2.3 Conceptual Design for Proposed ITS Components

2.3.1 Bengaluru Traffic Information System

(1) Traffic Data Collection and Traffic Information Provision System

(a) Purpose and Sub-system

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

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

It will comprise the following sub-systems;

- Probe Car System,
- Queue Length Measurement System,
- Automatic Traffic Counter-Cum-Classifier (ATCC) System,
- Variable Message Sign (VMS) System, and
- Centre System (B-TIC System)

The centre system is called 'Bengaluru Traffic Information Centre (B-TIC)' hereinafter.

The following clauses describe these sub-systems.

(b) Probe Car System

1) Purpose

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

It collects vehicle location information dynamically. A probe device installed in vehicle consists of Global Positioning System (GPS) unit, processor unit, communication unit and power supply unit.

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

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

An image of example of congestion on the road network identified by the probe car system is shown in the Figure 2.57.

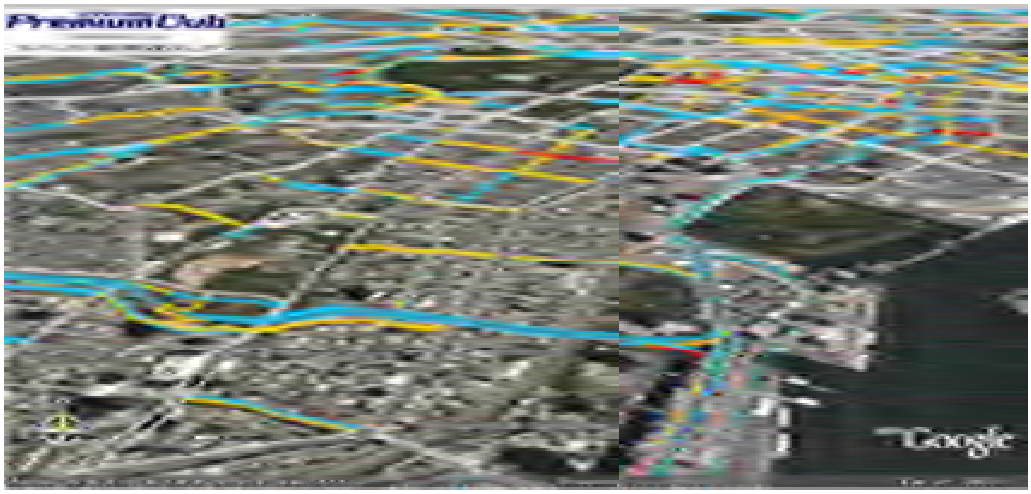


Figure 2.57 Example of Identified Congestion by Probe Car System

(Source: Internavi Premium Club, Honda)

2) Development Plan

Bangalore Metropolitan Transport Corporation (BMTC) plans to install GPS units on 6,700 city buses as part of their project for 'Vehicle Tracking and Passenger Information System'. The project has been started and a trial is now in progress, establishing BMTC command centre for bus monitoring.

Karnataka State Tourism Development Corporation (KSTDC) is using GPS system for taxi operation. The GPS units have been installed on approximately 500 taxis of KSTDC.

It is also expected that the data centres will be increasingly developed by private companies for such purposes as fleet management in Bengaluru in the future.

This indicates that a lot of probe data will be available in Bengaluru and it holds a potential that can be used as a kind of big data.

B-TIC will utilise the probe data transmitted from these data centres. The bus probe data obtained by BMTC command centre will be transmitted to B-TIC and utilised in the initial phase. The probe data from other centres will be used in the later phases.

It is recommended that the Government of Karnataka formulate the policy to mandate that all data centres share the probe data with B-TIC.

The entire image of the probe car system of B-TIC is shown in Figure 2.58.

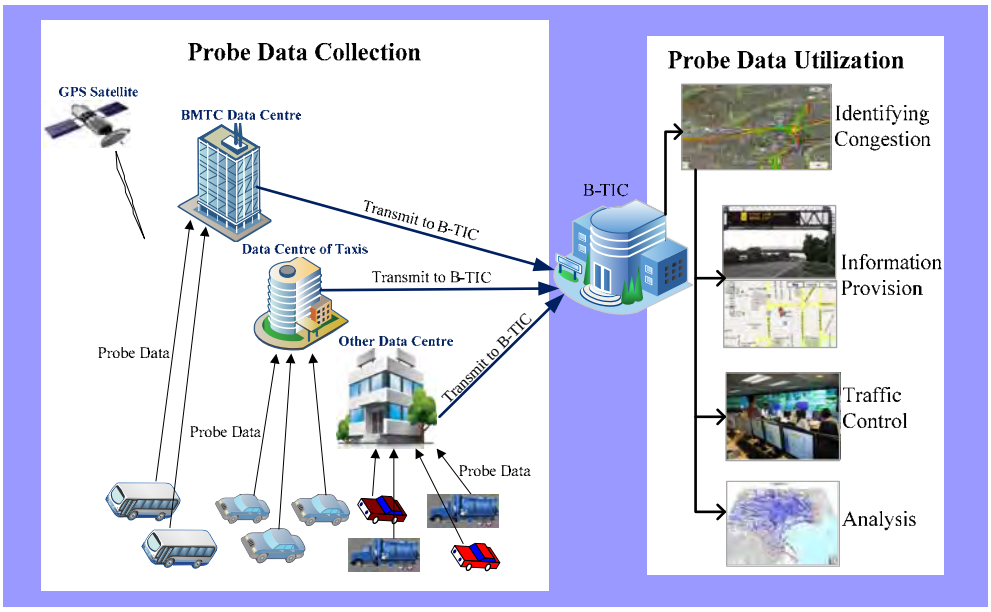


Figure 2.58 Entire Image of Probe Car System

(Source: JICA Study Team)

3) Communication System Diagram

Figure 2.59 shows a communication system diagram of the probe car system whose probe data is transmitted from BMTC command centre to B-TIC. The probe data is sent from bus, called probe car, to BMTC command control centre through mobile network communication. It is then transferred to B-TIC through optical fibre cable network.

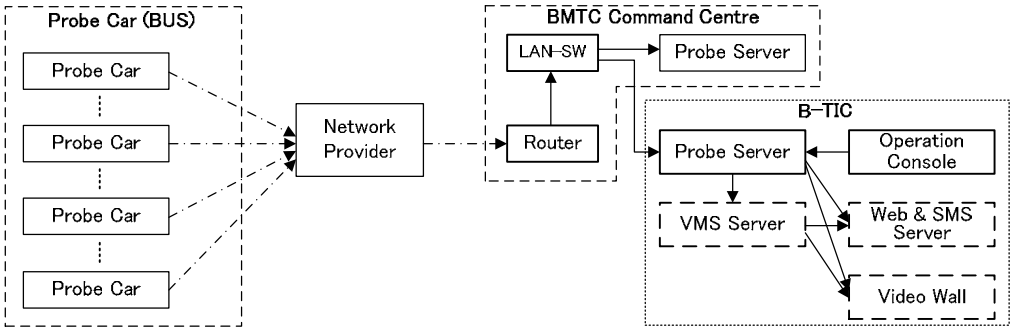


Figure 2.59 System Diagram of Probe Car System Communication

(Source: JICA Study Team)

(c) Queue Length Measurement System

1) Purpose

A queue length measurement system using queue detector will be installed for supplemental purpose for the probe car system.

The traffic condition will be identified by the probe data. However, degree of accuracy depends on availability of the probe data. There may be cases that the probe cars are not present in the section where the congestion frequently occurs. In order to cover the absence of the probe data, the queue detector will be installed at upstream of congestion-prone intersections. It measures occupancy rate, which is a parameter to judge the congestion level, and determine whether a queue has extended to the detector location or not. There are several kinds of vehicle detectors. Amongst them, ultrasonic type is considered most suitable because of reasonable cost and easy maintenance compared to other types.

An example of the ultrasonic queue detector is shown in the Figure 2.60.

Figure 2.60 Example of Ultrasonic Type Queue Detector

(Source: Hiroshima Prefectural Police in Japan)

2) Development Plan

The queue detectors judge queue length by occupancy rate from bottleneck point, which is usually an intersection. They will be installed at upstream of certain distance from the stop line of intersection, which are 300 m, 600 m and 900 m in principle. However considering condition of road infrastructure in Bengaluru, this principle may not be applied to all locations. In such case, adjustment will be made as necessary.

The installation policy of the queue detector is shown in the Figure 2.61.

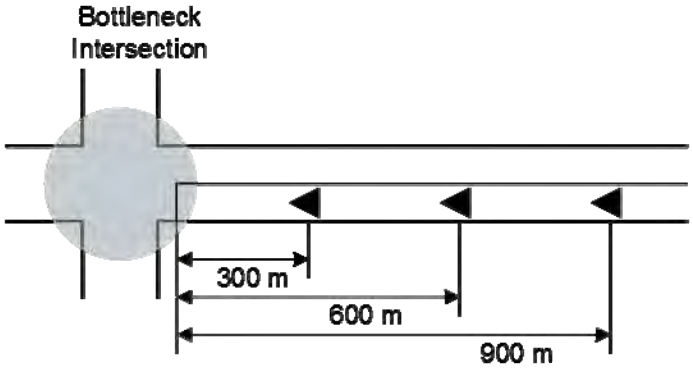


Figure 2.61 Installation Policy of Queue Detector

(Source: JICA Study Team)

The following thirteen (13) locations are identified as major bottleneck points where queue often develops, according to the information provided by the counterpart agency, DULT, and Bangalore Traffic Police.

Table 2.41 Major Bottleneck Points in Bengaluru

	Location
1.	Silk Bvoard Junction (ORR)
2.	Jayadeva Junction (Marenhalli Bridge)
3.	Bashyam Circle (Sadashivanagar)
4.	Central / Rajiv Gandhi Circle (Platform Road)
5.	Krishna Rajenda Circle
6	Jalahali Cross Junction (Tumkur Road)
7	Yeswanthpur Circle (Tumkur Road)
8	Hudson Circle
9	Richmond Circle
10	Siddia Circle
11	Minerva Circle (RV Road)
12	Mekhri Circle (Bellary Road)
13	Tin Factory (KR Puram)

(Source: DULT and Bangalore Traffic Police)

The map in Figure 2.62 shows the locations of bottleneck points and queue detectors to be installed. A total of 81 locations of queue detectors are identified.

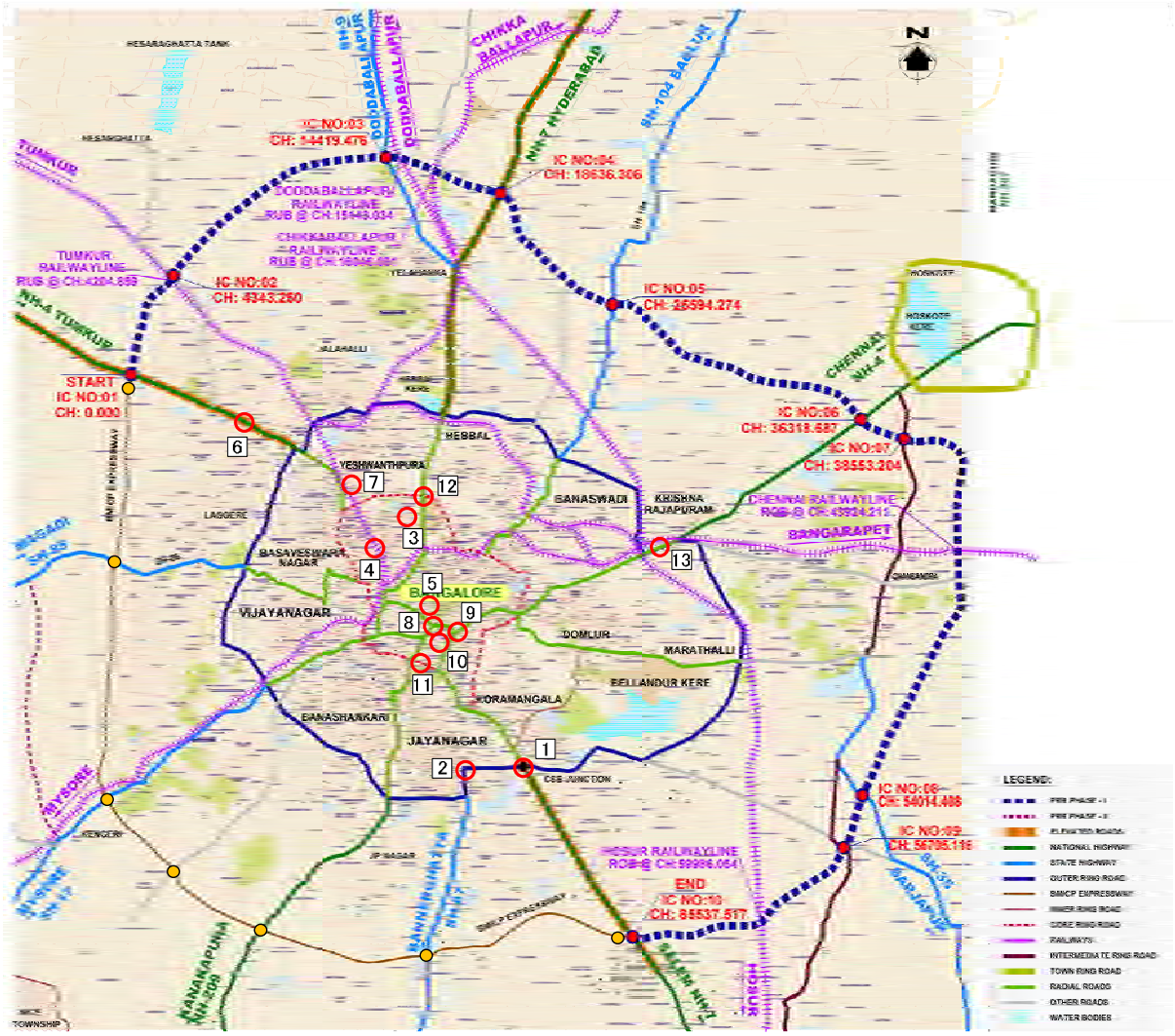


Figure 2.62 Locations of Bottleneck Points and Queue Detectors

(Source: JICA Study team)

3) Communication System Diagram

The measured data by the queue detector will be transmitted to B-TIC through communication network of telecommunication carriers. Optical fibre cable will be used if it is available near roadside terminal equipment. The mobile network will be used if the optical fibre cable is not available nearby. The system diagram is shown in the Figure 2.63.

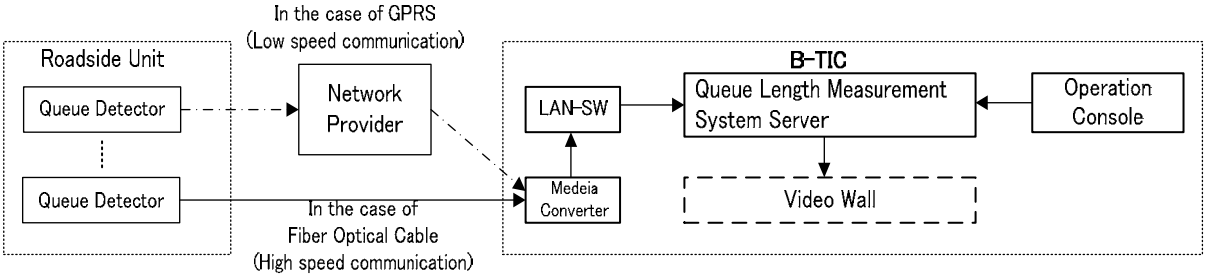


Figure 2.63 System Diagram of Queue Detector Communication

(Source: JICA Study team)

(d) Automatic Traffic Counter-Cum-Classifier (ATCC) System

1) Purpose

ATCC system will be installed to measure the traffic volume by vehicle-size at cross sections. The measured traffic volume will be utilised for proper traffic management and road administration such as planning/evaluation of new road construction, road-widening etc. In addition to the traffic volume, speed and occupancy can also be measured. They will also be stored in the centre.

2) Types of ATCC

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

The Figure 2.64 and Figure 2.65 show images of loop coil type and image processing type ATCC.

Figure 2.64 Loop Coil Type

Figure 2.65 Image Processing Type

(Source: JICA Study Team)

The loop-coil type measures the traffic by lane as shown in the Figure 2.66 of case-1 below. Therefore, absence of lane-keeping discipline results in low accuracy as depicted in the Figure 2.67 of case-2

below. Moreover, the loop-coil is embedded in the surface of the road and road excavation is required for maintenance.

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

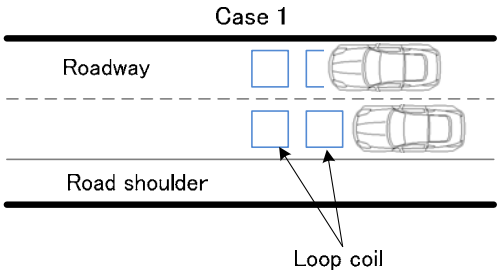


Figure 2.66 Loop Coil Type

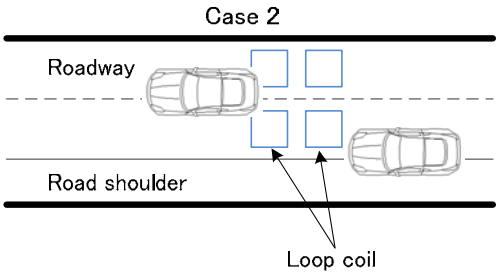


Figure 2.67 Loop Coil Type

(Source: JICA Study Team)

On the other hand, the image processing type can measure the traffic on 3 or 4 lanes by one camera because it captures the movements of vehicles and processes it. Typical standard views of installation are shown in the Figure 2.68 and Figure 2.69.

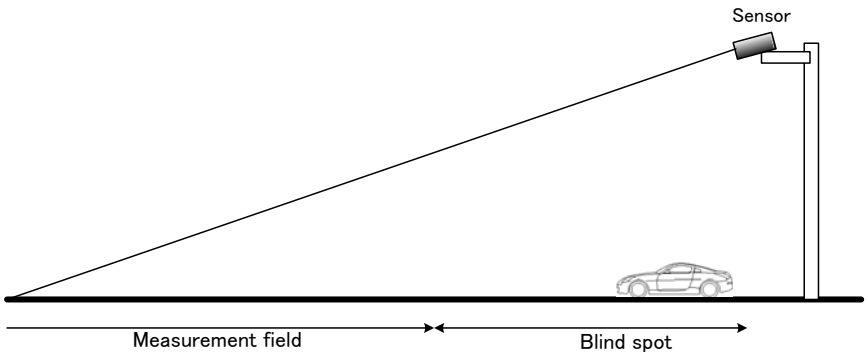


Figure 2.68 Image Processing Type: Standard Longitudinal View

(Source: JICA Study Team)

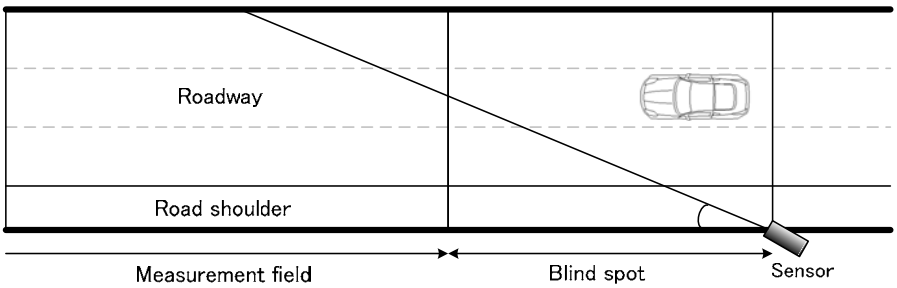


Figure 2.69 Image Processing Type: Standard Plane View

(Source: JICA Study Team)

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

3) Development Plan

Installation location of ATCC will be on the midpoint between major intersections of major roads. The major roads include National Highway, State Highway, Inner Ring Road, Outer Ring Road and radial roads outside Peripheral Ring Road. One ATCC unit measures the traffic in one direction. Thus, two ATCCs will be installed at one location to cover both directions.

The Figure 2.70 shows the steps for identifying the locations of ATCC.

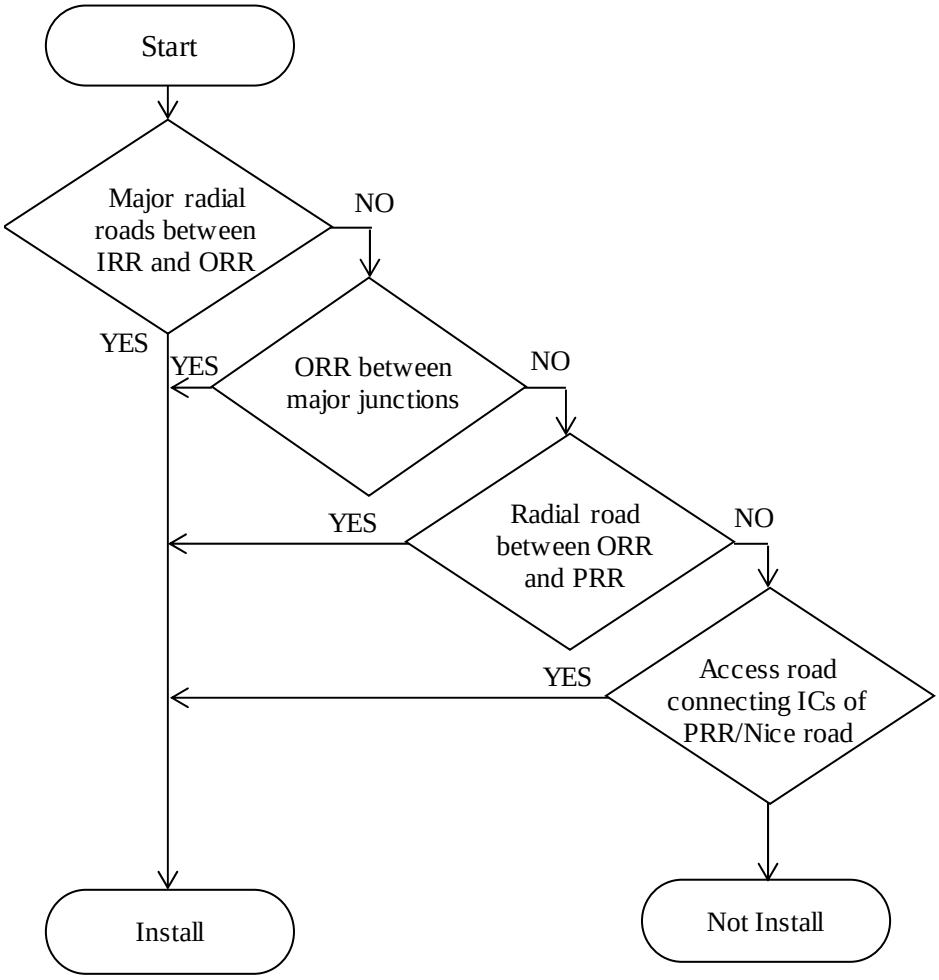


Figure 2.70 Steps for Identifying ATCC Locations

(Source: JICA Study Team)

136 locations of ATCC are identified based on the steps above and shown on the Figure 2.71. The number of ATCC will be increased in accordance with expansion/construction of new road or changing traffic situation in the future.

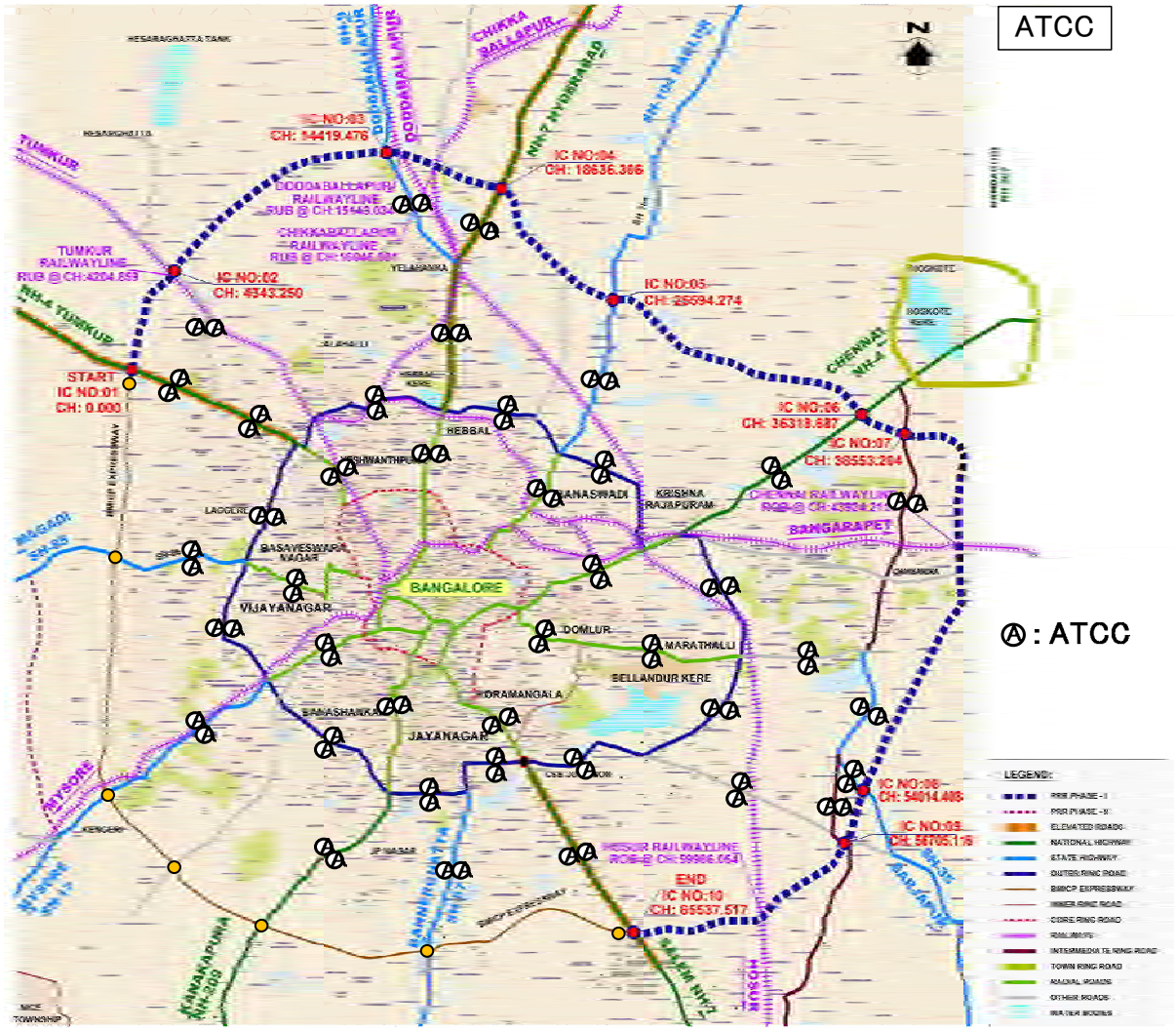


Figure 2.71 Location Map of ATCC

(Source: JICA Study Team)

4) Communication System Diagram

The measured data by ATCC will be transmitted to B-TIC through communication network of telecommunication carriers. Optical fibre cable will be used if it is available near roadside terminal equipment. The mobile network will be used if the optical fibre cable is not available nearby. The system diagram is shown in the Figure 2.72.

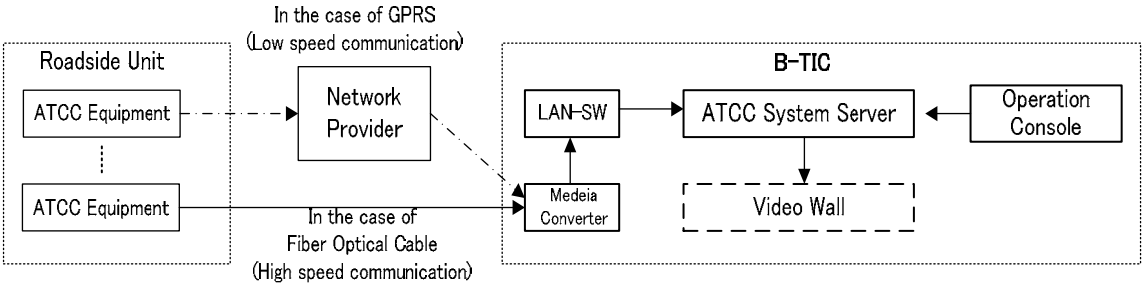


Figure 2.72 System Diagram of ATCC Communication

(Source: JICA Study Team)

(e) Variable Message Signboard (VMS) System

1) Purpose

The purpose of VMS system is to provide information on the road and traffic conditions to road users. VMS is one of the most effective methods of information provision because the information can be provided to all road users on the road even if the vehicle or driver does not have the devices to access information such as navigation unit, smart phone, etc.

2) Types of VMS

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

At least English and Kannada languages shall be as display language. They do not necessarily need to be simultaneously shown. They can be alternately displayed. The letter height needs to be at least 300 mm according to Indian Road Congress Code which is a guideline in India.

Examples of different types of VMS are shown in Table 2.42.

Table 2.42 Examples of VMS

Type	Image	Function
Text and Symbols		To inform the road, traffic and weather conditions by using text information and symbols. (Symbol indicates the congestion caused by road work)
Travel Time Display		To provide travel time information from VMS location to major destinations (Interchanges). (Orange color indicates the congestion and red color indicates the heavier congestion)
Graphic Information Signboard		To inform congested sections to allow drivers to select most suitable travel route by graphic image. Other information such as incidents, time to destination, etc. can also be displayed. (Orange colour indicates congestion and green colour indicates smooth traffic)

(Source: Text and Symbols: JICA Study Team, Travel Time Display: Hanshin Expressway Company Limited, Graphic Information Signboard: JICA Study Team)

3) Development Plan

VMS will be installed at upstream of major junctions with ORR and PRR on major radial roads. This is for the purpose of diverting the traffic to ORR or PRR by providing information to the vehicles incoming to the city. Thereby, the driver will be able to take alternative routes, knowing the traffic situation in advance and avoiding the congestion before entering into the central area of the city.

The Figure 2.73 shows the steps for identifying the locations of VMS.

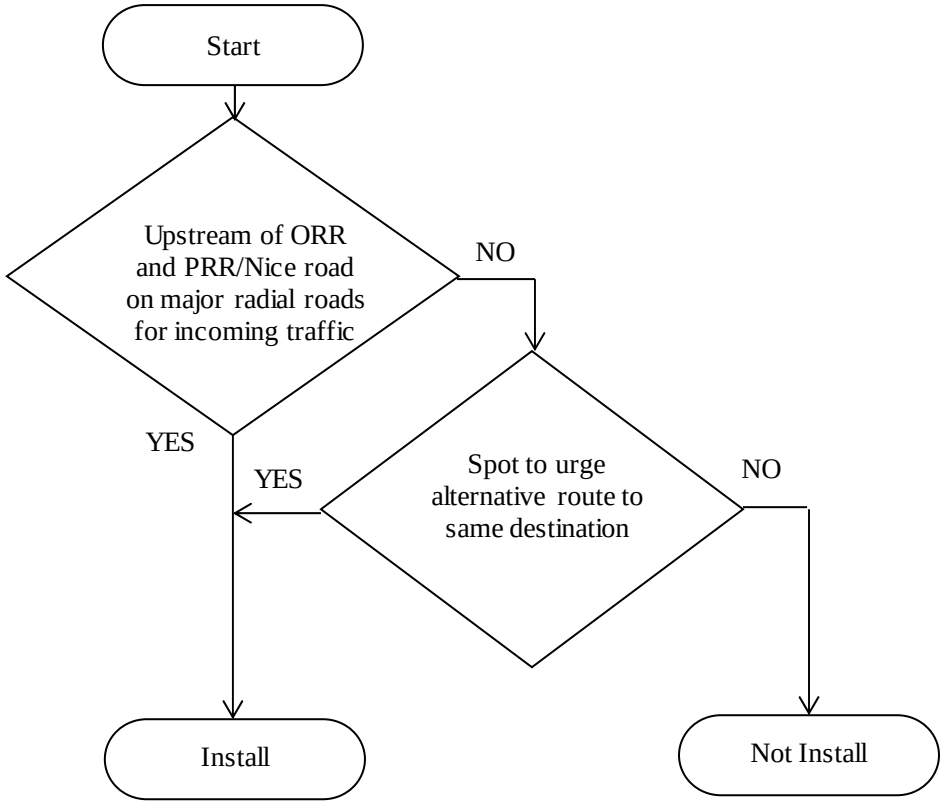


Figure 2.73 Steps for Identifying VMS Locations

(Source: JICA Study Team)

20 locations of VMS are identified based on the steps above and shown in the Figure 2.74. The number of VMS will be increased in accordance with expansion/construction of new road or changing traffic situation in the future.

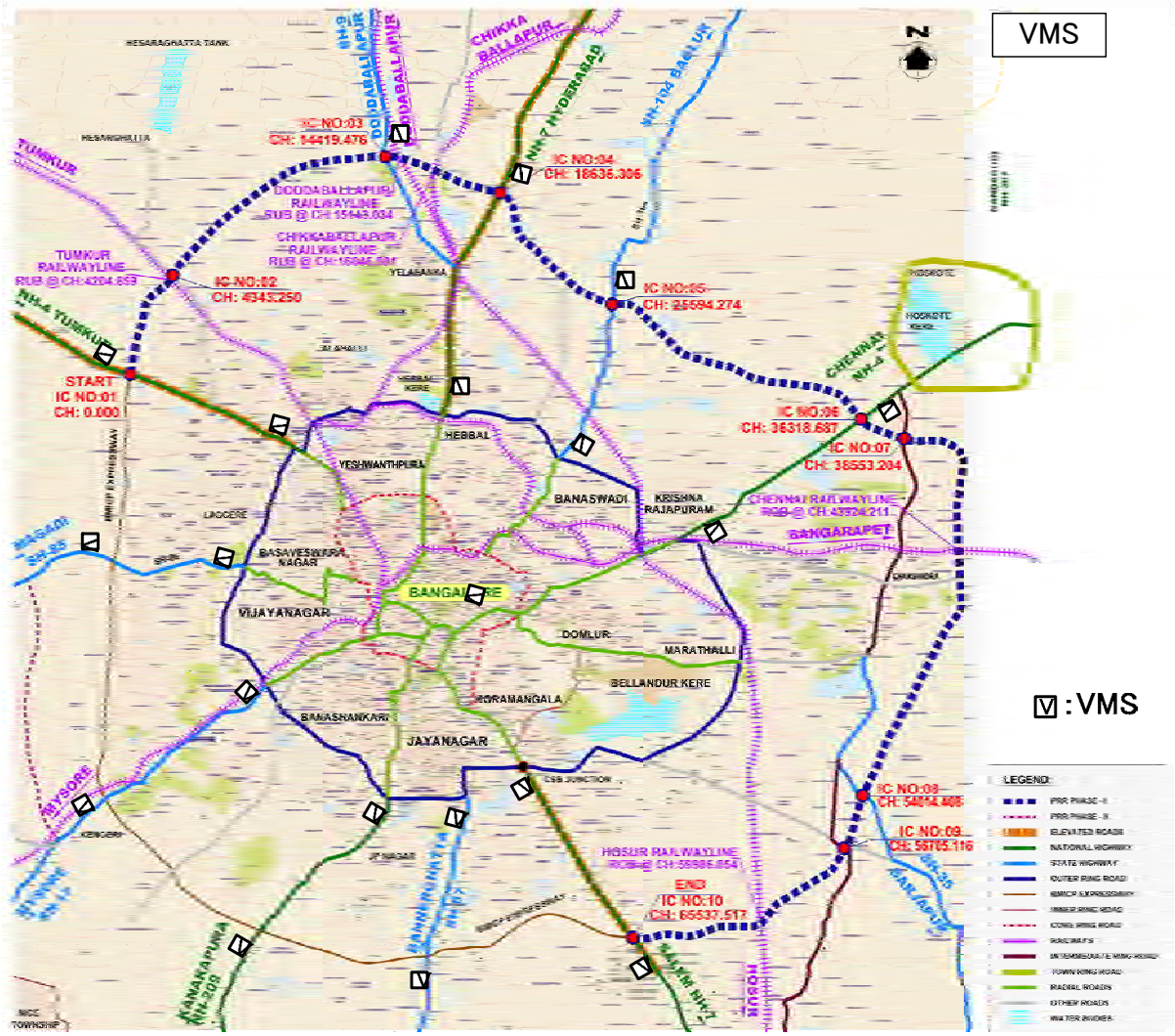


Figure 2.74 Location Map of VMS

(Source: JICA Study Team)

4) Communication System Diagram

The data for VMS will be transmitted between B-TIC and roadside terminal equipment through communication network of telecommunication carriers. Optical fibre cable will be used if it is available near roadside terminal equipment. The mobile network will be used if the optical fibre cable is not available nearby. The system diagram is shown in the Figure 2.75.

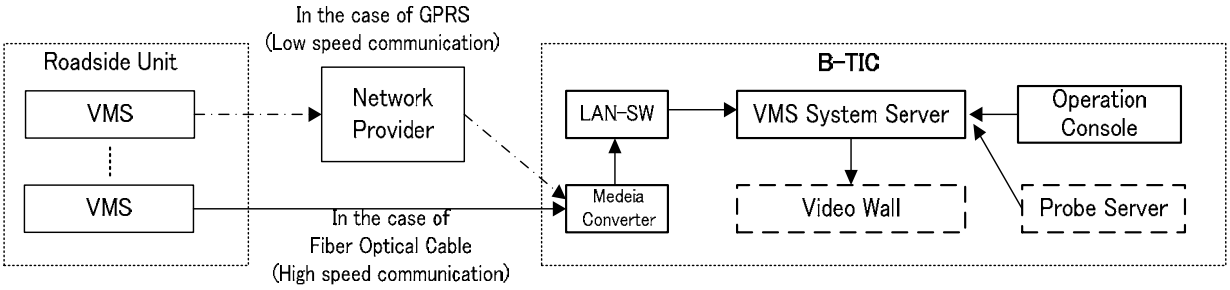


Figure 2.75 System Diagram of VMS Communication

(Source: JICA Study Team)

(f) Centre System (B-TIC)

1) Purpose

B-TIC is intended to achieve the following objectives:

- To collect real time data related to road and traffic condition information such as congestion, incident, event, and any other information that affects the operation of road traffic,
- To process the collected data into the information useful for road users as well as road administrators,
- To monitor the collected and processed information on a real-time basis,
- To disseminate the processed information to road users so that they can take note of road and traffic conditions such as congested area, event location, incident or hazardous area and take necessary actions,
- To compile and store processed data for effective planning, operation/maintenance and evaluation of the measures on urban transport,
- To initiate countermeasures in cooperation with the concerned agencies in the event of incident, and
- To manage the City ITS operation in the B-TIC, and
- To maintain ITS facilities of B-TIC

2) Function of B-TIC

B-TIC will collect the measured data such as traffic flow data, queue length data, etc from the following sub-systems and automatically process the collected data into usable road traffic information.

- Probe Car System,
- Queue Length Measurement System, and
- Automatic Traffic Counter-cum-Classifier (ATCC) System.

The usable road traffic information will be provided to the road users through VMS, Internet, e-mail and SMS. The e-mail and SMS will be sent to the registered subscribers. The processed data will be stored in the database and utilised for statistical analysis, and shared to the relevant stakeholders such as road/traffic administrators, etc. as necessary.

A video wall will be prepared in B-TIC. The collected and processed data will be monitored by operators in B-TIC. The road and traffic conditions will be displayed on the schematised road network on the video wall in B-TIC.

A call centre will be set up in B-TIC. It will handle enquiries from public and other agencies and share necessary information/data to the concerned agencies as required.

CCTV video images which are captured by B-TRAC centre will be shared by Bangalore Traffic Police and displayed on the video wall in B-TIC for the purpose of confirmation of condition at site as necessary.

The traffic data measured by ITS equipment of PRR and VMS message being displayed on PRR will be shared to B-TIC for the purpose of utilising them to guide the traffic to PRR as necessary.

The connection with the centres of the external agencies are summarised in Table 2.43.

Table 2.43 Connection with Centres of External Agency

Centre	Data to Be Collected	Purpose of Collecting Data
Traffic Control Centre (PRR)	• Traffic volume and average speed • Message being displayed on VMS on PRR	• To promote the traffic to shift from city centre to PRR • To divert the traffic which is not destined to Bengaluru
Traffic Management Centre of B-TRAC (Bangalore Traffic Police)	• CCTV image	• To confirm the traffic condition at site as necessary
Command Centre of City Bus (BMTC)	• Probe car data	• To generate congestion information

(Source: JICA Study Team)

The conceptual configuration of B-TIC is shown in Figure 2.76

.

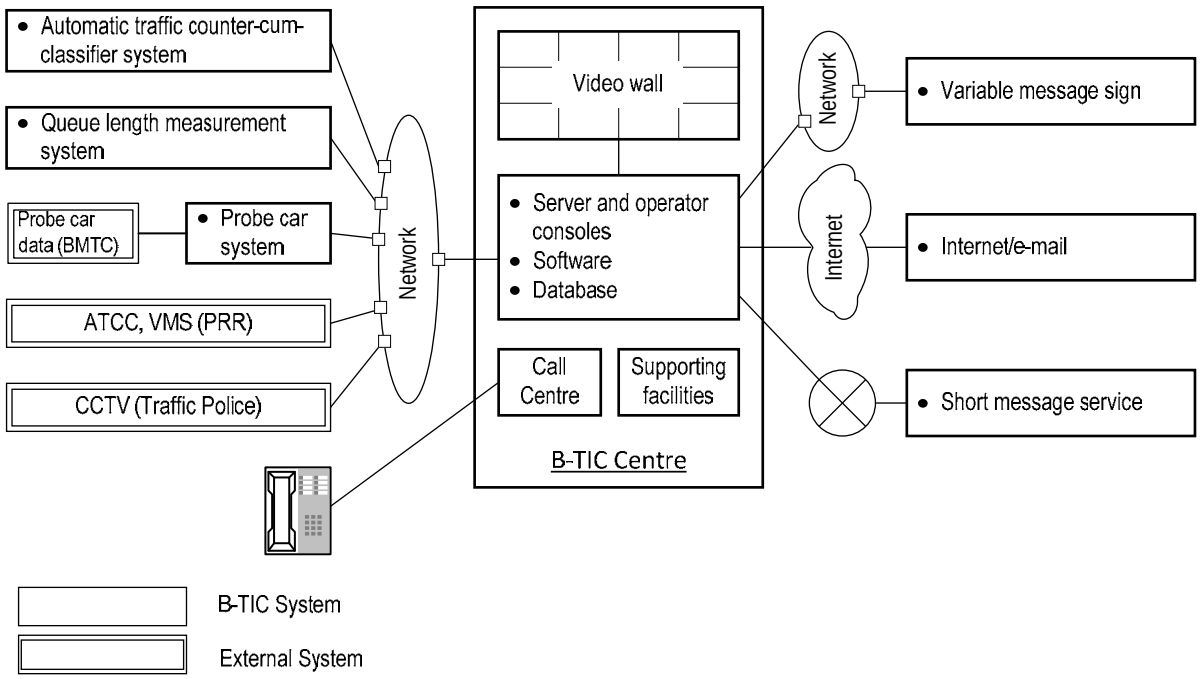


Figure 2.76 Conceptual Configuration of B-TIC

(Source: JICA Study Team)

3) Component of B-TIC

B-TIC consists of the following components and functions as shown in Table 2.44.

Table 2.44 Components and Functions of B-TIC

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

(Source: JICA Study Team)

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

The probe data contains location data consisted by longitude and latitude and time. The probe unit records this data at regular interval such as thirty (30) seconds, one minute, etc. The collected probe data is consecutively plotted on the map. However the location is usually measured with some errors ranging between 10 – 100 ms. Therefore, each plotted location is processed to locate onto the link of the road network. Then the route on which the vehicle has passed is visually identified on the road network. This is called Map-Matching. Consequently, the traffic conditions such as travel speed, required travel time, etc. are identified.

The video wall is one of the major components of B-TIC. The large-sized monitors and associate equipment will be installed in B-TIC to display the traffic conditions and other relevant information. It will be used for sharing information amongst the staff at the centre and necessary action will be taken as required. The schematic image of video wall in B-TIC is shown in Figure 2.77.

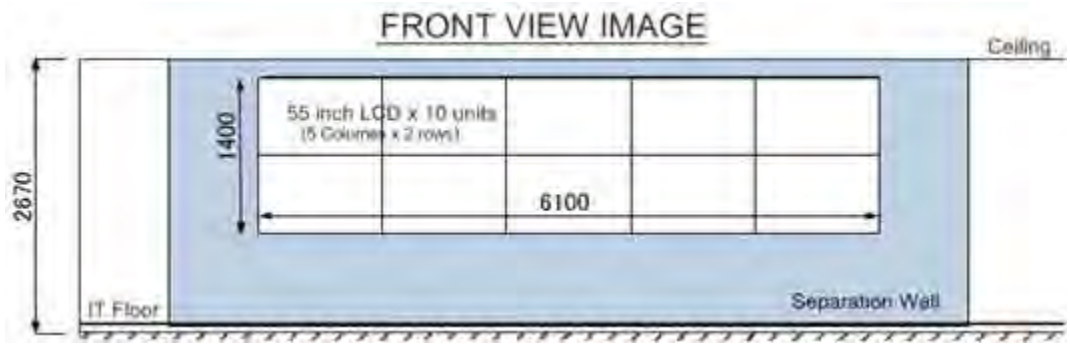


Figure 2.77 Schematic Image of Video Wall in B-TIC

(Source: JICA Study Team)

2.3.2 Traffic Management System

(1) Current Issues and Rationale for New Signal System

The existing traffic signal system is very limited in function. The controller is equipped only with time-of-day (TOD) control function, in which different signal timing is applied at different time of day and different day of the week. The technique is effective to a recurrent traffic flow pattern that repeats every day.

Field observation, however, revealed that TOD function is not properly applied. Most of the signals are operating with long cycle time causing unnecessary delay to queuing vehicles. No updating of TOD timing parameters seems to have been undertaken.

Except TOD control, signal system is merely a group of isolated traffic signals and no coordination is made between neighbouring signals. In the road network like Bengaluru where road network is dense and signals are closely installed, coordination between two signals is very important to efficiently manage the high volume of traffic by reducing the number of stops at each intersection

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

Currently signal timing is modified by the operator at Traffic Command Centre based on the observation of traffic condition through CCTV camera. Such practice, if being done, is not recommended. The operation from the centre is same as manual control of signal at intersection. More scientific approach must be taken

Signal system can produce large amount of benefits in terms of reduction in travel time, fuel consumption and air pollution. The magnitude of benefits is fractional for each vehicle. But it accumulates a substantial amount if the number of vehicles benefitted by efficient signal control is considered. The current traffic condition in Bengaluru warrants earlier introduction of efficient signal system.

(2) Area Traffic Control System

Area traffic control system is a signal system in which all signals are connected to a traffic control centre. Vehicle detectors are placed at various locations in the road network to collect traffic condition data. This data is gathered by the centre and traffic conditions are judged. Based on detector data, optimum signal timing parameter (a combination of cycle ($*^1$), split ($*^2$) and offset ($*^3$)) is then prepared for each signal. As the signals are controlled from the centre, coordination amongst the signals are maintained. The concept of area traffic signal is shown in Figure 2.78.

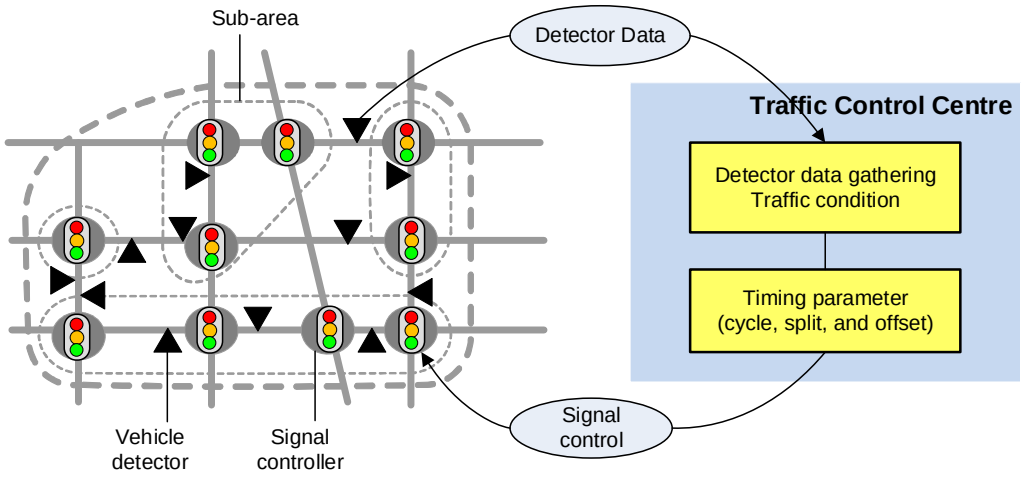


Figure 2.78 Concept of Area Traffic Control System

(Source: JICA Study Team)

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

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

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

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

Offset: Time difference of coordinated phases between two traffic signals.

(a) Functions Required

The functions required for new signal system are described below. These functions are realized either at local controller level or at centre level. They are standard function for area traffic control system and applicable to the new signal system for Bengaluru. More advanced signal control methods exist and can be applied to the system. But they require more resources in terms of budget and staff to design, operate and maintain. Considering the financial limitation, maintenance level of the existing facilities and human resources available, the system equipped with the functions described below is suitable to Bengaluru. The system can be upgraded by introducing additional detectors and more sophisticated software but without replacing controllers.

(b) Controller Level

The new controller must have the various signal control functions listed below.

1) Time-of-Day Control

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

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

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

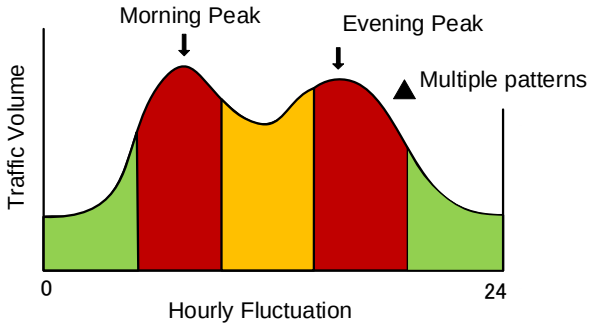


Figure 2.79 Concept of Time-of-Day Control

(Source: JICA Study Team)

2) Actuation Control

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

Vehicle detector is required for actuation control at approach lane at suitable distance from stop line for detection of approaching vehicle. Typical example of actuation control applied to right turn traffic is shown in Figure 2.80.

