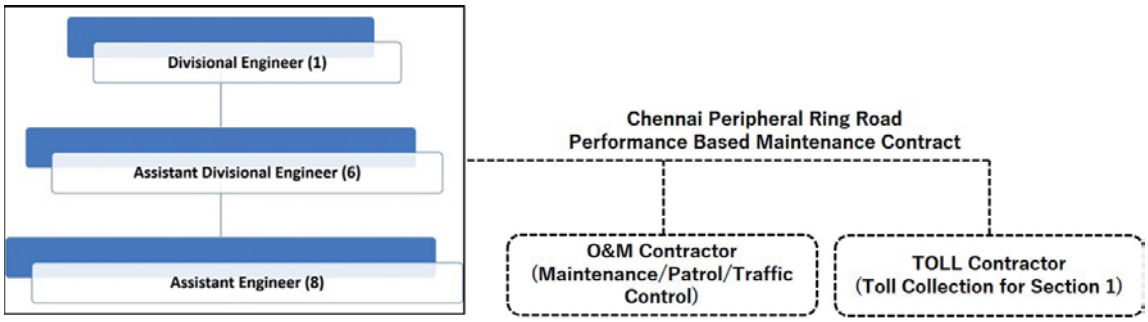


Chengalpattu Highways Division

Source: JICA Study Team

Figure 5.6.3 Highways Divisions Responsible for O&M of CPRR

The structure of the Thiruvallur Highways Division consists of one divisional engineer, six assistant divisional engineers, and eight assistant engineers. The Thiruvallur Highways Division will outsource the work of maintenance/patrol/traffic control with PBMC to an O&M contractor. There is a plan to collect toll for Section 1. When this is carried out, toll collection work will also be outsourced to a toll contractor (Figure 5.6.4). There is one field office for the divisional engineer and six field offices for the assistant divisional engineers (left side of Figure 5.6.5) taking charge of road construction other than large-scale projects and maintenance for SHs and MDRs (right side of Figure 5.6.5).



Source: JICA Study Team

Figure 5.6.4 Structure of Thiruvallur Highways Division

Field Office of Thiruvallur Highways Division

Removal of Sediment from Side Drain

Source: JICA Study Team

Figure 5.6.5 Examples of Field Office and Maintenance Work

2) Cost Estimate of O&M

Table 5.6.2 shows the examples of O&M costs for the four highways divisions that have already introduced the PBMC and the CORR. Although the cost of CORR is about 30% higher than those of other roads, it is assumed that the higher cost comes from the road composition of CORR, which contains service roads on both sides. The road composition of CPRR is like that of CORR and INR 0.223 crore/year/km is adopted for the calculation of the O&M cost.

Table 5.6.2 Examples of O&M Costs (INR in Crore)

No.	Highways Division	Length (km)	5-year Cost	5-year/km	1-year/km
1	Pollachi	377	233.9	0.620	0.124
2	Krishnagiri	581	450.0	0.775	0.155
3	Ramanathapuram	569	460.0	0.808	0.161
4	Thiruvallur	776	630.4	0.812	0.162
5	CORR	30	33.0	1.113	0.223

Source: JICA Study Team

This part is intentionally left blank

(3) Proposal on Improvement in O&M Manual

1) Preparation of O&M Manual

Regarding O&M of CPRR, an O&M manual, which will be a guideline for the work, should be prepared. The IRC: SP: 95-2011[4] will be the basis for the preparation. The road maintenance standards stipulated in this document is also the basis for Schedule-K in the model contract agreement for PPP and Schedule-E in the standard agreement for EPC.

[4] IRC: SP: 95-2011 Model Contract Document for Maintenance of Highways

CORR runs parallel to CPRR and is already carrying out O&M. This road was constructed using a semi-annuity contract in DBFOT and has service roads on both sides as CPRR for its road configurations. The O&M manual for this road is described in detail in "5.5 Operations and Maintenance (O&M) of Chennai Outer Ring Road (CORR)".