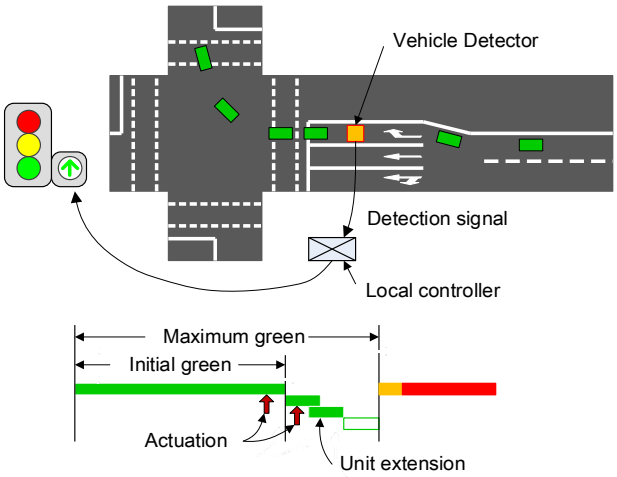


Figure 2.80 Example of Actuation Control

(Source: JICA Study Team)

3) Phase Sequence Plans

Traffic signal sequentially displays a green to vehicles moving in different directions. For a given intersection, multiple signal sequences can be defined to handle the traffic movement. To cope with the change in the traffic demand, different phase sequence would be suitable at different time of day. Example is shown in Figure 2.81. Right turn arrow phase is necessary during peak hours when right turn volume is high, while right turn is made by permissive right turn (filtering) without right turn arrow signal phase during off peak hours when right turn volume is small. The controller must have multiple phase sequences that is to be applied at different time of day.

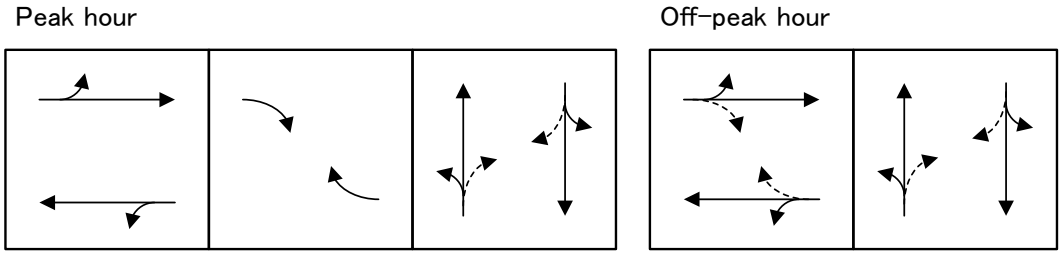


Figure 2.81 Example of Multiple Phase Sequence

(Source: JICA Study Team)

4) Offset Synchronization

Signal offset is the time difference of starting point of a cycle of the controller relative to the background cycle. Controller must be capable of synchronizing with the background cycle with the offset specified. If the current offset is not the offset specified, controller must adjust duration of signal indication to arrive at the offset specified. Maximum offset transition in a cycle must be specified and followed to prevent too long or too short signal indication.

5) Flashing Operating

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

6) Coordination

Signals installed at short distance need to be coordinated to offer green wave, in which vehicle that has passed an intersection during green will be given green at next signal to allow the vehicle to pass through next intersection without stopping. The reduction of waiting time at signals is illustrated in Figure 2.82. To provide green wave, neighbouring two signals must operate with the same cycle length and they must be coordinated.

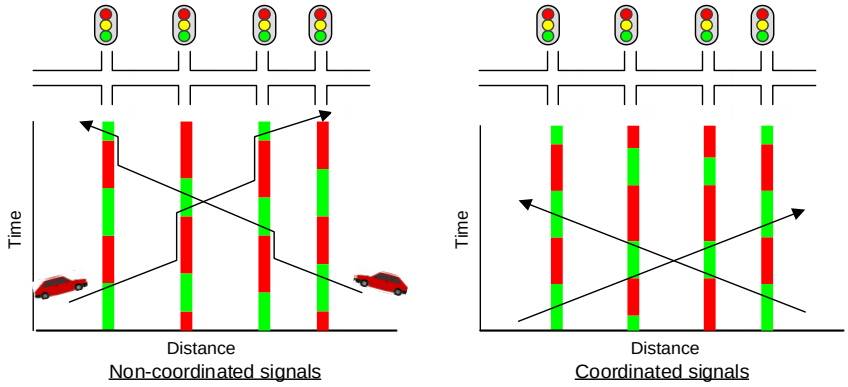


Figure 2.82 Signal Coordination

(Source: JICA Study Team)

7) Signal Operation Monitoring

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

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

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

(c) System Level

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

1) Sub-Area Formation

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

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

2) Responsive Control

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

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

3) Offset Transition

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

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

(d) Vehicle Detector Data

1) Data Gathering

Vehicle detector data must be gathered by the control centre at the specified interval. There are two ways to collect vehicle detector data. Vehicle detection signal is directly sent to the centre continuously and traffic volume and time occupancy are calculated at the centre at the specified interval. Alternatively, data accumulated for a specified interval by the detector is sent to the centre at the end of the interval. Either methods can be adopted. The former method requires real time data transmission and amount of data is much larger than the latter method. On the other hand, clock synchronization issue occurs if latter method is applied. The former method is recommended as it

simplifies the function of vehicle detector. Frequent data transmission is not a burden as detector data can be multiplexed with controller data.

2) Detector Data Processing

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

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

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

3) Detector Operation Monitoring

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

(e) Signal Operation Monitoring

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

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

(3) Stage-Wise System Construction

System upgrade is proposed to be made in three stages. The reason is that the number of signals is too large to implement upgrade in one time. If upgrade work is done in one time, it will take too long and during the work, and the system is continuously modified.

In stage 1 project, the control centre system, in particular, software shall be modified and new modules such as detector data processing, signal timing calculation and real time signal control shall be added. In addition, 100 signals in the core area of the city (green area in the map in Figure 2.83) shall be upgraded together with installation of vehicle detector.

In stage 2, the area will be expanded to the Outer Ring Road and another 180 signals (blue area in the in the map in Figure 2.83) shall be upgraded to the new system. In stage 3, signals beyond Outer Ring Road shall be upgraded. The area covered by each phase is shown in Figure 2.83.

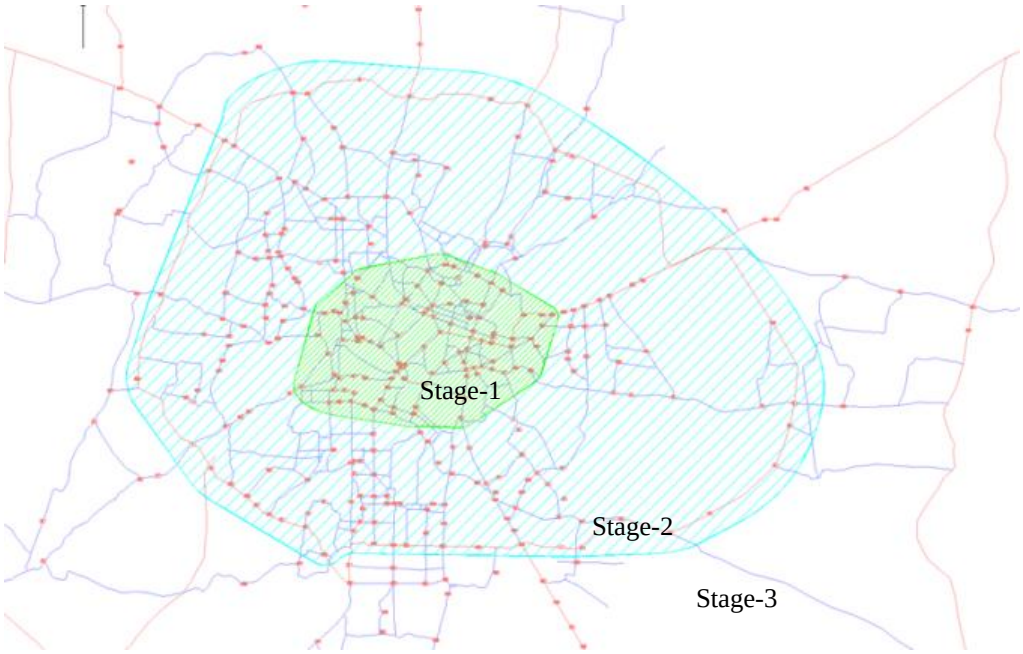


Figure 2.83 Stage-Wise Construction of Traffic Signal

(Source: JICA Study Team)

2.3.3 ITS for Peripheral Ring Road

(1) Outline of Peripheral Ring Road

The Peripheral Ring Road (PRR) is a semi-circle road surrounding Bengaluru at a distance of 17 to 25 km from the city centre. It starts at the intersection with National Highway 4 (Tumkur Road) in Madavara located in north-west of the city and ends at Konappana Agrahara connecting with Hosur Road in south-east of the city passing through northern and eastern parts of the city. NICE road[2] is another semicircle road with which PRR connects at both ends to form a full circle ring road around Bengaluru.

Service roads are provided to both sides of main road for local traffic. Another function of service road is to be used as access road to PRR.

The design speed as reported by the Draft Detailed Project Report for PRR as shown in Table 2.45.

Table 2.45 Design Speed of PRR

Nature of Terrain	Cross Slope of the Ground	Design Speed (km/h)	
		Ruling	Minimum
Plain & Rolling	Up to 25%	100	80
Mountainous & Steep	More than 25%	60	40

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

[2] Constructed and being operated by Nandi Infrastructure Corridor Enterprises (NICE), who is also a BOT operator for Bengaluru - Mysore Infrastructure Corridor connecting Bengaluru and Mysore.

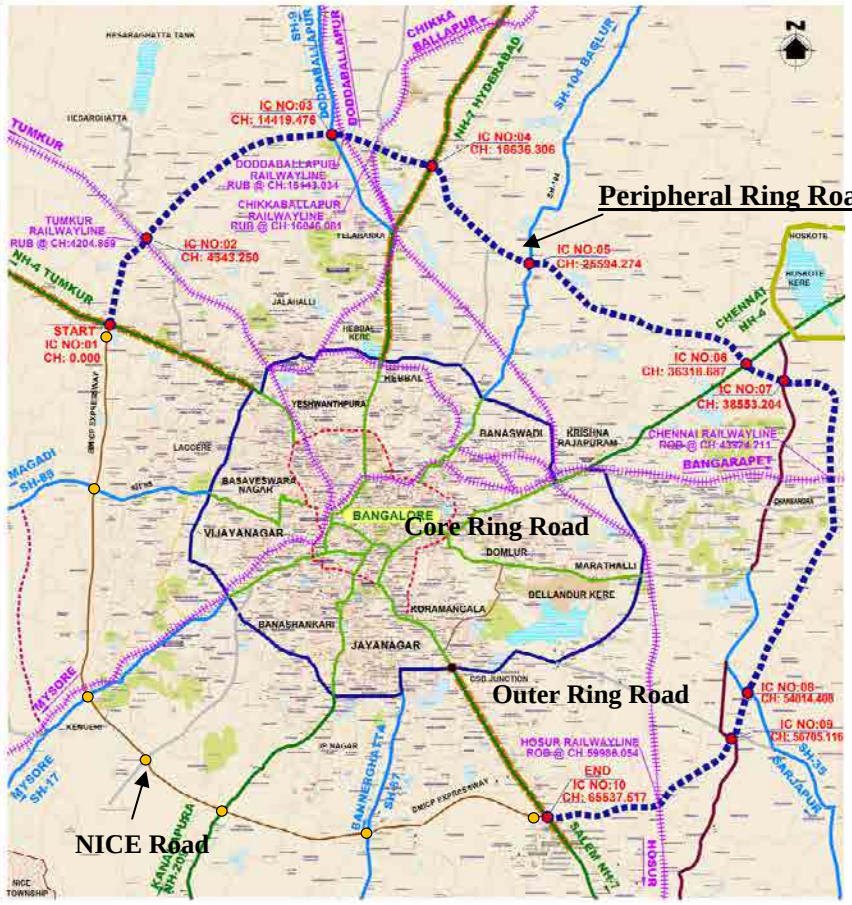


Figure 2.84 Peripheral Ring Road

(Source: JICA Study Team)

PRR is a fully access controlled toll road and interchange will be constructed at ten (10) locations including connecting with radial roads, and with NICE also at both ends. The location of interchange is listed in Table 2.46 together with type of interchange.

Table 2.46 Proposed Interchange along PRR

	Chainage (km)	Distance (km)	Intersecting Name	Interchange Type
1	0.000		Tumkur Road (NH-4)	Toll Barrier Type
2	4+344.969	4.34	Hesarghatta Road	Diamond Type
3	14+422.500	10.08	Doddaballapur	Diamond Type
4	18+637.242	4.22	Bellary Road (NH-7)	Diamond Type
5	25+596.788	6.96	Hennur Road	Diamond Type
6	36+233.070	10.64	Old Madras Road(NH-4)	Diamond Type
7	38+558.606	2.33	Whitefield – Hoskote Road	Diamond Type
8	54+023.348	15.47	Hosekote-Anekal Road	Diamond Type
9	56+710.979	2.69	Sarjapur Road	Diamond Type
10	65+537.517	8.83	Hosur Road (NH-7)	Toll Barrier Type

(Source: Edited by JICA Study Team based on Peripheral Ring Road Draft Detailed Project Report (R4))

The number of entry and exit tollgates is considered by Bangalore Development Authority (BDA) as summarized below. The following information was obtained from BDA as of December 2014.

According to BDA, it is considered that a total of 94 entry tollgates and 94 exit tollgates will be constructed on PRR. At two end interchanges (Tumkur Road and Hosur Road), a toll plaza will be constructed on the main line as all vehicles need to go through the tollgate. These toll plazas will have seven (7) entry tollgates and another seven (7) exist tollgates. At intermediate interchanges, two (2) entry toll plazas and two (2) exit toll plazas will be constructed on both sides of PRR separately for two directions. Each entry and exit toll plaza will have five (5) tollgates.

In addition to the number of toll gates, basic concept of PRR such as location/number of interchanges as shown in the table above is described in Peripheral Ring Road Draft Detailed Project Report Revision 4 (DPR (R4)).

ITS Master Plan considers ITS for PRR based on the information provided by BDA as of December 2014 as explained above and DPR (R4).

Table 2.47 Number of Toll Gates at Each Interchange

	Intersecting Name	Entry Lane		Exit Lane	
		To Hosur	To Tumkur	From Hosur	From Tumkur
1	Tumkur Road (NH-4)	7	-	7	-
2	Hesarghatta Road	5	5	5	5
3	Doddaballapur	5	5	5	5
4	Bellary Road (NH-7)	5	5	5	5
5	Hennur Road	5	5	5	5
6	Old Madras Road(NH-4)	5	5	5	5
7	White Field-Hoskote Road	5	5	5	5
8	Hosekote-Anekal Road	5	5	5	5
9	Sarjapur Road	5	5	5	5
10	Hosur Road (NH-7)	-	7	-	7
	Total		94		94

(Source: Summarised by JICA Study Team based on information provided by BDA)

(2) ITS Components for PRR

PRR is a fully access controlled toll expressway exclusive for 4-wheel or larger vehicles. As such, it requires facilities that manage toll collection operation and ensure safe and comfortable travel. The following two ITS facilities are proposed:

- Toll management system (TMS)
- Highway traffic management system (HTMS)

Main points of the proposal are briefly summarized below.

(a) Toll Management System

PRR adopts a closed toll system, in which vehicles are charged with a toll based on the distance travelled. The system requires tollgate at both entry and exit points of the PRR and toll is collected at exit tollgate.

Three types of toll collection methods (Manual, Touch And Go (TnG), and Electronic Toll Collection (ETC)) are proposed. Smart card that contains monetary value (prepaid card) is commonly used for TnG and ETC. Post-paid card, in which road users are charged with toll for the trips made and payment is made either by settling the bill sent to the registered owner of smartcard, or through credit card is not used. Dedicated Short Range Communication (DSRC), which was developed specifically

for wireless communication between vehicles and roadside devices, is used for communication between roadside ETC antenna and on-board unit (OBU) in vehicle.

All of three types of toll collection methods mentioned above will be provided to all toll plazas.

Each interchange shall have a toll plaza office that accommodates toll plaza system and rooms for TMS back office operation. In addition, Toll Management Centre will be established at a suitable location to manage toll management system.

(b) Highway Traffic Management System

Highway traffic management system refers to a system that gathers road, traffic, incident, adverse weather and other information related to road traffic and disseminates them to road users through various means after processing this information. Its main objective is to enhance safety, efficiency and comfort of travel on the road.

The proposed HTMS system comprises the following roadside facilities:

- Variable message sign
- Closed circuit television (CCTV) camera
- Automatic traffic counter-cum-classifier

In addition to the above components, a Traffic Control Centre will be established to monitor the road and traffic condition on the PRR and manage the system.

(3) Toll Management System

Toll management system comprises various equipment at three levels. They are toll lane equipment, plaza computer system and toll management centre system as depicted in Figure 2.85.

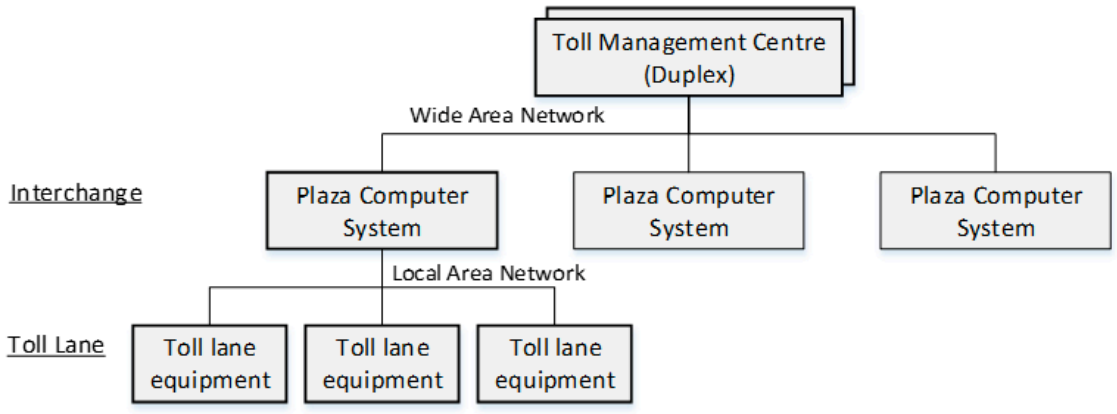


Figure 2.85 Configuration of Toll Management System

(Source: JICA Study Team)

A set of toll lane equipment is proposed to be installed in the tollbooth, on the toll island or its vicinity for toll collection operation. The operation of all lane equipment will be monitored continuously by a plaza computer system that will compile; audit and prepare the statistical data for printout, for display

in the Plaza building control room. A Toll Management Centre is proposed to be prepared at one of the interchanges along PRR. The centre system shall have duplex system configuration consisting of main and backup server systems. In case of stoppage of main server system, backup server system shall take over the operation so that toll management operation will not be interrupted.

The Plaza Computer System (PCS) also provides management functions at each interchange such as attendance recording, reconciliation between declared and expected toll collection and control of cash transferred from the plaza to the bank.

Each toll plaza is proposed to operate as an autonomous system with no real time data communication between plazas and between plaza and Traffic Control Centre.

(a) Toll Lane Equipment

Various equipment will be installed at toll lane either inside toll booth or on and around island. They are summarized below.

1) Toll Lane Controller (TLC)

Toll lane controller accommodates a computer that controls and monitor all toll lane equipment. It also stores transaction data and other data necessary for toll collection operation. In case of abnormality of any equipment, an alarm will be issued.

2) Toll Collector Terminal (TCT) with Receipt Printer (RPR)

Toll collector terminal has a monitor display and keyboard or keypad. It is an interface equipment with toll collector. Receipt printer issues receipt.

3) Smartcard Reader/Writer (SRW)

Smart card reader/writer reads or write data from or to smartcard used as transit card and TnG card. It shall be placed inside tollbooth for manual collection and on the wall of tollbooth for TnG operation.

4) Emergency Footswitch (FSW)

Emergency footswitch initiates an alarm at toll plaza office and activates amber siren beacon when a foot switch is pressed in case of emergency.

5) Intercom Slave Unit (ISU)

Verbal communication unit between toll operator and the staff in the toll plaza building. It has the following features:

- Hand free operation
- Broadcasting from toll plaza office to all tollgates
- Audio monitoring at toll plaza office

6) Overhead Traffic Light (OHTL)

Overhead traffic light is used to indicate whether a toll lane is open or closed.

7) ETC Antenna

ETC antenna communicates with on-board unit (OBU) installed inside vehicle and exchange data for ETC transaction.

8) Lane Traffic Light (LTL)

Lane traffic light is a two-aspect traffic light and indicates whether a vehicle stopped at tollbooth is allowed to proceed or not.

9) User Fare Display (UFD)

User fare display indicates amount of toll deducted or balance in the card. Other information may be displayed.

10) Automatic Lane Barrier (ALB)

Automatic lane barrier controls vehicle movement. It normally stays at closed position and opens when a vehicle is allowed to proceed.

11) Amber Siren Beacon (ASB)

Amber siren beacon is activated by toll collector and indicates emergency.

12) Incident Capture Camera

Incident capture camera takes an image of vehicle on the toll lane. Regardless of whether no abnormality is found at toll transaction, image will be kept for the period to be stipulated.

13) Automatic Vehicle Classifier System (AVC)

Automatic vehicle classifier system is a device that determines vehicle class based on the physical features of a vehicle measured by the system

(b) Plaza Computer System

A plaza computer system (PCS) is proposed to be provided in the control room of plaza building at each interchange. PCS has two main functions:

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

(c) Traffic Control Centre System

A Toll Management Centre (TMC) is proposed to be constructed at one of the interchanges. The TMC system has the following main functions:

- Data acquisition from plaza computer system (PCS).
- Data processing and validation via visual display units, printer terminals, portable memory modules and data/parameter transfer facilities.
- Downloading of operational parameters to PCS.
- Switching between main and backup server system in case of halt of a server or for maintenance.

(d) CCTV System

A CCTV system is proposed to be introduced as part of toll management system. The CCTV equipment is categorized as two types: CCTV for toll management system and CCTV for security.

The CCTV for toll systems will consist of:

1) Toll booth CCTV cameras

Toll booth CCTV cameras will be installed inside the booth to observe and record the activities of the toll collector during duty.

2) Plaza surveillance CCTV cameras

Plaza surveillance CCTV cameras will be installed on a sufficient height mast and are intended for general surveillance of the toll plaza and walkways.

The CCTV for security will consist of:

3) Plaza building security CCTV cameras

The plaza building security CCTV cameras are intended for monitoring of security areas such as the plaza compound, control room, change of shift room, cash counting room, lobby, hallway, garage, etc.

(4) Highway Traffic Management System

Highway Traffic Management System (HTMS) is a system that helps the operator of the Peripheral Ring Road (PRR) to safely and efficiently manage the traffic on the PRR. The system consists of three parts: information collection, information processing & surveillance, and information dissemination. In addition, information will be exchanged with other relevant organizations and road users.

Information collection system gathers the road and traffic condition on the PRR through automatic traffic-counter-cum-classifier and closed circuit TV (CCTV) camera installed along the PRR, and through communication system. The data collected by these devices are sent to the Traffic Control Centre through digital transmission system.

System operator monitors the conditions of the PRR through the video wall and workstations. Measures are taken in case of incident such as congestion, accident, road or lane closure, and construction work. The conditions of the PRR will be disseminated to PRR users through variable message signs installed on the PRR and also on the roads leading to the PRR, and through Internet. SMS will be sent to the registered users in case of incident. Cooperation with relevant organizations such as Traffic Police, ambulance and wrecker services must be arranged so that coordinated operation can be made in case of incident.

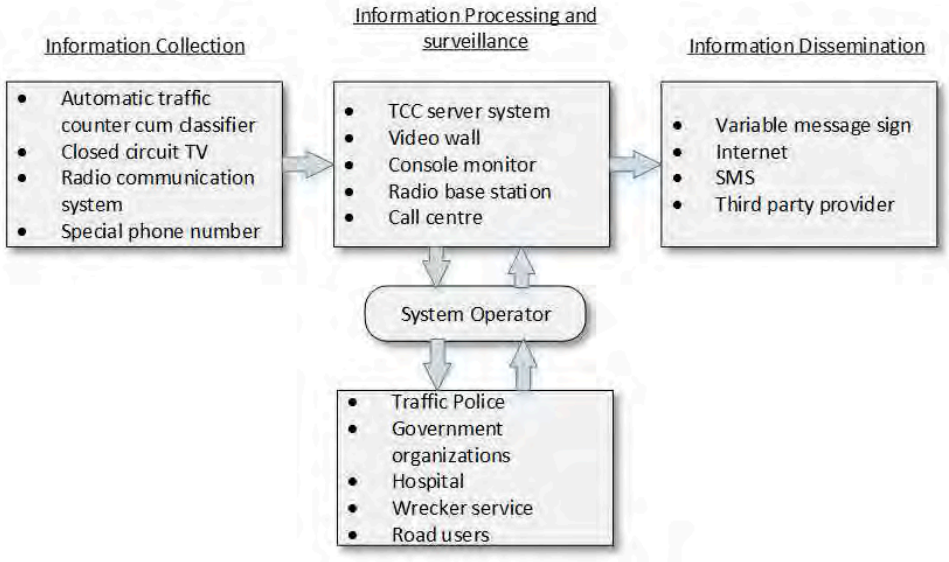


Figure 2.86 Conceptual System Configuration

(Source: JICA Study Team)

Figure 2.87 Example of Traffic Control Centre

(Source: JICA Study Team)

(a) Outline of the System

In order to ensure safe and comfortable flow of traffic along its entire stretch of Peripheral Ring Road, a Highway Traffic Management System (HTMS) is proposed to be introduced. The system shall have a Traffic Control Centre (TCC) at one of the interchanges to oversee traffic control 24/7. The centre

system shall have duplex system configuration consisting of main and backup servers. In case of malfunction of main server, backup server shall take over the operation so that system operation will not be interrupted.

The Highway Traffic Management System (HTMS) collects road and traffic data and provides this data 24/7 to road users, thereby serving as a traffic management system which ensures safe and smooth traffic flow on the PRR. The HTMS system comprises traffic condition gathering facilities as well as facilities for providing this information. The overall system configuration of the HTMS is shown in Figure 2.88.

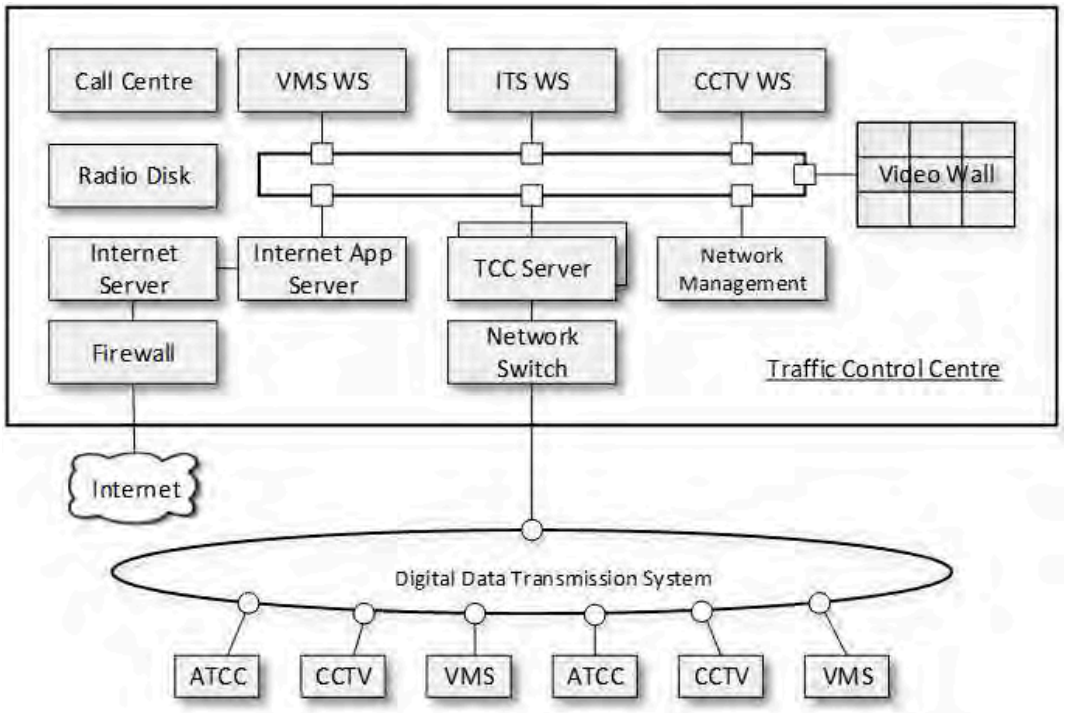


Figure 2.88 Configuration of Highway Traffic Management System

(Source: JICA Study Team)

(b) HTMS Component and Functions

1) Information Collection System

The information collection system consists of closed circuit television (CCTV) system and automatic traffic-counter-cum-classifier (ATCC) System. CCTV system will be used to monitor traffic flow. Incident detection function that can detect stationary object or object moving reverse direction will be provided to CCTV system.

Automatic traffic counter cum classifier (ATCC) counts number of vehicles in the sensing area and classifies them into two types: small and large vehicles.

Figure 2.89 CCTV Camera

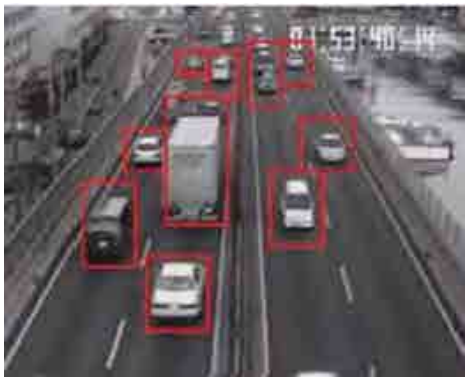


Figure 2.90 Image by ATCC

(Source: JICA Study team)

Emergency call box is not required to be installed on PRR as proliferation of mobile phone made it possible for drivers to contact the Traffic Control Centre or other party. A call centre shall be established and special phone numbers are assigned to it.

Radio communication system is proposed to be installed for PRR and possibly for traffic management system. A base station shall be constructed at Traffic Control Centre and satellite station or repeater station be constructed to cover entire stretch of PRR. Necessity and location of satellite station or repeater station shall be determined by conducting propagation test. Mobile unit for vehicle and handy walkie-talkie for staff are proposed to be used.

2) Information Processing at Centre

Traffic flow data collected by ATCC are processed at the Centre into the form suitable for statistical application. During the process, any abnormality, whether caused by incidental traffic condition or equipment malfunction, is detected by the processing software and warning is issued for operator's attention.

Image from CCTV camera is normally used for observation by the operator. At the same time, image is recorded by the digital video recorder. In case abnormality is found by the system, a warning is also issued.

All calls to the call centre and conversation over radio communication system will be automatically recorded for reviewing in the future.

3) Information Dissemination

Traffic and other information is proposed to be disseminated to the road users through variable message sign to be installed at and around interchange. It provides information regarding the road and traffic condition at the downstream section so that drivers can take appropriate action including diverting to detour, or prepared for the incident.

Figure 2.91 Variable Message Sign (Simulated Image)

(Source: JICA Study Team)

Traffic information is proposed to be disseminated through Internet in various formats. Congestion map showing congested locations, incident location or construction site shall be prepared for access by road users.

The Figure 2.92 shows an example of traffic map on highway.

Figure 2.92 Example of Traffic Map

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

Traffic alert e-mail or SMS shall be prepared. When there is incident, construction work, road closure, or other event that hampers normal traffic, e-mail of short message shall be sent to the registered subscribers.

It is expected that new service such as real time route guidance system is introduced by a third party. The HTMS system shall be designed in such a way that traffic information is provided to third party for free or for fee.

(c) Facility Deployment Standard

Roadside equipment are proposed to be installed at the locations selected based on the facility deployment standard as presented in the

Table 2.48 to standardize the location. It is noted that locations are adjusted to adjustment for a short distance to avoid the place which is not suitable for installation such as tunnel and bridges.

Table 2.48 Facility Deployment Standard

Facility	Location	Quantity
Variable message sign (VMS)	200 m upstream of the start of deceleration lane	16
	200 m upstream of on-ramp to PRR	22
Closed Circuit Television (CCTV) camera	Merging and diverting sections at on-ramp of each IC and junction To be installed on the gantry for VMS	18
Automatic Traffic Counters-cum-classifier (ATCC)	Each Section between ICs.	18

(Source: JICA Study Team)

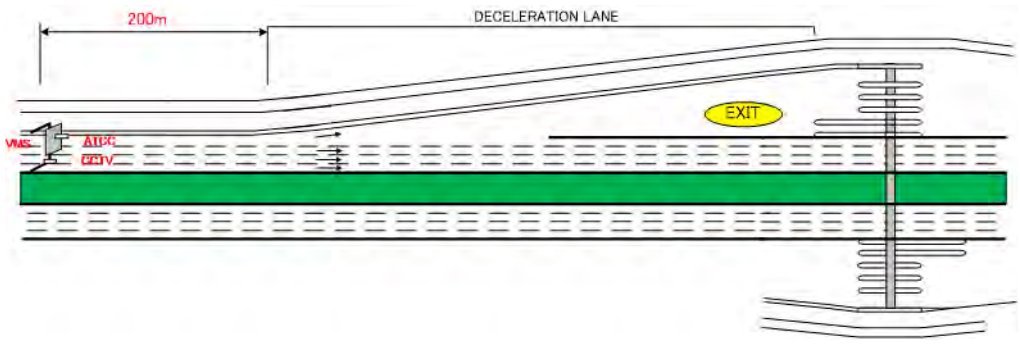


Figure 2.93 Locations of VMS

(Source: JICA Study Team)

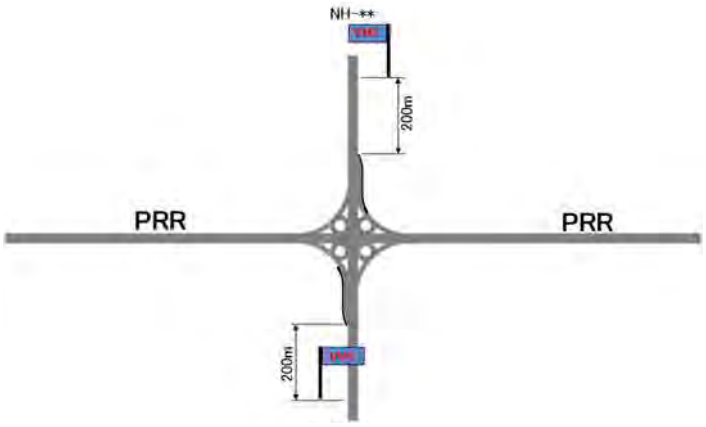


Figure 2.94 Locations of VMS

(Source: JICA Study Team)

(d) Central Server System

Traffic Control Centre system is proposed to be established at one of the interchanges preferably at the same interchange as Toll Management Centre. The server system shall have duplex configuration consisting of main and backup servers. Under normal condition, the main server shall operate the system. In the event of malfunction of the main server, the backup server will take over the system operation. The system is expected to operate on a 24/7 basis.

The Traffic Control Centre (TCC) system will have the functions listed below. These functions will be integrated into a Highway Traffic Management System.

- Data gathering from roadside equipment
- Monitoring and control of roadside equipment
- Data communication with roadside equipment
- Database Management
- Dissemination of information through variable message sign and Internet
- Human-machine interface

(e) Deployment Plan

The Figure 2.95 shows the locations of the ITS facilities of PRR.

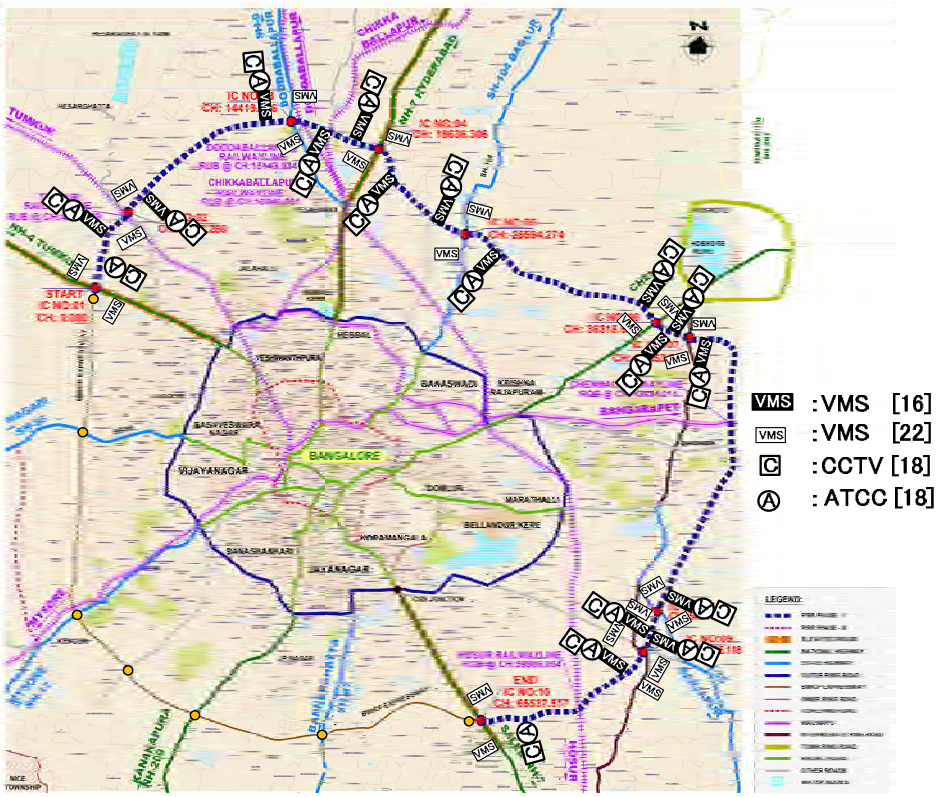


Figure 2.95 Location Map of ITS Facilities of PRR

(Source: JICA Study Team)

2.3.4 Electronic Road Pricing System

ERP for Bengaluru has been deliberated and prepared as a separate report on Appendix-2. The following clauses summarise and describe the major points. The details can be found on Appendix-2.

(1) What is ERP

To handle growing road traffic congestion, most cities strived to provide many supply measures such as improved road capacity and more seats in public transport. A worldwide trend in transport sector realises that it is impossible to build our way out of congestion. Therefore, nowadays most transport strategies include Traffic Demand Management (TDM).

One of major focuses of TDM is to discourage usage of private transport. There are a variety of measures such as providing more efficient modes of travel, restricting the provision of car parks/motorcycle parks in certain area of the city to discourage entry, allowing only high occupancy vehicle (HOV) to pass during certain period of a day, increasing petro tax/vehicle tax and etc. A congestion pricing comes under the umbrella of TDM. The motorists are imposed to pay for the use of the roads at times and places. The roads within a congestion priced areas can only be accessed on payment of charge which varies by time of day according to the traffic situation. The automated congestion pricing by system is called 'Electronic Road Pricing (ERP)'.

The concept of the congestion pricing is not the same as road tolling. The toll road intends that more motorists use the road, in many cases, to divert the traffic from certain area/route. Accordingly the toll roads want more motorists to maximise the revenue of the toll road operator. On the other hand, the congestion pricing intends that fewer motorists use the charged area/roads thereby urging them to use more efficient modes such as public transport or changing travel behaviour such as commuting at different time. Thus the main consideration is not the revenue but controlling the demand.

(2) ERP in Bengaluru

(a) Policy Set Out by Transport Plan

National Urban Transport Policy (NUTP), formulated by Government of India, sets out an objective to ensure safe, affordable, quick, comfortable, reliable and sustainable access for the growing number of city residents to meet their employment, education, recreation and other needs. To meet the objectives, the policy sets out the strategies of encouraging greater use of public transport and handling the increasing private transport and urges to introduce Intelligent Transport Systems (ITS) for traffic management.

In response to the directive from Government of India and NUTP, Comprehensive Traffic and Transportation Plan (CTTP), a regional transport plan in Karnataka state, looks at reducing private vehicle usage by a pricing policy or by providing a better level of public transport. It acknowledges

the difficulty in implementing the congestion pricing; nevertheless suggests restricting the private vehicles from entering into congested roads during the peak hours. It provides a broad suggestion but does not make specific plan.

(b) Purpose of ERP in Bengaluru

In line with the policy of national/regional urban transport such as NUTP and CTTP, Directorate Urban Land Transport (DULT) considers to implement ERP in Bengaluru as part of its policy. Implementing ERP aims to be a trigger for discouraging private transport and greater use of public transport.

The road network in Bengaluru is already operating close to capacity and certain parts experience congestion during the morning and evening peak hours. The average speed is less than 15 km/hour during the peak hours. The major public transport is the city bus, operated by BMTC which operates a fleet of 6,100 buses. The metro rail is under construction and yet to serve the most congested parts of the city such as near majestic in the CBD area. The last mile connectivity of the public transport is still limited and dependency on private transport remains high.

Under such situation, there still remain a number of required measures such as improvement of the last mile connectivity. Nonetheless, ERP is considered as one of the measures to alleviate the congestion thereby promoting the public transport in Bengaluru.

(3) Practices of ERP in the World

The congestion pricing has worked well in Singapore since 1975, London since 2003 and Stockholm since 2006. Only these 3 cities have so far implemented genuine congestion pricing. In all these 3 cities, the congestion pricing has managed to keep the traffic problems within manageable levels and the public transport usage has increased. The results of the 3 cities can be found in the table below.

Table 2.49 Practices of ERP in the World

Item	Area of Restricted Zone		
	Singapore (1975) 7 sq km	**London (2003) 8.5 sq km**	**Stockholm (2006) 14 sq km**
Traffic to controlled area	Reduced by 16%	Reduced by 30%	Reduced by 20%
Speeds in controlled area	Increased	Increased	Increased
Usage of public transport	Increased from 46% to 66% of all trips for work trips	50% of car reductions were transfers to public transportation	The total increase in boarding between spring 2005 and spring 2006 for the service area was 6 %.
Speed of Traffic on the peripheral roads	Decreased for a short period	10% more traffic on the peripheral roads, journey times on them have not increased because traffic signal systems on these roads were adjusted in anticipation of these traffic shifts.	Traffic on relief roads, bypass E4/E20 and Södra länken, have increased by about 5% since 2005
Accidents in the charged area	Reduced, but main reasons are the large numbers of traffic management schemes done to improve safety	-	-
Air pollution	About 32% reduction in carbon monoxide levels, no appreciable reduction in other pollutants (when the scheme started)	NOX emissions fell by 17%, PM10 by 24% and CO2 by 3%.	Reduction in the inner city of 10-14% in Carbon Dioxide), 7% in NOX and 9% in particulates
Public acceptance	Reluctantly, area has been increased over the years	Reluctantly, area has been reduced once	Referendum resulted in a wafer thin majority in favor

(Source: JICA Study Team)

(4) Area Pricing VS. Line Pricing

In area pricing, the motorists are charged to enter an area. In line pricing, the motorists are charged to pass through a road. There is a fundamental difference in the usage of roads between the area pricing and line pricing. In the area pricing, majority of the motorists will be affected in some way or other because they are going to a destination there. In the line pricing, majority of the motorists are less affected because they are just passing by and can avoid the road if they do not want to pay.

The congestion pricing is normally done area-wise encompassing the most congested area of the city. It is generally around Central Business District (CBD) because it attracts a lot of vehicle due to its

activities. Singapore, London and Stockholm have implemented the area-wise congestion pricing in the vicinity of the CBD.

In the light of these, the consideration of ITS Master Plan is paid to the area pricing in the following clauses.[3]

(5) Level of Service

A quantitative method to define congestion is to consult the speed-flow curves derived for different types of roads in the city. The speed-flow curve derived for a three-lane per direction of major arterial road in Chennai was provided by the Indian Institute of Technology, which is shown in Figure 2.96. The speed-flow is a standard method of working out traffic levels of service. The traffic low is categorised from Level of Service A (very free flowing) to Level of Service F (very slow traffic of stop-go conditions). The traffic flow breaks down at the bullet nose of the curve which is at a speed of 24 km/hr. So the speeds below 24 km/hr, called the critical speed, occur on normal Indian roads before it gets into the undesirable Level of Service F. For a city considering congestion pricing, the trigger point can be when the average speed along the roads in the area falls below the critical speed. The congestion pricing is intended to improve to a better Level of Service i.e. A to E by reducing the inbound traffic into the area.

The speed-flow curve shown in Figure xx is for the road in Chennai. It is assumed that the road conditions in Chennai are not very much different from those in Bengaluru. [4]

[3] DULT had carried out a study on the line pricing before ITS Master Plan Study. It was reviewed and alternatives were proposed as part of the study of ITS Master Plan. The details can be found on the Appendix-2.

[4] This is a theoretical curve obtained from practical measurements. Only the top part of the curve can be measured. The bottom half cannot be measured and is obtained from calculations. Hence the curve is, at best, an indication of what is happening, rather than an accurate description of the situation.

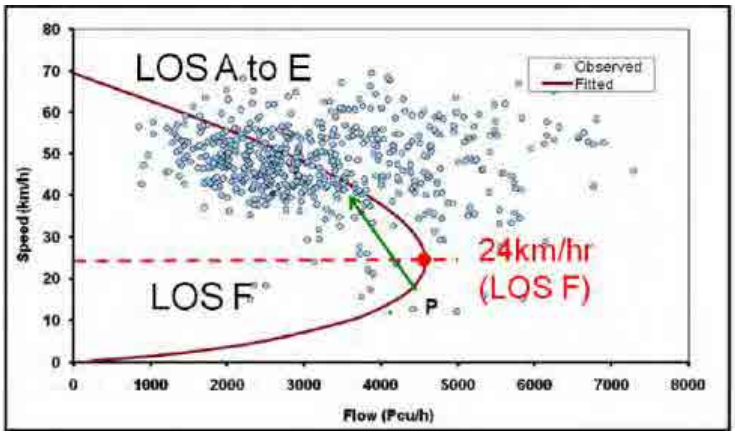


Figure 2.96 Speed-Flow Curve

(Source: Edited by JICA Study Team based on Speed-Flow Curve Shared by IIT Chennai)

(6) Consideration of Area Pricing in Bengaluru

To consider area pricing for a selected restricted area, it is to include the locations with land use which attract traffic. This will be the area with offices, commercial activities and with sufficient parking facilities which are used by motorists visiting these buildings. Such areas are usually defined as Central Business District (CBD) or Regional Centres. The congestion charging usually operates during certain restricted period when there is congestion, usually morning peak and evening peak periods.

If the area selected for congestion pricing is too large, it requires many entrances that have to be controlled. Too small an area results in the congestion pricing less effective. Singapore's area of restrictions is 7 sq km. The CBD itself in Singapore is about 3 sq km. It is surrounded by commercial and civic district areas where there are very few residences and it together with the CBD make up the restricted area of 7 sq km.

(a) Selection of Congestion Pricing Area in Bengaluru

The evaluation criteria were set out for selecting the area for congestion pricing. They comprise approx. peak hour travel speed, percentage of commercial/administration/industry land use of total land use in the area, availability of proper public transport e.g. metro stations and bus services, availability of alternative routes around the area, etc.

Based on various available information and data with support and advisory input of DULT, CBD and six other regional centres were identified according to the evaluation criteria. (The details of the identified areas can be found on Appendix-2.) Then, two areas, CBD area and Koramangala area, were shortlisted by further examination and discussions with DULT. The CBD area was then selected

as proposed area for implementation of ERP in Bengaluru after analyses of the results of the surveys in/around these two areas carried out together with DULT and JICA Study Team.

The major viewpoints of analyses for finalising the area are:

- Availability of public transport,
- Profile of land use e.g. residential land use
- Required number of entry point
- Expected affect on before/after pricing period in terms of traffic volume
- Other conditions such as escape routes, alternative routes, and etc.

The conducted surveys include: site reconnaissance, traffic count (1 week day from 8:00 am to 12:00 pm), travel time survey on major routes in and around the area (1 week day for on-peak and off-peak hours). The link counts and junction counts were also carried out along bypass routes to find out the locations of entry point for charging.

(b) Proposed Area for Congestion Pricing in Bengaluru: CBD

It can be judged that CBD is better candidate than Koramangala because of the presence of a more attractive public transport system. Within the CBD, there is a large bus terminal and future Namma metro rail stations, four of which are under construction. These make the restricted area very accessible to travel using public transport. According to the studies by Bengaluru metro, the number of passenger trips from different origins ending in CBD as a destination is 10,481 for one morning peak hour. About 25% of the land is estimated government offices and a small percentage of residential areas in the CBD area. As to Koramangala, it is more residential in nature and the public transport is not as extensive as in the CBD. The traffic conditions in Koramangala during pre-restricted period are expected to impose more problems than in the CBD. Further, more minor escape roads exist and 34 entry points for charging will be required in Koramangala whereas 18 entry points in CBD area. Therefore, CBD is the preferred option for area pricing.

(c) Boundary and Entry Point of CBD for Congestion Pricing

The proposed area of CBD is 2 sq km with 18 entry points for inbound traffic control. The boundary is chosen to exclude residential and recreational areas as many as possible and to prevent some of the bypass routes (for the vehicles wishing to avoid the restrictions) coming under restrictions which is not desirable. If the boundary is drawn to exclude much of the residential and recreational area and include administrative and some commercial areas, the area to be controlled becomes about 2 sq km.

CTTS (2010) recommends the Electronic Road Pricing (ERP) for the CBD cordon around Vidhana Soudha for a radius of 5 km. This will make the area larger. If a radius of 5 km is drawn, the restricted

area will include many residential areas, temples, mosques and churches, all of which are not large attractors of traffic during the peak periods. Including them will have negative consequences. Extending the area will result in some of the bypass routes coming under restrictions, which is undesirable because it is good to leave them for the vehicles not wishing to enter the restricted area to use.

It is a smaller area when compared to the charged areas implemented in Singapore, London and Stockholm. However as mentioned above, there are limitations in expanding the area. But the experience is that when an area charging is introduced, there are also improvements to traffic on the roads leading to it.

Based on the consideration above, CBD area of around 2 sq km is proposed for implementation of congestion pricing. The proposed are of CBD and entry points are shown in the figure below.

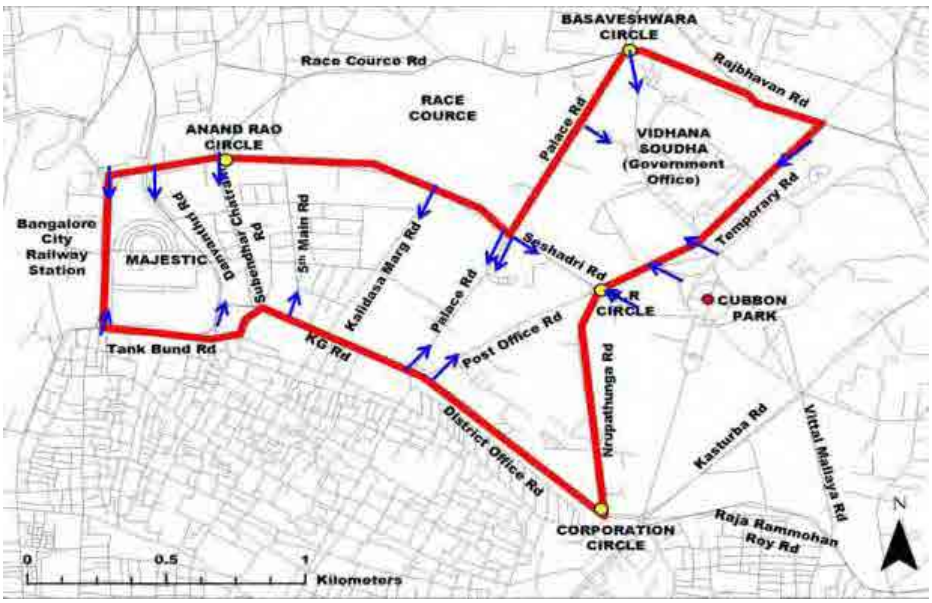


Figure 2.97 Boundary of CBD Area Charging and Entry Points

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

(7) Vehicles to be Included for Pricing

It is proposed to charge all motor vehicles except public transport buses and emergency vehicles. Table 2.50 explains the proposed pricing scheme for different vehicle type.

Table 2.50 Reasons for Congestion Pricing Based on Vehicle Type

Type of Vehicle	Reasons for Pricing	Reasons for Exemption	Remark
Car	Uses road space. Large numbers of users and steadily growing	None	Include
Motorcycle (Two Wheeler)	Uses road space. Largest numbers on the road. Exemption may lead to greater numbers, especially if cars are charged	Contributes much less to congestion. Easy for them to avoid paying	Include
Goods Vehicle	Uses road space. Can schedule and avoid peak hours to move	Will recover the charge from the clients that they serve	Include
Bus	Uses road space. The charge per passenger will be small as compared to a car which has a smaller occupancy	Efficient user of roads during peak hours, hence merit special consideration	Exempt city buses. But include interstate, intercity and private buses
Taxi/ Autorickshaw (or Auto)	Uses road space and the passenger should pay the charge	Taxis/Autos unlikely to cruise empty into a charged area/road and hence shortage could be expected	Passenger may pay. Autorickshaw may get reduction.
Residents within controlled area	Uses road space. May be able to schedule trips to avoid paying	Have no say in the choice of the controlled area	They will only be affected if they leave and return during the restricted period
Out of Karnataka registered	Uses road space. Numbers may be small	Difficult to administer charging unless there are methods	Include
Government and military vehicles	Uses road space. No reason to exempt. Will prevent indiscriminate use and encourage officials to seek better transport alternatives during the peak periods	Charges can be considered as paying from the right pocket to the left pocket	Include
Emergency vehicles	Uses road space. Numbers are small.	Merit special consideration because of the nature of their services	Exempt
Diplomatic cars	Uses road space. Numbers are small.	To follow protocol	Exempt

(Source: JICA Study Team)

(8) Pricing Concept

It is important to decide a proper first time rate for congesting pricing. If it is set too high, many motorists will avoid the area/road resulting in underutilisation of the road network that has been built at high cost. If it is set too low, the number of vehicles avoiding the area/road will be small resulting in no traffic flow improvements and the accusation that the charges are levied to collect money from motorists.

A proper way to assign the charges to vehicles is to use Passenger Car Unit (PCU). PCU describes the dynamic effect of the various types of vehicles in a moving traffic stream.

PCU values defined by Indian Road Congress (IRC) are shown in Table 2.51.

Table 2.51 Passenger Car Unit (PCU) Defined by Indian Road Congress (IRC)

Vehicle Class	Passenger Car Unit (PCU)
Car/taxi	1
Pickup van	1
Motorcycle	0.5
Light goods vehicle	1.4
Heavy goods vehicle	2.2.
Bus	2.2
Trailer	4
Auto-rickshaw	1.2 (*)

(Source: Indian Road Congress)

Note (*): The value of 0.5, instead of 1.2, for auto-rickshaw will be used for ERP based on the advice of DULT.

In consideration of above, two options of pricing concept are considered for Bengaluru.

Option 1: Fix a price for charging car and apply to other vehicles based on PCU used by IRC as shown in the table above.

Option 2: In Bengaluru, a large number of motorcycles (two-wheelers) contribute to the congestion. Considering this local traffic condition, it would be appropriate to use the two-wheeler to set the congestion pricing. In this case, the price is set for the two-wheeler and applied to other vehicles based on PCU as shown in the table above.

(9) Proposed Charging Time of Congestion Pricing

Most central business districts (or regional centers) and main roads experience two peak periods – one in the morning caused by the journey to work and one in the evening caused by the journey back home. The duration of the peak periods depends on the intensity of activities. In between the two peak periods, there is a off-peak period, which may also exhibit slightly higher traffic usage during the lunchtime.

The government has a duty to ensure that people get to work in time. Therefore the morning peak period charging is essential. It can be argued that the economic value of time is highest during the morning peak. It is often erroneously assumed that the morning charging will result in a mirror image effect in the evening i.e. if the morning charging improves traffic condition as a result of reduced traffic, there would be corresponding reduction of traffic flow in the evening, which is not always true.

Based on the traffic volume surveys conducted, it is observed that the peak traffic time for CBD area is from 10:00 am to 12:00 noon. Initially, collecting the congestion charge for two hours from 10:00 am to 12:00 noon is recommended.

For a start, it is advised to fix the hours of charging to the morning peak hours and later extend it, e.g. evening peak hour etc, as more experience is gained and the monitoring system gives a better idea of shifts in traffic movements.

(10) Inbound Traffic Volume in CBD

(a) Current Inbound Traffic Volume in CBD

The inbound traffic volume by vehicle type during morning peak hours, identified by the traffic surveys, is shown in the table below.

Table 2.52 Inbound Traffic Volume in Number by Vehicle Type during Morning Peak Hours

Time (AM)	Two-W	Auto (*)	Car	Bus	Pick up Van	LGV (*)	HGV(*)	Total
10:00 - 11:00	26,047	8,183	7,278	1,296	140	390	24	43,358
11:00 - 12:00	24,322	8,450	6,718	1,015	101	431	44	41,081

(Source: JICA Study Team)

Note (*) Auto: Auto-rickshaw, LGV: Light Goods Vehicle, HGV: Heavy Goods Vehicle

Table 2.53 Inbound Traffic Volume in PCU by Vehicle Type during Morning Peak Hours

Time (AM)	Two-W	Auto (*)	Car	Bus	Pick up Van	LGV (*)	HGV(*)	Total
10:00 - 11:00	13,024	4,092	7,278	2,851	140	546	53	27,983
11:00 - 12:00	12,161	4,225	6,718	2,233	101	603	97	26,138

(Source: JICA Study Team)

Note (*) Auto: Auto-rickshaw, LGV: Light Goods Vehicle, HGV: Heavy Goods Vehicle

(b) Estimated Traffic Volume during Charging Period

It has to be noted that it is difficult to estimate the reduction of the inbound traffic volume to the charging area affected by charging. For example, some regular commuters of two-wheeler may judge that the charged amount is good reason to opt bus which may be cheaper for them to commute. Others such as those who occasionally travel the charged area for such purpose as business may consider that the charged amount is not sufficient reason for them to abandon their trip. Detail opinion survey and motorist profile survey may provide some input for estimation. However the experiences in Singapore and other cities tell that the reduction percentage has always been based on operation of congestion pricing and not on theory. Therefore, the estimated reduction of the inbound traffic volume for this study was drawn for the purpose of study by referring to the experiences of these cities and discussion with the counterpart agency, DULT.

Singapore experienced 16% reduction of the inbound traffic volume during the charging time, Stockholm 20% and London 30%. Taking cues from these and through discussion with DULT, the expected reduction of the inbound traffic volume is assumed approximately 20% for the study as shown in the table below.

The current average traffic speed in CBD area during morning peak hours is 18.6 km/hr as measured by the survey on the important roads in the area. This falls into the Level of Service F i.e. stop-go conditions at some times which is below the critical speed of 24 km/hr. If the congestion pricing is

imposed and the reduction in 20% of traffic volume is maintained, it could be assumed that the traffic situation on a typical main road would improve from the Level of Service F to a level with better speeds and leads avoidance of stop-go conditions.

Table 2.54 Expected Inbound Traffic Volume in Number with 20% Reduction

Time (AM)	Two-W	Auto (*)	Car	Bus	Pick up Van	LGV (*)	HGV(*)	Total
10:00 - 11:00	19,536	7,774	5,458	1,296	140	371	22	34,597
11:00 - 12:00	18,242	8,028	5,039	1,015	101	409	42	32,876

(Source: JICA Study Team)

Note (*) Auto: Auto-rickshaw, LGV: Light Goods Vehicle, HGV: Heavy Goods Vehicle

Table 2.55 Expected Inbound Traffic Volume in PCU with 20% Reduction

Time (AM)	Two-W	Auto (*)	Car	Bus	Pick up Van	LGV (*)	HGV(*)	Total
10:00 - 11:00	9,768	3,887	5,458	2,851	140	519	48	22,672
11:00 - 12:00	9,121	4,014	5,039	2,233	101	573	92	21,173

(Source: JICA Study Team)

Note (*) Auto: Auto-rickshaw, LGV: Light Goods Vehicle, HGV: Heavy Goods Vehicle

(11) Expected Daily Income

Based on the assumptions so far, the expected daily income is estimated as shown in Table 2.56. The estimation shown in Table 2.56 is made for the purpose of ground understanding of revenue for Indian authorities after the discussions with DULT.

The congestion prices are set according to the pricing concept presented in the previous clause as follows:

- Option1: Set INR 100 on car and applied to other vehicles
- Option:2 Set INR 30 on motorcycle and applied to other vehicles

Table 2.56 Expected Daily Income (INR) with 20% Reduction in Inbound Traffic Volume

Class of vehicle	Estimated Traffic Volume			PCE Rate	Option1 (Base:Car/Taxi=100)		Option2(Base:Motorcycle=30)	
	10:00-11:00	11:00-12:00	Subtotal	(as per IRC)	Price(Rs)	Income(Rs)	Price(Rs)	Income(Rs)
Car/taxi	5,458	5039	10,497	1	***100***	10,49,700	60	6,29,820
Pick up van	140	101	241	1	100	24,100	60	14,460
Motorcycle	19,536	18242	37,778	0.5	50	18,88,900	***30***	11,33,340
Light goods vehicle	371	409	780	1.4	140	1,09,200	84	65,520
Heavy goods vehicle	22	42	64	2.2	220	14,080	132	8,448
Bus	1,296	1015	2,311	2.2	0	0	0	0
Trailer	0	0	0	4	0	0	0	0
Auto-rickshaw	7,774	8028	15,802	0.5	50	7,90,100	30	4,74,060
Total	**34,597**	**32,876**	**67,473**			**38,76,080**		**23,25,648**

(Source: JICA Study Team)

It is noted that the optimum congestion prices are supposed to be occasionally adjusted to maintain favourable traffic flow by monitoring traffic on a regular basis. The above estimation was made for the study purpose.

(12) Technology for Electronic Road Pricing

This clause reviews available technologies for ERP and makes recommendation for ERP in Bengaluru.

(a) Available Technologies for ERP

1) Direct Short Range Communication (DSRC)

Direct Short Range Communications (DSRC) using pre-paid card with powered OBU has an internal power source like a battery to work on the internal electronics and broadcast a signal to the reader/antenna mounted on the overhead gantry continuously.

The ERP charge is debited from the On-Board Unit (OBU) installed in the vehicle or the pre-paid card inserted into the OBU at the front-end (ERP overhead gantry control point) on a real-time basis when the vehicle passes under the overhead gantry at the control point. No backend prepaid account or monthly billing is necessary.

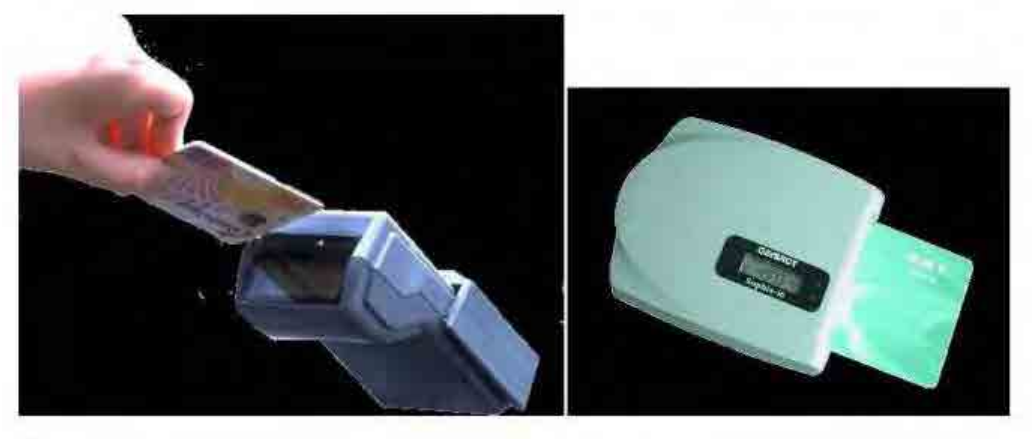


Figure 2.98 Active OBU and cash card

(Source: MSI Global)

Advantages of this system are:

- The driver knows the balance of money in the cash card (or the OBU in case of e money) for making subsequent trips;
- He knows that the debiting is successful or not when he passes under the gantry after hearing a confirmation “beep” sound of a deduction of the charge from the OBU;
- He is made aware that he has to pay for the price of using the road. i.e. the pain of paying helps him to make informed choices of travel.

Singapore uses the active ERP system for ERP since 1998 but deploying DSRC 2.45 GHz (Not 5.8 GHz) non-powered OBU.

2) Automatic Number plate Recognition (ANPR)

The method used in this system is simple: photographs of the license plates of all vehicles passing under the ERP gantry or of all vehicles moving around along the charged road or in the area are captured by cameras (or video footage) at selected locations and sent to the back office for further processing. Payment by drivers is either by monthly billing (post-paid) deduction from an account created with the ERP authority (pre-paid) at the back office or by an advance payment scheme (according to the route he wants to take or the areas he wants to enter) before the driver leaves his home. The driver can also be allowed to pay the ERP charge within a fixed period after he uses the controlled areas by SMS, internet etc.

Figure 2.99 ANPR

(Source: MSI Global)

Advantage of this system is that it is cheap and easy to implement. However, there are also disadvantages:

- Difficulty to read the license plates and to extract the license plate numbers from the licence plates because of various reasons: blockage by other vehicles, shadows from the surrounding structure causing uneven lighting on the vehicle license plates, dirt, bad weather, night time. This can lead to higher unsuccessful read rates and heavy human intervention
- There is need a robust and reliable OCR system
- There is a need for a large number of cameras to be installed at the ERP entry points and at other vantage points.
- High maintenance cost of the many camera – which need to be cleaned regularly;
- Backend office work is heavy and operational costs can be high
- A complete and up-to-date computerized vehicle database is important

London and Stockholm use the ANPR system for the ERP operations within its congestion price area. Singapore uses ANPR only for enforcement of violating vehicles.

3) Radio Frequency Identification (RFID)

When drivers apply for these tags, they should be required to fill up particulars of licence plate and particulars of owners and driver. For those who opt for the tags, the database of records of particulars will be captured and updated. The licence plate number will be linked to the tag number. There will be a small deposit for the tag. They will be required to maintain a bank account from which the ERP charges will be deducted as they use it. The other option will be for them to open an account with the ERP Authority and make regular cash top-ups. The backend system will capture all details of all entry of vehicles with tags. Those who are in arrears of payment will be highlighted. One of the problems of systems with accounts is that there will be bad debts and there is a need for a system of recovering bad debts.

Figure.2.100 RFID Tag Installed inside Windshield and on Headlight

(Source: JICA Study Team)

The system only recognizes tags not vehicles and will not pick up vehicles with no tags. This requires enforcement cameras catching violators. There are two ways of capturing the rear licence plates of violators. One way is to capture photos of all vehicles and then to sieve out at the backend those which have valid tags and then send enforcement notices only to the others. The other way is to capture photographs of only vehicles which have no valid tags which needs more sophisticated enforcement camera systems.

Enforcement photos need to be sieved out by an ANPR system. For recognition, it may be necessary so standardise the sizes and locations of number plates.

Advantage of this system is that it is cheap and easy to implement for vehicle users. However, there are also disadvantages:

- Accuracy of RFID communication and identification is not so high (90%), supporting ANPR system is necessary.
- RFID +supported ANPR can be done at the backend office. Back end office work is heavy.
- A complete and up-to-date computerized vehicle database is important

Toll collection system using RFID has many experience all over the world, but not yet used for ERP.

4) Global Navigational Satellite System/Cellular Network (GNSS/CN)

The location of the vehicle is tracked using GNSS receiver installed in the vehicle which transmits the location information to the control centre using Global System Mobile (GSM) or 3G networks for calculation of the charge.

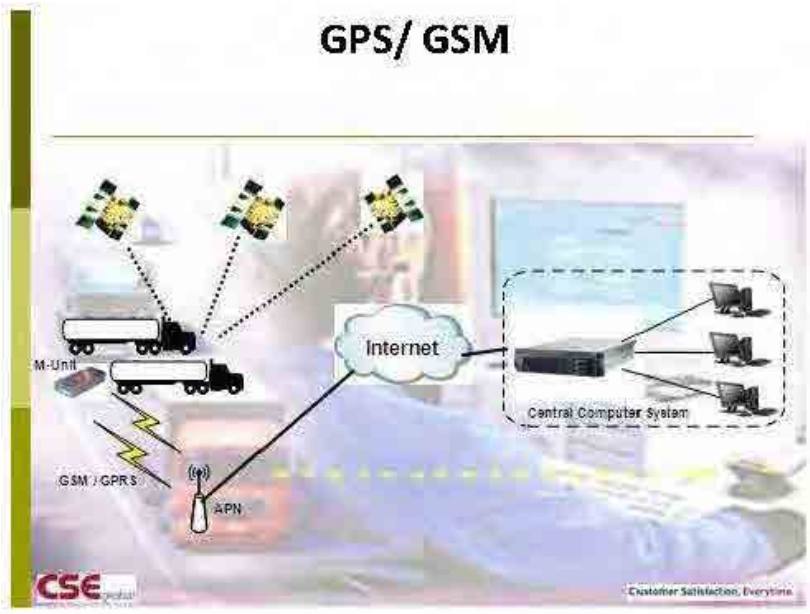


Figure 2.101 GNSS

(Source: CSE)

Such method eliminates the need of overhead ERP gantries across the roads. However, such system performance is subjected to a lot of factors such as the weather conditions, the surroundings (high rise buildings and dense trees), tunnels, shifting of GNSS satellites intentionally or unintentionally, etc.

GNSS/CN is being used in Germany for commercial vehicle tolling across its highways but not for ERP yet

(b) Comparison and Recommendation of ERP Technology

1) Comparison of Technologies

The table below compares the technologies described in the previous clauses.

Table 2.57 Comparison of Technologies

Item	DSRC	ANPR	RFID	GNSS
Accuracy of Identification	• Highest amongst others • But requires support of ANPR system	• Not so high • Requires many cameras • Affected by other vehicles	• Not so high • Accuracy is limited • Requires support of ANPR system	• Lower than others • Affected by weather and building
Easiness to use for motorists	• Not so easy • Requires OBU • Motorists can be notified success/failure of payment by OBU	• Very easy • No facility is required for users	• Easy • Requires RFID tag only	• Not so easy • Requires OBU
Easiness for enforcement	• Easy • Enforcement can be done at gate	• Not so easy • Requires backend system and number plate database	• Not so easy • Requires backend system and support of ANPR system	• Not so easy • Limited accuracy of identification
System Cost	• Backend :low • OBU: relatively high	• Backend: highest amongst others	• Backend: high	• Backend: low • OBU: moderate
World Experience of ERP	• Singapore for ERP	• London and Stockholm for ERP	• Not yet for ERP • Many for toll collection	• Not yet for ERP
Advantage	• Identification and enforcement can be surely done	• No burden to use for users	• Easy to use for users	• Low cost of system
Disadvantage	• Relatively higher cost for users	• Some difficulties to read license plates due to blockage by other vehicles, shadows of surroundings etc. • Necessity of number plate standardisation and database	• Necessity of number plate standardisation and database	• Some burdens of OBU cost for users • Some difficulties of identification due to blockage by other vehicles, shadows of surroundings etc.

(Source: JICA Study Team)

2) Recommendation for ERP in Bengaluru: RFID Technology

RFID technology is recommended for ERP in Bengaluru. A large number of motorcycles (two-wheelers) contribute to the congestion in Bengaluru. Therefore it is very important to control the two-wheelers. This implies in a sense that the system needs to be widely accepted by the motorists including the two-wheelers. According to the table above, ANPR System and RFID system hold advantage in terms of easiness to use for the motorists especially two-wheelers, a majority of whom are lower than middle class, because devices such as OBU are not required.

However for ANPR system, reading the license plate is an issue in the traffic condition of absence of lane-keeping discipline in Bengaluru. Therefore, RFID system is more suitable. It requires the support of ANPR for enforcement. Hence, the issue of reading the license plate still remains. Nonetheless, RFID system with a combination of ANPR for support is considered best for ERP in Bengaluru.

(c) RFID Technology System

1) Legal Aspect

DULT has informed that Bengaluru's Road Traffic Act may have the relevant clauses to deal with the legal aspects and there might not be a need to change the legislation. Nevertheless, ITS Master Plan advises some clues, as follows, so that the Indian authorities can take into consideration when they need. The following clauses in regard of system are considered based on the following conditions.

- Installing RFID Tag on the vehicle may not be necessarily legally compulsory.
- However the road users shall be obliged by the law to pay the charge if they use the road during pricing hours.
- Failure of payment at the time of using the charged road due to such cases as insufficient balance, e.g. zero balance or below charging amount may not necessarily be against the law.
- However if the road users do not make payment within prescribed period, say e.g. one week or 10 days, after issuance of notice for payment, such case shall be against the law.

2) Charging Procedure

The case in Taiwan (RFID for toll road) informs that the accuracy of RFID communication is less than 90%. Thus a support by camera (Automatic Number Plate Recognition/Picture Image) is important.

ID collected from RFID Tag and vehicle number plate are automatically matched for all passing vehicles at the centre. If it is matched and the sufficient balance is confirmed, the charging amount will be deducted from RFID balance database.

If it is judged that the balance is not sufficient or the vehicle does not have RFID Tag, the penalty notice (invoice) shall be issued and sent to the address of the road user. The address data is saved in the number plate database.

Above procedures are automatically done by the system for 90% of the passing vehicle (if takes the figure from the case in Taiwan). A manual confirmation of above is done for the remaining vehicles which cannot be covered automatically by the system, achieving higher accuracy.

3) Other System Technology and Services

The road users will receive SMS from ERP operation centre if the remaining balance in the account is decreasing e.g. less than the prescribed threshold amount.

The road users are able to confirm their remaining balance and charging history for a certain period through their mobile or PC.

The road users are able to top-up their account and also make payment for the noticed amount in case of insufficient balance at the time of passing the charged road at POS, e.g. service centre, convenience stores and etc.

The balance will be deducted from the account two or three days after using the charged road (as a grace date). The road users will be required to top-up within the grace date if the balance is insufficient.

4) System Configuration

An image of RFID system for Bengaluru is depicted below.

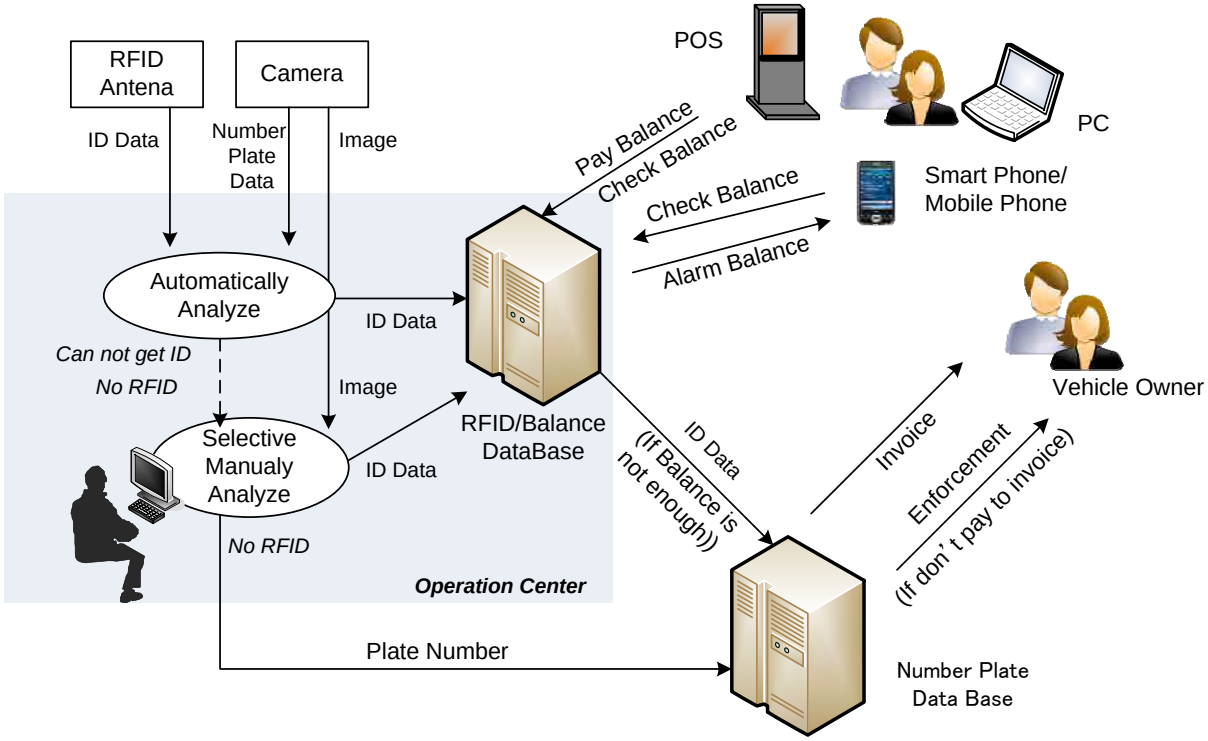


Figure 2.102 Image of RFID ERP System for Bengaluru

(Source: JICA Study Team)

(13) Implementation Scheme

The following three possible schemes of implementing ERP are compared and recommended for Bengaluru:

- Option-1: Implemented only by Government
- Option-2: Implemented by Government with operations contracted out
- Option-3: Implemented by private partner e.g. BOT

The congestion pricing is a sensitive topic. The motorists are not getting any new facility and they are now being asked to pay for the use of an existing facility. Most road users will see it as a ploy to collect revenue because it is applied to the existing roads, as against toll roads which are new. The government has to take the lead and also the complaints on the subject. The opposition that is bound to be generated, by any congestion pricing scheme, is better handled by government as in Option-1 or Option-2. If it is given out as in Option-3, it might be seen as the government letting the private sector makes profits from the existing roads.

The objectives of the private sector and the government for congestion pricing are different. The government wants to cut down road usage; which is probably not what the private sector wants. There may be no takers for Option-3 unless the private company expects to make some profits and this can only be done by way of the ERP charges. So if the revenue falls, there may be pressure from the private company to raise the ERP charges. Further, the government will have no access to the revenue from congestion pricing to improve other transport services in Option-3.

Option-2 is an in-between Option-1 and Option-3. The government contracts out maintenance and operations for a fee. The performance indicators can be specified and some incentives and penalties on the fee imposed for better than expected service and worse than the expected service. Hiring and firing employees which are more onerous in government service can be overcome by contracting out. High turnover of staff is better handled by the contracted party than by the government. The government still does not wash its hands on the project because there is a better oversight on all activities unlike in Option-3.

Therefore, Option-2 is the recommended scheme for congestion pricing for Bengaluru.

(14) Proposed Schedule for ERP

Based on local considerations and discussions with DULT, ERP implementation schedule is prepared as presented below.

Table 2.58 Proposed Implementation Schedule

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

ERP schedule	Phase-1					Phase-2					Phase-3	Remark
	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	
High level Steering Committee												
Study and Plan												
Prepare RFP												
Tender												
Design & Trial test												
System Installation (Full Project)												
Training of Operator												
Distribution of Tag												
Operation					▼	*In*						
Public Relation												
Legislation												

(Source: JICA Study Team)

(15) Other Recommendations

Other recommendations are made for successful implementation of ERP in Bengaluru.

(a) Technical Aspect

The violated vehicles cannot be identified at gate because payment is settled at the centre because of RFID system. Therefore for enforcement, photos of all vehicles including cars and two-wheelers need to be taken at the gate as they pass it. Then the violated vehicles that failed the payment at the gate due to such occasions as no tag or insufficient amount in the account need to be identified by checking the photos manually and a violation notice is sent to the owner. The procedure entails the following difficulties in this case:

- The process will be very tedious and in case of large number of violators, processing cost of violators would exceed the amount of charge and fine collected.
- If collection of charge and fine is not strictly enforced, people tend to ignore the system.
- Taking clear photo of all number plates of 2-wheelers running in group will be very difficult and number plate may not be identified.

Considering above, the following countermeasures are proposed:

- **Camera System:** RFID system will be supported by ANPR (Automatic Number Plate Recognition) for identification of vehicle. Yet as explained earlier, all passing vehicles cannot be automatically covered by the system. Hence, manual confirmation will be done at the centre for the vehicles which are not processed by the system.
- **Roadside Environment:** Improvement of road infrastructure and roadside environment such as intersection, lane marking, removal of roadside activities, and etc. in the vicinity of entry point for pricing is strongly recommended. This may help higher accuracy of system because such arrangements are expected to lead more orderly traffic on the road.
- **Technical Trial:** A trial test to estimate/evaluate the reliability of the system including RFID+Camera identification is recommended.
- **Standardisation:** Acceleration of standardisation of Number Plate and Vehicle Registration Database is recommended.

(b) Organisation Aspect

- **High-Level Steering Committee:** There are many different parties responsible for urban transport in Bengaluru, including DULT, Traffic Police, Bengaluru Development Authority and etc. The High-Level Steering Committee drawn from very senior officials of these organizations, headed by DULT shall be set up first.
- The following major roles shall be appointed;

  a) **Legislation**: Work on legislation for congestion pricing, if required. Enacting legislation is a lengthy process. Hence, it is necessary to embark on this vital activity very early in the process of decision making. For a pilot scheme, there may be other ways to carry out the trials without full legislation.

b) **Technical Committee:** Set up a technical committee to work on technical requirements and implementation

c) **Institutional Arrangement:** Set up an institutional arrangement of an ***implementing group*** and an ***operational group***. It should be noted that the number of staff required to operate the congestion pricing system depends on design of the system; hence this decision on the number of staff required can only be made after award of the contract for implementation.

d) **Special Fund:** Set up a special fund to receive revenue from congestion pricing and dedicate it to build infrastructure for roads/intelligent transport system/public transport

e) **Dialogue with Stakeholder:** Start dialogue with all interested parties and public. The interested parties include motorists' organisation, motor traders' organisations, chambers of commerce, trade unions, grass root organisations, and etc.

f) **Publicity**: Start talking on the possible publicly to help to imprint congestion pricing into the minds of public. The congestion pricing is a scheme that can only be accepted reluctantly due to its nature that the road which could be used freely will be charged. Further, the motorists in Bengaluru are not used to the concept of paying for road usage, although they are familiar with paying toll on National Highway. Thus a public dialogue is important.

(c) Others

- **Alternative Route:** Whilst the congestion pricing may improve traffic flow in the area, the congestion will transfer to outside the area or to another route. The alternative route will be used by those motorists who currently use the roads within the chard area to go from one place to another without having any business in the area itself. Such motorists are unlikely to pay a charge just to go through the roads within the charged area. They will need some fair alternatives. These alternatives may not be as convenient as going through the charged area. Therefore, these routes have to have sufficient capacity to cater for such traffic. The motorists should also be given information on a few alternative routes which could use to avoid the charged area.
- **Adequate Public Transport:** Changing the mode of travel to public transport is a much desired option. The capacity of the public transport system to serve the charged area is a critical factor. It is essential that those who divert to public transport as a result of congestion pricing find places in the buses/metro to get to their destination. Under the situation that metro stations are being constructed in CBD area, the metro project of Phase-1 is suggested to timely complete. In addition, improvement of quality of bus service in comfort, reliability and numbers will serve better alternatives for motorists affected by congestion pricing.
- **Feedback of Public:** It is likely that Bengaluru authorities will get adverse feedback from public. All feedback has to be carefully considered and dealt with in a satisfactory manner. For this, the assistance of a public relations firm is recommended.
- **Regular Monitoring on Effect of Congestion Pricing:** The effect of congestion pricing shall be regularly monitored and accordingly the charging price be adjusted. In Singapore, monitoring is done at 3 monthly intervals and appropriate rate of charging is accordingly adjusted. The interval could be longer for Bengaluru. However, the monitoring shall include such items as traffic counts, travel speeds, conditions on adjacent roads, violations, errors, revenue/costs, system availability, interviews with motorists and etc.
- **Total Package of Measures for Urban Transport:** The congestion pricing does not solve the traffic problem by itself. It is one component of a total package of urban transport measure which

includes transport planning, road construction, traffic management, continual improvement and upgrading of public transport and intelligent transport systems nowadays. Assurance shall be given that the government will not depend solely on congestion pricing for solving traffic problems. Thus, it is important to keep a close scrutiny of the progress on alternative measures so that the oversight ensures that the total package concept is strictly followed.

More details of recommendations can be found on Appendix-2.

2.3.5 Common Smartcard

(1) Purpose

Since Bengaluru is experiencing rapid growth of vehicles, immediate measures to encourage users to shift from private vehicles to public transport are required. Of these, minimizing barriers connecting different transport modes can generate strong incentives to users because convenience increases. Therefore, introducing inter-modal fare payment system across transport operators is expected to be an effective measure to mitigate traffic congestion.

In many countries, dissemination of smartcards, also known as IC (Integrated Circuit) card, is rapidly increasing and replacing magnetic card in various fields such as finance, retail, medical, education, transportation etc. The advantages of using smartcards include the following:

- Higher security
  - ✓ Safe independent data storage on one single card
  - ✓ Protection against duplicating or disrupting of information stored on the chip
- Higher durability
  - ✓ Long life span of up to 500,000 read/writes before failure
- Faster transaction
- Larger memory to handle a large volume of transactions

Using smart cards as common card for inter-modal fare payment across different transportation systems will enable increased comfort and convenience for users. Because a common smartcard makes it easy to travel on trains and buses by touching the card on the reader at the ticket gate or on board buses. Therefore, smartcard is used as a common card all over the world. In addition to the advantages mentioned above, the following are reasons why common smartcard is convenient to use:

- Fast payment processing at entry/exit gate of transportation modes
- Sufficient memory for saving inter-modal travel records
- Avoiding the necessity of carrying coins for passengers
- Allowing flexible payment such as discounts
- Possible to change from zoning or fixed fare collection to distance-based fare collection
- Possible to transfer modes without cash preparation
- Avoiding waiting in queues for purchasing ticket

Furthermore, it helps transport operators to minimize the leakage of fare collection and reduce the amount of back office processing and cash handling.

(2) Smartcard Use for Transportation in Bengaluru

(a) Current Status of Use of Smartcard Use

Presently, the common smartcard which can be used across different transport and services is not available in Bengaluru.

There are two public transport operators in Bengaluru, Metro rail and City bus.

- ✓ The Metro rail is operated by Bangalore Metro Rail Limited (BMRCL) and phase I of the project is now under implementation.
- ✓ Bangalore Metro Transport Corporation (BMTC) is operating around 6,700 buses inside the city.

BMRCL and BMTC either introduced or planning to introduce smartcard for their fare payment system based on different smartcard schemes. These smartcards can be used only on their terminal systems. That means, metro smartcards can only be used on metro rail terminals and BMTC smartcards can only be used on city bus terminals. Therefore, adding of new operators and new agencies for use of smartcard system by using the smartcards of BMRCL and BMTC is not possible. Therefore, to realise a smartcard system that can be used on existing operators and add new operators and agencies and use for parking, ITS master plan proposed a common smartcard system.

1) Bangalore Metro Rail Limited (BMRCL)

The fare collection system implemented by Metro train consists of two elements: sale of tokens and use of smartcards. Passengers can select to purchase either token or smartcard. Initial price of smartcard is INR 100 including INR 50 fare and it can be recharged (top-up) with value at stations and specific bank ATM machines. Smart card users get around 15% discount on token price. BMRCL contracted with Samsung as the vendor of the automatic fare collection system including supplying smartcard. The card framework is based on the proprietary protocol Mifare DESFire V which is a Type A card based on ISO 14443 architecture.

BMRCL also has an arrangement with banks like State Bank of India and Federal Bank to issue “Combo cards”, which can be used as travel card on Metro and also as Bank Debit card..

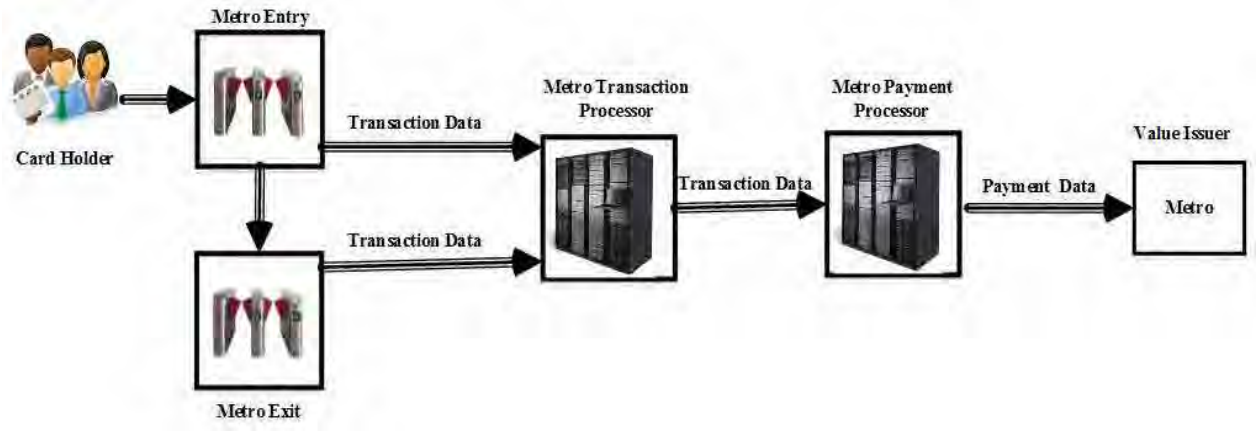


Figure 2.103 Smartcard Use for Metro Rail Payment

(Source: JICA Study Team)

2) Bangalore Metro Transport Corporation (BMTC)

The city bus operator, BMTC, is also planning to introduce automatic fare collection system and their own smartcard. BMTC contracted with AXIS Bank, a financial institution, as a concessionaire for implementation of automatic fare collection system utilising smartcards. This smartcard will be prepared, based on the framework that is developed by NPCI5, which is a public agency controlled by Indian central bank. NPCI claims that the smartcard framework developed by them is for interoperable card system. NPCI developed standard framework based on ISO 14443, EMV6 and NFC7 standards.

[5] NPCI – National Payment Corporation of India (NPCI) is a public agency controlled by the Indian central bank called “Reserve Bank of India (RBI)”. NPCI is responsible for developing all fare payment frameworks, policies and settlement procedures between various public sector and private banks in the country

[6] EMV - EMV stands for Europay, MasterCard and Visa, a global standard for inter-operation of integrated circuit cards (IC cards or "chip cards") and IC card capable point of sale (POS) terminals and automated teller machines (ATMs), for authenticating credit and debit card transactions.

[7] NFC : NFC stands for Near field communication, which is a set of standards for smart phones, smartcard and similar devices to establish radio communication with each other by touching them together or bringing them into proximity, usually no more than a few inches

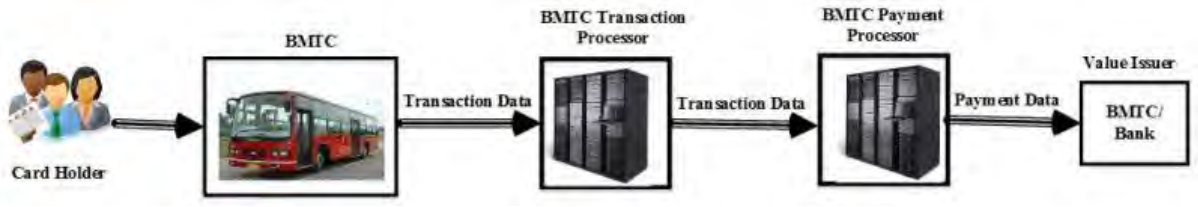


Figure 2.104 Smartcard Use In City Bus (BMTC) Fare Payment – In Planning

(Source: JICA Study Team)

3) Current Status of Ticketing Systems of BMRCL and BMTC

Table 2.59 shows current status of ticketing systems of BMRCL and BMTC.

Table 2.59 Current Status of Ticketing Systems of BMRCL and BMTC

Item	Metro Rail (BMRCL)	City Bus (BMTC)
Ticket Product	• Single Journey Ticket (Token) • Monthly Pass (Smartcard) • Prepaid Card (Smartcard)	• Single Journey Ticket (Paper) • Daily Pass (Paper) • Monthly Pass (Paper)
Smartcard Type	• Mifare DESFire • ISO 14443 Type A • Memory Size is 4 Kb	Planning to introduce based on NPCI developed framework published during October 2014
Smartcard Format	Proprietary	NPCI Framework
Vendor	Samsung	Trimax
Card Issuer	BMRCL, Banks	Axis Bank
Value Issuer	BMRCL, Banks	Axis Bank

(Source: JICA Study Team)

Note:

a. Although NPCI stated that the framework developed by them support interoperable smartcard development, the feasibility of such possibility need to be checked by implementing a pilot scheme.

b. The proposed scheme in the ITS Master Plan for the introduction of common card in Bengaluru is based on the assumption that NPCI developed framework will be feasible and accepted in the country as a common framework for introduction of all smart card schemes in transportation sector across various agencies.

(3) Requirement of Common Smartcard Scheme

1) Common Card for Automatic Fare Payment System

Bengaluru is planning to introduce a variety of public transport systems in the future besides metro and bus such as LRT, BRT and Monorail. Smartcard payment system is planned by PRR for both Touch & Go lane and ETC lane. In this scenario, introduction of a common card which enables users to travel with single card for all transport system would be a benefit to all users. For example, if user holds a common card, he/she can avoid waiting queue for purchasing ticket and he does not need to pay cash for any transportation system. In addition, the transport operators and PRR operator will be free to consider increasing ticket gate or toll booth since processing capacity of utilizing common card will be much higher than manual payment.

In addition to the public transport and PRR, common card scheme should be considered to cover many other city services such as parking, bicycle sharing, retail shops, etc.

So for the development of automatic payment systems and introduction of inter-modal smartcards for various transport and other services, it is necessary to prepare a common card system. The terminals which are available to use common card will be installed at usage points. Contract of installing common card terminal systems will not be tied up with a specific vendor for technical compatibility reasons but will be supplied by various vendors that introduce the system based on common standard protocols.

2) Different Agencies Involved in Common Card Scheme

Primary agencies involved in a common card scheme are explained below.

i) Transport Operator or Merchant

Transport operators include bus operator or Metro train operator or any other operator which has agreed to accept single smartcard payment as a transport fare across all operators. Merchants include a kiosk or a retail shop which has also agreed to accept single smartcard payment for purchasing goods.

ii) Card Issuer

Card issuer issues smartcards to users. The card issuer is sometimes the transport operator or bank. In case of metro, BMRCL is the card issuer. In case of city bus, it is proposed by BMTC that Axis Bank will be the Card Issuer.

iii) Value Issuer

Value issuer adds e-money value and manages the value balance on the smartcard. In many cases, the card issuer and value issuer is same organization. In case of metro, BMRCL is the card issuer. In case of city bus, it is proposed by BMTC that Axis Bank will be the Value Issuer.

Transport operator or Merchant, Card Issuer and Value Issuer are called alliance members of common card scheme.

3) Common Card Transaction Settlement Methods

The amount spent in common card by the transaction across different operators/merchants will be settled amongst operators/merchants. There exists two types of settlement methods and are as explained below.

i) Peer to Peer Settlement Method

Under this method, the operators will have peer relations and transfer transaction data to one another. In principle, each amount will be settled between two operators. The advantage of this method is that it is relatively easy to start because it is a simple system. However, the transaction data flow and procedures for settlement become complicated when many participants get involved. In case of multiple participants, clearinghouse should be established to settle transactions amongst the participants.

ii) Clearing House Settlement Method

Under this method, all transaction details are transmitted to a clearinghouse for settling the amount in accordance with fare for all alliance members. The data flow and settlement procedures are much simpler than the case of peer to peer settlement. But establishing the clearinghouse requires specific efforts in the initial stage such as formulating management committee, gaining various agreements amongst participants, etc.

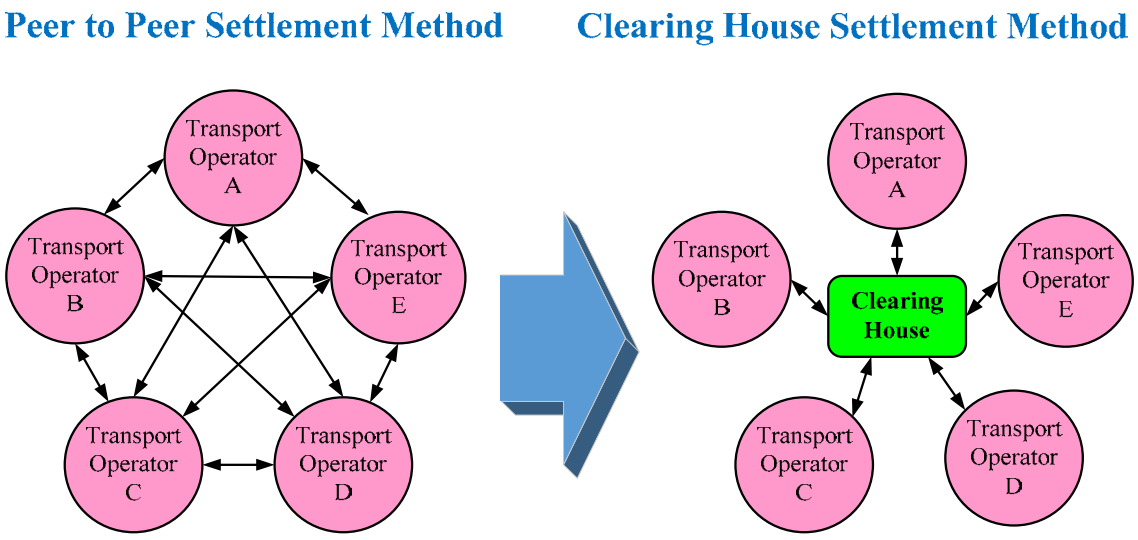


Figure 2.105 Types of Clearinghouse

(Source: JICA Study Team)

(4) Establishment of Clearinghouse

The clearinghouse settles the amount incurred in common smartcard by the transaction across different operators/merchants amongst alliance members. Clearing house is the agency which collects the whole transaction status by gathering all transaction data from all alliance members.

Clearing house receives a clearinghouse fee as a commission fee for settlement work from transport operator and value issuer. In other words, the clearinghouse stands between transport operator and issuers in order to execute necessary work for settlement amongst alliance members. The roles of clearinghouse are as follows:

- Gather fare payment data from transport operators
- Calculate fare transaction amount to be settled amongst alliance members
- Send fare payment transaction data and amount to transport operator and value issuer
- Receive commission fee from transport operators and value issuer.

Figure 2.106 provides a general view of the clearing house involved with various agencies.