Although the O&M manual for CORR covers all aspects of O&M activities, there are some points that need to be improved. Especially for the methodology in preventive maintenance, the description is no more than a concept. As for preventive maintenance standards, the Guidelines for Expressways[5] compiled by MORTH stipulates a detailed methodology. The O&M manual can be improved by incorporating this part. The JICA Study Team proposes that the detailed methodology in preventive maintenance should be incorporated to improve the O&M manual.

2) Merits of Preventive Maintenance

Preventative maintenance takes a proactive approach in the maintenance of roads by properly addressing defects and faults in the early stages of deteriorations to improve the effectiveness, and by grouping repairs to enhance the efficiency and to reduce hindrances to traffic, thereby minimizing the life-cycle cost of roads. It is widely known that repairs at an early stage of deterioration can be smaller in size and can be simpler, leading to a smaller total life-cycle cost including the maintenance cost.

Inspection is the key element in preventive maintenance which triggers all the necessary activities. By detecting an early symptom of deterioration and by checking the development pattern of deterioration, it is possible to find an optimal intervention level to arrest the deterioration. It lengthens the life span of road structures and reduces the life-cycle cost. This also helps to equalize the maintenance workforce and the cost over the maintenance period, consequently leading to pre-scheduled and efficient maintenance implementations.

Table 5.6.4 Merits and Contents of Preventive Maintenance

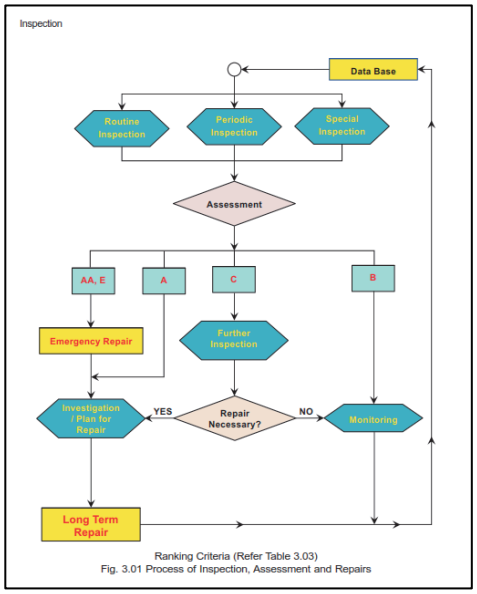
Benefit	Outcome
Pre-planned Maintenance	Maintenance intervention items and timing are known.
	Optimal usage of workforce, machine, spare parts, and equipment.
Optimal Maintenance Level (most cost-effective treatment)	Best intervention timing and type to treat the deterioration.
	Planning of grouping interventions, which will minimize disturbance to traffic.

Source: JICA Study Team

3) Inspection Assessment Methodology for Preventive Maintenance

Figure 5.6.6 shows various processes for each inspection works from Chapter 3 - Inspection, Volume IV - Maintenance, Guidelines for Expressways. It is important to establish this process to ensure that each inspection is followed up with appropriate action systematically. Any damage or defects detected during these inspections will be recorded and assessed according to the specified ranking criteria. Based on the results of the assessment, the maintenance plan over the year will be formulated and implemented.

[5] MORTH. 2010. Guidelines for Expressways. New Delhi. IRC



Ranking Criteria

Table 3.03 Typical Ranking of Inspection

Ranking			Typical Condition
Functional deterioration (including visual structural distresses)	AA		Has severe damage/deformation. **Requires immediate repair to recover its functionality**
	A		Has damage/deformation and functional deterioration. **Requires repair but not immediately**
		A1*	Does not require immediate repair, but has functional deterioration which is expected to worsen rapidly. **Estimated to require repair within 2 years.**
		A2*	Does not require immediate repair, but has functional deterioration which is expected to worsen gradually. **Estimated to require repair within 5 years.**
		A3*	Has functional deterioration but the speed of deterioration is slow. **Requires monitoring continuously or after 5 years' time, and determining the timing of repair accordingly.**
	B		No sign of functional deterioration albeit damage/deformation. **Requires continuous monitoring of damage/deformation**
	C		**Requires investigation** in order to assess its functionality
	OK		**No or only slight sign of damage/deformation**
Affect Traffic Safety	E		Has risk of affecting the safe traffic condition. **Requires immediate attention.**