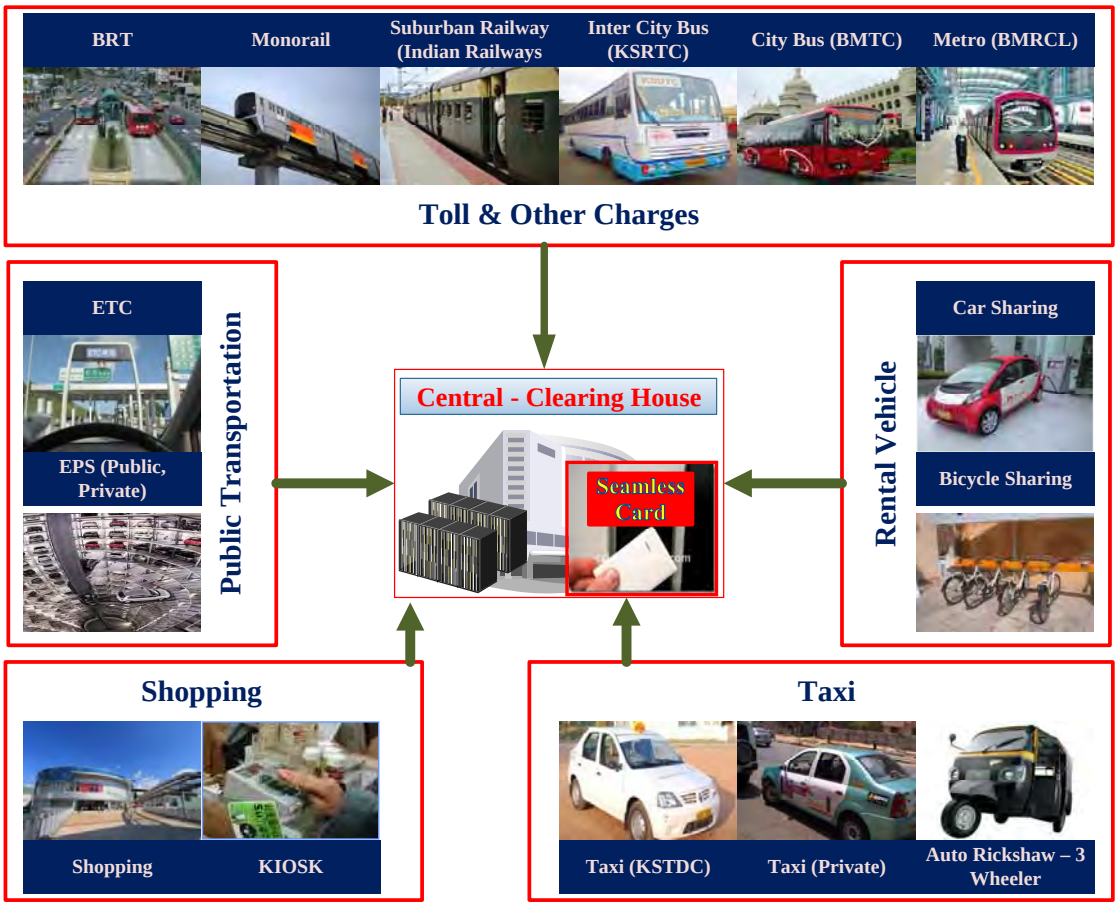


Figure 2.106 Central Clearinghouse

(Source: JICA Study Team)

Steps involved in the establishment of clearing house are as mentioned below.

- Forming Management Committee: stakeholder committee to decide policy, business rules and other measures for the establishment of clearinghouse
- Preparation of Business Model - Clearinghouse Establishment

(a) Forming Management Committee

Interoperability and sustainability need to be assured for the common smartcard across different transport operators. However, many issues need to be coordinated and agreed amongst participants involved in common smartcard system. Therefore, the initial step is to form a management committee with participants as members. Committee members are bound by agreement to follow its rules. Examples of agreement items to be agreed amongst participants are the following:

- Obligations of each participant
- Technology requirements
- Transaction processing timing
- Transaction data
- Test acceptance criteria
- Rule changing procedure
- Confidentiality
- Rules for acceptance of newcomers

The management committee will function as the decision making body for issues amongst participants (committee members) such as formulating policy framework, developing strategies, and deciding rules. The major roles of the management committee are:

- To formulate business rules and regulations under which interoperability is assured
- To determine specification and security policy in line with the framework of common smartcard
- To prepare a roll out schedule for establishing the clearinghouse
- To make operation and maintenance plan of clearinghouse
- To define data format for transactions
- To determine tariff for transfer amongst different transport operators such as metro, bus, parking, toll road, etc.
- To determine criteria for acceptance of new members to join such as value issuers, card issuers, acquirers, transport operators, retailers, etc.

It is recommended that the committee be formed in an early stage. In case of Bengaluru, it is recommended that the committee be initiated by DULT which is responsible for planning public transport across the state, because clearinghouse should cover the whole state to fully enhance traveller convenience.

1) Preparation of Business Model – Clearinghouse Establishment

Planning and implementation of clearinghouse system is a complex process since clearinghouse has to deal with large amount of transaction data and e-money amongst various participants. Therefore, business model of clearinghouse shall ensure high reliability for all participants. In addition, clearinghouse will require support from government, since major transport operators are belonging to government.

Two possible schemes of establishment of clearing house are explained below.

Scheme A

Scheme A is based on the consideration that all transaction data pass through a central clearinghouse. In this scheme, the central clearinghouse will receive all transaction data from operators and is responsible for performing settlement amongst the operators.

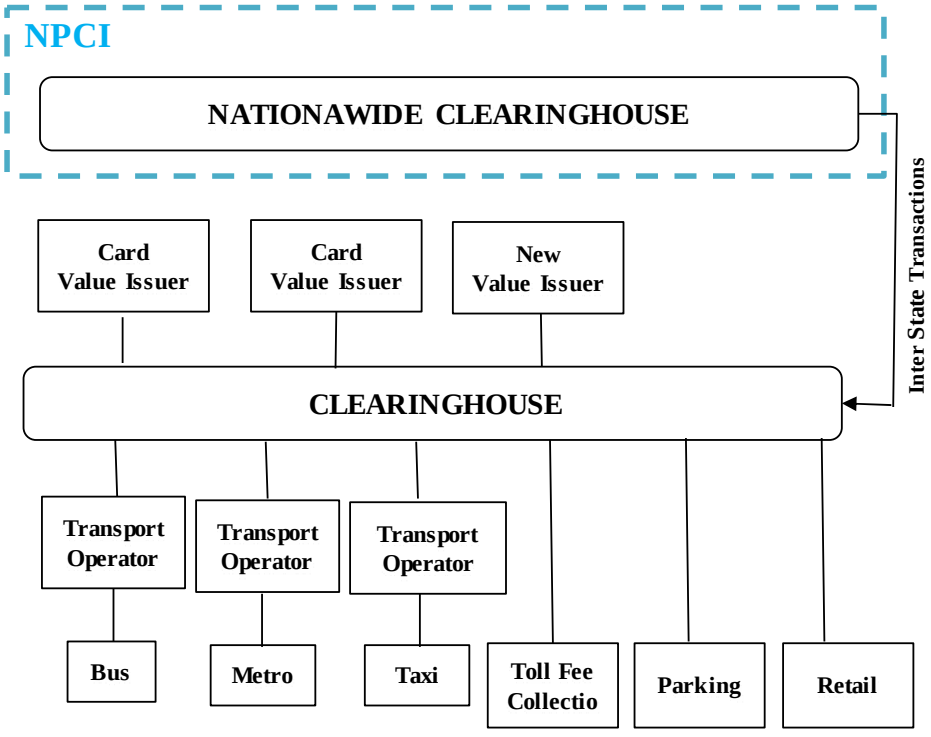


Figure 2.107 Central Clearinghouse: Scheme A

(Source: JICA Study Team)

Scheme B

Scheme B is a combined method of peer to peer settlement method, explained in the section above and a central clearing house. It is different from Scheme A in the way that the transaction settlement is handled by operators and also by clearing house. The transaction settlement method is explained below.

- The transactions of the same operator will be settled internally and will not be transmitted to the clearinghouse. For example, if the common smartcard issued by BMRCL is used on metro, then such transaction will be settled within BMRCL and transaction data is not transmitted to clearing house.
- Only the transaction details that require transfer of amount to other operators will be transmitted to the clearinghouse. For example, if the common smartcard issued by BMRCL is used on BMTC bus, then such transaction data will be transmitted by BMTC to clearing house. The clearing house is responsible to perform the settlement procedure between BMRCL and BMTC in this case.

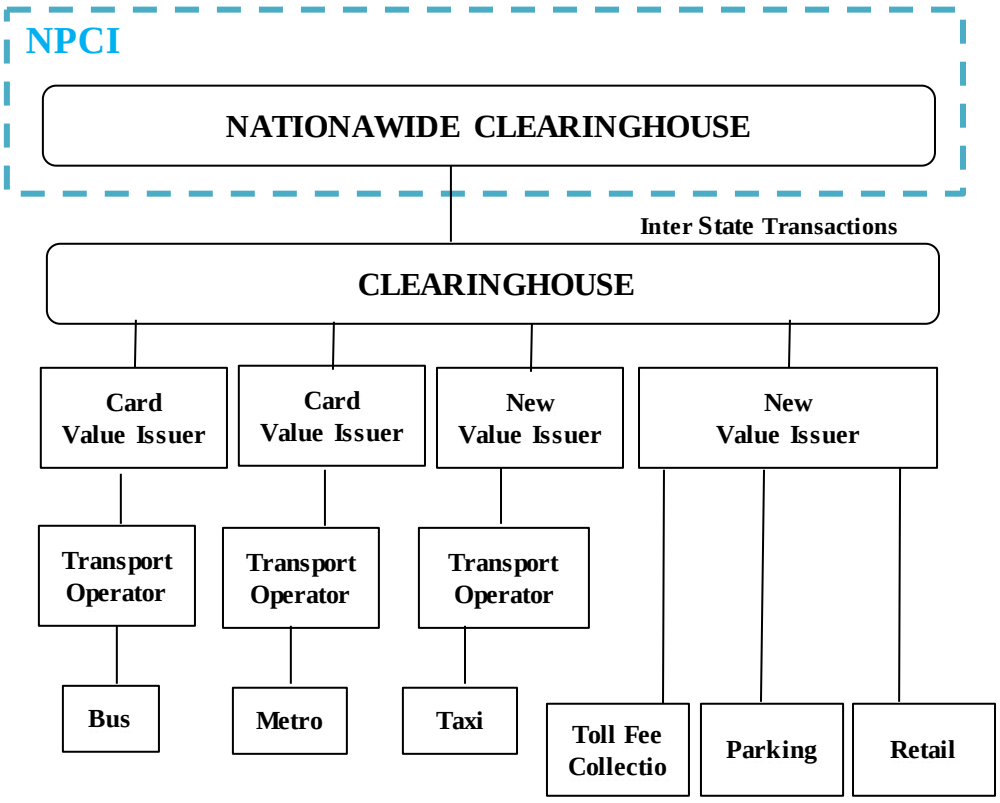


Figure 2.108 Central Clearinghouse: Scheme B

(Source: JICA Study Team)

(5) Best Practices in the World

In the world, some clearinghouses were established with government involved but some were established by private companies. This section reviews organizational structure and operation methodology of other major clearinghouses in the world. Based on review of world practice from Singapore, Hong Kong and Japan, proposal for Bengaluru clearinghouse will be considered in the latter part of this chapter.

(a) Singapore

Land Transport Authority (LTA) of Singapore launched the EZ-Link interoperable card system (common smartcard) in 2002 and issued more than 10 million cards since then. Every day approximately 8 million transactions are dealt with by the system, primarily for public transport fare payment. Since 2008, EZ-Link cards have been designed under a published standard for contactless payment technology for the entire country. Presently, both contact and contactless cards are being used and on-board unit for ERP (Electronic Road Pricing) and EPS (Electronic Parking System) supports both types of cards.

The Figure 2.109 shows the value flow in case of smartcard transactions in Singapore.

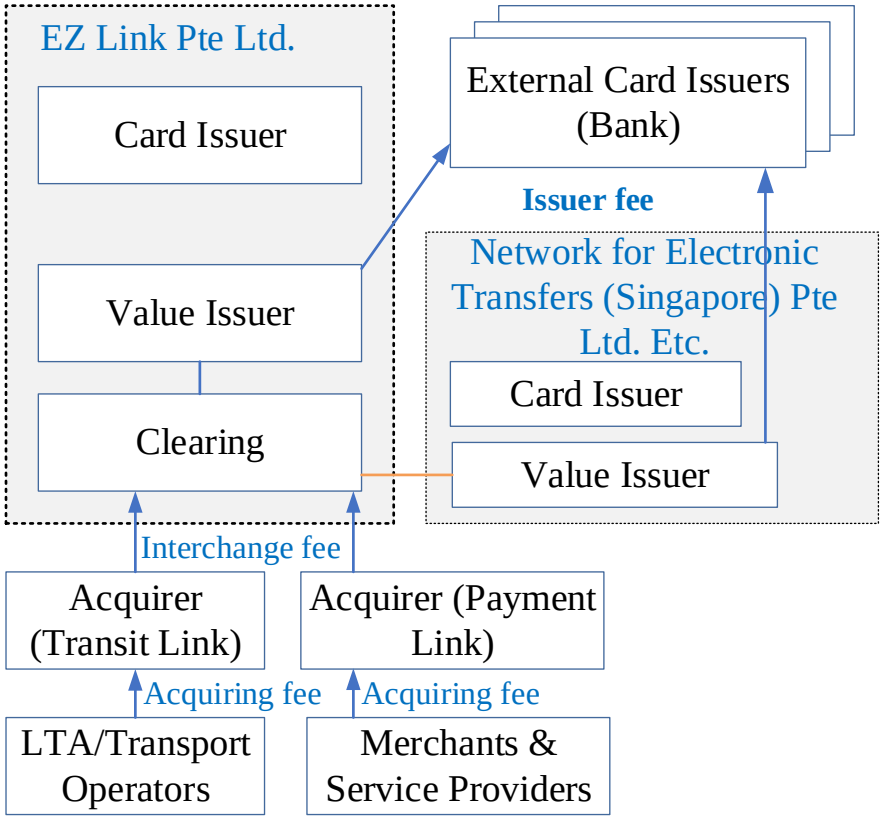


Figure 2.109 Common Card System: Singapore

(Source: JICA Study Team)

In Singapore, EZ-Link Pte Ltd, which is a subsidiary of LTA, is operating as clearinghouse, value issuer, card issuer and EZ-Link is regulated by the monetary authority of Singapore and the public Transport Council. Co-branded card, also issued in Singapore in association with banks, is being performed as same as EZ Link card. There are two acquirers in Singapore: Transit Link and Payment Link. Transit Link is a government subsidiary and performs work for transport operators. Payment Link is a private company but it has an agreement with LTA as a partner and performs work for non-transport sectors such as retail shops.

(b) Hong Kong

The common smartcards in Hong Kong are called "Octopus". It is a contactless smartcard system jointly developed by major public transport operators and launched in September 1997. Octopus cards are also available for non-transport transactions at supermarkets, convenience stores, fast food shops, vending machines, pay phones, etc. Today, over 25 million cards are in circulation and the number of daily transactions is over 12 million.

Figure 2.110 shows value flow of smartcard transactions in Hong Kong for Octopus card.

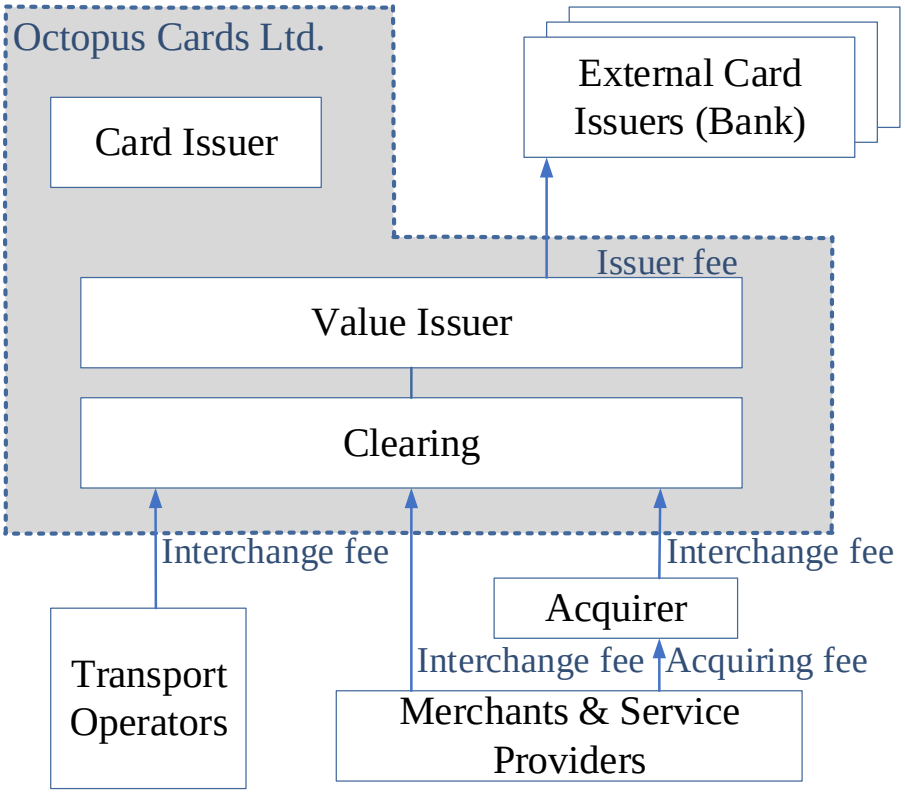


Figure 2.110 Common Card System: Hong Kong

(Source: JICA Study Team)

In Hong Kong, Octopus Holding Limited, which is owned by a major transport operator, was established in 2005. This company manages clearinghouse, value issuer, and card issuer internally. Co-branded cards are also issued in Hong Kong in association with banks. Transport operator and many merchants have acquirer section inside of organizations but there is an independent acquirer under the bank for some retail shops it invited.

(c) Japan

Smart cards have been used in Japan since 2001. These cards are used for various types of payments, but predominantly used for transportation. The most famous common smartcard is Suica card and is issued by Japan Railways East (JR-East), which operates longest rail network including Tokyo metropolitan area in Japan. Pasmo is the other major common smartcard which is being used in Tokyo area and is issued by an alliance group which is composed of various transportation companies (railway, metro, monorail, bus, etc.). Both Suica card and Pasmo cards were developed by private transport operators (JR-East and others). When these cards were initiated, they were not interoperable but now, Suica smartcard can be used for any transportation belong to Pasmo alliance group and vice versa. These two common smartcards cover almost all forms of transportation in Tokyo metropolitan area. They can also be used in almost all convenience stores, many vending machines, as well as many shops. Approximately 47 million cards were issued by November 2014.

JR-East was the first company to introduce automatic fare payment system by smartcard in Japan in order to increase the capacity of ticket gates of congested stations and roles of all related participants (such as issuer, clearinghouse and acquirer) are managed by internal section of JR-East. The reason JR-East requires clearinghouse and acquirer it that JR-East has a bus system and many kiosks at their stations beside the railway network.

On the other hand, Pasmo was introduced as an interoperable smartcard because Pasmo smartcard system was developed as a common smartcard across various transport operators from its first stage. Therefore, acquirers are outside of PASMO Co. in order to prevent limiting each operator's business activities.

In the year 2004, JR-East and PASMO Co. established the IC Card Interoperable centre to enable Suica card and PASMO card interoperable.

Figure 2.111 diagram shows value flow of smartcard transactions in Japan for Suica & Pasmo cards.

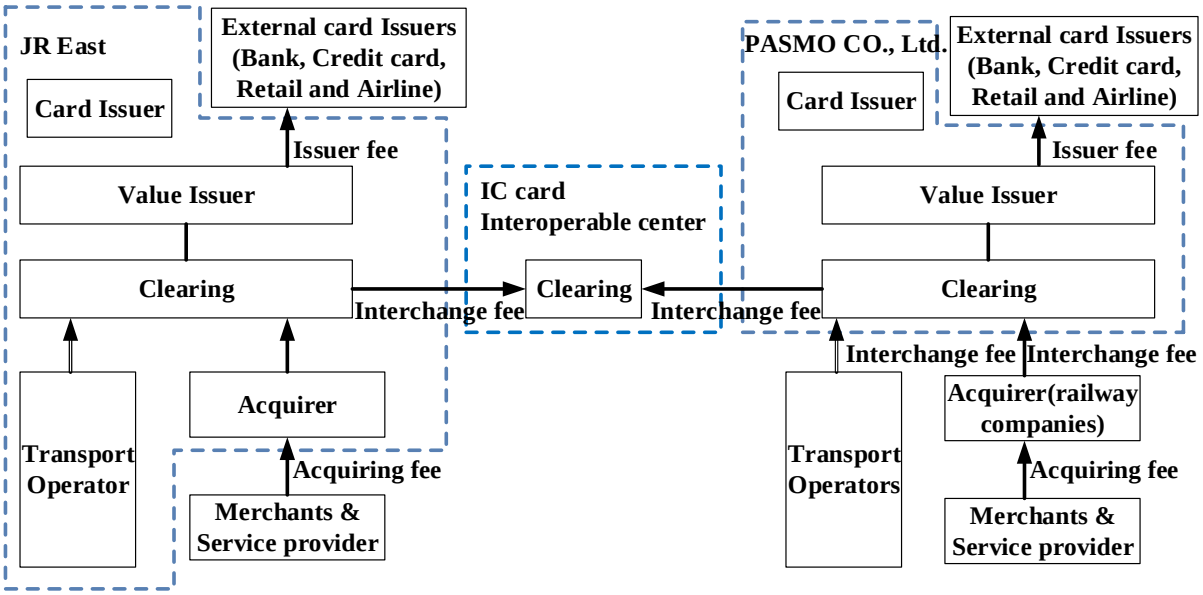


Figure 2.111 Common Card System: Japan

(Source: JICA Study Team)

(6) Clearinghouse Scheme for Bengaluru

(a) Current Status

Metro operator, BMRCL, implemented smartcard system and started issuing "Namma Metro" cards. These cards can be used by passengers on metro and can be recharged at any metro station. BMRCL awarded this contract to vendor Samsung to prepare fare payment system including smartcard implementation for Phase I of the metro project.

Public Bus operator, BMTC, awarded electronic payment system including smartcard implementation to vendors Axis Bank Ltd and Trimax for a period of 5 years. Axis Bank Ltd and Trimax are expected to implement this system based on smartcard framework published by NPCI.

With the initiative of DULT, the meetings were arranged with BMRCL, BMTC and their smartcard system vendors to explore the possibility of introducing a common smartcard in Bengaluru. The highlights of the discussed points are as mentioned below.

- BMRCL and BMTC agreed to explore the possibility of making their individual smartcards interoperable between the two operators. For this purpose, BMRCL and BMTC exchanged technical information of their smartcard systems and decision will be taken after further detailed discussions.
- It was basically agreed that BMRCL and BMTC work together to introduce a common smartcard scheme from the Phase II of metro rail, that is after 2020. Hence, it is proposed to implement common smartcard for the Bengaluru city by 2017 so that the clearinghouse is well prepared by 2020.

(b) Expected Short Term Outcome

1) Use of Smartcard for Bengaluru

As mentioned above, BMRCL and BMTC agreed to explore the possibility of making their individual smartcards interoperable. If such agreement is finalised and implemented by BMRCL and BMTC, then each other's card can be used on either of the operators.

But, to prepare an interoperable smartcard system on already implemented system like BMRCL, it will be a challenge for metro operator to overcome the technical and operational issues. To make this happen, metro operator may need to consider modification/replacement of terminals and modification of transaction and payment settlement procedures in their back-end. These kind of modifications may incur additional cost and time to the operator.

Furthermore, NPCI published their framework recently and no smartcard system was prepared yet based on this. BMTC is planning to prepare their smartcard system based on the published NPCI

framework and it is not clear how proprietary framework based smartcard of BMRCL will be supported on BMTC terminals.

2) Proposed Scheme for Clearinghouse for Bengaluru

Establishing the clearinghouse of the scheme B is recommended for Bengaluru. The following transaction will be processed for settlement under this scheme:

- The transport operators such as metro and city bus will settle internally by themselves the fare payment of their own transport which is made by the common smartcard issued by them. Only the transaction data of the common smartcards issued by other card issuers or value issuers will be transmitted to the clearinghouse and settled by the clearinghouse.
- It is expected that BMRCL and BMTC will be only two card/value issuers in short term in Bengaluru. Under this condition, if the common smartcards issued by BMRCL or BMTC are used for such services as ETC toll collection, electronic parking and bicycle sharing system, the transaction data will be transmitted to the clearinghouse and settled by the clearinghouse.
- If a new card issuer or value issuer issues the common smartcard for such services as ETC toll collection, electronic parking and bicycle sharing system, the transaction data of ETC toll collection, electronic parking and bicycle sharing system will be settled internally by the new card issuer or value issuer. If the common smartcard issued by the new card issuer or value issuer is used for the fare payment for metro or city bus, such transaction data will be transmitted to the clearinghouse and settled by the clearinghouse.

Based on above consideration, the clearinghouse of scheme B is proposed to establish by 2017.

Note: For the collection of O.D data, the transaction data of internal trip of all operators may be collected by the clearinghouse excluding the fare information.

(c) Expected Long Term Outcome

Under such conditions in Bengaluru as explained above, it is considered that BMRCL and BMTC will be only two operators preparing smartcard system for fare payment for next few years.

It is expected that a common smartcard system with the establishment of central clearing house will be realised after the start of the phase II of metro, construction of PRR, introduction of new operators, introduction of new value issuers and preparation of other systems like parking etc.

If the government considers in the future appointing a single agency to issue the common smartcard that is used for the fare payment for all transport, toll collection, parking and services, it is suggested to alter to scheme A which is explained in Figure 2.107.

Under such consideration, the responsibilities of the clearinghouse include

- Receive all transaction data from all operators and agencies.
- Responsible to settle all transactions received from operators and other agencies, amongst the operators/agencies.

(7) Approximate Cost of System Preparation of Clearinghouse

(a) Cost for System Preparation of Clearinghouse

The approximate cost for establishment of clearing house is calculated based on the following assumptions:

- Establishment cost of clearing house is calculated based on the proposal mentioned in the clause above (6) (2) (b).
- System preparation cost includes hardware/ software procurement and installation and development cost of clearing software application. Scale of hardware/ software equipment depends on daily transaction volume and thus the cost of this equipment will be based on design considerations**.**
- Clearinghouse is not responsible to issue common smartcard and thus, cost of the system that prepares common smartcard is not included in the approximate initial cost of clearinghouse. In future, if central clearing house is made responsible to issue common smartcard, cost incurred to prepare common smartcard system need to be calculated separately.
- Card/value issuers are responsible to install terminals for use of common smartcards at different transport operators and other system usage points. The cost of terminals and other facilities are not included in the approximate system preparation cost.

Based on above consideration, it is estimated that approximate system preparation cost of clearinghouse by 2017 will be INR 4756,63,920. It is explained in Table 2.60.

Table 2.60 Approximate System Preparation Cost of Clearinghouse (INR)

Year / Item	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027
System Preparation Cost	4756,63,920	0	0	0	0	4756,63,920	0	0	0	0	4756,63,920

(Source: JICA Study Team)

Note:

1) Establishment cost calculated for 2017 includes hardware/ software procurement and installation and development cost of clearing software application.
2) As per normal industry practice, hardware will be replaced for every 5 years because of advancement of technology and software upgrades. Based on this consideration, re-investment cost is proposed for the year 2022 and 2027. Because of technology improvements, hardware costs are not drastically changed over the years in general. It is estimated that the replacement cost of hardware in 2022 and 2027 is same as the cost of hardware in 2017.

(b) Approximate Cost for Operation and Maintenance of Clearinghouse

The cost for operation and maintenance of clearinghouse includes:

- System operation cost for servers, network equipment in the centre and communication cost,
- Cost of management staff who are required to support stakeholder enquiries, billing, statement handling and other activities, and
- Maintenance cost for hardware/ software clearing applications.

Staff requirements as mentioned in Figure 2.112 are considered for the operation and maintenance.

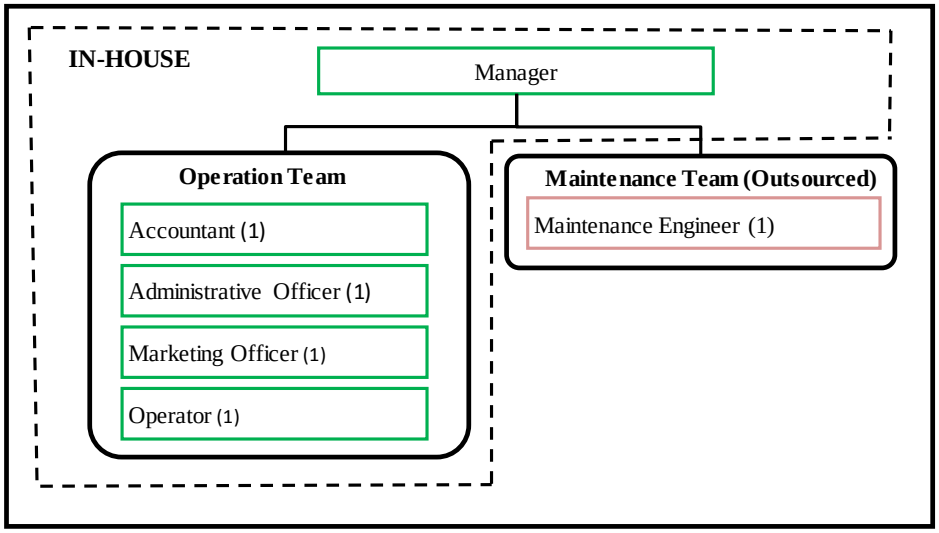


Figure 2.112 Required Staff for Operation & Maintenance of Clearinghouse

(Source: JICA Study Team)

Figure 2.112 shows the staff requirement for operation and maintenance of the clearinghouse. The value in the brackets indicates the required number of staff. (Note: The details of the required staff and organisation structure are explained in the next Chapter).

Estimated annual cost of operation and maintenance for 2017 is approximately estimated. From 2018 to 2027, the annual cost for operation and maintenance is estimated at 10% increase from year on year.

Table 2.61 shows the approximate cost.

Table 2.61 Approximate Annual Cost for Operation and Maintenance of Clearinghouse

Item \ Year	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027
Operation and Maintenance Cost	108,90,000	119,79,000	131,76,900	144,94,590	159,44,049	175,38,454	192,92,299	212,21,529	233,43,682	256,78,050	282,45,855

(Source: JICA Study Team)

Note:

1) The estimated system operation and maintenance cost is calculated for 2017.
2) The system operation and maintenance cost includes, operation and maintenance team cost, communication cost and other costs that include transaction data process in clearinghouse.
3) To estimate system operation and maintenance cost from 2018 to 2027, a 10% increment from previous year's system operation and maintenance cost is considered.

(8) Estimated Approximate Income for Clearinghouse

It is proposed to establish a clearinghouse by 2017 similar to scheme B, as explained above. In this scheme, each operator settle transactions in their system when a smartcard issued by them is used on its own terminals. But when a smartcard issued by other operator or value issuer is used on its terminals, such transaction data is transmitted to clearinghouse for settlement.

The expected approximate income for the clearinghouse from 2017 to 2027 is calculated considering the expected daily ridership, average fare per user and expected (assumed) percentage of usage of common smartcard for transport operators; BMTC, Bangalore Metro and operator for bicycle sharing.

(a) Expected Daily Ridership

The estimated daily ridership from 2016 to 2020 for city bus, metro and bicycle sharing was provided by the respective agencies; BMTC, BMRCL and DULT (for bicycle sharing). Based on this base data, the approximate daily ridership from 2021 to 2027 was estimated with approximate percentage of increase in ridership at 3% to 5% every year. The estimated ridership from 2017 to 2027 is shown in Table 2.62.

Table 2.62 Approximate Estimated Number of Daily Ridership

Item \ Year	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027
BMTC	44,00,000	46,20,000	48,51,000	50,93,550	53,48,228	56,15,639	58,96,421	61,91,242	65,00,804	68,25,844	71,67,136
Metro	12,60,000	12,97,800	13,36,734	13,76,836	14,18,141	14,60,685	15,04,506	15,49,641	15,96,130	16,44,014	16,93,335
Bicycle Sharing	8,741	9,178	9,637	10,119	10,625	11,156	11,714	12,299	12,914	13,560	14,238

(Source: JICA Study Team approximately calculated daily ridership up to 2027, based on estimated data (2016 – 2020) provided by BMTC, BMRCL and DULT)

(b) Average Daily Fare Per User

The expected average daily fare per user from 2016 to 2021 of city bus, metro and bicycle riding was provided by the respective agencies; BMTC, BMRCL and DULT (for bicycle sharing). Based on this base data, the approximate average daily fare per user from 2017 to 2027 was estimated. The approximate daily fare per user from 2017 to 2027 for city bus, metro and bicycle ride is shown in Table 2.63.

Table 2.63 Expected Approximate Average Daily Fare Per User (INR)

Item \ Year	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027
BMTC	19.08	20.03	21.04	22.09	23.19	24.35	25.57	26.85	28.19	29.60	31.08
Metro	17.61	18.14	18.69	19.25	19.83	20.42	21.03	21.66	22.31	22.98	23.67
Bicycle Sharing	10.00	10.50	11.00	11.50	12.00	12.50	13.00	13.50	13.50	13.50	14.00

(Source: JICA Study Team based on base estimated (2016 – 2021) provided by BMTC, BMRCL and DULT)

Note:

The approximate daily fare data estimated in the table above is based on the estimated daily fare information provided by BMTC, BMRCL and DULT for 2016 to 2020. The actual daily fare from 2017 to 2027 may be different from the above estimate, because the daily fare will be revised by these agencies based on various influencing factors at that time.

(c) Expected Common Smartcard Use

The metro operator, BMRCL, has already implemented smartcard system for its customers. The city bus operator, BMTC, is expected to issue smartcards to customers soon. Currently, most of the fare collection system is manual and the use of smartcard for fare payment is expected to slowly increase. Considering the current situation, the respective operators will have an expected percentage use of common smartcard.

The construction of PRR is expected to complete by 2020 and electronic toll collection system will be in operation from 2021 on PRR. It is estimated that approximately 10% of toll collection in 2021 will be collected by common smartcard on PRR. The use of common smartcard for the toll collection on PRR is expected to gradually increase by 2027.

The expected approximate percentage of smartcard use from the year 2017 to 2027 for different operators is shown in Table 2.64.

Table 2.64 Expected Percentage of Common Smartcard Use

Item \ Year	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027
BMTC	55%	60%	65%	70%	75%	80%	80%	85%	85%	85%	85%
Metro	65%	70%	75%	80%	80%	85%	90%	90%	90%	90%	90%
Bicycle Sharing	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
PRR					10%	15%	20%	25%	30%	35%	40%

(Source: Approximate calculation by JICA Study Team based on data/information provided by DULT)

(d) Expected Average Daily Fare Collection by Common Smartcard

Based on consideration of daily ridership, the average daily fare per user and percentage of common smartcard usage, approximate daily fare collection of PRR using common smartcard is estimated for 2017 to 2027.

Table 2.65 Expected Average Daily Fare Collection Using Smart card

Item \ Year	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027
BMTC	461,73,600	558,83,520	670,99,032	799,02,519	943,84,850	1109,96,584	1223,73,734	1433,49,357	1580,42,666	1742,42,039	1921,01,848
Metro	144,26,488	164,82,373	187,35,161	212,03,275	224,94,554	253,56,002	284,82,546	302,17,133	320,57,357	340,09,650	360,80,837
Bicycle Sharing	87,410	96,370	1,06,006	1,16,366	1,27,497	1,39,450	1,52,279	1,66,043	1,74,345	1,83,062	1,99,334
PRR	0	0	0	0	7,85,034	13,24,745	19,75,890	27,90,945	37,84,522	49,89,261	64,43,274
Total Daily Fare Collection	606,87,498	724,62,263	859,40,199	1012,22,160	1177,91,936	1378,16,781	1529,84,450	1765,23,478	1940,58,889	2134,24,012	2348,25,294

(Source: JICA Study Team)

* Note:

1. Latest DPR of PRR rev 4 estimated income from toll collection: INR 254.70 crore for 2020, INR 360.60 crore for 2023, INR 674.60 crore for 2028 and INR 1038.40 crore for 2032.
2. Based on the above mentioned income projection of PRR in DPR, expected income from 2021 to 2027 is calculated in the ITS master plan.

(e) Inter Value Ratio

As explained above for the proposed clearinghouse scheme, each transport operator will transmit the transaction data to the clearinghouse that require transfer of amount to/from other operators. The transactions of the same operator and/or value issuer will be settled internally and will not be transmitted to the clearinghouse.

"Inter Value Ratio" means the average percentage of transactions transmitted by different operators to the clearinghouse. In the case of Bengaluru, "Inter Value Ratio" is considered 20% in 2017 and gradually increase to 47% by 2027. The reason is that the common smartcards issued by each transport operator to users are expected to be used more for his own transport and less for others in the initial stage. Then the single common smartcard will be increasingly used for different transport modes. Based on this scenario, it is considered that Inter Value Ratio will gradually increase up to 47% by 2027.

In Singapore, a single authority, "Land Transport Authority (LTA)", is responsible for all transport related policy matter, implementation and operation and management. LTA is responsible to issue common smartcard and operate and maintain clearinghouse. If an authority similar to LTA in Singapore is established in Karnataka state which manages all transport related activities in the state, the common smartcard can be issued by such authority. When the common smartcard scheme is implemented by such central authority, all transactions from different operators will be transmitted to the clearinghouse for settlement and consideration of Inter Value Ratio is not required.

(f) Expected Approximate Annual Income to Clearinghouse

The calculation of expected approximate annual income of clearinghouse from 2017 to 2027 is described below.

It is proposed to collect 1% commission fee from operators/value issuers by the clearinghouse for the transactions settled by it. The annual income to clearinghouse is calculated by the following steps:

- Sum the daily fare collection from all operators and calculate the annual fare collection
- Multiply it with the Inter Value Ratio to arrive at total number of transactions settled by clearinghouse annually
- Calculate 1% of the above to get annual income for clearinghouse

Table 2.66 Expected Approximate Annual Income of Clearinghouse

Item	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027
Daily Fare Income by Smart card	606,87,498	724,62,263	859,40,199	1012,22,160	1177,91,936	1378,16,781	1529,84,450	1765,23,478	1940,58,889	2134,24,012	2348,25,294
Inter Value Ratio	20%	25%	27%	30%	32%	35%	37%	40%	42%	45%	47%
Clearinghouse Commission	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%
Annual Income for Clearinghouse	443,01,873	661,21,815	846,94,066	1108,38,265	1375,80,981	1760,60,938	2066,05,499	2577,24,278	2974,92,277	3505,48,940	4028,42,792

(Source: JICA Study Team)

(9) Expected Revenue and Payback Schedule for Clearinghouse

Table 2.67 describe the revenue generated and payback schedule of clearinghouse for the estimated period of 2017 to 2027.

Table 2.67 Expected Revenue and Payback Schedule of Clearinghouse

Item	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027
System Preparation Cost	4756,63,920	0	0	0	0	4756,63,920	0	0	0	0	4756,63,920
System Operation and Management Cost	108,90,000	119,79,000	131,76,900	144,94,590	159,44,049	175,38,454	192,92,299	212,21,529	233,43,682	256,78,050	282,45,855
Total Annual Income	443,01,873	661,21,815	846,94,066	1108,38,265	1375,80,981	1760,60,938	2066,05,499	2577,24,278	2974,92,277	3505,48,940	4028,42,792
Remaining Cost to pay back		4422,52,047	3881,09,232	3165,92,066	2202,48,391	0	4157,52,895	0	0	0	0
Revenue (Profit/Loss)	-4422,52,047	-3881,09,232	-3165,92,066	-2202,48,391	-986,11,459	-4157,52,895	-2284,39,695	80,63,054	2822,11,649	6070,82,538	5060,15,555

Red coloured revenue figure indicates loss

Green coloured revenue figure indicates profit

Annual total cost of the system will be system preparation and annual operation and maintenance costs together. System preparation cost is invested once in every five years i.e. 2017, 2022 and 2027. From Table 2.67, it can be understood that the total costs will be recovered with the revenue of the clearinghouse by 2021. In 2022, government need to invest some amount for upgrading of the clearinghouse system and this cost will be recovered by following year 2023. From 2023 onwards, revenue of clearing house will be able to take care of total costs including annual operation and maintenance and system upgrading costs, if any.

2.4 Organisation for Operation of ITS

2.4.1 Existing Related Organisations

The existing related organisations in transport sector in Bengaluru and outline of their roles are shown in Table 2.68.

Table 2.68 Existing Organizations Related to ITS in Bengaluru Metropolitan Area

	Category	Name of Organisation	Outline of Roles
Public Sector	Planning Agency	Directorate of Urban Land Transport (DULT)	Planning of urban transport in Karnataka State
	Traffic Administrator	Bangalore Traffic Police (BTP)	- Enforcement of traffic regulation - Monitoring of traffic situation - Operation of traffic signals
	Road Administrator	Bruhat Bangalore Mahanagar Palike (BBMP)	Operation and management of roads in Bengaluru metropolitan area
		Bangalore Development Authority (BDA)	Planning of Road constuction in Bengaulru metropolitan area
	Public Transport Agencies	Bangalore Metropolitan Transport Corporation (BMTC)	Operation and management of city bus transport service in Bengaluru metropolitan area
		Karnataka State Road Transport Corporation(KSRTC)	Operation and management of inter-state and inter-city bus transport service in Karnataka State
		Karnataka State Tourism Development Corporation (KSTDC)	Operation and management of taxi service and tour bus service in Bengaluru metropolitan area
	Emergency Vehicle Authorities	Emergency Authoritie (108 Services)	Operation and management of ambulance
		Karnataka Fire and Emergency Services	Operation and management of fire-fighting vehicle
Private Sector	Road Concessionnair	Nandi Infrastructure Corridor Enterprises (NICE)	Operation and management of NICE road
		Other Concessionnaires	Operation and management of other toll roads, e.g. Tumkur Road, Kanakapura Road, Hosur Road, etc.
	Taxi / Bus Companies	Private Taxi Companies	Operation and management of taxi
		Private Bus Companies	Operation and management of bus transport
	Logistics	Logistic companies	Operation and management of truck

(Source: JICA Study Team)

2.4.2 Data/Information on Road and Transport Possessed by Existing Organisations

The existing related organisations possess several kinds of data/information on road and transport in Bengaluru. The major data/information possessed by the existing related organisations are summarised in Table 2.69.

Table 2.69 Organisations and Data/Information Available

	Category	Name of Organisation	Possessed Data/Information on Road and Transport
Public Sector	Planning Agency	Directorate of Urban Land Transport (DULT)	
	Traffic Administrator	Bangalore Traffic Police (BTP)	- CCTV video image - Accident information - Black spot/hot spot information - Others (e.g. VIP vehicle movement, road closure, etc)
	Road Administrator	Bruhat Bangalore Mahanagar Palike (BBMP)	- Road management information (e.g. road closure, road works, etc)
		Bangalore Development Authority (BDA)	- Road management information (e.g. road closure, road works, etc)
	Public Transport Agencies	Bangalore Metropolitan Transport Corporation (BMTC)	- Bus operation and management information - Bus probe data
		Karnataka State Road Transport Corporation(KSRTC)	- Bus operation and management information - Bus probe data (in future)
		Karnataka State Tourism Development Corporation (KSTDC)	- Tax operation and management information - Tax probe data (in future)
	Emergency Vehicle Authorities	Emergency Authoritie (108 Services)	- Emergency management information, ambulance information
		Karnataka Fire and Emergency Services	- Fire works management information, fire-fighting vehicle informaiton
Private Sector	Road Concessionnair	Nandi Infrastructure Corridor Enterprises (NICE)	- Road management information (e.g. road closure, road works etc)
		Other Concessionnaires	- Road management information (e.g. road closure, road works etc)
	Taxi / Bus Companies	Private Taxi Companies	- Tax operation and management information - Tax probe data
		Private Bus Companies	- Bus operation and management information - Bus probe data (in future)
	Logistics	Logistic companies	- Logistic vehicle management information - Logistics probe data

(Source: JICA Study Team)

2.4.3 Organisational Measures Required for Implementing ITS

The strategies to realise the ITS goals are described in the clause 3.2.1 of Chapter 3. The following clauses after the clause 2.2.2(1) in Chapter 3 elaborated the required measures to execute the strategies in view of ITS by identifying ITS focus area and ITS components. The organisational measures also need to be taken in parallel to execute the strategies. The required organisational measures for the strategies are summarised below.

- **Coordination Amongst Related Organisation**

  There are a number of existing organisations related to urban transport in Bengaluru metropolitan area as summarised in the previous clauses. However, as several existing study reports such as CTTP and officials of Karnataka Government point out, the measures for urban transport such as improvement of road infrastructure, public transport, traffic management, etc. are not taken in coordinated manner amongst these related organisations. Therefore the measures for sufficient coordination amongst the related organisations are required under a proper organisation framework.

- **Utilisation of Information and Data**

  These related organisations possess several kinds of information and data as summarised in the previous clause. Due to lack of coordination amongst the organisations, such information is not properly shared and used. For example, a scheduled road work could be informed to the relevant authorities and announced to public prior to the road work e.g. to properly plan to divert the traffic and take other necessary actions in advance. Probe data obtained from the bus location system which is planned by BMTC holds potential that can be utilised as a kind of big data e.g. for congestion information. Therefore the measures to share and utilise the available data/information are required under the proper organisation framework.

- **Proper Planning, Evaluation and Improvement**

  The improvement of urban transport need to be planned and evaluated based on quantitative traffic data. The measures that enable processing and analysing the collected quantitative traffic data and utilising it for proper planning and evaluation are required.

- **Preparation of Centres for ITS**

  Various ITS components are proposed by ITS Master Plan. These ITS components are new to Bengaluru and require their ITS centres for operation. The existing centre in Bangalore are traffic management centre of Bangalore Traffic Police, called B-TRAC, metro centre of Bangalore metro of BMRCL and command control centre of city bus of BMTC. Other centres for the ITS components proposed in ITS Master Plan are required.

- **Sustainable ITS Promotion**

  ITS implementation is not a one-time activity. A continuous engagement is important. It involves such activities as evaluating existing ITS, incorporating new technologies and local requirement which may change in accordance with further development of road/transport infrastructure and urbanisation and harmonising with Indian national ITS policy when it is ready in the future. Establishing the proper organisation framework to realise sustainable engagement is important.

2.4.4 Proposed Institutional Framework

The steps towards implementing the proposed ITS in Bengaluru require establishing institutional framework. The existing ITS facilities i.e. traffic management centre of B-TRAC, Bangalore metro system, command control centre of city bus are implemented under the respective organisations. Likewise, the responsible organisations need to be designated or newly set up for the ITS components proposed by ITS Master Plan. These recommendations are made in the next clause.

It is then recommended that an "ITS Society" *[8] is formed by government to oversee all activities of ITS in Bengaluru. ITS will require planning, developing, operating/maintaining, enforcing, evaluating effect, updating and assuring necessary budget. Taking into consideration that ITS is a part of soft measure to support the measures on urban transport, cross-cutting issues are inevitably entailed. Thus it is best that the involved organisations work closely together with. Each organisation has different policies, procedures and working culture. Therefore it is suggested that the ITS Society be organised by senior official of these organisations, headed by DULT, and it functions as a body for monitoring, coordinating and proposing decisions to realise the required organisational measures explained in the previous clause, incorporating views of constituent members.

The constituent member organisations of the ITS Society shall include the major stakeholders in urban transport sector in Bengaluru such as Bangalore Traffic Police, road administrators, city/inter-city public bus operators, metro rail operator, Department of Transport, other newly formulated department if any, and etc.

[8] The 'Society' is a body which is entitled with legal authority and responsibility to achieve the objectives of the society. It is to be formed under Indian Society Act 1860 and registered in the Register of Society. A memorandum of association is signed by the constituent members of the society. The memorandum of association contains the name of the society, its objectives, details of the constituent members, and etc. Once registered, the society will be legally responsible for making decisions and implementing as per the objectives.

There is a high-level decision making body on urban transport issues in Bengaluru, called Bangalore Metropolitan Land Transport Authority (BMLTA). It is responsible for overseeing all the urban land transport initiatives in Bengaluru metropolitan region. It has been formulated under the concept framework of National Urban Transport Policy (NUTP). BMLTA is chaired by Chief Secretary, Government of Karnataka and constituted by Additional Chief Secretary, Government of Karnataka and high ranking officials of other departments, with a member convener of the commissioner of DULT. Sub-groups and sub-committees have been organised under BMLTA to expedite certain activities such as intermodal bus terminals, Bengaluru traffic and transport initiatives, parking policy and infrastructure, commuter rail system, etc. It is proposed that the ITS Society work together with these existing sub-groups and sub-committees to deal with the cross-cutting urban transport issues.

The early formulation of this ITS Society is important.

The major roles of the ITS Society are:

- Preparing policy for efficient coordination amongst the member organisations: A policy document would be prepared and it defines the procedures and rules by which the coordination amongst the organisations is assured, including areas such as decision making and dispute resolution,
- Assigning roles and responsibilities to the member organisations: This defines obligations and responsibilities of the member organisations of the ITS Society,
- Overseeing activities of ITS and handling cross-cutting urban transport issues related to ITS,
- Scrutinising the required budget and propose to BMLTA to obtain the funds for implementing/upgrading ITS,
- Working on required legislation in such areas as congestion charging, and
- Working on technical requirement and implementation such as incorporating new technology, introducing new ITS components, etc.

Figure 2.113 shows a recommended institutional framework for ITS in Bengaluru.

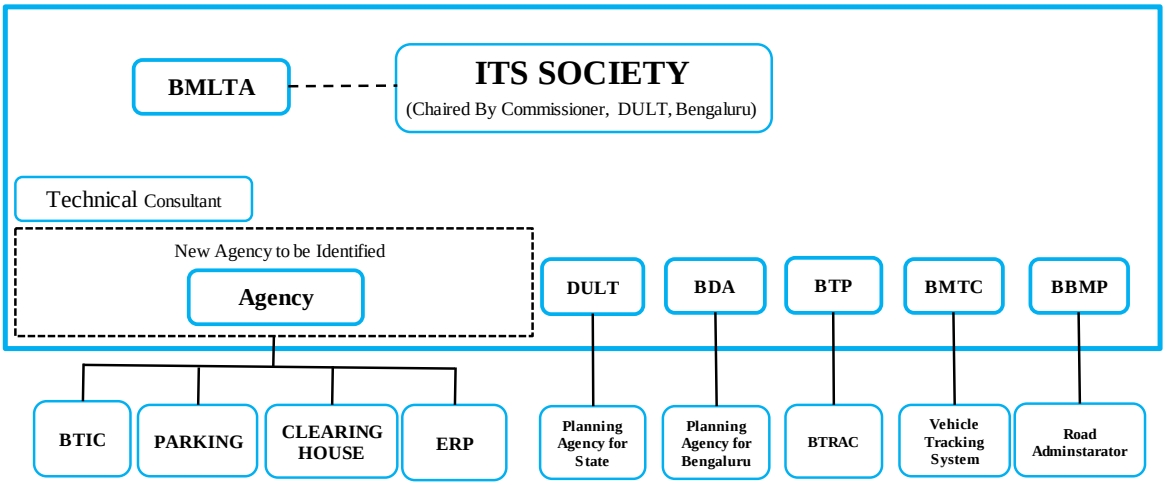


Figure 2.113 Institutional Framework: ITS Society of Bengaluru

(Source: JICA Study Team)

2.4.5 Required Centres and Organisations for Proposed ITS

This clause discusses the required centres and organisations for ITS components proposed by ITS Master Plan. It should be noted, as to the organisations, that the decisions on the organisation set up are to be made by the Government of Karnataka. Thus what are described about the organisations hereunder shall be construed as reference information of suggestion so that the Indian authorities can consider when they make decisions.

The following centres exist in Bengaluru;

- Traffic Management Centre of B-TRAC: Bangalore Traffic Police
- Command Centre of City Bus (under trial): Bangalore Metropolitan Transport Corporation
- Metro Centre of Bangalore Metro: Bangalore Metro Railway Corporation Limited

The newly-required centres for ITS proposed by ITS Master Plan are;

- Bengaluru Traffic Information Centre (B-TIC)
- Traffic Control Centre of Highway Traffic Management System (HTMS) for PRR
- Toll Management Centre of Toll Management System (TMS) for PRR
- Centre for Electronic Road Pricing (ERP)
- Clearing House for Multimodal Smart Card

(1) Bengaluru Traffic Information Centre (B-TIC) and Organisation

The purposes of B-TIC are providing dynamic traffic information to the road users and utilising cumulated quantitative data and other related useful information collected by B-TIC for the measures on urban transport. In the light of the intended purposes of B-TIC, it would be appropriate that B-TIC be implemented under the planning related agency for urban transport. In Bengaluru, Directorate of Urban Land Transport (DULT) has been set up by the Government of Karnataka under the Urban Development Department. It is responsible for overseeing all the urban transport initiatives and coordinating planning and implementation of urban transport projects and programmes. The executing agency for B-TIC could be set up and B-TIC may not be executed by DULT itself in terms of its roles in nature as planning. Nonetheless it is advised that B-TIC be implemented under the jurisdiction of DULT.

(2) Centres for HTMS and TMS for PRR and Organisation

The purposes of the centres of HTMS and TMS for PRR are respectively highway traffic management and toll collection. These activities need to be taken care together with the management of PRR itself. In the light of the nature of HTMS and TMS, it is recommended that both of them be implemented under the executing agency for PRR. Bangalore Development Authority (BDA) has been entrusted as the executing agency for implementation of PRR. Hence, BDA is considered the most likely agency which will be responsible for the centres of HTMS and TMS.

It should be noted that the purposes of HTMS and TMS are different in nature even though both of them are for PRR. HTMS is for highway traffic management whereas TMS is for collection and management of toll fare. Hence it is advised that the individual departments be respectively designated to HTMS and TMS.

(3) Centre for ERP and Organisation

The Electronic Road Pricing (ERP) will be implemented as part of traffic demand management aiming to alleviate congestion in the charging area. The charge will be imposed on the existing general roads in the city, not on the highway. The activities required for implementing ERP extends broad ranges such as monitoring and evaluating the effect at a regular basis which is accordingly reflected to adjustment of the charging amount, overseeing the charging stations, enforcing the violation of ERP, operating and maintaining the facilities and etc. It is unlikely that there will be one existing authority with the jurisdictions which cover all the issues. One possibility is to create a new one and the other is to designate the existing setup of authority to implement ERP. In the latter case, one possible candidate could be Bengaluru city authority, Bruhat Bangalore Mahanagara Palike (BBMP). However in this case, it will be required to consolidate its implementing capacity and the roles backed up by legal bases. Considering these aspects, it is suggested that a new organisation for ERP be set up.

(4) Clearing House for Multimodal Smart Card and Organisation

The clearing house for multimodal smart card is different in nature from others mentioned above. The major purpose is settlement of e-money used by the multimodal smart card for different transport and other services such as shopping. The activities required for implementing the clearing house include reliable and secure collection of transaction data and settlement amongst the agencies, handling and taking care of the new participants to the common card scheme, i.e. transport operators, other agencies and value issuers, maintenance of the system and associated facilities, and etc. In the light of the nature of such roles and responsibilities, it is recommended to prepare a central clearing house for the Karnataka state. It is then advised that a new organisation be set up and designated to implementation of the central clearing house.

(5) Area Traffic Signal Control (ATSC) and Organisation

In addition to the above listed ITS components which require the new centres, ITS Master Plan proposes Area Traffic Signal Control System (ATSC). The existing traffic signals are operated under the jurisdiction of Bangalore Traffic Police. It is an authority entrusted with controlling traffic in the city. Therefore ATSC is proposed to implement under Bangalore Traffic Police. Accordingly, the facilities of ATSC will be installed under the existing traffic management centre of B-TRAC aiming to strengthen the function of their existing centre. Table 2.70 and Table 2.71 summarise the existing and newly-required centres, purposes and organisations.

Table 2.70 Existing Centres, Purposes and Responsible Agencies

ITS Centre	Purpose		Responsible Organisation
Traffic Management Centre (B-TRAC)	Existing	♦ Enforcement on Road Traffic ♦ Operation of Existing Traffic Signals ♦ Maintenance of Associated Facilities	Traffic Administrator (Bangalore Traffic Police)
	New (*)	♦ Operation of Area Traffic Signal Control ♦ Maintenance of Area Traffic Signal Control	
Command Centre of City Bus	♦ Monitoring and Management of City Bus Operation ♦ Maintenance of Associated Facilities		City Bus Operator (BMTC)
Bangalore Metro Centre	♦ Monitoring and Management of Bangalore Metro Operation ♦ Maintenance of Associated Facilities		Metro Rail Operator (BMRCL)

Note (*): Newly added to the existing centre for strengthening function

(Source: JICA Study Team)

Table 2.71 Newly-Required Centres, Purposes and Recommended Agencies

ITS Centre	Purpose	Recommended Organisation (*)
Bengaluru Traffic Information Centre (B-TIC)	♦ Collection of Road Traffic Information in Bengaluru Metropolitan Area ♦ Provision of Dynamic Road Traffic Information to Road Users ♦ Utilising Quantitative Data for Measures on Urban Transport	Planning Agency for Urban Transport
Traffic Control Center of HTMS for PRR	♦ Monitoring and Management of Highway Traffic on PRR ♦ Maintenance of Associated Facilities	Executing Agency for PRR
Toll Management Centre of TMS for PRR	♦ Monitoring and Management of Toll Collection on PRR ♦ Maintenance of Associated Facilities	Executing Agency for PRR
Centre for Electronic Road Pricing (ERP)	♦ Implementation of Congestion Pricing ♦ Maintenance of Associated Facilities	Executing Agency for ERP
Clearing House for Common Smartcard	♦ Settlement of E-money Used by Common Smartcard ♦ Maintenance of Associated Facilities	Executing Agency for Clearing House for Common Smartcard

Note (*): Actual name of organisation is not shown in the table due to difficulty in specifying. Instead, the organisation expressed in category is indicated as recommendation.

(Source: JICA Study Team)

2.4.6 Organisation Arrangement

The following clauses propose organisational arrangement for operation and maintenance for the individual ITS components proposed by ITS Master Plan. These clauses include the proposed structure of organisation including number of staff by designation, roles and responsibility of staff and shift arrangement.

It should be noted that detail arrangement of each organisation depends on the design of the systems and contract for operation and maintenance. For example, the number and positions of staff required for operation and maintenance, which are shown in the following clauses, can vary. These decisions can only be made in the design stage. Hence, what are shown in the clauses shall be construed as reference information of suggestion made on the basic concept of the individual ITS components of ITS Master Plan so that the Indian authorities can refer when they make decisions in the subsequent stages.

(1) Organisation for Bengaluru Traffic Information System

Bengaluru Traffic Information Centre (B-TIC) will be established to function as a single central body for collection of data on traffic, processing and provision of dynamic traffic information to road users. The collected and cumulated quantitative data on traffic is aimed to utilise for planning and evaluation of measures on urban transport as well. The information and data will be shared with the concerned agencies as necessary.

The major activities of B-TIC are:

- Collecting data and information on traffic from ITS equipment,
- Disseminating the processed dynamic information on traffic to road users,
- Sharing the compiled information to the related organisations,
- Requesting to take necessary actions to the related organisations when hazardous situation is found, and
- Monitoring operation status of ITS equipment of B-TIC and taking necessary actions when malfunction is found.

(a) Proposed Structure of Organisation for Operation and Maintenance: B-TIC

It is proposed that B-TIC is operated and maintained under supervision of government agency in charge of B-TIC. Actual operation and maintenance would be outsourced to contractor. Therefore the structure of organisation of B-TIC comprises the in-house members of the government agency; project director, manager for operation and manager for maintenance, and the operation and maintenance teams organised by the contractor under them.

Figure 2.114 shows the proposed structure of organisation for operation and maintenance of B-TIC and staff. Number in the brackets in the figure indicates the required number of staff.

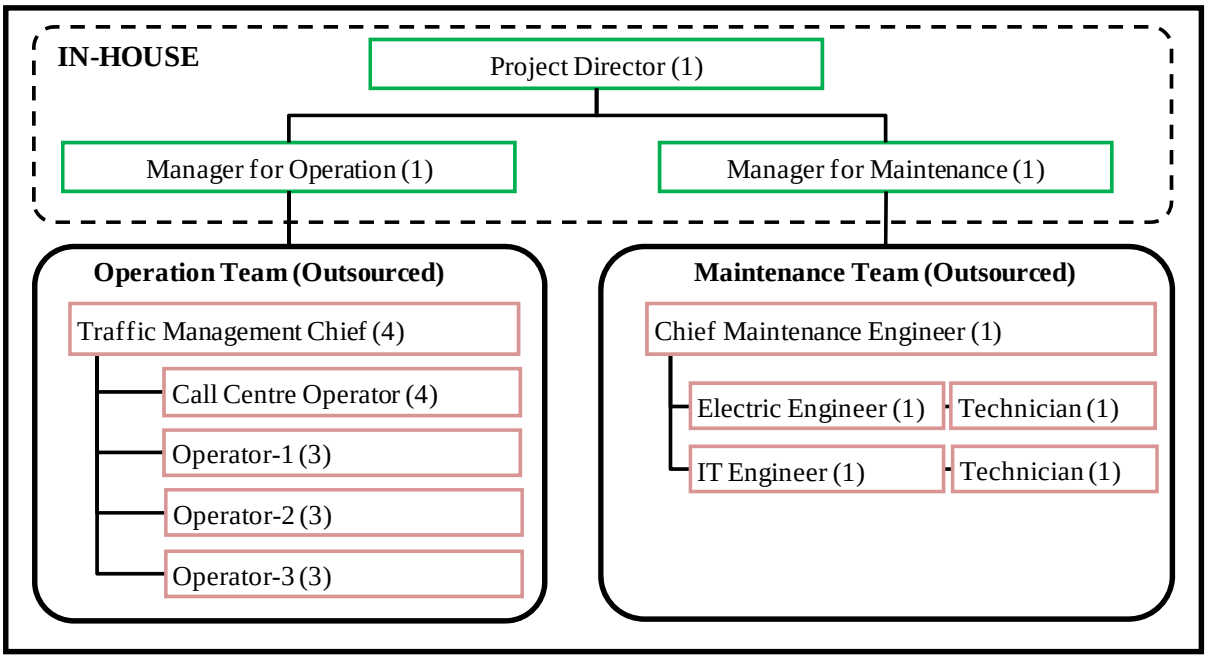


Figure 2.114 Proposed Structure of Organisation for Operation and Maintenance: B-TIC

(Source: JICA Study Team)

(b) Roles and Responsibilities of Staff: B-TIC

The roles and responsibilities of staff are explained in Table 2.72, Table 2.73 and Table 2.74. Their working hours are explained in the next clause.

Table 2.72 Roles and Responsibilities of In-house Staff: B-TIC

Position	Roles and Responsibilities	Working Hours
Project Director	♦ Responsible for supervising and controlling all activities of B-TIC ♦ Coordinate all activities between B-TIC and other centres such as ERP, EPS, Traffic Management Centre of Traffic Police, and other related organisations ♦ Provide data/information to related organisations based on request	Daytime only
Manager for Operation	♦ Responsible for the operation of B-TIC ♦ Supervise and control the outsourced operation team	Daytime only
Manager for Maintenance	♦ Responsible for the maintenance of B-TIC ♦ Supervise and control the outsourced maintenance team	Daytime only

(Source: JICA Study Team)

Table 2.73 Roles and Responsibilities of Operation Team Staff (Outsourced): B-TIC

Position	Roles and Responsibilities	Working Hours
Traffic Management Chief	♦ Supervise the operation team's work and coordinate with the Manager for Operation of the in-house member ♦ Prepare necessary reports and submit to the Manager for Operation of the in-house member ♦ Make judgement on determining the data/information collected from related organisations to input database	By Shift
Call Centre Operator	• Receive and answer enquiries from general public and the related organisations ♦ Inform necessary information to the related organisations ♦ Request the related organisations to provide necessary information	By shift
Operator-1	♦ Monitor traffic condition on schematic map of video wall ♦ Inform the Traffic Management Chief of malfunction of ATCC system and probe system when it is detected	By Shift
Operator-2	♦ Provide necessary information through VMS ♦ Inform the Traffic Management Chief of malfunction of VMS system when it is detected	By Shift
Operator-3	♦ Stand by and take charge of any of above operator's work in their absence	By Shift

(Source: JICA Study Team)

Table 2.74 Roles and Responsibilities of Maintenance Team Staff (Outsourced): B-TIC

Position	Roles and Responsibilities	Working Hours
Chief Maintenance Engineer	♦ Supervise the maintenance team's work (*) and coordinate with the Manager for Maintenance of the in-house member ♦ Manage preventive maintenance work and plan ♦ Prepare necessary reports and submit to the Manger for Maintenance of the in-house member	Daytime and On Call
Electric Engineer	♦ Carry out preventive maintenance for electrical equipment ♦ Carry out repair works for electrical equipment in case of malfunction	Daytime and On Call
IT Engineer	♦ Carry out preventive maintenance for system ♦ Carry out repair works for system in case of malfunction ♦ Carry out system modification as necessary	Daytime and On Call
Technician	♦ Assist the electric engineer and IT engineer ♦ Maintain spare parts	Daytime and On Call

*Note: Maintenance work includes (i) preventive maintenance, (ii) repair work for fault and recovery, (iii) system modification, and (iv) spare parts inventory.

(Source: JICA Study Team)

(c) Proposed Shift Arrangement: B-TIC

B-TIC shall function 24/7. Thus the operation team shall be arranged in three-shift and one party as stand-by.

The in-house members will station during day-time working hours.

One party of maintenance team shall be organised. They will take care of preventive maintenance, repair work for fault and recovery on the occasion of malfunction, system modification as required and spare parts inventory. Table 2.75 shows an example of time shift of the operation team.

Table 2.75 Example of Time Shift of Operation Team: B-TIC

	Shift-1 06:00AM - 02:00PM	**Shift-2** 02:00PM - 10:00PM	**Shift-3** 10:00PM - 06:00AM	**Remarks**
Party 1	On-duty	Off	Off	
Party 2	Off	On-duty	Off	
Party 3	Off	Off	On-duty	
Party 4	Off	Off	Off	Stand By

(Source: JICA Study Team)

(2) Organisation for Area Traffic Control System

The area traffic control signal system (ATCS) aims to improve traffic flow by optimising signal timing parameters according to traffic volume and coordinating amongst signals.

The existing traffic signal is operated by the traffic management centre, B-TRAC, of Bangalore Traffic Police. ATCS is proposed to prepare under B-TRAC, upgrading the existing signals in phases and preparing the centre system.

This section proposes the organisation structure and staff required for operation and maintenance of ATCS.

(a) Proposed Structure of Organisation for Operation and Maintenance: ATCS

It is proposed that ATCS is operated and maintained under supervision of Bangalore Traffic Police. The operation of traffic signal is a part of traffic control which is a jurisdiction of traffic police. Therefore the actual operation is also recommended to carry out by the in-house member of Bangalore Traffic Police. The maintenance work would be undertaken by maintenance contractor. But supervision of their work is required as part of duty of Bangalore Traffic Police.

Figure 2.115 shows the proposed structure of organisation for operation and maintenance of ATCS and staff. Number in the brackets in the figure indicates the required number of staff.

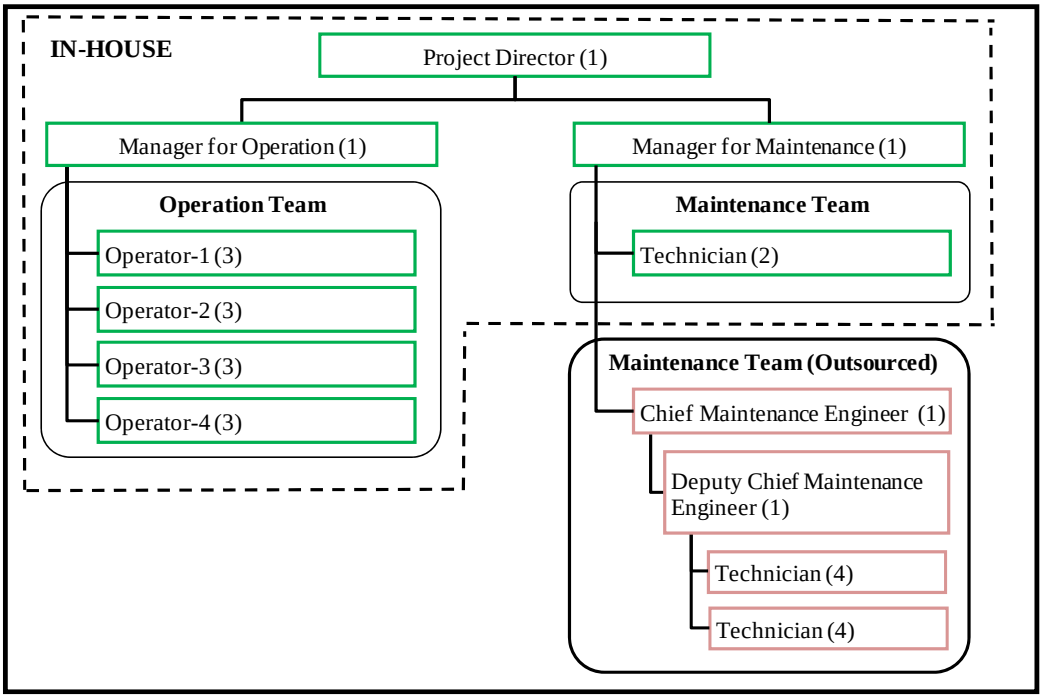


Figure 2.115 Proposed Structure of Organisation for Operation and Maintenance: ATCS

(Source: JICA Study Team)

(b) Roles and Responsibilities of Staff: ATCS

The roles and responsibilities of staff are explained in Table 2.76 and Table 2.77. Their working hours are explained in the next clause.

Table 2.76 Roles and Responsibilities of In-house Staff: ATCS

Position	Roles and Responsibilities	Working Hours
Project Director	♦ Responsible for traffic control in the city ♦ Supervise and control all activities of ATCS	Daytime only
Manager for Operation	♦ Responsible for the operation of the system ♦ Supervise and control operation team	Daytime only
Manager for Maintenance	♦ Responsible for the maintenance of the system ♦ Supervise and control maintenance team	Daytime only
Operator-1	♦ Monitor and manipulate signal ♦ Inform malfunction of system/equipment to Manager for Operation when find	By Shift
Operato-2	♦ Monitor and manipulate signal ♦ Inform malfunction of system/equipment to Manager for Operation when find	By Shift
Operator-3	♦ Monitor and manipulate CCTV and other associated equipment ♦ Inform malfunction of system/equipment to Manager for Operation when find	By Shift
Opeator-4	♦ Monitor and manipulate CCTV and other associated equipment ♦ Inform malfunction of system/equipment to Manager for Operation when find	By Shift
Technician	♦ Take care technical works as required	Daytime only

(Source: JICA Study Team)

Table 2.77 Roles and Responsibilities of Maintenance Team Staff (Outsourced): ATCS

Positions	Roles and Responsibilities	Working Hours
Chief Maintenance Engineer	♦ Supervise maintenance team' work (*1) and coordinate with the Manager for Maintenance of the in-house member ♦ Prepare necessary reports and submit to the Manager for Maintenance of the in-house member	Daytime and On Call
Deputy Chief Maintenance Engineer	♦ Manage the maintenance work (*1) ♦ Instruct and supervise technician and labourer ♦ Report to Chief Maintenance Engineer	Daytime and On Call
Technician	♦ Carry out the maintenance work under supervision of Deputy Chief Maintenance Engineer	Daytime and On Call
Labourer	♦ Carry out civil work and other related work as instructed by Deputy Chief Maintenance Engineer	Daytime and On Call

*Note: Maintenance work includes (i) preventive maintenance, (ii) repair work for fault and recovery, (iii) system modification, and (iv) spare parts inventory.

(Source: JICA Study Team)

(c) Proposed Shift Arrangement: ATCS

The system operates 24hours a day and 7days a week. But the operator will station from 6:00 am until 9:00 pm i.e. for 15 hours in two-shift. The system operates unmanned from 9:00 pm to 6:00 am. An extra shift shall also be organised. Thus, three-shift in total is required.

The managing members of in-house staff; project director, manager for operation and manager for maintenance will station during day-time working hours.

One party of maintenance team shall be organised. They will take care of preventive maintenance, repair work for fault and recovery on the occasion of malfunction, system modification as required and spare parts inventory.

Table 2.78 shows an example of time shift of the operation team

Table 2.78 Example of Time Shift of Operation Team: ATCS

	Shift-1 06:00AM - 01:00PM	**Shift-2** 01:00PM - 09:00PM	**Remarks**
Party 1	On-duty	Off	
Party 2	Off	On-duty	
Party 3	Off	Off	Stand By

(Source: JICA Study Team)

(3) Organisation for Highway Traffic Management System of PRR

Peripheral Ring Road (PRR) is planned to be full access-controlled toll road. It means that a high quality operation and management of highway is required. The main purpose of Highway Traffic Management System (HTMS) for PRR is ensuring safety and smooth traffic flow on PRR. "Traffic Control Centre for PRR" ("TCC") shall be established to realise this. TCC manages the traffic on PRR by monitoring traffic status and disseminating necessary information to users 247. To ensure continuous monitoring and dissemination of necessary information to users, the roadside equipment and centre system shall always be functional. Therefore, the maintenance work is also critical to minimise downtime of the systems on the occasions of failure.

TCC and maintenance office for facilities, inspections and patrolling need to be constructed along the PRR for the following reasons:

- TCC shall be connected with all roadside ITS equipment by optical fibre cable which will be installed both inside and outside of PRR
- The maintenance team shall be dispatched to the site immediately to handle the incident or system failure upon request from TCC.

(a) Proposed Structure of Organisation for Operation and Maintenance: HTMS

It is proposed that HTMS is operated and maintained under supervision of government agency in charge of PRR. Actual operation and maintenance would be outsourced to contractor. Therefore the structure of organisation of HTMS comprises the in-house members of the government agency; project director, manager for operation and manager for maintenance, and the operation and maintenance teams organised by the contractor under them.

Figure 2.116 shows the proposed structure of organisation for operation and maintenance of HTMS and staff. Number in the brackets in the figure indicates the required number of staff.

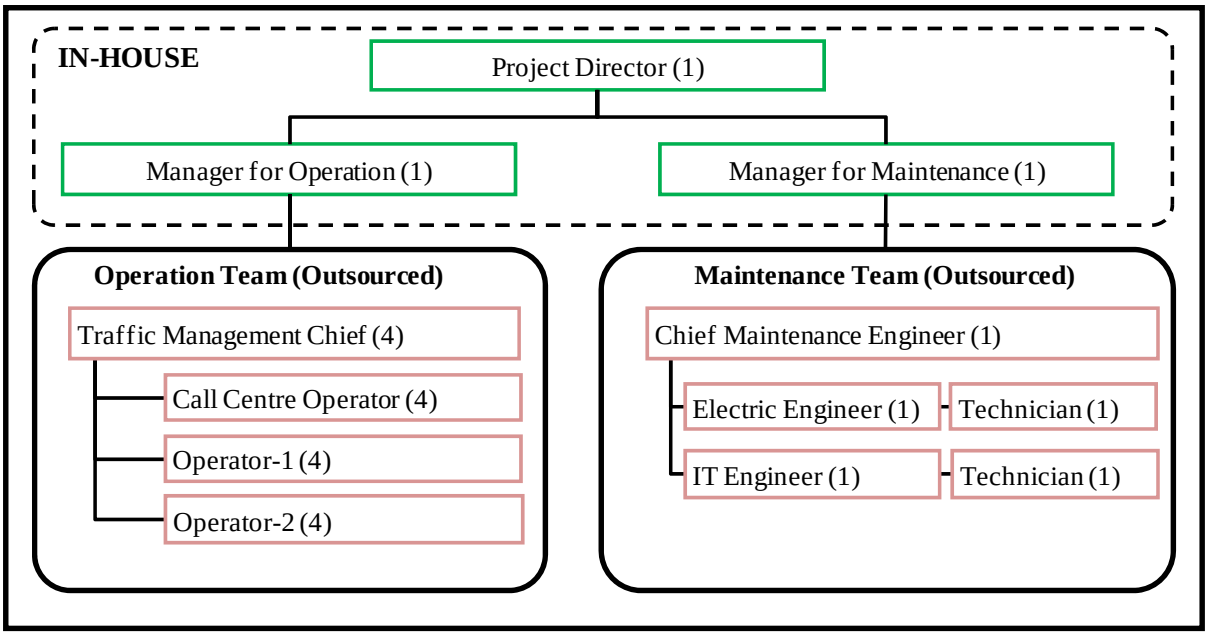


Figure 2.116 Proposed Structure of Organisation for Operation and Maintenance: HTMS

(Source: JICA Study Team)

(b) Roles and Responsibilities of Staff: HTMS

The roles and responsibilities of staff are explained in Table 2.79, Table 2.80 and Table 2.81. Their working hours are explained in the next clause.

Table 2.79 Roles and Responsibilities of In-house Staff: HTMS

Position	Roles and Responsibilities	Working Hours
Project Director	♦ Responsible for supervising and controlling all activities of HTMS ♦ Coordinate all activities between HTMS and B-TIC, and other related organisations ♦ Provide data/information to related organisations based on request	Daytime only
Manager for Operation	♦ Responsible for the operation of HTMS ♦ Supervise and control the outsourced operation team	Daytime only
Manager for Maintenance	♦ Responsible for the maintenance of HTMS ♦ Supervise and control the outsourced maintenance team	Daytime only

(Source: JICA Study Team)

Table 2.80 Roles and Responsibilities of Operation Team Staff (Outsourced): HTMS

Position	Roles and Responsibilities	Working Hours
Traffic Management Chief	♦ Supervise the operation team's work and coordinate with the Manager for Operation of the in-house member ♦ Prepare daily, monthly and annual report and submit to the Manager for Operation of the in-house member ♦ Make judgement on determining the data/information collected from related organisations to input database	By Shift
Call Centre Operator	♦ Receive and answer enquiries from general public and the related organisations ♦ Inform necessary information to the related organisations ♦ Request the related organisations to provide necessary information	By Shift
Operator-1	♦ Monitor and manipulate ATCC and CCTV ♦ Monitor traffic volume, speed, occupancy and etc. ♦ Inform the Traffic Management Chief and Operator-2 of incident on PRR and malfunction of ATCC and CCTV system when it is detected	By Shift
Operator-2	♦ Provide necessary information from VMS ♦ Inform the Traffic Management Chief of malfunction of VMS system when it is detected	By Shift

(Source: JICA Study Team)

The important duty of the maintenance team is to respond in timely manner to the maintenance request made by the Manager for Maintenance to assure safety on PRR. Sufficient knowledge of ITS is critical for the members of the maintenance team. Patrolling on PRR is also an important duty for the maintenance team.

Table 2.81 Roles and Responsibilities of Maintenance Team Staff (Outsourced): HTMS

Positions	Roles and Responsibilities	Working Hours
Chief Maintenance Engineer	♦ Supervise the maintenance team's work (*) and coordinate with the Manager for Maintenance of the in-house member ♦ Manage preventive maintenance work and plan ♦ Prepare necessary reports and submit to the Manager for Maintenance of the in-house member ♦ Carry out patrol on every section of PRR	Daytime and On Call
Electric Engineer	♦ Carry out preventive maintenance for electrical equipment ♦ Carry out repair works for electrical equipment in case of malfunction ♦ Carry out patrol on every section of PRR in compliance with instruction given by the Chief Maintenance Engineer	Daytime and On Call
IT Engineer	♦ Carry out preventive maintenance for system ♦ Carry out repair works for system in case of malfunction ♦ Carry out system modification as necessary ♦ Carry out patrol on every section of PRR in compliance with instruction given by the Chief Maintenance Engineers	Daytime and On Call
Technicians	♦ Assist the electric engineer and IT engineer ♦ Maintain spare parts ♦ Carry out patrol on every section of PRR in compliance with instruction given by the Chief Maintenance Engineers	Daytime and On Call

*Note: Maintenance work includes (i) preventive maintenance, (ii) repair work for fault and recovery, (iii) system modification, and (iv) spare parts inventory.

(Source: JICA Study Team)

(c) Proposed Shift Arrangement: HTMS

HTMS shall function for 24/7. Thus the operation team shall be arranged in three-shift and one party as stand-by.

The in-house members will station during day-time working hours.

One party of maintenance team shall be organised. They will take care of preventive maintenance, repair work for fault and recovery on the occasion of malfunction, system modification as required and spare parts inventory.

Table 2.82 shows an example of time shift of the operation team.

Table 2.82 Example of Time Shift of Operation Team: HTMS

	Shift-1 06:00AM - 02:00PM	**Shift-2** 02:00PM - 10:00PM	**Shift-3** 10:00PM - 06:00AM	**Remarks**
Party 1	On-duty	Off	Off	
Party 2	Off	On-duty	Off	
Party 3	Off	Off	On-duty	
Party 4	Off	Off	Off	Stand By

(Source: JICA Study Team)

(4) Organisation for Toll Management System of PRR

PRR is a closed-toll expressway and distance based toll charge will be applied. It is planned that the interchanges will be constructed at ten (10) locations on PRR. Out of ten (10) interchanges, two interchanges are toll barrier type at both ends and the remaining eight interchanges are diamond type.

At the interchanges of toll barrier type, seven entry lanes and seven exit lanes will be prepared on each direction. At the interchanges of diamond type, five entry lanes for on-ramp and five exit lanes for off-ramp will be prepared on each direction.

At all the interchanges, one entry lane and one exit lane will be dedicated to Electronic Toll Collection (ETC). Other lanes will be used for manual and Touch & Go toll collection.

One toll plaza will be prepared at each interchange, totalling ten (10) toll plazas. Each toll plaza monitors and manages toll collection at its interchange. A toll management centre will be prepared at one of the ten (10) toll plazas, and it overseas and manages all activities of toll collection of PRR.

(a) Toll Lanes and Interchange Structure Planned for PRR

The toll lanes and interchange structures of toll barrier type and diamond type are schematised in Figure 2.117 and Figure 2.118 , according to the existing plan. The number of toll lanes at each interchange is summarised in Table 2.83.

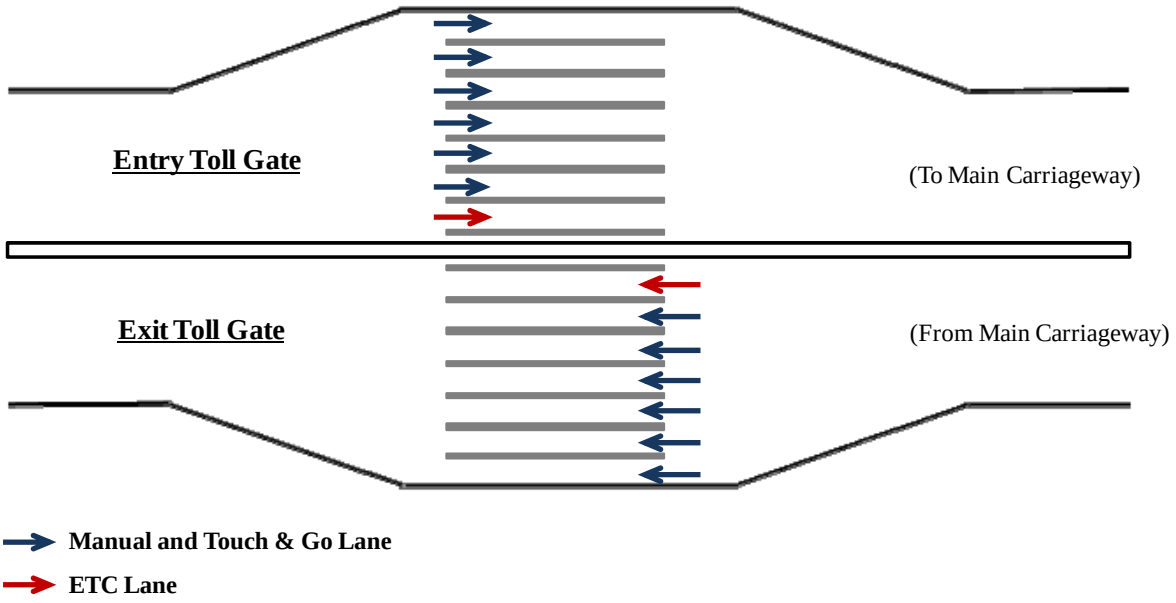


Figure 2.117 Toll Lanes and Interchange Structure: Toll Barrier Type

(Source: Prepared by JICA Study Team based on interview to BDA)

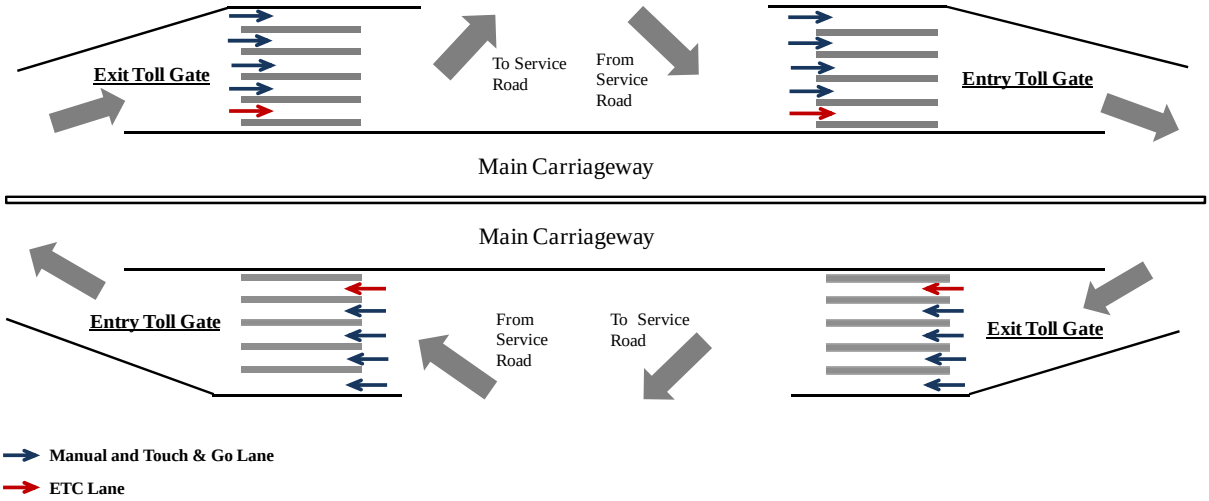


Figure 2.118 Toll Lanes and Interchange Structure: Diamond Type

(Source: Prepared by JICA Study Team based on interview to BDA)

Number of lanes at each interchange is shown in Table 2.83.

Table 2.83 Number of Toll Lane by Interchange

No.	IC Name	IC Type	Toward	Entry /Exit	No. of ETC Lane	No. of Manual and T&G Lane	Total No. of Lane
1	Tumkur Road (NH-4)	Toll Barrier	Hosur	Entry	1	6	7
			NICE road	Exit	1	6	7
2	Hesarghatta Road	Diamond	Hosur	Entry	1	4	5
			Out to service road	Exit	1	4	5
			Tumkur	Entry	1	4	5
			Out to service road	Exit	1	4	5
3	Doddaballapur	Diamond	Hosur	Entry	1	4	5
			Out to service road	Exit	1	4	5
			Tumkur	Entry	1	4	5
			Out to service road	Exit	1	4	5
4	Bellary Road (NH-7)	Diamond	Hosur	Entry	1	4	5
			Out to service road	Exit	1	4	5
			Tumkur	Entry	1	4	5
			Out to service road	Exit	1	4	5
5	Hennur Road	Diamond	Hosur	Entry	1	4	5
			Out to service road	Exit	1	4	5
			Tumkur	Entry	1	4	5
			Out to service road	Exit	1	4	5
6	Old Madras Road (NH-4)	Diamond	Hosur	Entry	1	4	5
			Out to service road	Exit	1	4	5
			Tumkur	Entry	1	4	5
			Out to service road	Exit	1	4	5
7	White Field-Hoskote Road	Diamond	Hosur	Entry	1	4	5
			Out to service road	Exit	1	4	5
			Tumkur	Entry	1	4	5
			Out to service road	Exit	1	4	5
8	Hosekote-Anekal Road	Diamond	Hosur	Entry	1	4	5
			Out to service road	Exit	1	4	5
			Tumkur	Entry	1	4	5
			Out to service road	Exit	1	4	5
9	Sarjapur Road	Diamond	Hosur	Entry	1	4	5
			Out to service road	Exit	1	4	5
			Tumkur	Entry	1	4	5
			Out to service road	Exit	1	4	5
10	Hosur Road (NH-7)	Toll Barrier	Tumkur	Entry	1	6	7
			Out to service road	Exit	1	6	7
Total					36	152	188

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

(b) Proposed Structure of Organisation for Operation and Maintenance: TMS

It is proposed that TMS is operated and maintained under supervision of government agency in charge of PRR. Actual operation and maintenance would be outsourced to contractor. Therefore the structure of organisation of TMS comprises the in-house members of the government agency; project director, manager for operation and manager for maintenance, and the operation and maintenance teams organised by the contractor under them.

Figure 2.119 shows the proposed structure of organisation for operation and maintenance of TMS and staff. Number in the brackets in the figure indicates the required number of staff.

The required number of staff and their positions shown below are proposed in consideration of the structure of the interchange and the number of the interchange and lane as shown in the previous clause. These are further explained in the following clauses.

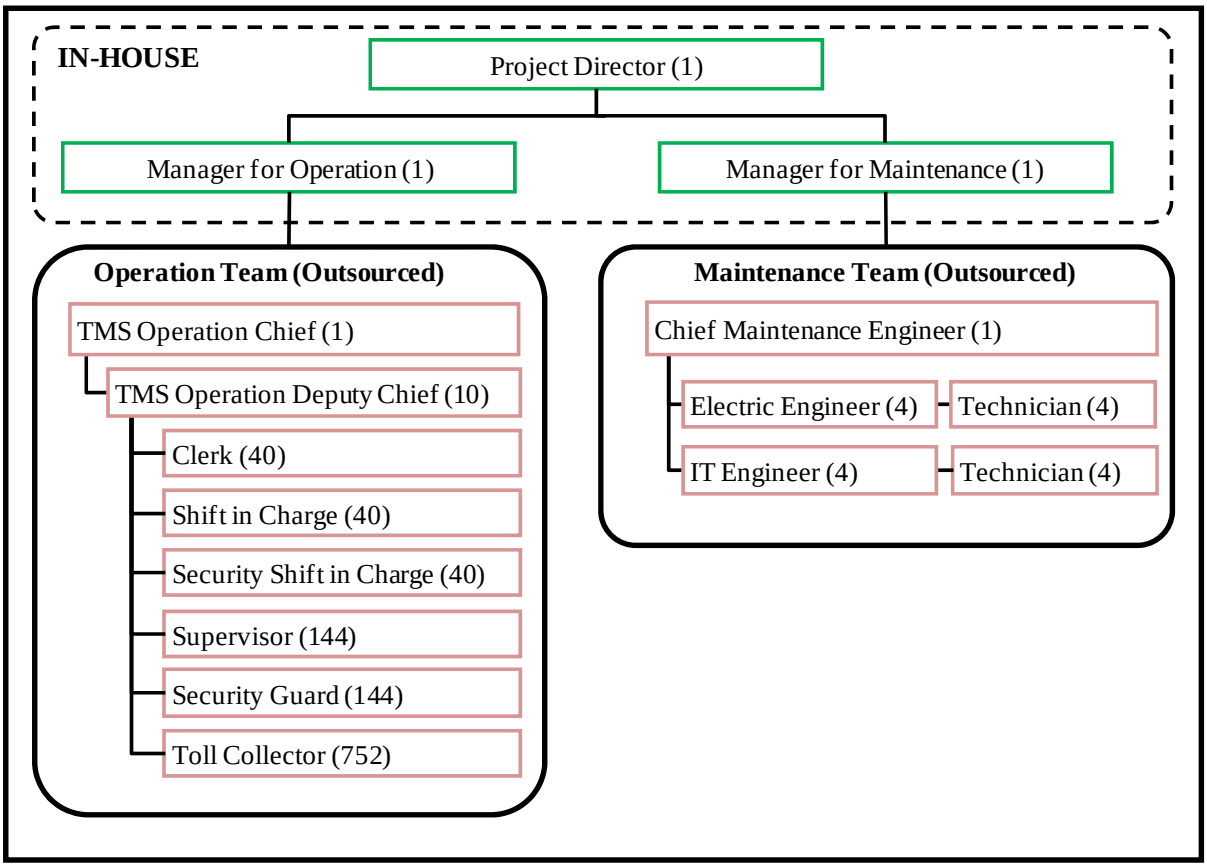


Figure 2.119 Proposed Structure of Organisation for Operation and Maintenance: TMS

(Source: JICA Study Team)

(c) Required Number of Staff for Operation Team (Outsourced): TMS

The required number of staff for the outsourced operation team is summarised in Table 2.84.

Table 2.84 Required Number of Staff for Operation Team (Outsourced): TMS

No	Interchange Name	Toll Plaza					For Entry/Exit Gate		Toll Booth	Total (*1)
		TMS Operation Chief	TMS Operation Deputy Chief	Clerk	Shift In Charge	Security Shift in Charge	Supervisor	Security Guard	Toll Collector	
1	Tumkur Road (NH-4)	1	1	4	4	4	8	8	56	85
2	Hesarghatta Road		1	4	4	4	16	16	80	125
3	Doddaballapur		1	4	4	4	16	16	80	125
4	Bellary Road (NH-7)		1	4	4	4	16	16	80	125
5	Hennur Road		1	4	4	4	16	16	80	125
6	Old Madras Road (NH-4)		1	4	4	4	16	16	80	125
7	White Field-Hoskote Road		1	4	4	4	16	16	80	125
8	Hosekote-Anekal Road		1	4	4	4	16	16	80	125
9	Sarjapur Road		1	4	4	4	16	16	80	125
10	Hosur Road (NH-7)		1	4	4	4	8	8	56	85
Total		1	10	40	40	40	144	144	752	1170

Note (*1): It excludes TMS Operation Chief.

(Source: JICA Study Team)

TMS operation chief will be assigned to be responsible for overseeing the entire activities of toll collection on PRR as a contractor. S/he will be a contact point with the Manager for Operation of the in-house member of the government agency in charge of PRR.

TMS operation deputy chief will be assigned to each interchange. S/he will be responsible for overseeing the activities of toll collection at her/his interchange.

A single-shift of day-time working hours would be sufficient for both positions according to the practices of highway toll management implemented in the world.

One personnel of three-shift and one extra personnel as stand-by will be assigned to each interchange as to clerk, shift in charge and security shift in charge.

One personnel of three-shift and one extra personnel as stand-by will be assigned to the entry toll gate and exit toll gate respectively as to supervisor and security guard.

One personnel of three-shift and one extra personnel as stand-by will be assigned to each tollbooth as to toll collector.

The basis of calculation of the required number of staff for the outsourced operation team shown in Table 2.84 above is further explained by Table 2.85, Figure 2.120 and Figure 2.121. Table 2.85 includes the positions other than TMS operation chief and TMS operation deputy chief.

The roles and responsibilities of all staff are explained in the next clause.

Table 2.85 Basis of Calculation of Number of Staff for Operation Team (Outsourced): TMS

Position	IC Type	No. of	No. of Toll Gate	No. of Shift	No. Staff per	Total No. of Staff	Remarks
Clerk	Toll Barrier	10	-	4	1	40	Station at each IC
	Diamond						
Shift in Charge	Toll Barrier	10	-	4	1	40	Station at each IC
	Diamond						
Security Shift in Charge	Toll Barrier	10	-	4	1	40	Station at each IC
	Diamond						
Supervisor (*3)	Toll Barrier	2	2	4	1	16	144 in total
	Diamond	8	4	4	1	128	
Security Guard (*3)	Toll Barrier	2	2	4	1	16	144 in total
	Diamond	8	4	4	1	128	
Toll Collector (*3)	Toll Barrier	2	2	4	7	112	752 in total
	Diamond	8	4	4	5	640	

Note (*1): Refer Figure 2.120 and Figure 2.121 on the next page for No. of Toll Gate by IC type.

Note (*2): 3 shifts + 1 party for stand by

Note (*3): The concept of assignment is depicted by Figure 2.120 and Figure 2.121 on the next page

(Source: JICA Study Team)

Figure 2.120 and Figure 2.121 show the concept of assignment of supervisor, security guard and toll collector.

One personnel per shift is assigned to the entry toll gate and exit toll gate respectively as to the supervisor and security guard as shown below. Each supervisor and security guard will be responsible for each entry/exit toll gate.

One personnel per shift is assigned to each tollbooth as to the toll collector as shown below. The toll collector at the tollbooth of ETC lane will not always station at site.

The above concept is applied to both types of interchange; toll barrier type and diamond type.

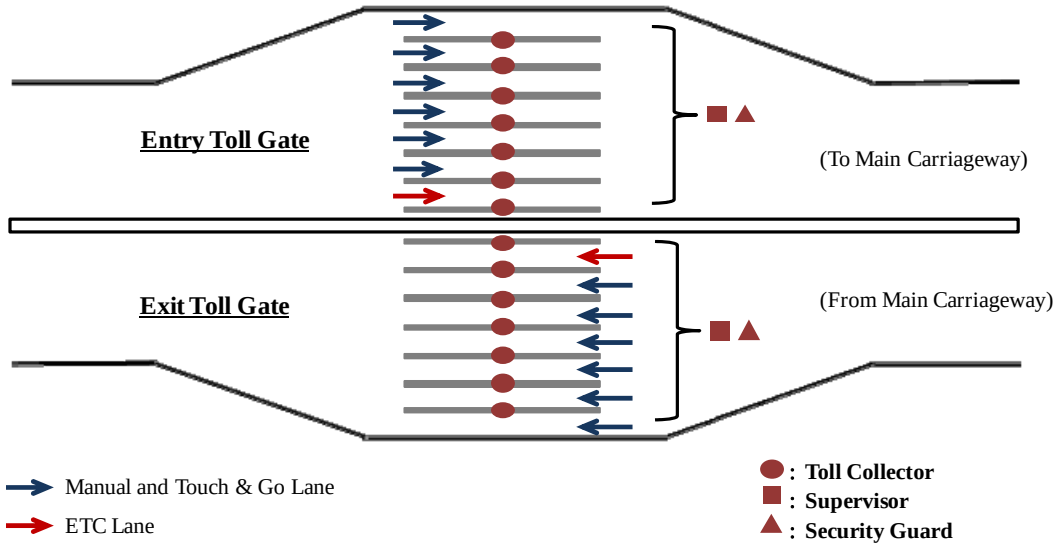


Figure 2.120 Assignment Concept of Personnel: Toll Barrier Type

(Source: JICA Study Team)

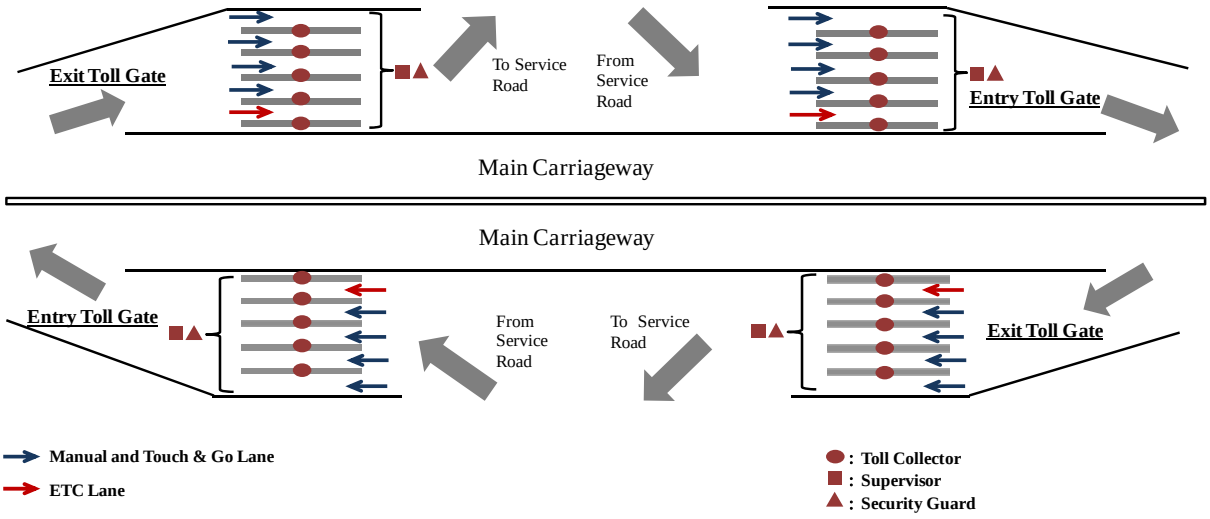


Figure 2.121 Assignment Concept of Personnel: Diamond Type

(Source: JICA Study Team)

(d) Roles and Responsibilities of Staff: TMS

The roles and responsibilities of staff are explained in Table 2.86,

Table 2.87 and Table 2.88.