Typical Ranking of Inspection

Source: MORTH. 2010. Volume - IV Maintenance: Chapter - 3 Inspection: *Guidelines for Expressways*. New Delhi. IRC

Figure 5.6.6 Inspection Assessment Methodology for Preventive Maintenance

(4) Proposal on O&M of ITS

The total length of CPRR is 133.23 km (including the original alignment of TPP Link Road), and it is divided into five sections. Section 1, or the Northern Port Access Road (NPAR), is connected to the Ennore Port. Although it has not been decided yet, the Government of Tamil Nadu is considering to make Section 1 an access-controlled toll road. Therefore, it is recommended that a toll management system (for Section 1) and a highway traffic management system (for all sections) be introduced as ITS components for the CPRR.

1) Toll Management System, TMS (Section 1)

The completion of CPRR will contribute to the drastic improvement of connectivity from suburban areas to the Ennore Port. A great number of large vehicles on CPRR is then accordingly expected. Large vehicles are likely to damage the pavement; therefore, maintenance will be a very important issue. A toll management system collects toll, and the revenue can be utilized for the maintenance of CPRR. Regulating over-loaded vehicles is also crucial to protect the pavement. An access-controlled Section 1 makes it possible to monitor over-loaded vehicles by installing a weight measurement equipment at the entrance to the road.

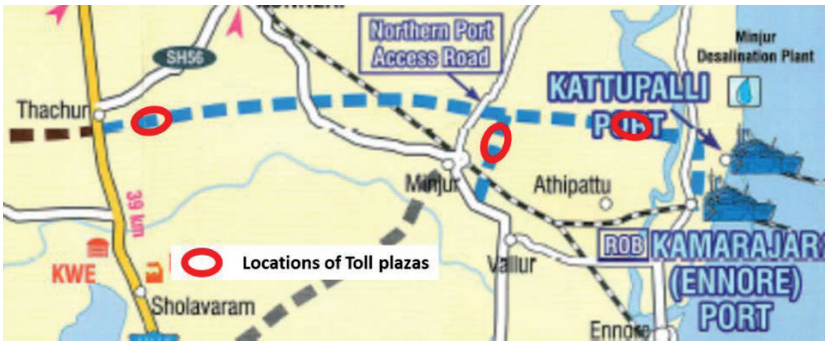
Therefore, a toll management system together with a weigh-in-motion to regulate over-loaded vehicles, is proposed on Section 1 of CPRR for both purposes of collecting toll and controlling over-loaded vehicles.

In Section 1, toll plazas will be required at least in three locations. They are Thatchur, the ending point of Section 1 which connects Section 2 and NH-5, Minjur, which is an ending point of the branch line of Section 1 near the north end of ORR, and the other ending point of Section 1, which is near the gate of the Ennore Port.

Regarding the implementation of a toll system to the CPRR, it has not yet been determined whether a distance-base or a fixed rate system will be used for the toll rates. Considering the configuration of the roads in Section 1, it is better to adopt the distance-based toll, which varies the fee according to the travelled distance in view of the sense of fairness for the users of the CPRR.

In the case of distance-based toll rates, toll plazas will be required at both entry and exit points of the toll road. There are mainly three methods for toll collection, namely manual collection, Touch-and-Go, and ETC. For manual collection, a ticket or transit card carries information such as vehicle class, entered interchange, and date and time of entry. Toll collectors confirm this information at the exit booth, and the toll calculated based on the length traveled is charged to the driver. For Touch-and-Go and ETC, the basic procedure is the same but is processed automatically by the system.

The figure showin in Figure 5.6.7 shows the proposed locations of the toll plazas in Section 1 of CPRR.