Table 2.86 Roles and Responsibilities of In-house Staff: TMS

Position	Roles and Responsibilities	Working Hours
Project Director	♦ Responsible for supervising and controlling all activities of TMS ♦ Coordinate and handle the issues arouse between TMS and HTMS, and other related organisations ♦ Provide data/information to related organisations based on request	Daytime only
Manager for Operation	♦ Responsible for the operation of TMS ♦ Supervise and control the outsourced operation team	Daytime only
Manager for Maintenance	♦ Responsible for the maintenance of TMS ♦ Supervise and control the outsourced maintenance team	Daytime only

(Source: JICA Study Team)

Table 2.87 Roles and Responsibilities of Operation Team Staff (Outsourced): TMS

Position	Roles and Responsibilities	Working Hours
TMS Operation Chief	♦ Supervise and manage the entire activities of toll management operation of PRR ♦ Audit and confirm the daily amount of the collected toll fare of all interchanges reported by the TMS Operation Duty Chief ♦ Report the number of vehicle, collected amount of the toll fare and other activities, as required, of all interchanges of PRR to the Manager of Operation of the in-house member	Daytime only
TMS Operation Deputy Chief	♦ Supervise and manage the activities of toll management operation at each interchange ♦ Audit and confirm the daily amount of the collected toll fare of each interchange ♦ Report the number of vehicle, collected amount of the toll fare and other activities, as required, of each interchange to the TMS Operation Chief	Daytime only
Clerk	♦ Calculate and confirm the amount of the collected toll fare by manual payment, Touch & Go and ETC ♦ Manage sales of smart card at POS station at interchange ♦ Report the amount of the collected toll fare and sales activities of smart card to the TMS Operation Deputy Chief	By Shift
Shift in Charge	♦ Prepare monthly schedule of operation activities ♦ Monitor in the toll plaza the work of toll collectors at the tollbooth ♦ Take necessary measures on such occasions as accident, fraudulent payment, breaking through the toll gate, disasters and etc. ♦ Confirm, by monitoring camera in toll plaza, the vehicle type between the one determined by the toll collector and the other measured by the system (This is carried out to minimise the errors of the system and mistakes by the toll collector)	By Shift
Security Shift in Charge	♦ Supervise security activities as head of security in charge ♦ Plan and manage security activities	By Shift

Position	Roles and Responsibilities	Working Hours
Supervisor	♦ Supervise at site the work of the toll collectors ♦ Handle the work at site on the occasion of passage of special vehicles such as emergency vehicle, VIP vehicle, military vehicle and etc. ♦ Handle the troubles at site on such occasions as fraudulent payment, breaking through the toll gate, complaint of drivers and etc. ♦ Verify the collected toll fare at duty completion of the toll collector ♦ One of the supervisors takes the roles of the TMS Operation Deputy Chief during night shift	By Shift
Security Guard	♦ Carry out security activities such as patrolling toll plaza site and lane site, protecting the collected toll fare and equipment at site, and etc.	By Shift
Toll Collector	♦ Collect toll fare from vehicle for manual payment and handle smartcard payment at tollbooth ♦ Determine vehicle type that passes through the gate at both entry and exit ♦ Report the amount of the collected toll fare to the supervisor at duty completion ♦ Report the system failure to the supervisor when it occurs ♦ Open and close the toll lanes as necessary	By Shift

(Source: JICA Study Team)

Table 2.88 Roles and Responsibilities of Maintenance Team Staff (Outsourced): TMS

Position	Roles and Responsibilities	Working Hours
Chief Maintenance Engineer	♦ Supervise the maintenance team's work (*) and coordinate with the Manager for Maintenance of the in-house member	Daytime and On Call
Electric Engineer	♦ Carry out preventive maintenance for electrical equipment ♦ Carry out repair works for electrical equipment in case of malfunction	By Shift
IT Engineer	♦ Carry out preventive maintenance for system ♦ Carry out repair works for system in case of malfunction ♦ Carry out system modification as necessary	By Shift
Technician	♦ Assist the electric engineer and IT engineer ♦ Maintain spare parts	By Shift

*Note: Maintenance work includes (i) preventive maintenance, (ii) repair work for fault and recovery, (iii) system modification, and (iv) spare parts inventory.

(Source: JICA Study Team)

(e) Proposed Shift Arrangement: TMS

TMS shall function for 24/7. Thus the operation team shall be arranged in three-shift and one party as stand-by except the TMS operation chief and deputy chief as detailed in the precious clause.

The in-house members will station during day-time working hours.

Malfunction of the toll management system such as ETC in particular causes serious accidents. Therefore it is recommended that the maintenance team is organised in three-shift with one party as stand-by so that the measures on system failure are taken in timely manner.

They will take care of preventive maintenance, repair work for fault and recovery on the occasion of malfunction, system modification as required and spare parts inventory.

Table 2.89 shows an example of time shift of the operation and maintenance team.

Table 2.89 Example of Time Shift of Operation and Maintenance Team: TMS

	Shift-1 06:00AM - 02:00PM	**Shift-2** 02:00PM - 10:00PM	**Shift-3** 10:00PM - 06:00AM	**Remarks**
Party 1	On-duty	Off	Off	
Party 2	Off	On-duty	Off	
Party 3	Off	Off	On-duty	
Party 4	Off	Off	Off	Stand By

(Source: JICA Study Team)

(5) Organisation for Electronic Road Pricing System

Electric Road Pricing (ERP) will be established to function as a single central body for collection of RFID data and charging fee when charging time. RFID will be distributed at the service counter and payment will be done through POS system in kiosk etc near the charging area.

The major activities of ERP operation are:

- Distributing RFID Tag and managing registration of Tag account
- Confirming RFID data and camera data collected from the charging point and identifying violated vehicle owner at ERP centre
- Confirming collection of ERP charge as necessary
- Managing payment through top-up agency and POS
- Monitoring operation status of ITS equipment of ERP and taking necessary actions when malfunction is found

(a) Proposed Structure of Organisation for Operation and Maintenance: ERP

It is proposed that ERP is operated and maintained under supervision of government agency in charge of ERP. Some operation and maintenance would be outsourced to contractor. Therefore the structure of organisation of ERP comprises the in-house members of the government agency; project director, manager for operation and some operation groups, and the some operation teams organised by the contractor under them.

Figure 2.122 shows the proposed structure of organisation for operation and maintenance of ERP and staff. Number in the brackets in the figure indicates the required number of staff.

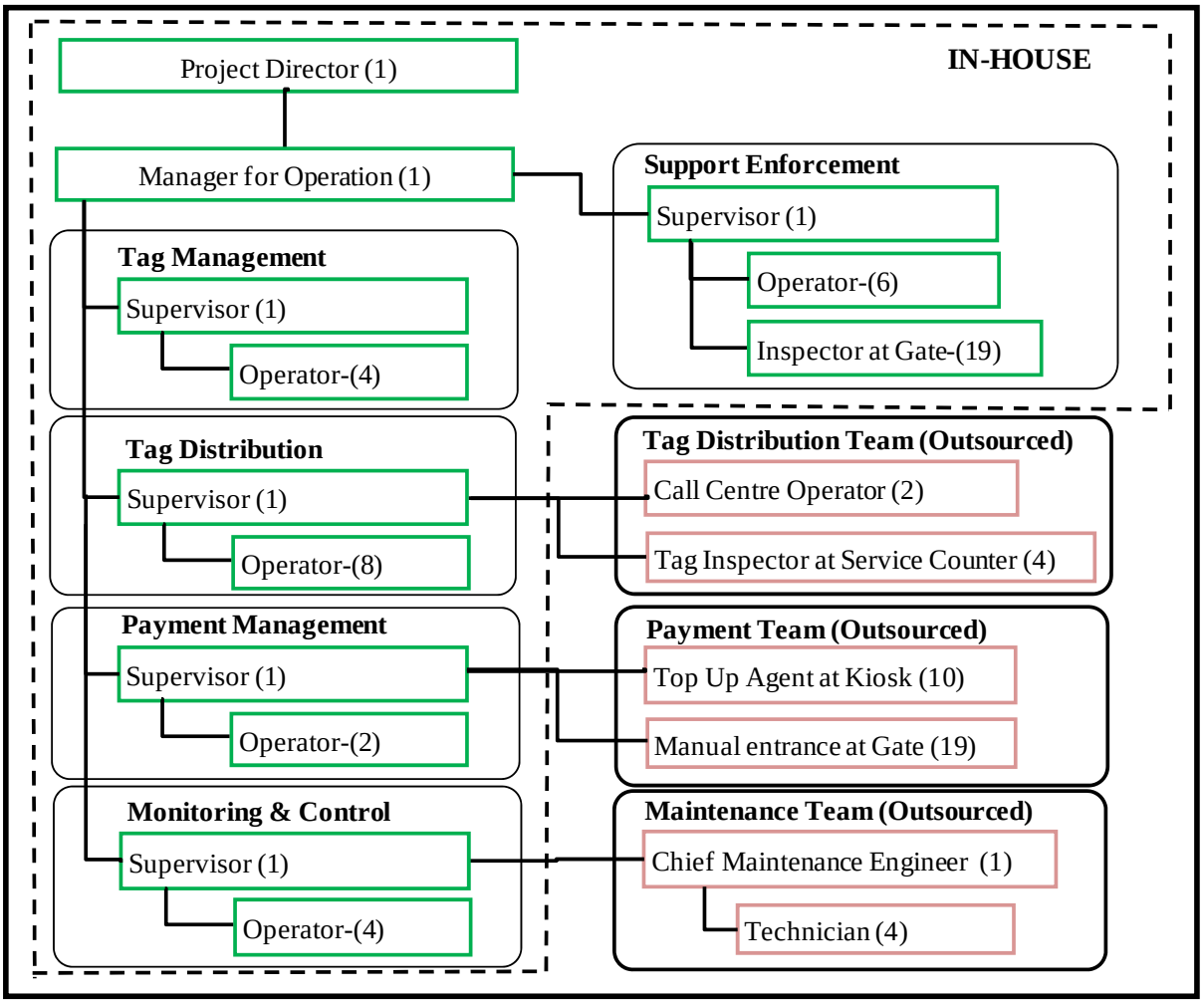


Figure 2.122 Proposed Structure of Organisation for Operation and Maintenance: ERP

(Source: JICA Study Team)

(b) Roles and Responsibilities of Staff: ERP

The roles and responsibilities of staff are explained in the table below. Their working hours are explained in the next clause.

Table 2.90 Roles and Responsibilities of In-house Staff: ERP

Position	Roles and Responsibilities	Working Hours
Project Director	♦ Responsible for supervising and controlling all activities of ERP ♦ Coordinate all activities between ERP and other centres such as B-TIC, EPS, Traffic Management Centre of Traffic Police, and other related organisations ♦ Provide data/information to related organisations based on request	Daytime only
Manager for Operation	♦ Responsible for the operation of ERP ♦ Supervise and control the outsourced operation team	Daytime only
Tag Management	♦ Order, receipt of RFID Tag from supplier ♦ Monitor stock level of RFID Tags ♦ Distribute RFID Tags to various service counter for distribution ♦ Update vehicle-owner database of those who apply for RFID tags	Daytime only
Tag Distribution	♦ Customer Service for Tag distribution at Service Counters ♦ Tag registration/ programming and installation ♦ Handle Tag Account opening, replacement and termination ♦ Provide Tag Account Top-up and Refund ♦ Settlement of fines ♦ Perform Tag inspection for faults	Daytime only
Payment Management	♦ Ensure payment and top-up are settled ♦ Perform daily transaction reconciliation ♦ Check and verify black list for non-payment account with insufficient fund in account ♦ Ensure fine payment is properly processed	Daytime only
Monitoring & Control	♦ Monitor the operation status of all equipment ♦ Ensure all roadside equipment has the latest blacklist ♦ Ensure all equipment are properly time synchronized ♦ Control the operation status of all equipment ♦ Activate the maintenance team for any fault reported ♦ Monitor the performance of the maintenance team	Daytime only
Support Enforcement	♦ Manual verification of violation images that cannot be processed automatically by system ♦ Investigation of complaints of fines or payment received from call centre ♦ Support enforcement action on owner of vehicle with long overdue outstanding payment	Daytime only

(Source: JICA Study Team)

Table 2.91 Roles and Responsibilities of Operation Team Staff (Outsourced): ERP

Position	Roles and Responsibilities	Working Hours
Tag Distribution Team	♦ Call Centre Provide Hotline phone service for any enquiry, complaints etc. ♦ Inspection Centre Inspect Tag if suspected faulty, replace it with new Tag	Daytime only
Payment Team	• Account Top-up Agent ♦ Provide the necessity tag account top-up facility ♦ Provide the facility for fine settlement ♦ Manual entrance payment at gates	Daytime only
Maintenance Team	♦ Frontend Systems an Backend Maintenance contractor ♦ Provide corrective maintenance ♦ Provide routine preventing maintenance	Daytime only

(Source: JICA Study Team)

(c) Proposed Shift Arrangement: ERP

ERP shall function for 2 hours a day for charging and 7 days a week. But, operation shall be done during daytime.

The in-house members will station during day-time working hours.

One party of maintenance team shall be organised. They will take care of preventive maintenance, repair work for fault and recovery on the occasion of malfunction, system modification as required and spare parts inventory.

(6) Organisation for Clearinghouse for Common Smartcard

The introduction of common card and establishment of clearinghouse are proposed under the situation that the smart card payment for different transport and services such as Bangalore metro, city bus, Touch & Go and ETC on Peripheral Ring Road and etc. are increasingly expected in Bengaluru.

The clearinghouse settles the payment of different transport and services used by a single smart card. The major operation duties of the clearinghouse are:

- Making settlement of payment by transport operator and agencies,
- Handling enquiries from card users and involved parties such as transport operator,

- Taking care of issues of settlement and others if they arise,
- Promoting usage of the common card,
- Contracting new agency to join the common card payment under the clearinghouse,
- Handling other administrative work for operating the clearinghouse, and
- Taking care of system maintenance.

This section proposes the organisation structure and staff required for operation and maintenance of the clearinghouse of the common card.

(a) Proposed Structure of Organisation for Operation and Maintenance: Clearinghouse

It is proposed that the clearinghouse is operated and maintained under supervision of government agency in charge of the clearinghouse. The settlement of fare payment is a major activity and it entails a financial responsibility. Therefore it is recommended that the operation team consists of the in-house members of the government agency. Actual maintenance would be undertaken by contractor.

Figure 2.123 shows the proposed structure of organisation for operation and maintenance of clearinghouse. Number in the brackets in the figure indicates the required number of staff.

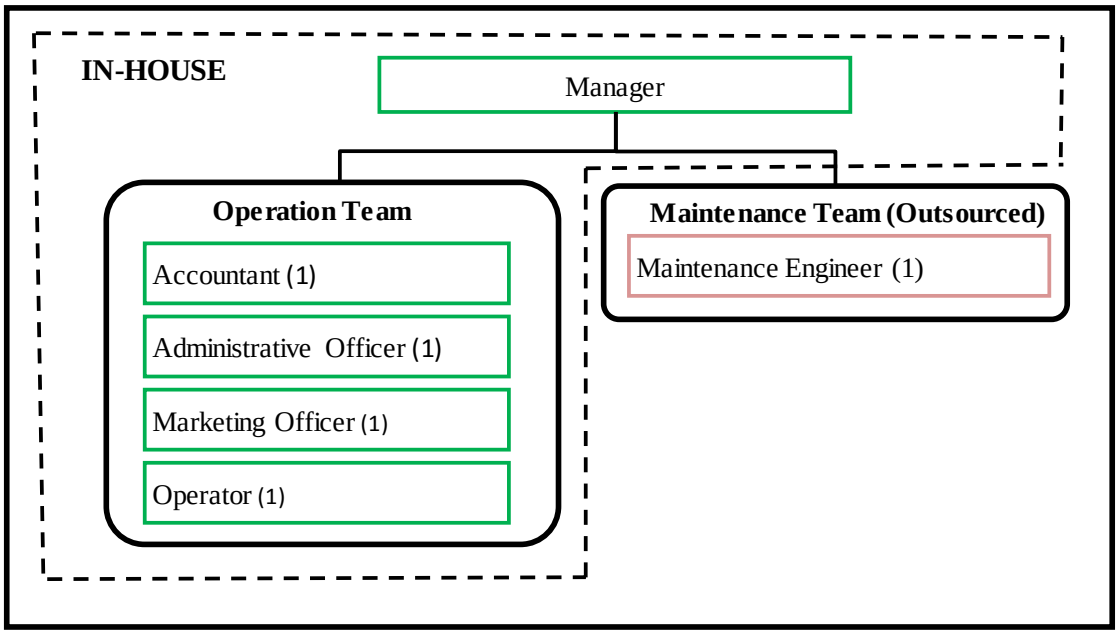


Figure 2.123 Proposed Structure of Organisation for Operation and Maintenance: Clearinghouse

(Source: JICA Study Team)

(b) Roles and Responsibilities of Staff: Clearinghouse

The roles and responsibilities of staff are explained in Table 2.92 and Table 2.93. Their working hours are explained in the next clause.

Table 2.92 Roles and Responsibilities of In-house Staff: Clearinghouse

Position	Roles and Responsibilities	Working Hours
Manager	♦ Supervise and control all activities of clearinghouse ♦ Handle the issues between operators/agencies and clearinghouse, and other related organisations if they arise ♦ Responsible for the operation of the system ♦ Responsible for the maintenance of the system	Daytime only
Accountant	♦ Responsible for accounting and financial work of clearinghouse	Daytime only
Administrative Officer	♦ Responsible for all administrative work of clearinghouse	Daytime only
Marketing Officer	♦ Responsible for promoting the use of common card ♦ Contracting and taking care of agency to join common card payment under clearinghouse	Daytime only
Operator	♦ Handling enquiry calls from operators/agencies/card users ♦ Checking transaction settlement amongst operators/agencies	Daytime only

(Source: JICA Study Team)

Table 2.93 Roles and Responsibilities of Maintenance Team Staff: Clearinghouse

Position	Roles and Responsibilities	Working Hours
Maintenance Engineer	♦ Responsible for maintenance work for clearinghouse	On Call

(Source: JICA Study Team)

(c) Proposed Shift Arrangement: Clearinghouse

The daily settlement process will be automated in such way as a scheduled batch job during mid-night. The activities of the operation staff such as handling enquiries, taking care of issues, promoting common card use, contracting new agencies, and etc. will be carried out during day-time working hours.

Therefore it is proposed that the in-house members will station during day-time working hours.

The outsourced maintenance staff will take care of preventive maintenance work, repair work for fault and recovery on the occasion of malfunction, system modification as required and spare parts inventory.

2.5 Implementation Scheme of ITS

Choosing a implementation appropriate scheme for ITS preparation, operation and maintenance is critical for the success of the ITS systems. There are various schemes by which ITS systems can be prepared, operated and maintained. These schemes are described below.

2.5.1 Three Schemes

- Scheme 1: Prepared, Operated and Maintained by a Government Agency

In this scheme, the government will own, operate and maintain the system. An existing government department or a special agency formulated by government will be assigned the responsibility for implementation of the ITS system. The system will be implemented with funds allocated by the government. The government will be responsible for preparing specification as a system requirement, procuring a vendor and ensuring that the vendor installs the system as per the specification within the agreed time line.

The system will be installed by the vendor and handed over to the government upon completion of the installation. The government will deploy its resources to operate and maintain the system. For this purpose, the government requires necessary skill and team members who can manage the operation and maintenance.

- Scheme 2: Build, Operate and Transfer (BOT) by Private Vendor

In this scheme, the government will procure the vendor by BOT method. The vendor will design and install the system with his own funds. In return the vendor will be given the contract of operation and maintenance for a specified period, owning the system. The vendor is entitled to collect the total income generated by the system and pay the commission fee on the income to the government as per the contract. The government requires limited resource for implementation. They monitor the service levels agreed between both parties and the vendor is responsible for meeting the service levels. Upon completion of the contract period, the vendor hands over the system to the government.

- Scheme 3: Owned by Government Agency, and Build, Operate and Maintain by Private Vendor

This scheme is a combination of scheme 1 and scheme 2. The government owns the system and outsources the operation and maintenance to the private company. The government will prepare specification as a system requirement and procure the vendor. The system will be implemented with funds allocated by the government. The system will be installed by the vendor and handed over to the government upon completion of the installation.

Government procures a vendor and give the contract of operation and maintenance for a specified period. The Vendor will be paid annuity based payment by the government during operation and maintenance period.

2.5.2 Advantages and Disadvantages of Three Schemes

Table 2.94 describe some of the advantages and disadvantages of the three schemes explained above.

Table 2.94 Advantages and Disadvantages of Implementation Schemes

Scheme	Advantages	Disadvantages
Scheme 1	• Government owns the system • Revenue from the system goes to the government • Government builds up capacity of knowledge	• Government may not have capability and skill to operate and maintain the system on its own • Government is required to return a large number of his own in-house members
Scheme 2	• Greater flexibility for innovation by private sector can be expected • Revenue from the system goes to vendor • Effective management of cost and time by private sector because of necessity of efficiency as BOT contractor	• Government does not gain knowledge and dependency on private sector becomes large degree • This results in higher cost in long term, controlled by private sector • Data/Information generated by the system will be owned by the vendor • This Scheme is applicable to ITS which generate revenue
Scheme 3	• Government owns the system • Revenue from the system goes to the government • A minimum number of in-house members of government is enough	• A sense of ownership of government is still required • Capable personnel of government are required for proper monitoring of operation and maintenance which are executed by private company

(Source: JICA Study Team)

2.5.3 Recommended Scheme for Proposed ITS Components

ITS components proposed by ITS Master Plan are outlined below.

- Bengaluru Traffic Information Centre (B-TIC) will be developed to function as a single central body for collection of data on traffic, processing and provision of dynamic traffic information to road users. Traffic Data Collection System and Traffic Information Provision System will be prepared under B-TIC. The cumulated quantitative data will be utilised for the measures on urban transport.
- Area Traffic Signal Control System (ATCS) will be prepared under the existing traffic management centre of B-TRAC of Bangalore Traffic Police for controlling traffic flow in the city.
- Highway Traffic Management System (HTMS) and Toll Management System (TMS) will be developed for Peripheral Ring Road (PRR). They will be developed for highway management and toll collection management of PRR.
- Electronic Road Pricing (ERP) system will be developed to alleviate traffic congestion in the charging area as traffic demand management (TDM).
- A clearinghouse of common smartcard will be prepared for settlement of e-money.

The scheme recommended for above ITS components is summarised in the table on the next page.

Table 2.95 Recommended Scheme for Proposed ITS Component

ITS Component	Recommended Scheme	Reasons
B-TIC	Scheme 1 or Scheme 3	• B-TIC is a traffic information centre and does not generate revenue. • B-TIC will hold a lot of traffic data, much of which shall be owned by government. • B-TIC is aimed to function as a central body to facilitate close coordination amongst related agencies. • In consideration of these, Scheme 1 is primarily recommended. Scheme 3 is also considered acceptable.
ATCS	Scheme 3	• ATCS is a signal system and thus does not generate revenue. • The existing traffic management centre of B-TRAC is already implemented by Scheme-3. • Hence, Scheme-3 is considered most relevant.
HTMS/TMS for PRR	Scheme 3	• TMS generate revenue. • However, the construction of PRR is planned to implement by Japanese loan. • HTMS and TMS will be a part of Japanese loan of PRR. • BOT scheme is not relevant with a scheme of the loan. • A large number of staff of operation and maintenance is required for HTMS and TMS. • Hence, Scheme-3 is considered most relevant. • In this case, the contractor for operation and maintenance could be paid on annuity base.
ERP	Scheme 3	• ERP generates revenue. • However the purpose of ERP is to discourage usage of motor-vehicle, and the prime concern of ERP is to reduce traffic, not revenue generation. • ERP is to be implemented as part of traffic demand management (TDM) on which government is supposed to take a prime role. • A large number of staff for operation and maintenance is required for ERP. • Hence, Scheme-3 is considered most relevant.
Clearinghouse	Scheme 1 or Scheme 3	• Reliable and secure transaction settlement is required amongst different operators/agencies. • The majority of operators who are expected to come under the scheme of clearinghouse are government agency. • Karnataka government has an intension that the revenue generated by the clearinghouse will be used for transport measures in the future. • The proposed clearinghouse is a state-wise clearinghouse. • In consideration of these, either Scheme 1 or Scheme 3 is considered relevant.

(Source: JICA Study Team)

2.6 Rough Cost Estimate

Based on the studies so far, the rough cost of the ITS components is estimated as shown in Table 2.96 on the next page.

Table 2.96 Rough Cost Estimate of ITS Component

Unit=INR

ITS Component		Equipment			O&M (Annual)
		Phase-1	Phase-2	Total	
Bengaluru Traffic Information System (B-TIC)	Centre System (including Probe Car System)	691,778,188	44,523,400	736,301,588	50,281,440
	Queue Length Measurement System	138,934,950		138,934,950	
	Automatic Traffic Counter-Cum Classifier (ATCC) System	197,324,820		197,324,820	
	Variable Message Sign (VMS) System	161,475,353	161,475,353	322,950,705	
	Internet System	66,792,000	1,265,000	68,057,000	
Subtotal		**1,256,305,310**	**207,263,753**	**1,463,569,063**	
ITS for Peripheral Ring Road	Highway Traffic Management System (HTMS)	703,752,149		703,752,149	39,551,318
	Toll Management System (TMS)	676,745,031		676,745,031	798,905,184
Subtotal		**1,380,497,180**		**1,380,497,180**	**838,456,502**
Area Traffic Signal Control System (ATCS)		848,880,665	2,309,515,215	3,158,395,880	133,660,208
Electronic Road Pricing (ERP) System		1,100,002,931		1,100,002,931	72,822,288
Clearinghouse for Common Smartcard		475,663,920		475,663,920	10,890,000
Grand Total		**5,061,350,006**	**2,516,778,968**	**7,578,128,973**	**1,106,110,438**

Notes for Equipment Cost and O&M Cost are provided on the next page.

Note: Equipment Cost

- The consultant fee for preparing bidding documents, tendering assistance and supervision is included.
- The design fee carried out by contractors is included.
- The contingency and other required cost other than equipment/system are considered at 15% of equipment cost.
- Area Traffic Signal Control System (ATCS) is proposed to install in three stages, completing by middle of Phase-2 of ITS Master Plan as shown in the implementation schedule in the previous chapter. The equipment costs in three stages are summarised in Phase-1 and Phase-2 inTable 2.96.
- The operation of HTSM and TMS for PRR will start in Phase-2 of ITS Master Plan as per the implementation schedule presented in the previous chapter. The costs are included in Phase-1 in Table 2.96 considering that the preparation will start in Phase-1.

Note: O&M Cost

- The cost for operation and maintenance shown in Table 2.96 is annual cost.
- They are estimated based on average labour cost (according to position) in Bengaluru as of 2015.
- The costs of electricity and communication are included.
- The management cost is considered at 10% of O&M cost.

2.7 Evaluation of Proposed ITS Component

2.7.1 Economic and Financial Evaluation by ITS Component

The listed below in Table 2.97 are ITS components planned by ITS Master Plan. The table below summarises economic and financial evaluations which are carried out by ITS component under ITS Master Plan Study as per discussions with counterpart agency, DULT.

Table 2.97 Evaluated ITS Components

ITS Component	Economic Evaluation	Financial Evaluation
Bengaluru Traffic Information Centre (B-TIC)	X	-
Area Traffic Signal Control (ATCS)	X	-
Highway Traffic Management System (HTMS) for PRR	-	-
Toll Management System (TMS) for PRR	-	-
Electronic Road Pricing (ERP)	-	X
Clearinghouse for Common Smartcard	-	X (*)

'X' indicates that the evaluation is carried out.

(Source: JICA Study Team)

Bengaluru Traffic Information Centre (B-TIC) and Area Traffic Signal Control (ATCS)

The effect of implementing these components can be quantitatively measured by such indicators as reduction of Travel Time Cost (TTC) and Vehicle Operation Cost (VOC). The socioeconomic benefits are evaluated based on monetary value derived from these indicators. However these components do not generate revenue due to its nature of information provision and signal control. Therefore the economic evaluation is carried out.

Highway Traffic Management System (HTMS) and Toll Management System (TMS) for PRR

HTMS and TMS are ancillary facilities of highway. The socioeconomic benefits are brought about by construction of the highway supported by ITS. Therefore the economic viability is to be evaluated by the effect of the construction of the highway together with ITS. Likewise, the financial viability is to be evaluated as a whole project of construction of the highway including ITS. The construction of Peripheral Ring Road (PRR) is planned by Government of Karnataka. ITS Master Plan estimates the cost of HTMS and TMS for PRR, as shown in the previous chapter, so that the Indian authority is able to refer for the project of PRR.

Electronic Road Pricing (ERP)

Implementing ERP is expected to bring about the effect in terms of reduction of traffic volume by charging, thereby increasing in travel speed in the charging area. However it is difficult to quantify the socioeconomic benefit as to what happens to the reduced traffic in the charging area. Some motorists may abandon their travels and others may change their transport mode or commuting time, as experiences of ERP in Singapore, London and Stockholm inform. Therefore, only financial evaluation is carried out. It is analysed based on the assumptions made in the clause of ERP in Chapter 4.

Clearinghouse for Common Smartcard

The primary purpose of common smartcard is to enhance convenience of users. However it is difficult to quantify the convenience in terms of socioeconomic benefit. Therefore the economic evaluation is not carried out. The clearinghouse settles the amount for different transport operators or services used by a single common smartcard. The revenue of the clearinghouse is a commission charge imposed on each payment transaction. However it is not clear how much payment across different operators or services will be made. Further, an entire smartcard system including new operators to join in the proposed scheme in the future is not clear. Considering these aspects, an idea of financial prospect as a ground understanding based on rough assumption is presented in the previous chapter of common smartcard, instead of carrying out the evaluation of financial viability in this chapter.

2.7.2 Project Evaluation

(1) Basic Idea of Evaluation

(a) Outline of Evaluation

The provision of traffic information and traffic signal control largely contribute to reduction of travel time of the road users by optimizing traffic flow. The road users will become enabled to choose the optimal route and avoid bottleneck points, resulting in reduced travel time. Hence, the immediate major beneficiaries are road users in Bengaluru metropolitan area such as 2-wheelers, cars, buses, commercial vehicles, etc. Furthermore, the collected traffic data will be utilised for planning and evaluation of measures on traffic management and infrastructure development. Therefore other beneficiaries are planning agencies of Karnataka State Government.

The effectiveness of ITS implementation is evaluated in this section. Two ITS component groups are evaluated as shown in Table 2.98 to understand the impacts and to quantify the benefits focusing on traffic. The impact is measured by a reduction of travel time expressed in unit of vehicle-hour. The

reduction is compared with 'with case' and 'without case'. The 'with case' is the case that ITS is implemented. The 'without case' is the case that ITS is not implemented.

The evaluation target year is set in 2025. This has been drawn taking into consideration that all equipment of the following ITS components will be introduced by middle of the phase-2 of ITS Master Plan as shown in the implementation schedule in Table 2.40 in Chapter 2.2.

Table 2.98 Evaluated ITS Components

ITS Component		Installation by Target Year: 2025
Bengaluru Traffic Information Centre (B-TIC)		Centre + All Equipment
Area Traffic Signal Control (ATCS)	Stage-1(*)	Centre + 100 Signals
	Stage-2(*)	Additional Signals (180)
	Stage-3 (*)	Additional Signals (120)

Note (*): ATCS will be installed in three stages completing by mid of Phase-2 of ITS Master Plan as shown in the implementation schedule in the previous Chapter.

(Source: JICA Study Team)

(b) Traffic Information Dissemination by B-TIC

B-TIC is a system to provide information such as the road condition and traffic information to the drivers. The dynamic traffic information will be available to the road users. It will be possible for the drivers to effectively drive and choose the optimal routes to the destinations using the information generated/provided by B-TIC. The effect is calculated based on the data of traffic survey carried out. The traffic demand was forecasted by five step traffic assignment method. For the analysis of effect of ITS implementation, the road assignment was carried out on the assumption that the traffic flow on all target road network will be optimised. The searching reaction is not considered here. The effect indicator is directed to a reduction of travel time. The environmental benefit such as reduction of emissions, fuel consumption and etc. is not included in this evaluation.

(c) Area Traffic Signal Control (ATCS)

The area traffic signal control is expected to reduce delay time at intersection by coordinating the optimal cycle time of signal and timing of green light time. As a result, the traffic capacity at intersection will be increased. For the evaluation, it is assumed that the implementation of the area traffic signal control realises 10% increase of road link capacity. The calculation is conducted by traffic assignment.

(2) Result of Evaluation

The result of evaluation is shown in the table below. The total vehicle-hour in peak hour is calculated by aggregated product of link traffic and link travel time. The data in Table 2.99 shows the reduction of total vehicle-hour per year by comparing with the 'Without Case'. The reduction of 51,400 veh.-hour (-9.2%) is achieved by implementing ITS. The breakdown shows that 1.6% is reduced by the traffic information dissemination (B-TIC) and 7.6% is by area traffic signal control.

Table 2.99 Reduction of Total Vehicle-hour by Implementation of ITS

ITS Component		Installation by Target Year: 2025	Reduced Vehicle-hour
Bengaluru Traffic Information Centre (B-TIC)		Centre + All Equipment	9,100 (1.6%)
Area Traffic Signal Control (ATCS)	Stage-1	Centre + 100 Signals	42,300 (7.6%)
	Stage-2	Additional Signals (180)	
	Stage-3	Additional Signals (120)	
Total			51,400 (9.2%)

*Above figures are in peak hour.

**Above figures are reduction from without case.

(Source: JICA Study Team)

2.7.3 Economic Analysis

(1) Methodology

The economic analysis has been carried out to evaluate economic viability of ITS component. The analysis adopts cost benefit analysis and discounted cash flow methods which are one of the standard methods. The economic indicators, i) Economic Internal Rate of Return (EIRR), ii) Net Present Value (NPV) and iii) Cost Benefit Ratio (B/C Ratio), are calculated for economic evaluation.

(a) Economic Analysis and Evaluation for the ITS Components

The economic analyses were for the following two (2) ITS components:

- Area Traffic Signal Control (ATCS)
- Bengaluru Traffic Information Centre (B-TIC)

The benefits are evaluated with a combination of implementing these two (2) ITS components due to the reason that maximum effect is attained in a mutually reinforcing way by providing dynamic traffic information and optimising traffic control.

(b) Work Flow for Economic Evaluation

The Figure 2.124 shows the work flow for the economic evaluation.

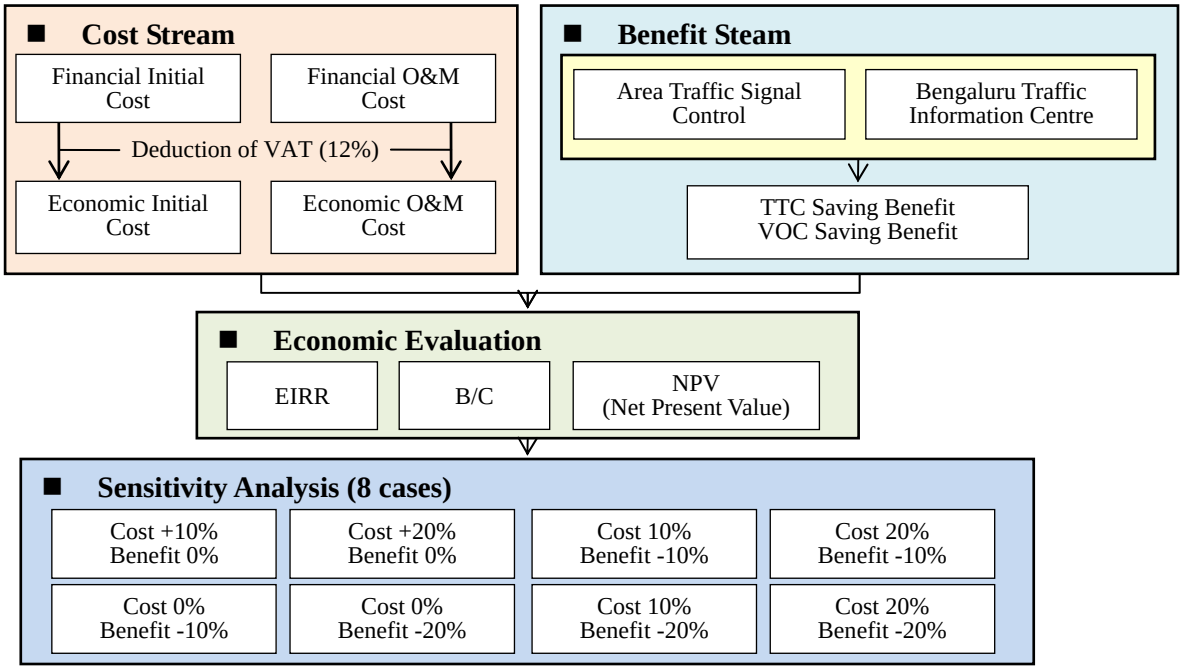


Figure 2.124 Work Flow for Economic Evaluation

(Source: JICA Study Team)

(c) Economic Evaluation Indicator and Condition of Economic Analysis

The economic costs and benefits throughout the project life periods are compared by a discount cash flow analysis. 12% discount rate is adopted because this is widely used in India as a social discount rate. For economic evaluation, three indicators are calculated which are: Economic Internal Rate of Return (EIRR), Benefit/Cost Ratio (B/C) and Net Present Value (NPV) as shown below.

Table 2.100 Economic Evaluation Indicators

No.	Indicator	Calculation Formula or Value
1	Discount Rate	12% as a social discount rate generally used in India
2	EIRR	$\sum \frac{Bn}{(1+r)^n} = \sum \frac{Cn}{(1+r)^n}$ r = satisfying B = Benefit, C = Cost
3	B/C	$\sum \frac{Bn}{(1+DR)^n} = \sum \frac{Cn}{(1+DR)^n}$ DR = Discount Rate
4	NPV	$\sum \frac{Bn - Cn}{(1+DR)^n}$
5	Project Evaluation Period	Period for 2016-2032 (17 years)

(Source: JICA Study Team)

The economic analysis has been carried out based on the following conditions;

- Evaluation Period: From 2016 to 2032 (for 17 years)
- Preparation for development of the system will start from 2016 as per the implementation schedule presented in Table 2.40 in Chapter 2.2.
- The systems will be expanded in phased manner as per the above implementation schedule.
- The operation will start from 2018 as per the above implementation schedule.
- The minor system modification and maintenance are included in the operation and maintenance cost.
- The system lifecycle is considered for 15 years, according to general practice, from the commencement of the operation, totalling 17 years of evaluation period.

(2) Economic Cost of ITS

(a) Initial Cost

The initial economic cost is calculated based on the initial cost estimated in the previous section. It includes contingency and overhead cost as explained in the Chapter of Rough Cost Estimate. VAT at 12% is not included in the economic cost. The annual amount of the economic cost proportionately distributed by year is considered for the economic evaluation. Table 2.101 shows the economic cost calculated evaluation items. The figures in the table below show the total initial economic costs of ITS component for Phase-1 and Phase-2 of ITS Master Plan.

Table 2.101 Economic Cost

ITS Menu	Economic Cost (Unit: Million INR)
Bengaluru Traffic Information Centre (B-TIC)	1,463.6
Area Traffic Signal Control (ATCS)	3,158.4
Total	4,622.0

(Source: Calculated by JICA Study Team)

(b) Operation and Maintenance Cost

The economic costs for operation and maintenance are calculated as shown in Table 2.102. The figures in the table below show annual cost.

Table 2.102 Economic Cost of O&M

ITS Menu	Economic Cost (Unit: Million INR)
Bengaluru Traffic Information Centre (B-TIC)	50.3
Area Traffic Signal Control (ATCS)	133.7
Total	183.9

(Source: Calculated by JICA Study Team)

(3) Economic Benefit

The economic benefits are evaluated in terms of reduction of Vehicle Operation Cost (VOC) and Travel Time Cost (TTC). The benefits are drawn by difference of multiplied VOC and TTC between 'Without Case' and 'With Case'. 'Without Case' means the case that ITS is not implemented. 'With Case' means the case that ITS is implemented.

(a) Vehicle Operation Cost (VOC)

VOC per unit distance is estimated by type of vehicle. They are two-wheeler, auto-rickshaw, car, bus and truck. The VOC is composed of: a) fuel cost, b) tire cost, c) engine oil cost, d) other oil cost, e) greasing cost, f) spare parts cost and g) maintenance cost, h) fixed cost and i) depreciation cost.

A section of 'Manual on Economic Evaluation in Indian Road Congress' (IRC) defines the baseline value of VOC at free flow speed of 40 km/h by vehicle type, incorporating these above components as of 2009. VOC in 2009 was converted into 2014 applying the Consumer Price Index (CPI) rate, 8.7%, by JICA Study Team.

VOC defined by IRC in 2009 and converted VOC to 2014 by JICA Study Team are shown in Table 2.103 and Table 2.104.

Table 2.103 VOC by Type of Vehicle in 2009

Unit: INR per veh-km

	Two-Wheeler	Auto-rickshaw	Car	Bus	Truck
Free Flow Speed (40 km/h)	1.86	1.86	5.81	15.05	11.23

(Source: Indian Roads Congress (IRC))

Table 2.104 Converted VOC in 2014

Unit: INR per veh-km

Km/h	Two-Wheeler	Auto-rickshaw	Car	Bus	Truck
5	6.54	6.54	40.05	70.33	54.93
10	4.55	4.55	22.93	46.37	37.70
15	3.83	3.83	17.16	37.26	30.67
20	3.45	3.45	14.24	31.88	26.21
25	3.26	3.26	12.57	28.35	23.07
30	3.17	3.17	11.41	29.18	22.32
35	3.55	3.55	9.69	27.57	21.65
40	2.83	2.83	8.84	22.91	17.10
45	2.84	2.84	8.89	23.02	17.18
50	2.87	2.87	8.97	23.24	17.34
55	2.91	2.91	9.10	23.57	17.59
60	2.97	2.97	9.27	24.02	17.92
65	3.04	3.04	9.49	24.60	18.35
70	3.13	3.13	9.77	25.30	18.88
75	3.23	3.23	10.09	26.14	19.51
80	3.35	3.35	10.48	27.14	20.25

(Source: Calculated by JICA Study Team based on IRC)

(b) Travel Time Cost (TTC)

Travel Time Cost (TTC) by type of vehicle has been set by JICA Study Team. TTCs of two-wheeler, auto-rickshaw, car and truck were defined based on the result of ITS Opinion Survey carried out by JICA Study Team. They were drawn by referring average salary (INR/month) of drivers. TTC of bus was defined by applying ratio of car and bus base on Manual on Economic Evaluation of Highway Projects in India (Second Revision) (IRC: SP 030-2009).

They are shown in Table 2.105.

Table 2.105 Travel Time Cost in 2014

(Unit: INR per veh-min)

Vehicle Type	TTC
Two-Wheeler	1.63
Auto-rickshaw	1.63
Car	3.36
Bus	20.00
Truck	1.43

(Source: JICA Study Team)

(4) Result of Economic Analysis

(a) Estimation of Economic Benefit

The economic benefits are estimated as shown in Table 2.106. They have been drawn based on reduction of the aggregated unit VOC and TTC by ITS incorporating the future traffic demand forecast. It is evaluated that ITS components generate the economic benefit from the year 2022 onward as below.

Table 2.106 Economic Benefit

Year	Economic Benefit (Million INR)
2022	1720.0
2023 (onward)	3,440.0

(Source: JICA Study Team)

(b) Economic Analysis

The results of economic analysis by economic indicators are shown in Table 2.107. It shows that EIRR (29.0%) is greater than 12% and B/C (2.44) is more than 1.0. This indicates that the implementation of ITS is appropriate from economic viewpoint.

Table 2.107 Result of Economic Analysis

Economic Benefit (1,000 INR)		
EIRR	**B/C**	**NPV (Million INR)**
29.0%	2.44	5,048.4

(Source: JICA Study Team)

Table 2.108 Cost-Benefit Stream

Undiscounted Benefit Cost Stream Revenue

Million Rs

sq	Year	Construction Cost	O &M	Cost Total	Benefit	Benefit - Cost
1	2014			0.0	0.0	0.0
2	2015			0.0	0.0	0.0
3	2016	526.3		526.3	0.0	-526.3
4	2017	526.3		526.3	0.0	-526.3
5	2018	526.3	183.9	710.2	0.0	-710.2
6	2019	526.3	183.9	710.2	0.0	-710.2
7	2020	1,131.1	183.9	1,315.0	0.0	-1,315.0
8	2021	923.8	183.9	1,107.7	0.0	-1,107.7
9	2022	461.9	183.9	645.8	1,720.0	1,074.2
10	2023		183.9	183.9	3,440.0	3,256.1
11	2024		183.9	183.9	3,440.0	3,256.1
12	2025		183.9	183.9	3,440.0	3,256.1
13	2026		183.9	183.9	3,440.0	3,256.1
14	2027		183.9	183.9	3,440.0	3,256.1
15	2028		183.9	183.9	3,440.0	3,256.1
16	2029		183.9	183.9	3,440.0	3,256.1
17	2030		183.9	183.9	3,440.0	3,256.1
18	2031		183.9	183.9	3,440.0	3,256.1
19	2032		183.9	183.9	3,440.0	3,256.1
		4,622.0	2,759.1	7,381.1	36,120.0	28,738.9

Discounted Benefit Cost Stream Revenue

Million Rs

sq	Year	Discounted	Construction Cost	O &M	Cost Total	Benefit	Benefit - Cost
1	2014	1.00	0.0		0.0	0.0	0.0
2	2015	1.12	0.0		0.0	0.0	0.0
3	2016	1.25	419.6		419.6	0.0	-419.6
4	2017	1.40	374.6		374.6	0.0	-374.6
5	2018	1.57	334.5	116.9	451.4	0.0	-451.4
6	2019	1.76	298.6	104.4	403.0	0.0	-403.0
7	2020	1.97	573.0	93.2	666.2	0.0	-666.2
8	2021	2.21	417.9	83.2	501.1	0.0	-501.1
9	2022	2.48	186.6	74.3	260.8	694.7	433.8
10	2023	2.77		66.3	66.3	1,240.5	1,174.2
11	2024	3.11		59.2	59.2	1,107.6	1,048.4
12	2025	3.48		52.9	52.9	988.9	936.0
13	2026	3.90		47.2	47.2	883.0	835.7
14	2027	4.36		42.2	42.2	788.4	746.2
15	2028	4.89		37.6	37.6	703.9	666.3
16	2029	5.47		33.6	33.6	628.5	594.9
17	2030	6.13		30.0	30.0	561.1	531.1
18	2031	6.87		26.8	26.8	501.0	474.2
19	2032	7.69		23.9	23.9	447.3	423.4
			2,604.7	891.7	3,496.5	8,544.9	5,048.4

Net Present Value (Millio	5,048.4
B/C Ratio	2.44
EIRR	29.0%

(Source: JICA Study Team)

(5) Sensitivity Analysis for the ITS Master Plan

Sensitivity analyses were carried out. This aims to evaluate the relevance of ITS implementation under some risks. For example, there may be the case that the estimated costs would be increased. Other cases would be that the expected benefit in terms of reduction of VOC and TTC may not be attained as expected. In this regard, the following nine (9) cases were evaluated.

As a result, the strictest condition which is Cost + 20% and Benefit - 20% still shows that EIRR value stays above the social discount rate.

Table 2.109 Result of Sensitivity Analyses

Sensitivity Analysis			Cost		
			0%	+10%	+20%
Benefit	0%	EIRR	29.0%	27.1%	25.3%
		NPV (*)	5,048.4	4,698.8	4,349.1
		B/C	2.44	2.22	2.04
	-10%	EIRR	26.9%	25.0%	23.3%
		NPV (*)	4,193.9	3,844.3	3,494.6
		B/C	2.20	2.00	1.83
	-20%	EIRR	24.5%	22.7%	21.0%
		NPV (*)	3,339.4	2,989.8	2,640.1
		B/C	1.96	1.78	1.63

Note (*): Unit=Million INR

(Source: JICA Study Team)

2.7.4 Financial Analysis

(1) Methodology

Financial analyses were carried to evaluate the financial viability. The financial viability is evaluated by Turnaround to Profit and Project IRR. Electronic Road Pricing (ERP) system was evaluated.

(a) Work Flow for Financial Evaluation

Figure 2.125 shows the work flow for the financial evaluation.

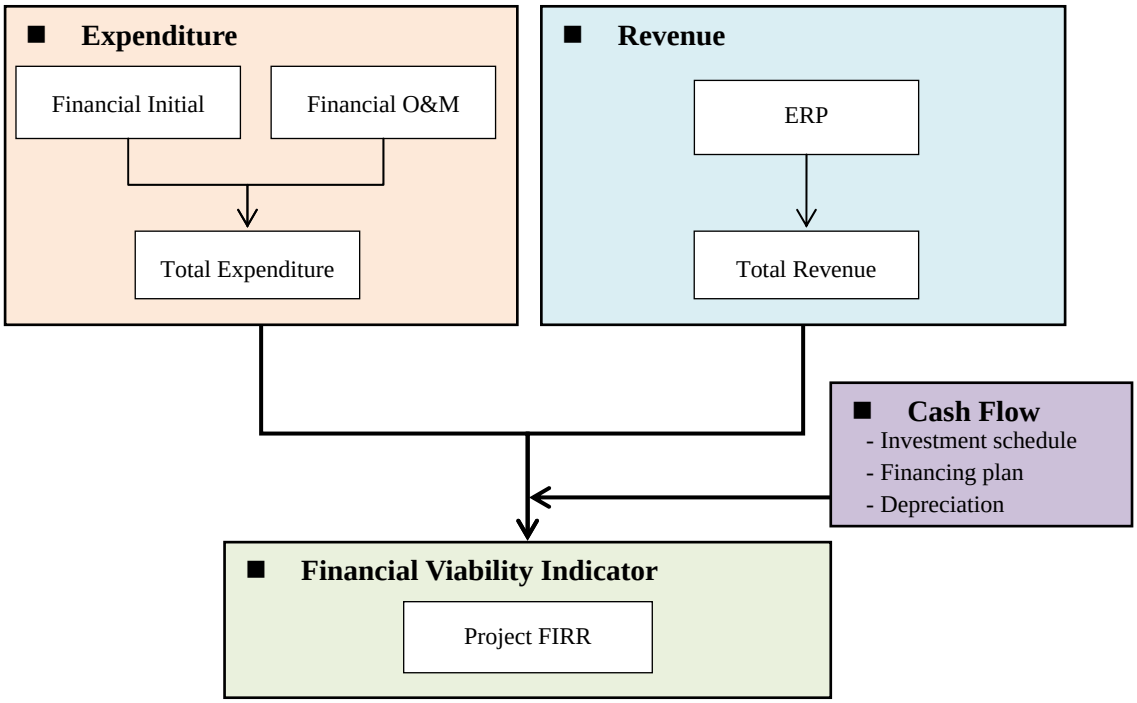


Figure 2.125 Work Flow for Financial Evaluation

(Source: JICA Study Team)

(b) Indicators of Financial Viability

The following indicators are calculated for evaluation of financial viability.

Table 2.110 Indicator of Financial Analysis

Indicator	Calculation Formula/Description
Project FIRR	$\sum \frac{Ri - Ii - Ci}{(1 + \text{Project } IRR)^i} = 0$ *Ri: Annual revenue from Congestion Pricing at year i* *Ii: Annual project costs at year i* *Ci: Annual operating costs at year i*
Turnaround to Profit (on single-year basis)	A year from which the balance on a single-year basis turns to positive
Turnaround to Profit (on accumulated basis)	A year from which the investment is recovered and the balance turns to positive

(Source: JICA Study Team)

(c) Preconditions for Financial Analysis

1) Case of Analysis

Two (2) options were evaluated for financial analysis as follows:

Option-1: Base Congestion Price (Motorcycle=30 INR)

Option-2: Base Congestion Price (Car/Taxi=100 INR)

Table 2.111 shows the base congestion price of each vehicle type. They are attained based on Passenger Car Unit (PCU).

Table 2.111 Base Congestion Price of Each Vehicle Type

Unit: INR

	Car/taxi	Pickup/ van	Motor cycle	Light goods vehicle	Heavy goods vehicle	Bus[*1]	Trailer	Auto-rickshaw
PCU Rate	1.0	1.0	0.5	1.4	2.2	2.2	4.0	0.5
Option-1	**100**	100	50	140	220	-	400	50
Option-2	60	60	**30**	84	132	-	240	30

*1: No Charging

(Source: JICA Study Team)

2) Financial Cost

The financial cost of ERP is set as shown in Table 2.112. It includes contingency, overhead cost and design/supervision cost as explained in the Chapter of Rough Cost Estimate. Additionally, the financial cost shown below includes VAT at 12%.

Table 2.112 Financial Cost for ERP

Items	Financial Cost
Initial Cost for Equipment/System	**1232.0 Million INR**
Operation and Maintenance Cost	**81.6 Million INR/year (Without Inflation Rate)**

(Source: JICA Study Team)

3) Project Revenue

The project revenue is considered as the revenue of ERP. The project revenue for ERP was calculated with the base congestion price and estimated traffic volume (2 hours of weekdays from 10:00 AM to 12:00 PM) as described in the clause 2.3.4 Electronic Road Pricing System in Chapter 2.3. Table 2.113 shows the expected revenue from ERP.

Table 2.113 Project Revenue

Revenue	Revenue (Million INR/year)
Option-1	969.0
Option-2	581.4

(Source: JICA Study Team)

4) Implementation Schedule and Evaluation Conditions

The financial analysis was carried out according to the implementation schedule shown in Table 2.40 in Chapter 2.2. It was evaluated based on the following conditions:

- Evaluation Period: From 2016 to 2033 (for 18 years)
- Preparation for development of the system will start from 2016 as per the implementation schedule.
- The operation will start from mid of 2019 as per the implementation schedule.
- The minor system modification and maintenance are included in the operation and maintenance cost.
- The system lifecycle is considered for 15 years, according to general practice, from the commencement of the operation.

(2) Result of Financial Analysis

The results of the financial analysis for the option-1 and option-2 are shown in Table 2.114. The option-1 shows that the turnaround to profit of single year and accumulated are in 2019 and 2020 and the Project IRR is 40.4%. The option-2 shows 2019, 2022 and 22.2% respectively. The investment cost can be recovered in four years after commencement of operation even in the case of the option-2. Considering the world experiences of ERP, i.e. Singapore, London and Stockholm that the ERP investment cost have been recovered in two to four years, the case in Bengaluru is also considered relevant.

Table 2.114 Result of Financial Analysis

	Turnaround to Profit		Project IRR
	Single-Year Basis	Accumulated Basis	
Otpion-1	2019	2020	40.4%
Option-2	2019	2022	22.2%

(Source: JICA Study Team)

2.8 Conclusions and Recommendations

(1) Firm Commitment of Government of Karnataka for Implementing ITS Envisaged by Master Plan

ITS Master Plan for Bengaluru has been jointly formulated by the member organisations of Joint Coordinating Committee, Technical Advisory Group consisted by a variety of important stakeholders in Bengaluru and JICA. A strong commitment of the policy makers and relevant authorities is important for implementation of ITS. The implementation of ITS requires close coordination and collaboration amongst stakeholders. The firm commitment of the government makes it possible.

(2) Development and Improvement of Transport Infrastructure Together with ITS

ITS is one of soft measures to alleviate traffic congestion. The road and transport infrastructure need to be sufficiently and properly developed in order for ITS to exert effectiveness. As described in the Master Plan, there are a number of issues of infrastructures in Bengaluru. They include, for example, improvement of intersection/junction, transfer facilities, parking spaces, pedestrian foot paths, etc. Therefore, it is important that the development and improvement of road transport infrastructures be carried out together with ITS.

(3) Incorporating ITS Master Plan into Transport Plan in Bengaluru Metropolitan Area

ITS is one of the soft measures in the transport sector. It is important that ITS be planned and developed under the framework of transport planning. ITS Master Plan for Bengaluru reflected the existing transport plans and visions which have been envisaged by such plans as CTTP, but was prepared as an independent document. It would be appropriate to incorporate ITS Master Plan into the comprehensive transport plans such as CTTS, urban transport master plan in Bengaluru, etc.

(4) Adopting New Technologies

Innovation and advancement of information and communication technology are rapidly progressing. ITS Master Plan was prepared based on currently available technologies. However, it is most likely that the new technologies which do not exist today will become available in a few years later. Therefore, it is important that attention always be paid to explore the latest technologies to apply.

(5) Revising ITS Master Plan

ITS Master Plan was prepared by Phase-1 for 5 years, Phase-2 for 10 years and Phase-3 after 10 years. However, as described above, information and communication technologies evolve very rapidly. Moreover, the traffic characteristics will become different in the near future in accordance with further urbanisation, development of road transport infrastructures such as completion of peripheral ring road, metro network, etc. Thus, ITS Master Plan shall be continuously reviewed and revised at every 4 – 5 years.

(6) Continuous Promotion of ITS and Harmonising with ITS National Policy

ITS is not 'one-time implementation'. Once it is deployed, it needs to be sustainably operated and maintained. It shall then be reviewed, evaluated, planned and upgraded in accordance with advancement of technology and changes of traffic conditions as time goes on. Therefore, ITS needs to be continuously taken care of and promoted. Further, it is ideal that ITS be developed in the individual cities under the framework of the national policies. However established national policies have yet to be prepared in India. The Ministry of Urban Development, a Government of India, is currently working on developing a national ITS policy. It is recommended that the regional ITS in Bengaluru be harmonised with the framework of national ITS policy.

(7) Capacity Development

Capacity building is one of the most important factors to assure sustainable operation, maintenance, reviewing, planning and upgrading of ITS over a long period. The involved personnel and officials shall be equipped with adequate skills and competencies of ITS technologies and operations. Thus, it is important to draw plans for training and carry out them to enable continuous improvement of their skills.

(8) Establishment of Strong Central Body

Establishing a central body for continuous initiatives is important. The measures for urban transport needs to be taken together with ITS. The required measures involve issues across different stakeholders/agencies. Therefore, the central body shall be formed with participation of the related agencies such as DULT, BDA, BBMP, BMTC, Traffic Police, BMRCL, etc. Then it shall take strong and continuous initiative for ITS and urban transport in a coordinated manner.

(9) Strengthening Driver/Pedestrian Education and Enforcement of Traffic Rules and Regulations

One of the most serious issues of urban transport in Bengaluru is traffic manners. The traffic conditions cannot be improved only by developing infrastructure and applying ITS. The education of drivers/pedestrians and enforcement of traffic rules and regulations need to be strengthened in parallel to realise smooth traffic and safety.

(10) Standardising Motor Vehicle Number Plate and Improvement of Vehicle Registration

Standardised number plates and properly registered motor vehicle information are indispensable factors for ITS. Proper enforcement by ITS cannot be realised without these. The Government of India mandated standardisation of number plate in 2005. However few states have accomplished it in India and Karnataka state has not implemented yet. Although registered vehicle information is in the process of computerisation, the authorities are facing difficulties in identifying second-hand vehicles

for enforcement. Therefore, the standardisation of the number plate and improving vehicle registration need to be accelerated.

3 Study Contents for Mysore

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

3.1 Current Conditions and Issues in Mysore

3.1.1 Socio-Economic Conditions

(1) Historical City Overview

Mysore was a former capital of the Kingdom of Mysore. It served as the capital city of princely kingdoms from 1399 to 1947. It spreads across an area of 128.42 km^2. Mysore is noted for its palaces, including the Mysore Palace. During festival season (generally in the months of September to October every year), a large number of tourists visit Mysore.

Socio-economic conditions in Mysore such as population, economy, industry, tourism, and etc. are reviewed and utilised as basic information for the study. The following clauses provide the overview.

(2) Demographic Outlook

The population of Mysore has recorded a growth of around 25% from 2001 to 2011.

The following table lists an overview of demographics of Mysore in 2011.

Table 3.1 Overview of Demographics of Mysore in 2011

No.	Indicators	Unit	Mysore	Karnataka
1	Geographical Area	Sq.km	128.42	1.91 Lakh
2	Population	Lakhs	8.87	625
3	Decadal Growth Rate	%	25	15.67
4	Literacy Rate	%	86.87	75.60

(Source: http://censuskarnataka.gov.in/)

Mysore is an educational, commercial and administrative centre and also an important tourist and heritage centre. It is connected to the adjoining states of Kerala and Tamil Nadu by National Highways.

Mysore, the cultural capital of the state, was a home for great musicians, music composers, dancers, and Sanskrit scholars. Mysore University and many other academic and scientific institutions are located here. This led to the residence of great scholars, writers particularly in the field of Kannada literature.

Hinduism is the dominant religion in the city. Hindus constitute 87.44% of the population with Muslims making up 8.87% of the population. The remaining part of the population is made up by Christians, Buddhists and other religious groups. . A majority of the citizen speak Kannada, whilst other languages such as Tulu, Tamil and Hindi are also spoken. Approximately 19% of the population live below poverty line, and 9% live in slums.

(3) Culture

Mysore is called as a cultural capital of Karnataka state. It is known for the festivities that take place during the period of Dasara. Dasara festival, celebrated usually in September and October as state festival nowadays, were first introduced by King of Mysore in 1610. On the ninth day of Dasara, the royal sword is worshipped and taken on a procession of decorated elephants, camels and horses. On the tenth day, the traditional Dasara procession, locally known as Jumboo Savari, is held on the streets. The image of the Goddess is placed on a golden chariot on elephant and taken on the procession.

Figure 3.1 Mysore Dasara Procession

(Source: KSTDC Website)

(4) Tourism

Mysore is a major destination in Karnataka state for foreign and domestic tourists. The magnificent palaces, proximity to the historical city of Srirangapatna, traditional handicrafts, cultural and health tourism facilities have been the major attractions for international tourists. For the domestic tourists, the place also offers some important and popular religious and recreational destinations.

Major attractions in Mysore are Mysore Palalce, Chamundi Hills and Mysore Zoo. In addition, other attractions are Jagan Mohan Palace, St. Philomena's Church, Bridavan Gardens, and Srirangapatna Tipu fort. The following figures are some major tourists' spots in and around Mysore.


Mysore Palace


Somnathpur Temple


St. Philomena's Church

Figure 3.2 Tourist Spot in and around Mysore

(Source: KSTDC Website)

(5) Tourist Visiting Mysore

It is noted that the annual number of domestic tourist is made based on interview to Department of Tourism as 3.19 million in 2012 because official figure of number of tourist is not available.

According to the interview to Department of Tourism in Karnataka, Karnataka state is one of top tourist destination in the country. The interview revealed that approximately 15% of the total number of tourists in Karnataka state visit Mysore every year. During the years of 2011 and 2012, Mysore recorded the highest number of tourist due to economic boom. They informed that general tendency is that the number of tourist visiting Mysore has been on the increase in recent years and the months of April and May is a peak season in a year in general. A total of approximate 270,000 tourists visited Mysore in April in 2014. This was the highest number in recent years except 2011 and 2012.

Figure 3.3 shows a trend in number of domestic tourists visit Mysore in a year from January to December in 2012. The trend shows that domestic tourists mainly visit Mysore in the month of May for school summer vacation and, October, November and December for festival.

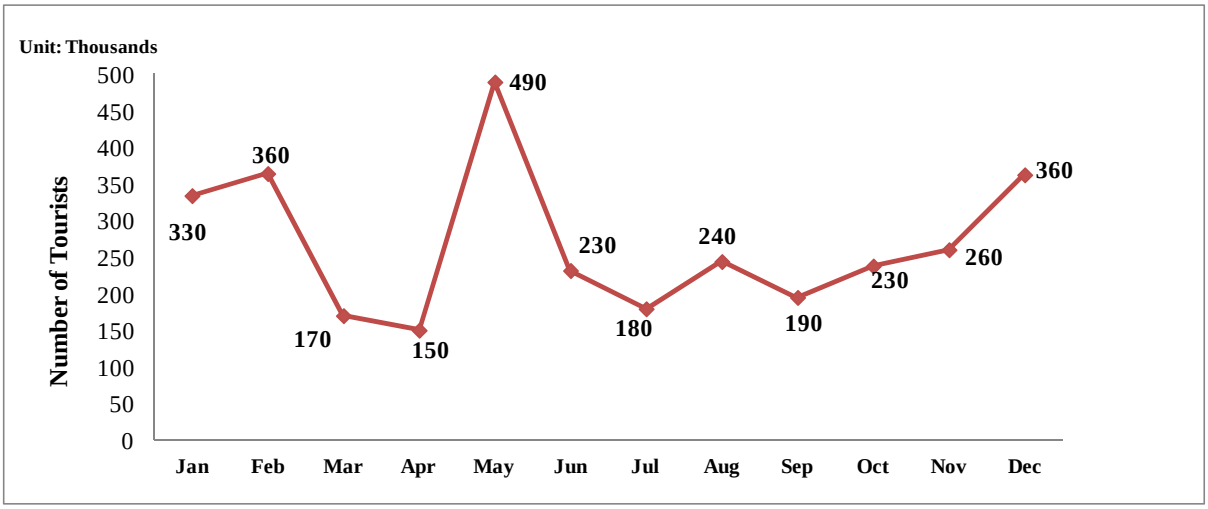


Figure 3.3 Trend of Number of Domestic Tourists Visiting Mysore in a Year (2012)

(Source: Summarised by JICA Study Team based on interview to Department of Tourism)

(6) Other Industries

Other industries in Mysore include tyre manufacturing, textiles and silk factories, information technology, electronic systems and agriculture industry. Mysore is also one of the fastest growing places of IT, ITES and Biotechnology industries after Bengaluru. Articles made of silk, lacquer, and sandalwood are some of the most famous products of Mysore contributing to Mysore economy.

Mysore city has become a new hub for IT and Information Technology Enabled Services (ITeS) industry. It is the second largest exporter of software after Bengaluru. Infosys has established one of the largest technical training centres in the world and Wipro has established its Global Service Management Center (GSMC) in Mysore.

3.1.2 Environment

(1) Ambient Air Quality

Karnataka State Pollution Control Board (KSPCB) implements National Air Quality Monitoring Programme (NAMP). Sulphur dioxide (SO_2), nitrogen oxides (NO_2) and respirable suspended particulate matter (RSPM/PM_{10}) are major pollutants that are monitored by the monitoring station of KSPCB in Mysore.

The National Ambient Air Quality Standards for Sulphur dioxide (SO_2), nitrogen oxides (NO_2) and respirable suspended particulate matter (RSPM/PM_{10}) are shown in Table 3.2.

Table 3.2 National Ambient Air Quality Standards (μg/m^3)

Categorized Area	Sulphur dioxide (SO_2)	Nitrogen oxides (NO_2)	Respirable suspended particulate matter (RSPM/PM_{10})
Industrial Area Urban Area	50.0	40.0	60.0
Sensitive Area	20.0	30.0	60.0

The Figure 3.4 shows annual average value of three pollutants monitored at K.R. circle monitoring station which is one of the busiest intersections in the core area in Mysore.

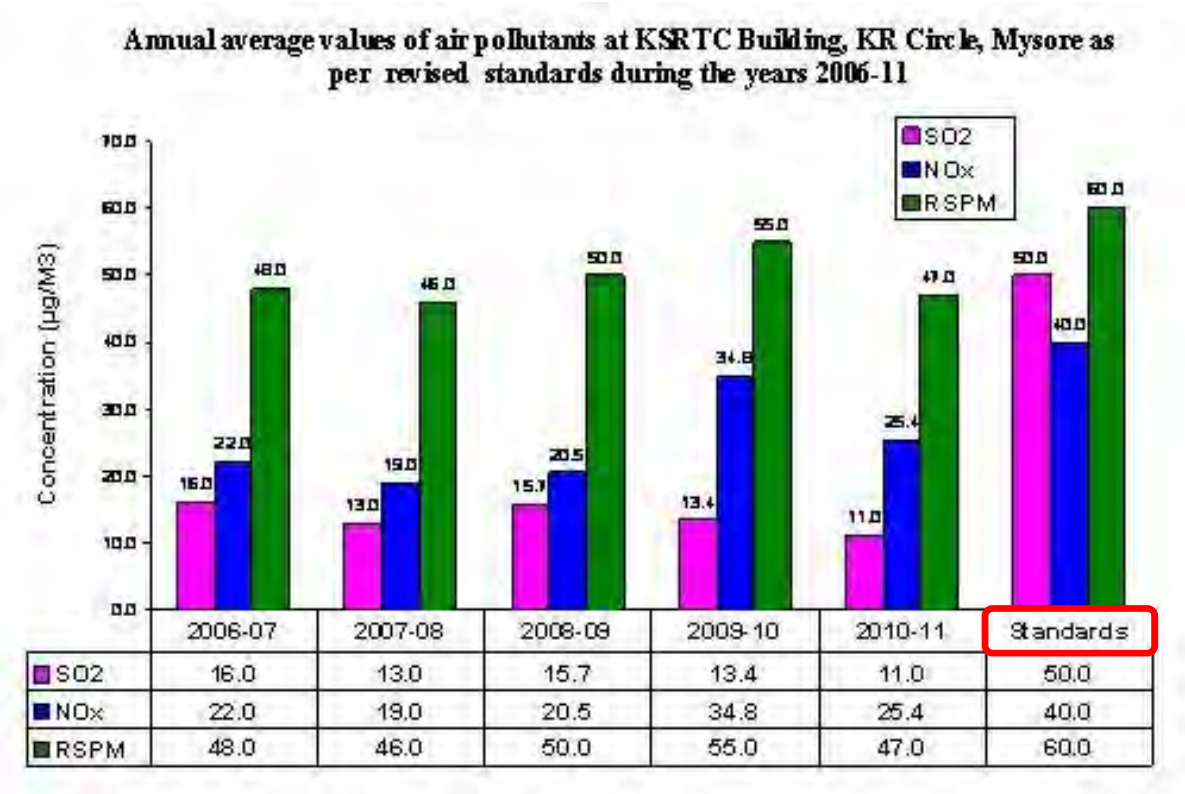


Figure 3.4 Annual Average Value of Air Pollutants in K.R.Circle

(Source: KSPCB)

According to the above figures, the annual average values of the air pollutants in the core area in Mysore (K.R.Circle) have been within the national ambient air quality standards.

3.1.3 Present Traffic Conditions and Issues

(1) Road Traffic

(a) Existing Road Network

There are eight radial roads and three ring roads in Mysore. Amongst the eight radial roads, four of them are state highways and one of them is national highway. SH17, called Bangalore Road, connects Mysore and Bengaluru. Some sections of these roads are developed as four-lane road. However the remaining sections are mostly two-lane. The innermost ring is Inner Ring Road (IRR) and covers the core area which is the busiest area in Mysore. Intermediate Ring Road (IMRR) encircles the IRR. The outermost ring road in Mysore is Outer Ring Road (ORR) and constructed as six lane road. The south-east section is missing. Neither continuous grade separations nor flyover are developed on these ring roads.

Table 3.3 Radial Road and Ring Road in Mysore

Type	Road Number/Name		Connected Cities/Areas/Roads	Remarks
Radial Road	NH-212,	Nanjangud Rd	Mysore, Nanjangud, Gundlupet, Kozhikode	Nanjangud Rd connects Mysore and Kozhikode in Kerala state. NH212 passes through centre of Mysore.
		T.Narasipura Rd	Kollegal, Mysore,	
	SH-17, Bangalore Rd		Bengaluru, Ramanagara, Mandya, Mysore	It is also known as Mysore Rd connecting Bengaluru and Mysore.
	SH-33, HD Kote Rd		Mysore, Heggada Devana Kote (HD Kote)	
	SH-88, Hunsur Rd		Mysore, Bantval	It connects NH-48 in Bantval and destines to port city Mangalore.
	KRS Rd		Mysore, Krishnarajasagara	
	Mahadevapura Rd		Mysore, Mahadevapura	
	Bogadi Rd		Mysore, Bogadi (Inside Mysore), Mudukuthore	
Ring Road	Inner Ring Road (IRR)		Mysore Palace, Mysore railway station	It covers core area, the busiest are, in Mysore.
	Intermediate Ring Road (IMRR)		Mysore Zoo, University of Mysore Campus	
	Outer Ring Road (ORR)		Hinkal, Bogadi, Bandipalya	It covers most of the developed area in Mysore by four or six lane road.

(Source: JICA Study Team)

The road network in Mysore is shown in Figure 3.5.

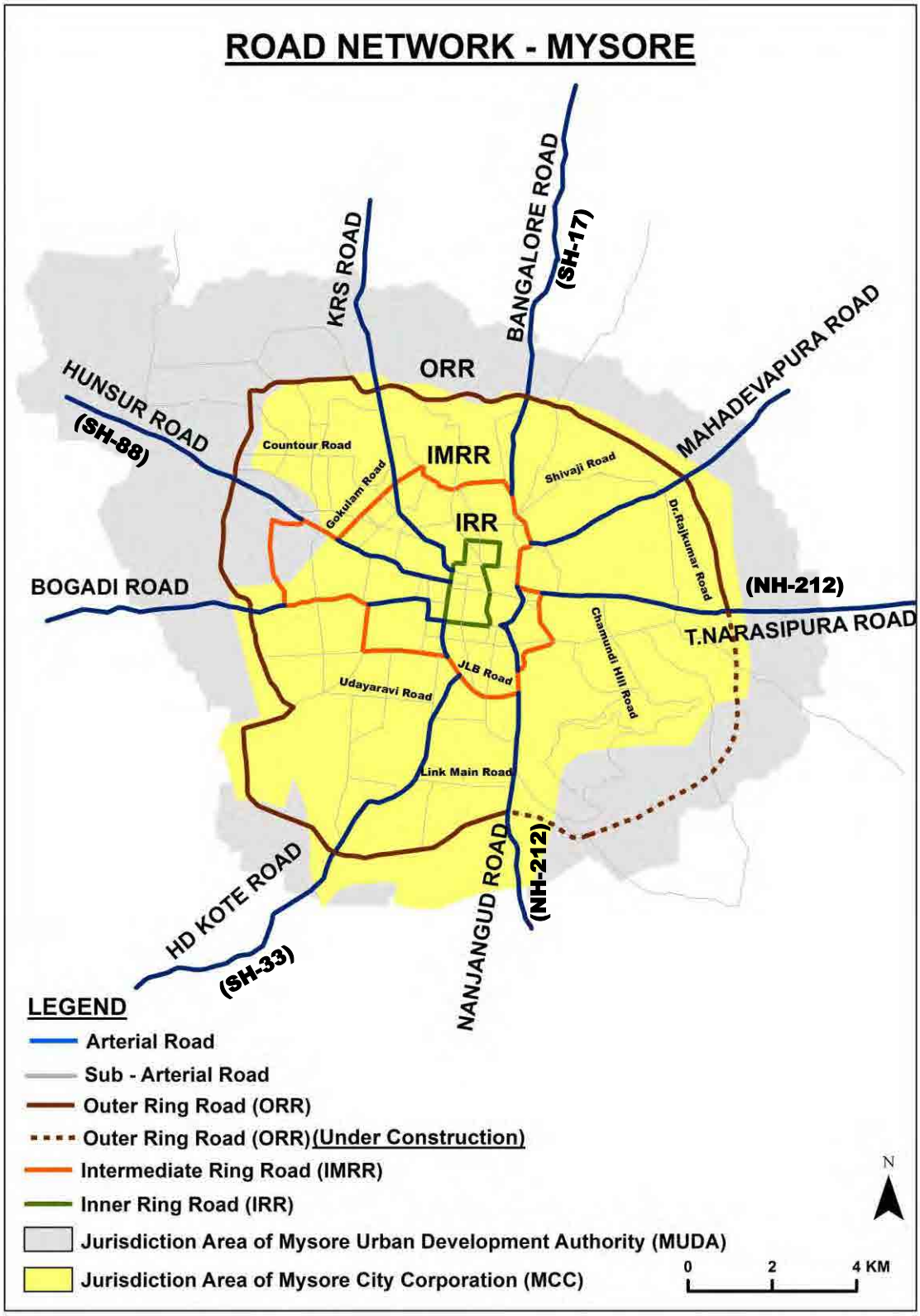


Figure 3.5 Road Network in Mysore

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

Number of lanes in road network in Mysore is shown in Figure 3.6.

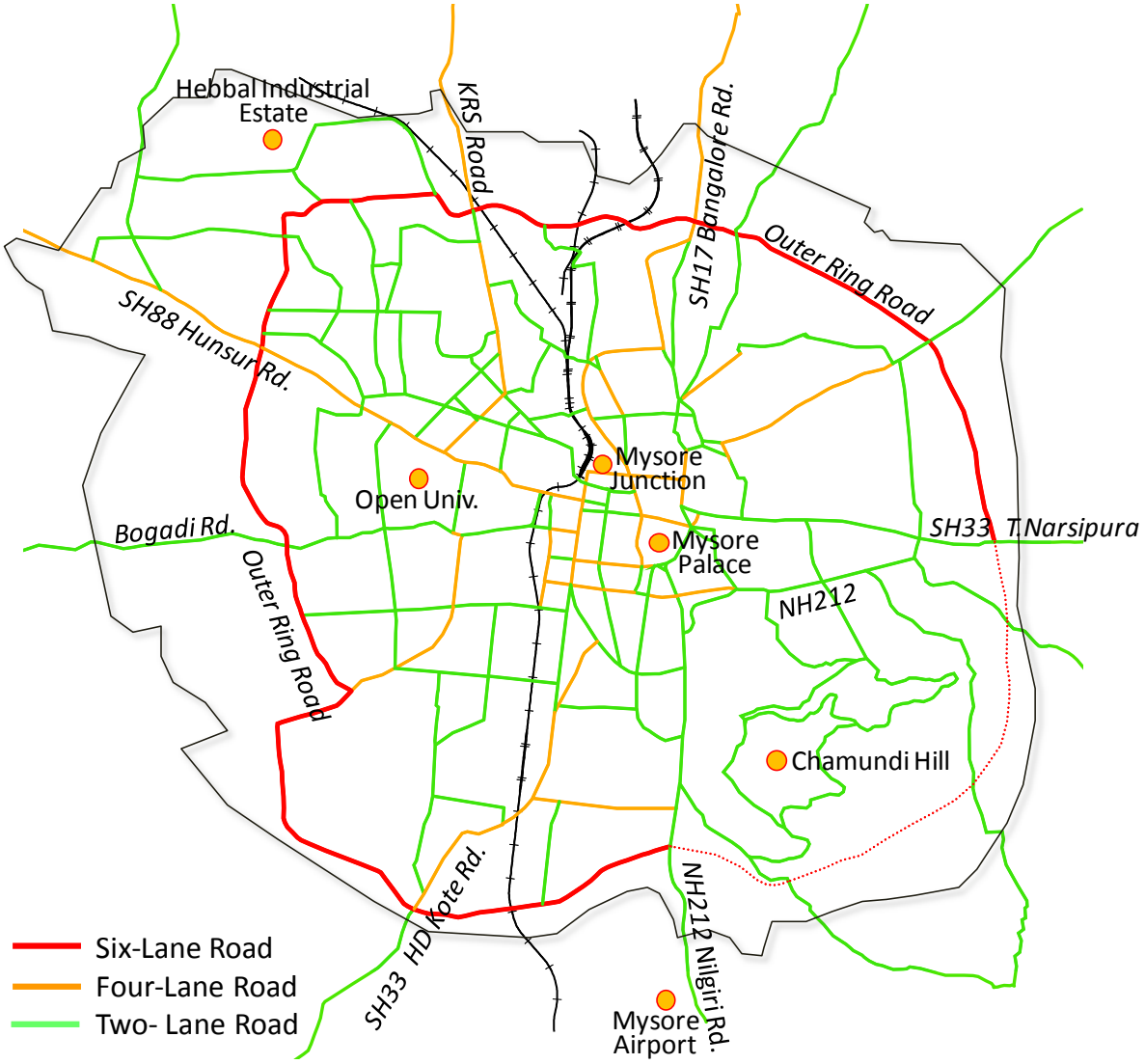


Figure 3.6 Number of Lanes in Road Network

(Source: JICA Study Team)

(b) Traffic Volume

The current condition of the road traffic was reviewed and analysed based on the data of the traffic surveys carried out for Comprehensive Traffic and Transport Plan for Mysore 2012 (CTTP for Mysore 2012). Figure 3.7 shows the annual average daily traffic volume (AADT). The obtained survey data was based on 2009. Thus, it was adjusted into 2014 by JICA Study Team. It is identified that SH 17 (Bengaluru Road) that leads to Bengaluru, KRS Road that is toward north-eastward from the city centre to the Hebbal Industrial Area and NH212 (Nilgiri Road) that is toward southward from the city centre to Nanjangud are major traffic routes. The traffic volume survey reveals that the commercial vehicle ratio is highest on SH 17 and NH 212. These roads are considered the major

logistic routes in this region. According to the interview to Mysore Traffic Police, the traffic volume usually peaks between 09:00 and 10:30 in the morning.

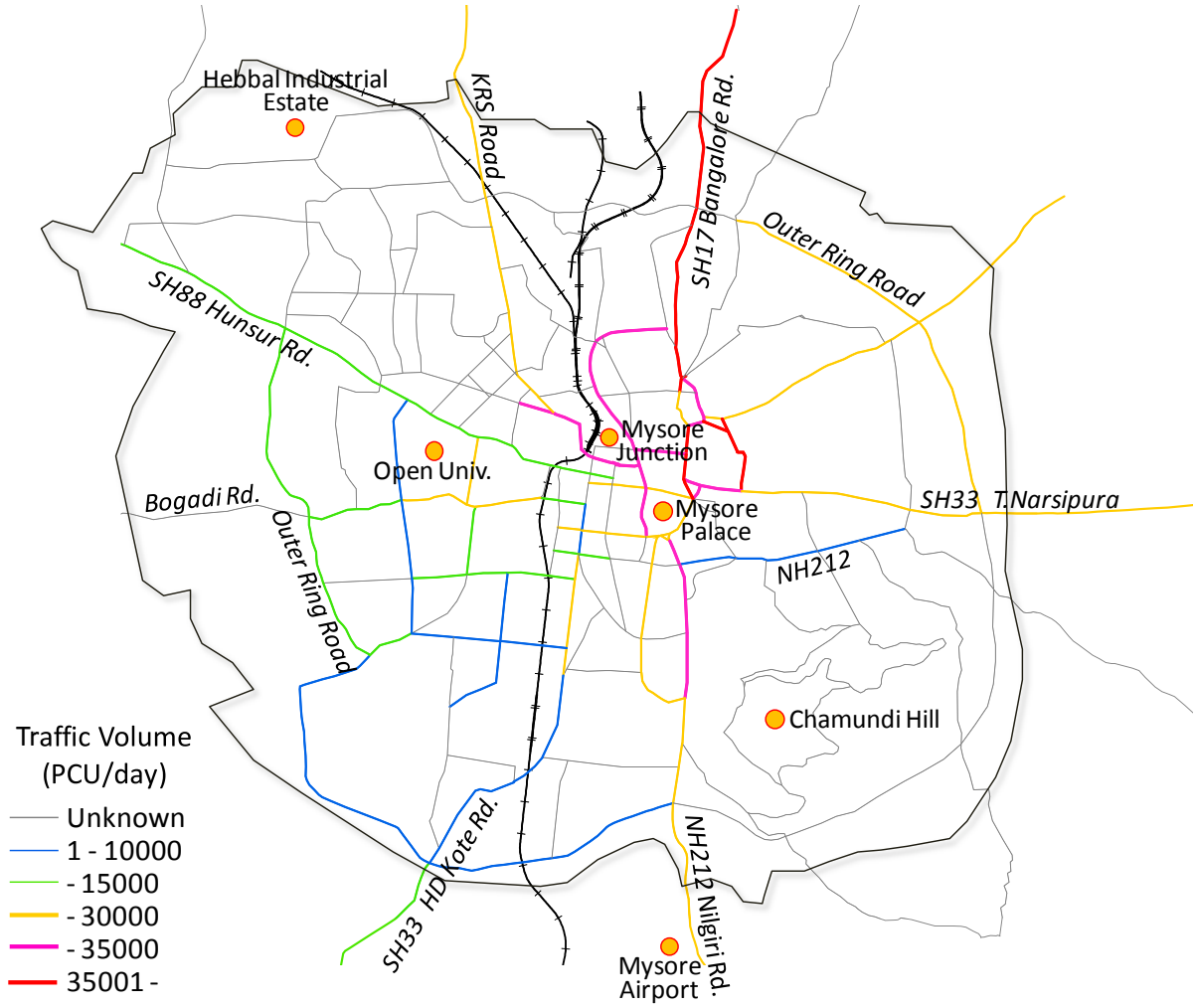


Figure 3.7 Annual Average Daily Traffic Volume on Major Road in Mysore in 2014 (in PCU)

(Source: Estimated by JICA Study Team based on CTTP for Mysore 2012)

(c) Travel Speed

The traffic surveys carried out for CTTP for Mysore 2012 and the travel speed survey conducted by JICA Study in 2014 reveal that the travel speed in the morning peak hour inside Outer Ring Road (ORR) generally ranges in 20 to 40 km/hour. The travel speed on the major roads such as National Highways and State Highways outside the core area is more than 40km/hour and on the roads outside ORR more than 50km/hour even in the morning peak hour. However, it becomes nearly equal to or less than 20km/hour at some sections in the core area of the city, such as the locations near Krishna Rajendra Circle near Mysore Palace and Central Bus Terminal.

The results inform that the overall situation in terms of travel speed in Mysore still remains moderate but the traffic is concentrated in the core area of the city. It can be considered that the increase in

traffic volume in recent years and delay caused by the intersections and traffic signals, explained more in the next clause, have adversely contributed to the deterioration of traffic condition in the core area.

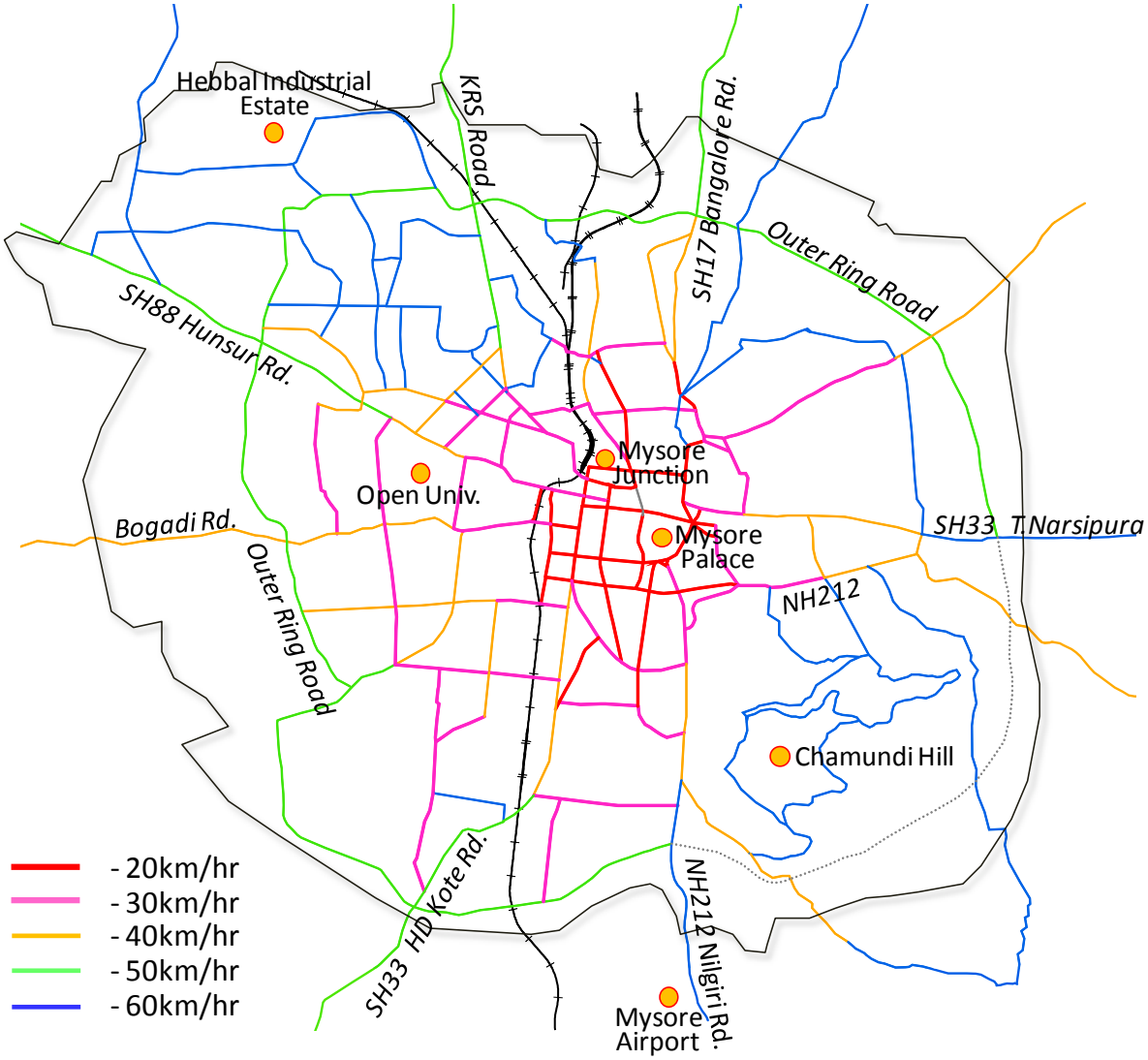


Figure 3.8 Travel Speed on Major Road in Mysore in Morning Peak Hour

(Source: JICA Study Team based on traffic survey data of CTTP for Mysore 2012 and travel speed survey carried out by JICA Study Team in November 2014)

(d) Major Traffic Congestion Points

There are many roundabouts at the major intersections in the city where traffic is heavy. The capacity of roundabout intersection is generally lower than the signalised intersection especially if it is inside the city with heavy traffic. Under the situation that the traffic increases in Mysore, the roundabout intersections are considered as one of the major factors contributing to the traffic congestion.

Table 3.4 shows the share of signalised intersection, intersection that is manually controlled by traffic police and the one that is not manually controlled in Mysore. The ratio of the signalised intersection is low. The ratio of the signalised four-lane and four-lane intersection becomes only 11%.

Further, the site reconnaissance by JICA Study Team found that there were several signalised intersections where the cycle length of the signal was longer than 180 seconds. Such intersections are considered to have led to the slowdown of the traffic flow and improvement of the signal is important. In addition, absence of a right turn lane on the major radial roads is also considered obstructing traffic flow.

Table 3.4 Share of Signalised Intersection, Manually Controlled Intersection and Not Controlled Intersection

Intersection Type (*1)	Signalised	Manually Controlled (*2)	Not Controlled (*3)	Total
4/6 LANE	25%	0%	75%	100%
4/4 LANE	11%	7%	82%	100%
4/2 LANE	20%	12%	69%	100%
2/2 LANE	7%	16%	77%	100%

Note (*1): X/Y LANE is an intersection between X lane road and Y lane road.

Note (*2): An intersection where Traffic Police manually control traffic.

Note (*3): An intersection where there is no signal and Traffic Police do not manually control traffic.

(Source: CTTP for Mysore 2012)

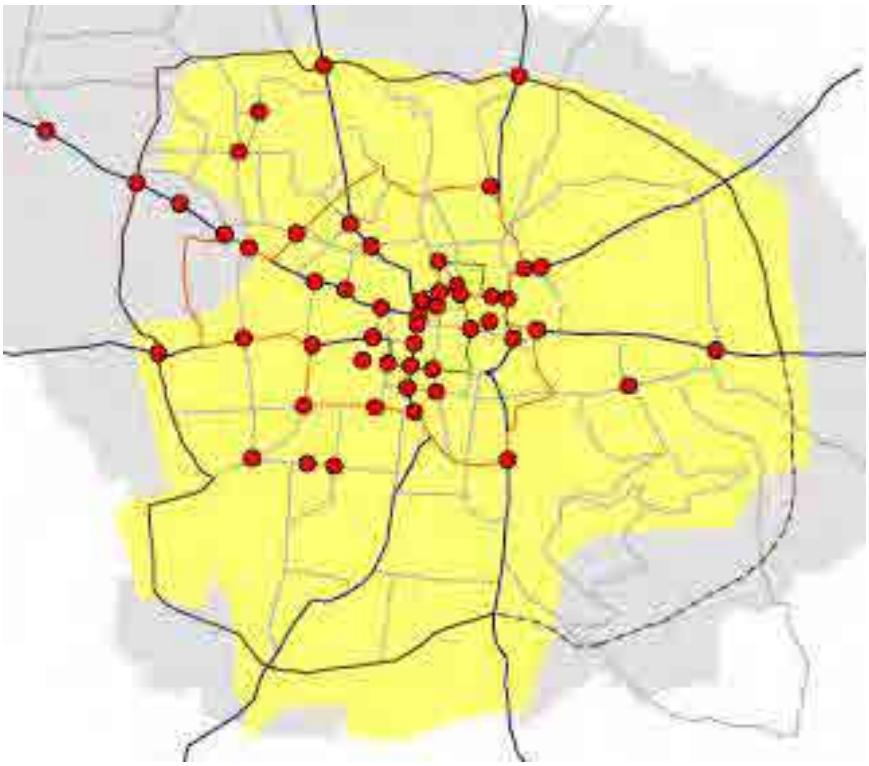


Figure 3.9 Locations of Signalised Intersections in Mysore

(Source: Jointly Prepared by DULT and JICA Study Team based on interview to Mysore Traffic Police)

(2) Public Transport

(a) Bus Network

The major public transport in Mysore is bus transport. It is operated by Karnataka State Road Transport Corporation (KSRTC).

KSRTC is a governmental bus transport agency, established in August 1961 under the provisions of the Road Transport Corporation Act 1950. It offers inter-city bus services in Karnataka state and inter-state bus services. The city bus services in Mysore is offered by KSRTC.

KSRTC offers the following three kinds of bus services in the region of Mysore:

- City Bus Services: Services within the city boundary
- Suburban Bus Services: Services which connects the city with nearby villages located within 20 km
- Moffusil Bus Services: Services which connects the city with 'taluk headquarters', an administrative unit in India, which are located within 50 km from the city.

KSRTC comprises 15 divisions including 14 operating division with approximately 37,800 permanent employees. It operates as a whole 5,824 routes of 551,164 km in total. The city bus route network in Mysore consists of 192 routes with average route length of 14.5 km, according to the annual report of KSRTC. There are 220 bus schedules on these routes with approx. 400 buses. Approximate daily passengers are 175,000, trip bases, and average daily service kilometer in Mysore is 226 km. It is reported that there are 8,300 buses and they carry approximately 15,000 passengers travelling between Mysore and Bengaluru every day. 500 buses are operated on the route between these cities.

The bus route network in Mysore is consisted of hub and spoke pattern. The city bus terminal is located in the core area of Mysore near Palace and all routes from outside the city converge on the bus terminal. The bus services are operated on radial routes which are fanning out from the core area of the city and terminating at the city bus terminal. It means that all passengers including those who destine to the places other than the core area of the city are required to come to the core area to take a changeover because all the routes terminate in the core area. This situation is considered contributing to congestion in the core area of the city.

(b) Intermediate Public Transport (IPT)

There are two kinds of intermediate public transport (IPT) in Mysore; non-motorised IPT called 'Tonga' and motorised IPT such as auto rickshaw and taxi. Tonga is a horse-drawn carriage and offers service for tourist in a limited area in Mysore. Approximately 70 Tongas currently ply on the roads in Mysore. The motorised IPT have been increasingly popular these days. The major IPT in Mysore nowadays is auto rickshaw, approx. 15,000 in number according to the information provided by DULT.

Figure 3.10 Tonga in Mysore

(Source: KSTDC Website)

(3) Trip Pattern

(a) Trip Pattern of Passenger Vehicle

The land use for commercial and business purpose in Mysore is concentrated in the core area of the city. Thus the traffic flows converge in the core area through the major radial roads. The major traffic inflow into the city from outside is accordingly seen on SH 17 (Bangalore Road) connecting Mysore with Bengaluru and NH 212 (Nanjangud Road) connecting Mysore with Nanjangud in the south. The recent development of the Hebbal Industrial Area in the north-western part of the city is considered contributing to alleviate the traffic concentration on the core area to a certain degree.

(b) Trip Pattern of Tourist Vehicle

Mysore is a tourist destination and attracts many tourists. Even though concrete figure in terms of increasing number of tourist e.g. for the past years is not available in Mysore, a general experience of similar urban region with much attraction of tourists leads an assumption that the road traffic generated by trip of tourist is increasing. It is then also assumed that the localised heavy traffic is further generated by tourist due to the situation that the major tourist sites are located around the core area of the city.

(c) Trip Pattern of Commercial Vehicle

According to the CTTP for Mysore 2012, agricultural products account for the largest proportion, 44%, of the freight transport in Mysore. It is followed by manufactured products, other goods and petroleum products which account for 37%, 13% and 6%, respectively, as shown in the table below. As the major consumption areas, i.e. markets and shops, are located inside the city, the freight traffic also converges in the core area of the city. The major freight traffic flow is found on the SH 17, Bengaluru Road. SH 17 is considered a major road used for transportation of general merchandise and agricultural goods. The heavy freight traffic is also found on NH212, Nanjangud Road. Nanjangud City is located in the south of Mysore and it is a major industrial area in the region. NH 212, Nanjangud Road connects Nanjangud City with other areas outside Mysore and it passes through the core area of Mysore. The products manufactured in Nanjangud City are shipped to not only Mysore but also other locations including Bengaluru. These facts tell that the vehicles carrying those products are required to pass through the core area of Mysore on their way to the destinations.

Table 3.5 Share of Freight Goods by Commercial Vehicle

Items	Share
Agricultural Products	44%
Manufactured Products	37%
Others	13%
Petroleum Products	6%
Total	100%

(Source: CTTP for Mysore 2012)

(4) Other Major Issues

The major issues other than explained in the previous clauses are described as follows.

(a) Parking

Some public parking lots in the core area of Mysore such as near Mysore Palace, Mysore Zoo, and Chamundi Hills are developed. However, the space of parking lots has not been able to cater to the increased demand under the situation that the number of vehicle has been increasing in recent years.

The vehicles are generally found to be parked on the roads causing traffic congestion and conflict points. The parking on the road eats up the valuable space for movement leaving less space for the vehicles to move. This reduces the travel speed and service level of the roads. Thus, efficient parking is important. The parking survey carried out under CTTP for Mysore 2012 reveals the following highlights:

- Percentage of two-wheelers is highest followed by cars at all road parking,
- Maximum number of vehicles are parked during 10:00-11:00 in the morning, and
- Average parking utilisation ratio is more than 90%.

The parking survey shows that the long-time parking users at commercial areas accounts for 40 % to 60%. This indicates that a large proportion of the parked vehicle may be occupied by such people as shop owners or their employees, not temporary parking users such as customers and visitors. This leaves very little space for the visitors and results in spilling over of their parking vehicles on the roads. The measures such as developing more parking lots, introducing car-pooling and improvement of connectivity of public transport in peak hours are considered to contribute to improve the situation.

(b) Pedestrians and Bicycles

According to a household survey carried out under CTTP for Mysore 2012, 23% of the total trips are walking trips and 10% are by bicycle. A site reconnaissance by JICA Study Team found that the footpaths in many locations, especially in the commercial areas, are occupied or encroached upon by

vendors and hawkers. This results in spilling over of the pedestrians on the roads. Most of the footpaths are not constructed with proper surfaces and force the pedestrians to walk on roads as well. Further, the pedestrian crossing facilities are not generally provided on the busy roads in the core area of the city. For example, there are no pedestrian phases in the signal cycle at the signalised intersections. The zebra crossings are not provided at the major intersections. These make it difficult for the pedestrians to cross the road.