Source: JICA Study Team

Figure 5.6.7 Locations of Toll Plazas in Section 1 of CPRR

2) Highway Traffic Management System (HTMS) (All Sections)

The highway traffic management system is to ensure safety and smooth traffic on CPRR. The system consists of the following major parts:

a) Data/information collection

b) Data processing and monitoring

c) Information dissemination

The above information will be exchanged with the Chennai Traffic Information Center (CTIC) and other related agencies as well.

Data on road and traffic conditions is collected by Automatic Traffic Counter cum Classifier (ATCC), video incident detection system (VIDS), meteorological monitoring system (MET), and CCTV camera installed along the CPRR. Data collected by these devices are sent to the Traffic Control Center of CPRR through the digital transmission system.

The operators in the Traffic Control Center monitor the conditions of CPRR through the video displays and workstations. Certain measures, if necessary, are taken in case of incidents such as congestion, accident, road or lane closure, and construction/maintenance work. The information on traffic/road/weather conditions of CPRR will be disseminated to road users through the VMS Boards installed on the CPRR and on the access roads through the internet. An SMS will also be sent to the registered users in case of an incident. The same data and information is also sent to the CTIC, which covers all areas in Chennai City. Cooperation with relevant organizations such as traffic police, ambulance, and wrecker services will be arranged so that coordinated operations can be made for all incidents.

3) Cost Estimate of ITS O&M

This part is intentionally left blank

Item	Location			Objective	Q'ty
Variable Message Sign (VMS)	Main Road	Section 1	200 m upstream of starting point of off-ramp	To provide information of CPRR	1
		Other Sections	200 m upstream of junction		9
	Access Road	Section 1	200 m upstream of on-ramp toward the city	To provide information of CPRR and city roads	1
		Other Sections	200 m upstream of junction of major radial road toward the city		4
CCTV	Main Road	All Sections	200 m upstream of diverting and merging point	To monitor traffic condition at site	20
Video Incident Detection System (VIDS)	Main Road	Section 1	200 m upstream of diverting and merging point	To detect abnormal traffic event	3
Automatic Traffic Counter cum Classifier (ATCC)	Main Road	All Sections	Every 2 km	To measure traffic volume, vehicle speed, and occupancy (for CTIC as well)	134
Meteorological Monitoring System (MET)	Main Road	All Sections	In vicinity of interchange/major junction	To measure weather condition	6

Source: JICA Study Team

Figure 5.6.8 Highway Traffic Management System Equipment Deployment Plan

(5) Proposal on Training in Japan for Technical Enhancement in O&M

CPRR is the third semicircle ring road centering Chennai and running outside the IRR and the ORR. It connects four national highways (NH5, NH205, NH4, and NH45) that radiate from the center of Chennai, extending to the Ennore Port in the north and to the East Coast Road in the south. The radii of the ring road are about 25 km in the north, about 50 km in the south, and about 40 km in the west.

In comparison with the Tokyo Metropolitan area, it resembles the Metropolitan Inter-City Expressway with radii varying between about 40 km and about 60 km from the center of Tokyo. The role of CPRR includes alleviating traffic flow in urban areas, improving environment condicitons, strengthening intercity connections in the corridor, supporting regional development, and offering alternative routes during disasters. The function is widely diversified and very important to keep daily life safe and comfortable in the region.

The Metropolitan Inter-City Expressway has completed 90% of its total length of 300 km and is already carrying out the O&M works. The expressway is not only seeking for efficient O&M works but also enhances wide-ranging functional effects such as logistics management, attracting enterprise, developing tourist resources, preventing the effects of disasters, and protecting environment.

It is very valuable for the staff of the Highways Department of Tamil Nadu State, who are in charge of the CPRR, to learn this example as precedent of the Metropolitan Inter-City Expressway. The JICA Study Team proposes a training in Japan for technical enhancement in O&M, where attendees can acquire wide-ranging practical knowledge including O&M structures, actual examples of O&M manuals, responses to various traffic incidents at site, information dissemination at traffic control centers, structure and management of toll collection, emergency response to disasters/accidents, and ways to enhance road functions among others.