(c) Traffic Safety

According to Mysore Traffic Police, the number of traffic accidents is on the increase with the increase in the use of automobiles. The increase in the number of traffic accidents is recognised as a social problem in Mysore nowadays. Mysore Traffic Police informed that the head-on collisions and rear-end collisions at intersections account for a large proportion of the traffic accidents. It was informed that the number of accidents at non-signalised intersections is particularly large. The poor road structure and absence of pavements are also considered factors contributing to the traffic accidents. It was also informed that the accidents caused by first-time visitors to Mysore are on the increase. Considering these aspects, such measures as improvement of traffic signs, installation of traffic signs and improvement of road structures/pavement are important.

It is noted that the data on the traffic accident in Mysore was not available. Thus above descriptions are made based on the interview to Mysore Traffic Police.

3.1.4 Future Traffic Demand

(1) Socio-Economic Framework

(a) Demographic

According to the Master Plan Mysore 2031, the population of Mysore is expected to increase from the current figure of approx. one million to 1.45 million in 2021 and two million in 2031, twice the current figure. The Master Plan Mysore 2031 expects the population growth mostly in the area outside ORR in the future and thus plans to increase the areas for residential use almost doubling the current area.

Table 3.6 Socio-Economic Framework of Mysore

Year	Population	Average Annual Growth Rate	Employment	Average Annual Growth Rate
2011	920,000	-	837,000	-
2021	1,450,000	4.6%	1,182,000	3.4%
2031	2,040,000	3.5%	1,532,000	2.6%

(Source: Master Plan Mysore 2031)

(b) Growth Number of Vehicles

Based on the data provided by Department of Transport (DOT) in Karnataka state, the number of registered vehicles in Mysore is expected to constantly increase by twofold in the period between 2010 and 2030. While two-wheelers are expected to continue to comprise the largest proportion of the registered vehicles in the future, the rates of the increase in the number of four-wheelers and trucks/buses are expected to be larger than the average rate of the increase for all the vehicles.

Table 3.7 Growth of Number of Reregistered Vehicles in Mysore

Vehicles	2010	2015	2020	2025	2030	Increasing Ratio: Times (2010-2030)
Two wheeler	351,074	439,774	525,180	627,172	748,972	2.13
Auto-rickshaw	17,155	20,745	24,324	28,520	33,441	1.94
Four-wheeler	39,180	46,583	57,471	70,904	87,476	2.23
Truck/Bus	9,223	15,538	18,704	22,515	27,103	2.94
Others	371	713	1,055	1,561	2,310	6.23
Total	417,003	523,353	626,734	750,673	899,302	2.16

(Source: Department of Transport, Karnataka State)

(c) Urban Structure and Land Use

The urban structure and the area development plan influence the future traffic demand. It is assumed that the existing urban structure will be maintained in future in Mysore. The existing urban area is mostly located within ORR. The urban structure with a thinly populated area expanding radially from the existing city area is expected to be formed. The policy of urban area expansion of Master Plan Mysore 2031 states that the existing city centre will be expanded radially to the east, west and southwest. The development of sub-city centres is not planned. It is targeted that the areas of the land for residential, commercial and industrial uses will be increased by 2.1 times, 1.6 times and 1.4 times respectively in 2031 from the land use in 2009. It intends conversion of the land currently used for agriculture as the means to increase the land for those uses. The existing Hebbal Industrial Area will be expanded further to the northwest to increase the land for the industrial use. The south part of the city will be also developed for industrial use. Increasing the industrial agglomeration in the Thandavapura Industrial Estate located in the southern suburb of Mysore is also stated.

The following two major plans are mentioned in the Master Plan Mysore 2031:

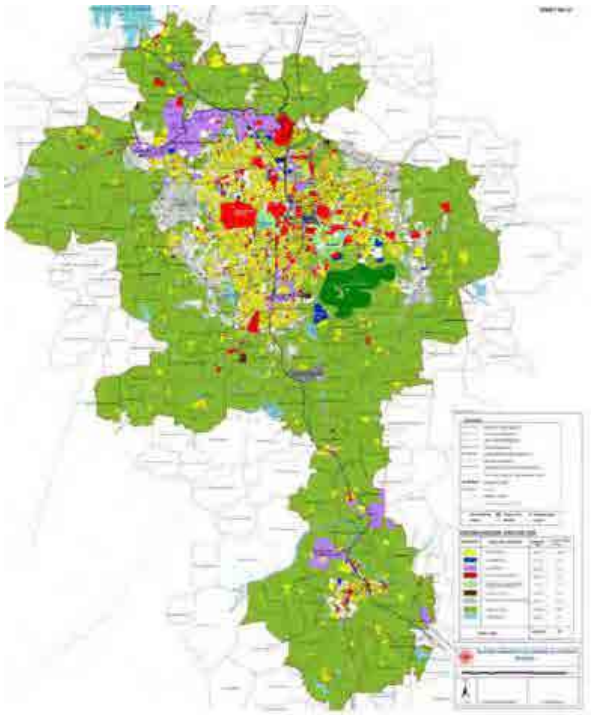
- A project to improve the airport and construct a convention centre: There is a plan to construct a 1.7km to 2.4km-long runway at the candidate site beside the Bengaluru-Nilgiri Road. The construction of an exhibition centre, hotels and sports village adjacent to the airport is also proposed.
- Film City Development: A 256-ha area located in the south of the airport has been allocated to the construction of the film city. A golf course, craft village and sports village close to the area are planned.

The land use proposed by Master Plan Mysore 2031 are summarised in Table 3.8 and shown in Figure 3.11.

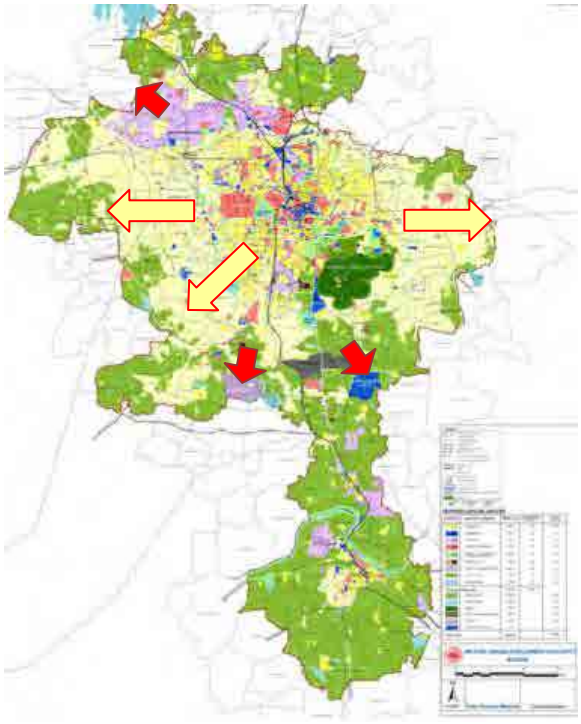
Table 3.8 Land Use in 2031 Proposed by Master Plan Mysore 2031

Land Use Category	2009		2031		Increasing Ratio: Times (2009-2031)
	Area (ha)	%	Area (ha)	%	
Residential Area	7,033	25%	14,958	54%	2.1
Commercial Area	474	2%	758	3%	1.6
Industrial Area	1,309	5%	1,827	7%	1.4
Public Area	1,653	6%	2,075	7%	1.3
Open Space	766	3%	1,584	6%	2.1
Traffic and Transportation	3,385	12%	4,310	15%	1.3
Agricultural Area	12,168	44%	1,249	4%	0.1
Others	1,076	4%	1103	4%	1.1
Total	27,864	100%	27,864	100%	1.0

(Source: Master Plan Mysore 2031)



Existing Land Use in 2009



Proposed Land Use in 2031

Figure 3.11 Existing and Proposed Land Use in Mysore

(Source: Master Plan Mysore 2031)

Figure 3.12 show the development of the facilities already in progress in the area along/outside of ORR.

Land Use of Outside ORR Near SH17

Land Use Along ORR Near SH17

Figure 3.12 Development of Facilities in Progress along/outside ORR

(Source: JICA Study Team)

(2) Transport Development Proposed by CTTP for Mysore 2012

The major transport developments proposed by CTTP for Mysore 2012 are:

- **Construction of Bus Rapid Transit (BRT):** It is proposed to development the BRT corridors, five corridors, along the major radial roads connecting the central area of Mysore and suburbs.
- **Important Road Development/Upgrade**: It is proposed to complete the missing link in south-east section of ORR and upgrade nine radial roads to the standard cross section.
- **Intersection Improvement**: It is proposed to improve 34 intersections together with introduction of signal and introduce area traffic control system at major intersections (however it remains a broad description).

Table 3.9 lists the transport development proposed by CTTP for Mysore 2012.

Table 3.9 Transport Development Proposed by CTTP for Mysore 2012

Item	Description
Bus Rapid Transport System (BRT)	Five corridors on major radial roads
Improvement of Existing City Bus Service	Increase of bus vehicles Development of bus terminal cum traffic & transit management centres Development of new bus station / bus shelter Development of IT infrastructure Development of satellite bus terminal
Upgrade of Intermediate Public Transport	Introduction of CNG for auto-rickshaw Development of parking for auto-rickshaw Enhancing convenience of tourist taxis
Road Development	Completion of missing link of Outer Ring Road Upgrade of Intermediate Ring Road (23.5km in length) Upgrade of Inner Ring Road (6.5km in length) Rehabilitation of major radial road (29.4km) Development of outer city road Development of secondary road system Development of rail over/under bridges Development of roads in heritage core area
Intersections	Improvement of 34 intersections Introduction of area traffic control system at major intersections
Others	Grade separated facility for pedestrian at nine locations Development of footpath network (111km in length) Cycle facilities (126km in length) Car Parking (seven additional locations) Truck terminal (two locations)

(Source: Summarised by JICA Study Team based on CTTP for Mysore 2012)

Figure 3.13 and Figure 3.14 show the development/upgrade of ring roads and major radial roads, and BRT corridors proposed by CTTP for Mysore 2012.

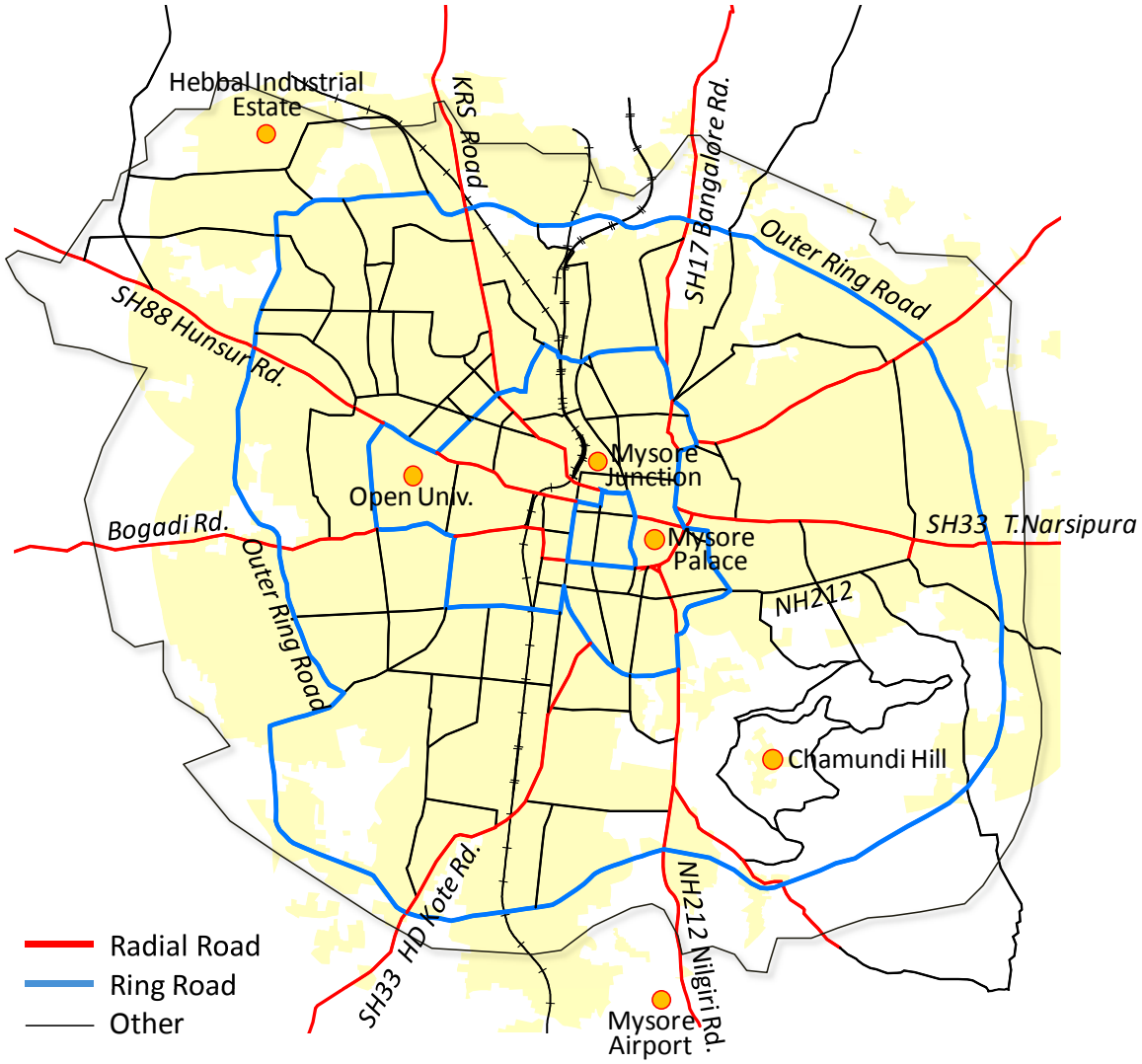


Figure 3.13 Proposed Road Development/Upgrade: Three Ring Roads and Nine Radial Roads

(Source: JICA Study Team based on CTTP for Mysore 2012)

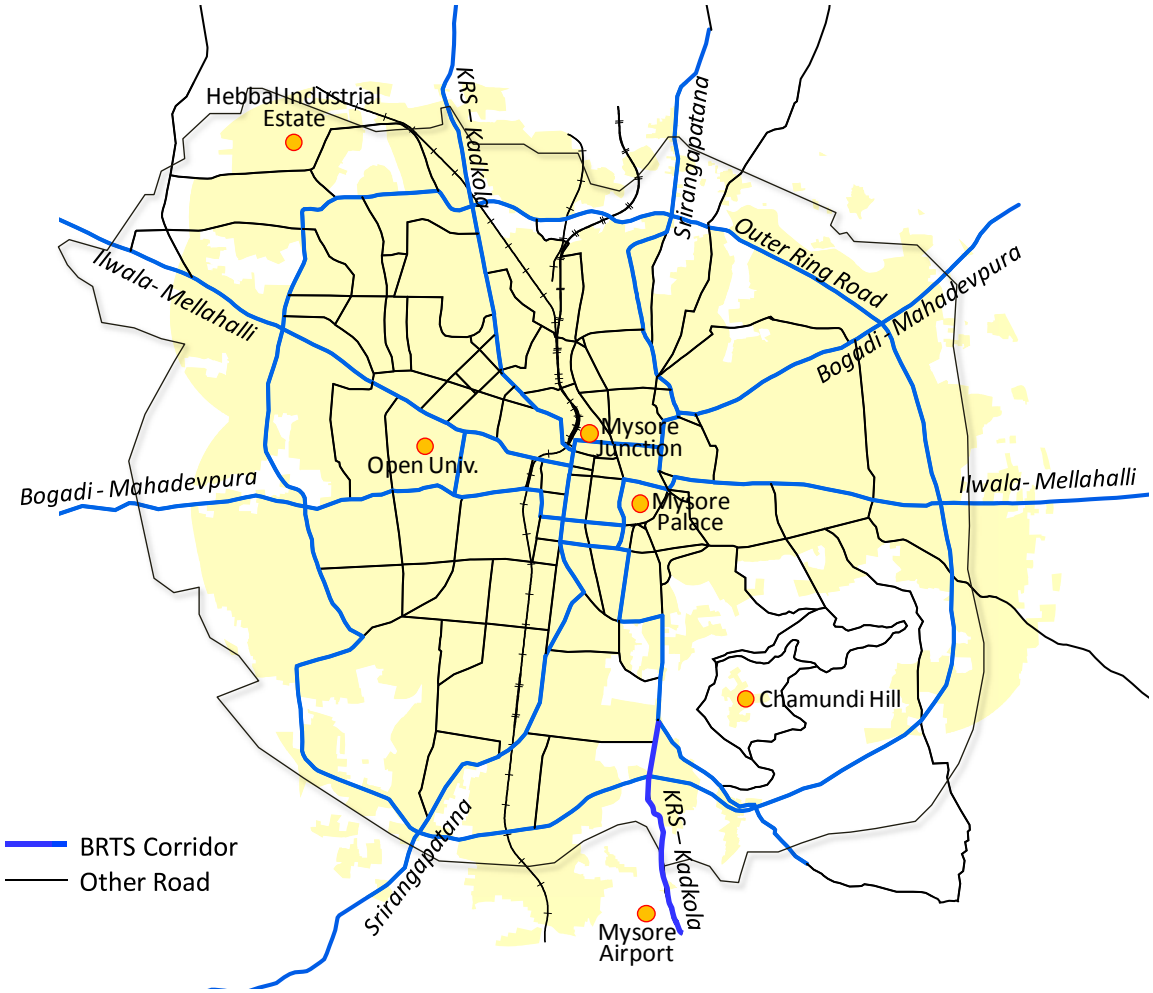


Figure 3.14 Proposed BRT Corridors

(Source: prepared by Study Team based on CTTP)

(3) Future Traffic Demand Analysis

Table 3.10 shows the traffic demand in Mysore in 2024, which has been derived from CTTP for Mysore 2012. The figures in the table indicate that the demand in 2024 is expected to be approximately 1.3 times the current demand on trip basis and 4.7 times in vehicle-hour. The chronic congestion especially in the core area can be expected in view of current tendency of concentration of traffic in the core area, urban structure, future road network and land use plan in the future.

Table 3.10 Performance Indicator of Future Traffic Demand

Performance Indicator	2014	2024	Increasing Ratio: Times (2014-2024)
Trips assigned in peak hour (in trips)	97,000	128,000	1.3
Vehicle hour in peak hour (in vehicle-hours)	9,000	42,000	4.7

(Source: Estimation derived by JICA Study Team based on CTTP for Mysore 2012)

3.1.5 Road and Traffic Issues

The major issues observed on the road and traffic in Mysore city are summarised as:

- Continuous growth of traffic demand and expansion of motorisation,
- Concentration of traffic to the major radial roads and the roads in the core area and its continuous tendency due to road network structure and land use in the future,
- Increase of visitors mainly tourist,
- Necessity of strengthening public transport to shift the road traffic demand (Introduction of BRTS and improvement of current bus services are considered by Indian authority),
- Necessity of improvement of shortage of road capacity and intersection including traffic signals,
- Necessity of alleviating traffic concentration on the core area, and
- Necessity of reducing external diseconomies of car such as traffic accidents, exhaust gas, etc.

3.1.6 Major Development Plans

(1) National Urban Transport Plan

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

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

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

(Source: JnNURM, MOUD)

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

(a) Objectives and Visions of NUTP

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

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

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

(Source: NUTP published by MOUD)

(b) Target Areas of NUTP

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

Table 3.11 Targets Identified by NUTP

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

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

(2) Master Plan Mysore 2031

Mysore Urban Development Authority (MUDA) is a planning authority for Mysore. The Master Plan Mysore 2031 has been prepared by MUDA. It is a comprehensive plan and covers Local Planning Area (IPA) which includes Mysore City Corporation, Nanjangud Town Municipal Counsel Area, 84 villages within Mysore taluk area, 19 villages within Nanjangud taluk area and 14 villages within Srirangapatna taluk area.

(a) Visions of Master Plan Mysore 2031

The vision of Master Plan Mysore 2031 sets out framework and direction of urban development. The principles of the vision of Master Plan Mysore 2031 are as follows:

- Promote and conserve cultural heritage, preserve natural characteristics of city and its environment through special development regulations,
- Promote Mysore as destination for investment in such non-polluting economic activities as information technology, bio-technology, service sectors and tourism related activities,
- Plan for an emerging metropolis with options for mono/metro rail system, peripheral roads and suitable linkages with surrounding settlements, access to urban infrastructure in peri-urban areas and de-concentration of economic activities through district commercial centres, and
- Suitable planning measures to prevent misuse of natural landscapes such as water bodies, natural valleys and hills through declaring a special eco-planning district.

(Source: Summarised by JICA Study Team based on Master Plan Mysore 2031)

(b) Salient Feature of Master Plan (Transport Sector)

Master Plan covers comprehensive sectors including land use, sewage, power supply and etc. The salient features of transport sector are:

- Strengthening capacity of existing airport, reinforcing Bangalore-Nilgiri road which connects the city with the airport and promoting tourism related activities such as development of convention centres, exhibitions, hotels, sports villages, film city near the airport,
- Developing peripheral ring road to divert passing traffic, upgrading the existing ring roads to standard cross section, completing the missing link of outer ring road, developing parking facilities,
- Increasing capacity and quality of bus services and proposing consideration of urban public transport such as mono rail to cope with increasing demand of road transport, thereby preserving environment

(Source: Summarised by JICA Study Team based on Master Plan Mysore 2031)

(3) Comprehensive Traffic and Transportation Plan for Mysore

The Comprehensive Traffic and Transportation Plan (CTTP) is a policy document and a basis for the development of Mysore addressing transportation issues and proposing a transportation plan in Mysore. The preparation of CTTP for Mysore comes under the directive of the Directorate of Urban Land Transport (DULT), Government of Karnataka. The CTTP 2012 was prepared by DULT in line with the framework of National Urban Transport Policy(NUTP), 2006.

(a) Study Goals of CTTP for Mysore 2012

The study goals of the CTTP 2012 are:

- Development of a comprehensive, cohesive and an integrated Traffic, Transportation and Mobility Plan,
- Delineation of the key interventions to be undertaken by respective stakeholders to enable Plan implementation, and
- Optimal Utilization of funds, human and institutional resources to affect project implementation (towards efficient & effective city transportation).

(Source: Comprehensive Traffic and Transportation Plan for Mysore 2012)

(b) Salient Feature of CTTP for Mysore 2012

The CTTP for Mysore 2012 addresses the following aspects:

- Making proposals and recommendations of transport development in Mysore for the next 20 years, ensuring sustaining environment preservation,
- Proposing financial plan for funding of development of transport in Mysore, and
- Proposing institutional framework to strengthen the institutional capacity for planning, development, operation and management of the city transport.

(Source: Summarised by JICA Study Team based on Comprehensive Traffic and Transportation Plan for Mysore 2012)

3.1.7 Conditions of ITS in Mysore

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

(1) Mysore Traffic Police M-TRAC

Mysore Traffic Police initiated Mysore Traffic Improvement Project called 'M-TRAC' in 2014. The main objective of project is to monitor traffic and enforcement. A Special Purpose Vehicle (SPV), "Karnataka Road Development Corporation Limited (KRDCL)", was formed by the state government to implement M-TRAC.

The proposed ITS components of M-TRAC system are as below:

- Traffic Management Centre
- Area Traffic Control
- Variable Message Sings (VMS) for traffic information provision
- Surveillance and Enforcement cameras at junctions
- Upgrade of existing traffic signals

The project is under progress and the following ITS components are functional at present.

Table 3.12 ITS Components of M-TRAC

Component	Description
Command Centre	• Known as Mini Traffic Management centre • Located in headquarters of Mysore Traffic Police • Video wall with LED TV of 4 numbers of 40" size • 4 operator work stations
CCTV Camera	• 42 CCTV cameras are installed at intersections • CCTV is equipped with pan, tilt and zoom functions • They are connected to command centre via Wimax.
Over-speed Enforcement Camera	• 5 speed detection cameras are installed in the city • Speed camera captures over-speeding vehicle and transmit the information to command centre
Traffic Signal	• 52 signals are installed in the city • Manually operated signal operation
Traffic Violation Enforcement System	• "E-Challan" system. • Takes pictures of vehicle of traffic violation • Manual identification of vehicle number from the captured images by operator and generates penalty notice
Vehicle Database	• Online connection from TCC to vehicle database of transport department

(Source: Mysore Traffic Police)

(a) Command Centre

The command centre is equipped with video wall (40" size) to view live images captured by CCTV at 42 intersections in the city. There are 4 workstations for operators. Figure 3.15 shows the image of Command Centre of Mysore Traffic Police.

Figure 3.15 Video Wall at Traffic Management Centre of MysoreTraffic Police

(Source: Mysore Traffic Police)

(b) Enforcement System

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

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

In the case of on-street enforcement, the traffic police officer on the street uses a handheld blackberry device. It records the details of violation and prints out the penalty slip, called “challan”, on the spot. Sometimes special traffic police known as ‘Cobra Police’ takes the picture of the violated vehicle and send to the command centre.

Figure 3.16 On-Street Enforcement using Blackberry Device

(Source: M-TRAC)

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

(2) ITS of Karnataka State Road Transport Corporation (KSRTC)

The Karnataka State Road Transport Corporation (KSRTC) is the major inter-city and intra-city service provider in Mysore. KSRTC currently operates in 384 schedules with a fleet strength of 500 and provides services to about 179,000 commuters per day.

KSRTC implemented Mysore Intelligent Transport called 'MITRA' in August 2012 at a cost of INR 20.13 Crore. The main objective is to use GPS technology to track KSRTC buses and provide real time information to passengers. The project is implemented under the Sustainable Urban Transport Programme with financial assistance from World Bank's Global Environment Fund, Government of India's JNNURM Fund of Ministry of Urban Development, Government of Karnataka and KSRTC.

The KSRTC ITS project include the following components:

Table 3.13 ITS Components

No.	Components	Description
1	Vehicle Tracking System (VTS)	• GPS is installed on all 500 city buses • Vehicle tracking application • Probe data recorded by GPS unit is sent to Command Control Centre in real-time
2	Electronic Ticketing System (ETS)	• Electronic Ticketing Machine (ETM) to issue printed ticket
3	Passenger Information System (PIS)	• Provision of real-time bus information • 193 LED display board at major bus terminals and bus stops • 500 in-bus display boards • Information provision through web site, SMS, automated voice service, etc
4	Data Centre	• Database Server (GPS Server, ETM Server) • Communication Server • Application Server • IVRS Server for automated voice service • LED Display Server • SMS Server

5	Command Control Centre	• Major activities comprise of monitoring real time data and managing bus services • Video Wall • 4 Workstations

(Source: KSRTC Mysore)

The major ITS components are shown in Figure 3.17.

Passenger Information Display Board at bus terminal

Passenger Information Display Board at bus stop

Control Station

Video Wall at Control Station

Figure 3.17 KSRTC ITS Components

(Source: KSRTC Mysore)

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

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

(a) Registration of Motor Vehicle

Computerisation of activities of the department has been underway since June 2009. The initiative is called 'Computerised Service Delivery System'. Under this initiative, the registered motor vehicle information has been computerised in a database. The vehicle owners are required to register their

vehicles in the office of the department at the time of purchasing the vehicles. The information such as name of owner, her/his address, vehicle type, date of purchase, etc. is registered.

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

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

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

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

(b) Number Plate Standardization

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

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

Figure 3.18 shows an example of HSRP number plate.

Figure 3.18 HSRP Number Plate for Karnataka State

(Source: Department of Transport)

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

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

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

Figure 3.19 shows typical example of number plates currently used on vehicles. The left picture shows the printed number plate on 4-wheeler and right picture shows the handwritten number plate on 2-wheeler.

Figure 3.19 Typical Examples of Number Plates Currently in Use

(Source: Pictures taken by JICA Study Team)

3.1.8 Outcome of ITS Opinion Survey

This section describes the outline and results of ITS Opinion Survey. The details can be found in Appendixt-1: ITS Opinion Survey Report for Mysore and Appendix-2: ITS Opinion Survey Report for Mysore (Tourist).

(1) Outline

ITS Opinion Survey in Mysore was carried out for the purpose of identifying potential needs. The surveyors randomly distributed the interview sheets and collected the responses on the spot in the vicinity of shopping malls, parking lots of government institutions, Mysore palace and other places in Mysore. The surveys were carried out for (i) Drivers, called 'Users' in this report, and (ii) Tourits.

The outline of the ITS Opinion Survey is shown in Table 3.14.

Table 3.14 Outline of ITS Opinion Survey

Target	Samples	Location	Question
Motorcycle User	50	Hunsur Road, Kuvempu Nagar, Kalidasa Road, Sayyaji Rao Road, Irwin Road, Mandi mohalla Road, Mysore City Corporation, Devaraj URS Road, Saraswathipuram, Mysore Medical College, Mysore City Bus Stand, Mysore University	**1. General Information** • User (Driver) Profile • Frequency of Trips • Purpose of the Trip and Travel Time (Motorcycle, Car) • Trip Purpose: Commuters (Bus) • Mode of Payment (Bus) • Reason for not Opting Public Transport (Motorcycle, Car) • Parking Facility and Willingness to Pay (Motorcycle, Car) • Transfer to/from Other Modes (Motorcycle, Car) **2. Traffic, Transportation and ITS** • Congestion and Current Traffic Information Facility (Motorcycle, Car, Truck) • Required Information (Motorcycle, Car, Truck) • Method to obtain information (Motorcycle, Car) • Choice of Mode of Information (Motorcycle, Car) • Improvement for Public Transportation facilities (Bus) • Reasons for Congestion • Solution for Traffic and Transportation Problems • Introduction of Congestion Charging for Congested Area • Improvement for Public Transportation Service (Bus)
Car User	50	Same as Motorcycle User	
Bus User	50	Mysore City Bus Stand, Railway Station, Bus Stops adjacent to Railway Stations, Mysore City Corporation, Mysore Medical College, Hunsur Road, Kuvempu Nagar, Kalidasa Road, Mysore University	
Truck Driver	50	Bandipalya (on Nanjungud Road), H.D. Kotte Road, Hunsur Road	
Domestic Tourist	70		**1. General Information** • Tourist Profile • Frequency of Visit • Route to Mysore (Via Bangalore or not) • Transportation Modes and Travel Time • Origin of Travel (Local Tourist) **2. Traffic, Transportation and ITS** • Traffic Related Problem • Kinds of Transportation in Mysore • Required Information and Provision Method • Solution of Traffic and Transportation Problem • Reasons for Congestion • Improvement of Bus Service • Enhancement of Traffic Signal
International Tourist	34		

(Source: JICA Study Team)

(2) Summary of ITS Opinion Survey Results

Various issues have been identified by the ITS Opinion Survey. The results of the survey are summarised in Table 3.15.

Table 3.15 Summary of ITS Opinion Survey Results

Target	Required Information and ITS Facilities	Traffic and Transportation Problems	Solutions	Congestion Pricing	Others
Motorcycle User	• Congested location information • Alternative Route Information • Traffic Incident	• Increasing vehicle	• Strict enforcement of traffic rules • Improvement of public transport	Not required	• Traffic condition is generally good, but increasing vehicle is emerging issue
Car User	• Congested location information • Alternative Route Information • Traffic Incident		• Strict enforcement of traffic rules	Not required	
Bus User	• Smartcard • Information display board at bus stops		• Strict enforcement of traffic rules	Not required	
Truck Driver	• Congested location information • Alternative Route Information • Traffic Incident		• Strict enforcement of traffic rules	Not required	
Domestic Tourist	• Sight visit information • Route guidance information	• Lack of tourist spot guidance information • Insufficient tourism information	• Improvement of basic pedestrian infrastructure	-	• Introducing eco-friendly vehicle • Improvement of clearness and hygiene
International Tourist				-	

(Source: JICA Study Team)

(3) Major Findings

(a) Travel Time by Different Mode and Usage of Public Transport (Bus)

1) Average Travel Time by Transport Mode

The travel time from origin (home) to destination (schools, work place) by transport mode is shown in the Figure 3.20. Majority of average travel time for private vehicles lies in the range of 15-29 minutes and public transport (Bus) users take more time. This is because bus users have to wait the bus at the bus stops. As shown in Figure 3.21, half of bus users spend more than 10 minutes at bus stops.

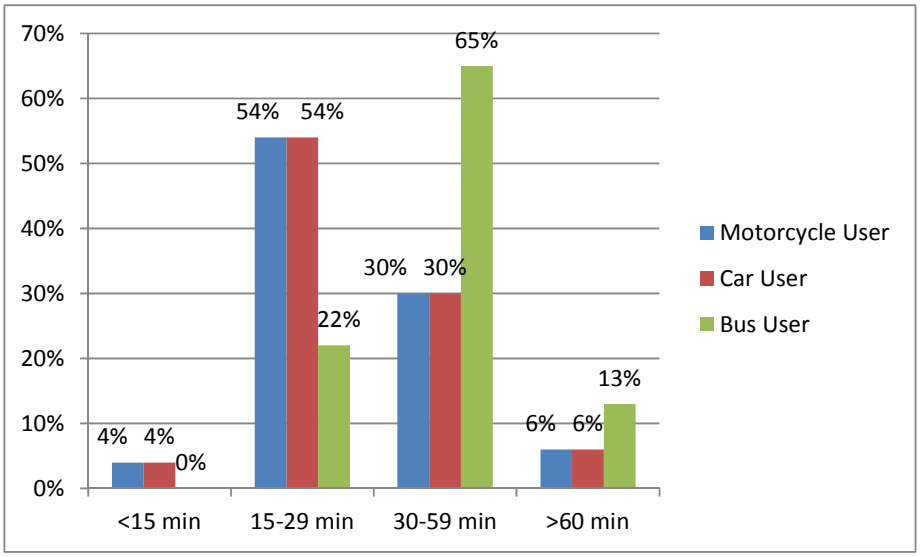


Figure 3.20 Average Travel Time by Transport Mode

(Source: JICA Study Team)

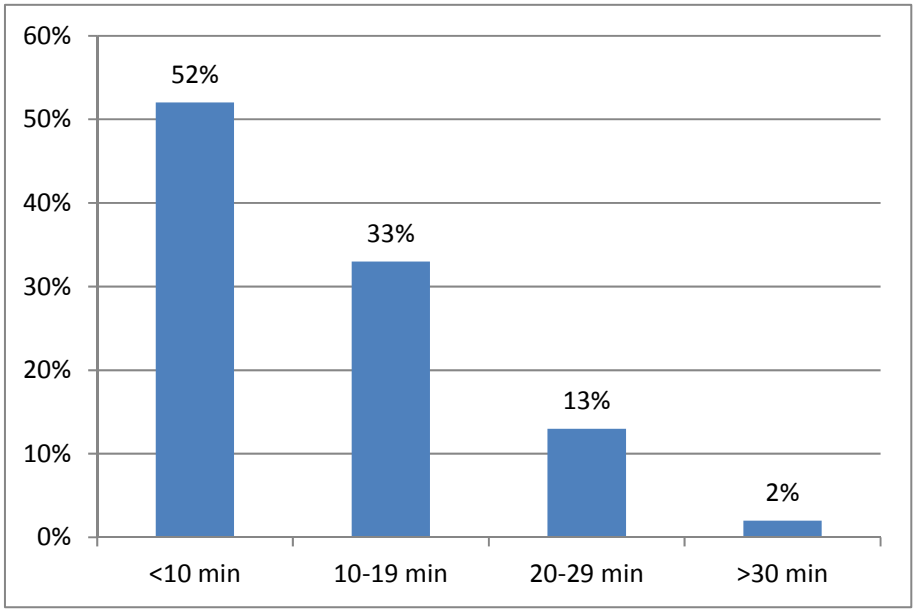


Figure 3.21 Waiting Time at Bus Stop

(Source: JICA Study Team)

2) Mode Shift Situation in Mysore

This analysis was carried out to understand the mode shift situation of each transport mode. The data was collected from only bus users. Almost all bus users take only buses as shown in Figure 3.22. More than 67% of bus users change the bus during their travel as shown in Figure 3.23. The results indicate that the bus contributes most of the people's movement in the city.

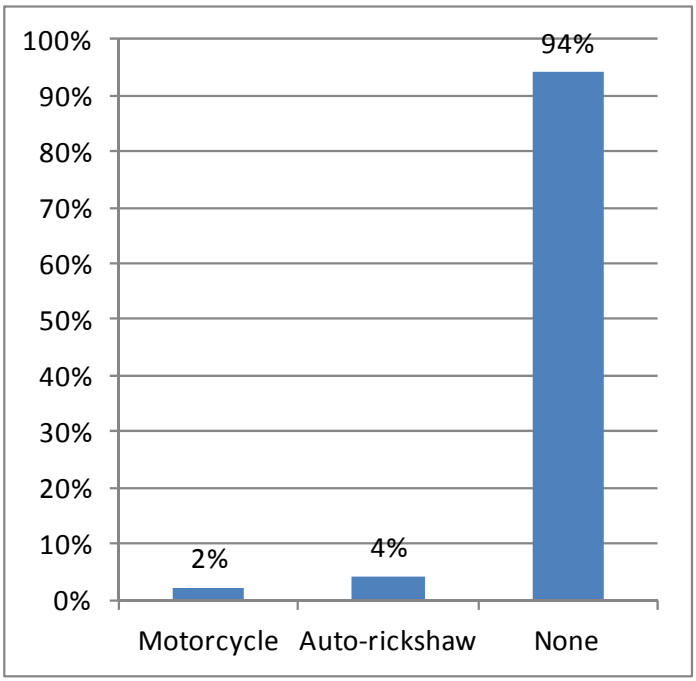


Figure 3.22 Other Mode Used by Bus Users

(Source: JICA Study Team)

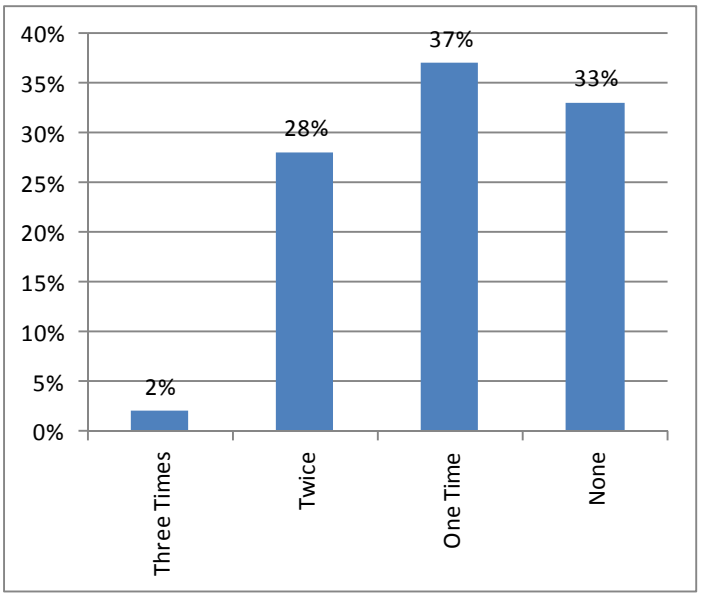


Figure 3.23 Bus Changeover Time by Bus Users

(Source: JICA Study Team)

(b) Issues and Solutions

Many responders evaluated that Mysore traffic is in a good condition and they are hardly involved in traffic congestion. However many of them responded that the congestion is an emerging issue in Mysore. Figure 3.24 shows the reasons of the congestion responded by the interviewers. Increasing number of vehicles and insufficient capacity of roads are considered major causes of the congestion.

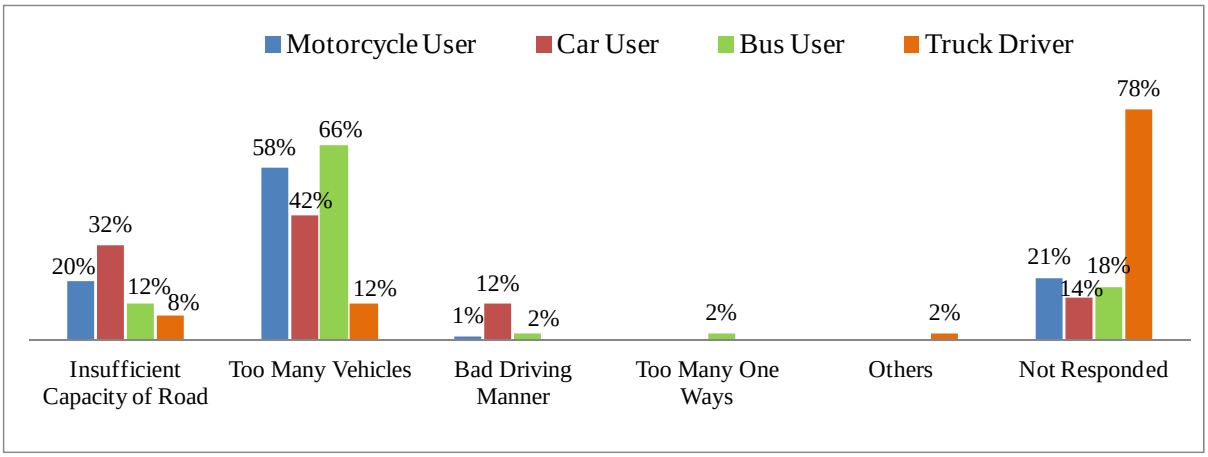


Figure 3.24 Reason of Congestion in Mysore

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

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

(Source: JICA Study Team)

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

- Construction of flyover at junction
- Provision of realtime traffic congestion information
- Improvement of bus service
- Strict enforcement of traffic rules
- Traffic signal improvement
- Provision of traffic congestion information and route guidance.

Figure 3.25Figure 3.36 shows the results responded as 'Very Necessary' by users. The majority responded that more strict enforcement of traffic rule is required.

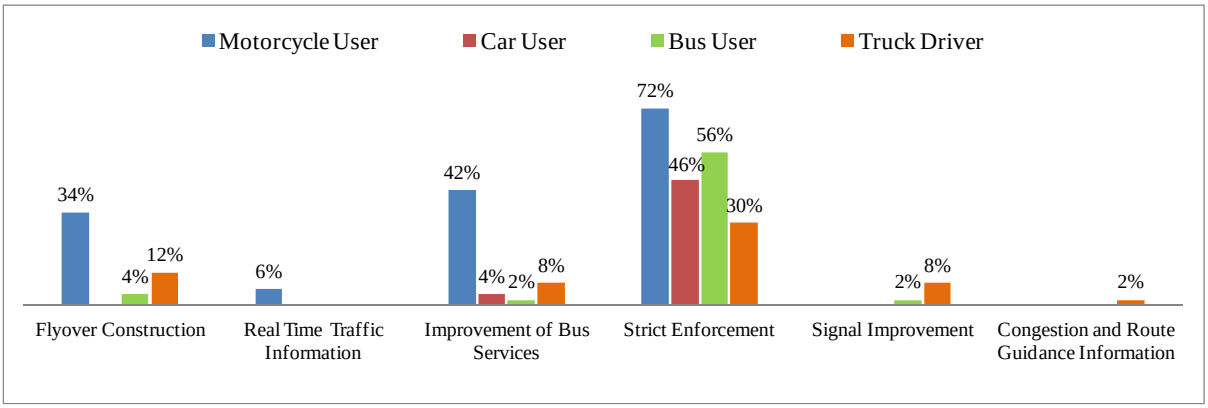


Figure 3.25 Solutions for Traffic Problems in Mysore (Very Necessary)

Note: The figure indicates the percentage of response corresponds to 'Very Necessary', thus it does not make 100% in total by user nor by item.

(Source: JICA Study Team)

(c) Required Facilities and Information by Transport Mode

The required facilities and information by transport mode were analysed.

1) Bus Users

The bus users were given multiple choices of issues in use of bus. Figure 3.26 summarises the major issues responded by the bus users. They were also asked their opinions on the usefulness of ITS related items. All users responded that information board at bus stop and smartcard are useful as shown in Figure 3.27.

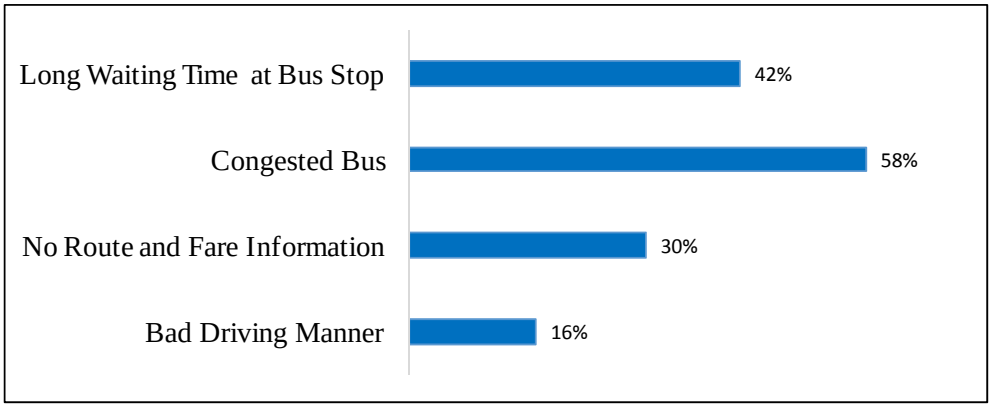


Figure 3.26 Major Issues in Use of Bus

Note: It shall be noted that many of bus users responded that they are not facing serious problems in bus usage. The above figures are drawn by those who responded facing some problems.

(Source: JICA Study Team)

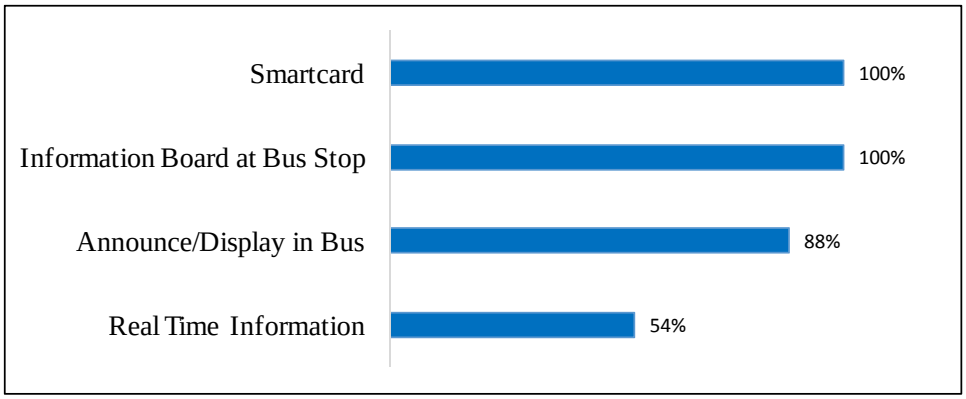


Figure 3.27 Useful ITS Related Items (Bus User)

Note: The users were requested to answer whether it is useful or not by each item. The figure above shows the percentage of the users who answered useful.

(Source: JICA Study Team)

2) Motorcycle, Car Users and Truck Drivers

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

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

Figure 3.28 shows the percentage of the respondents who answered 'very helpful' on each information category. The congested location and alternative route were viewed very helpful by many users, followed by traffic incident.

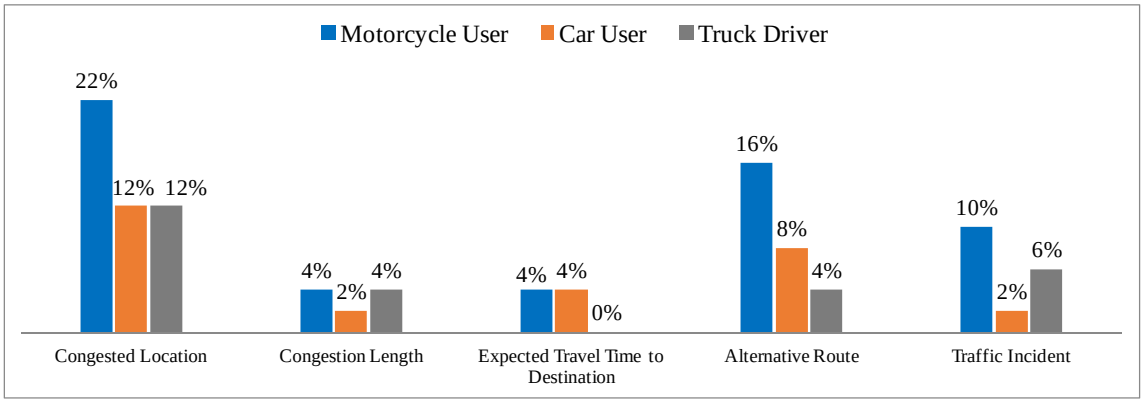


Figure 3.28 Realtime Information Viewed as Very Helpful

(Source: JICA Study Team)

(d) Opinions on Congestion Pricing

The opinions on congestion pricing were asked. Since the congestion in Mysore is not severe, majority of the users responded negatively.

It should be noted that those who answered required responded on the condition that the charging be imposed on the tourist vehicles. Being a tourist city where many tourists visit, they view that the tourist vehicles are major cause of congestion.

Table.3.16 Opinions on Congestion Pricing

Category	Required	Not Required	Don't Know
Bus Users	10% (Tourist Vehicles)	88%	2%
Motorcycle Users	18% (Tourist Vehicles)	82%	0%
Car Users	10% (Tourist Vehicles)	90%	0%
Truck Drivers	2%	98%	0%

(Source: JICA Study Team)

(e) Origins of Tourists for Opinion Survey

The following clauses report the summary of the results of opinion survey interviewed to the tourists. The origins of the interviewed tourists are summarised below.

1) Domestic Tourists

The majority of domestic tourists came from south Indian states; 20 visitors from Karnataka state, 37 visitors from Tamilnadu and Kerala state and rest of them, 13, from other states. A total of 70 domestic tourists were interviewed.

Table 3.17 Number of Domestic Tourists by Region

State	Number of Tourist
Karnataka State	20
Tamilnadu and Kerala State	37
Other States	13
Total	70

(Source: JICA Study Team)

2) International Tourists

The largest number of international tourists came from Europe. Most of them visited India for the first time, except two visitors. A total of 34 international tourists were interviewed.

Table 3.18 Number of International Tourists by Country

Country	Number of Tourist
Poland	6
Netherlands	6
England	6
Switzerland	5
Germany	4
New Zealand	2
Hong Kong	2
China	2
France	1
Total	34

(Source: JICA Study Team)

(f) Travel Route Taken by Tourists

It was observed that 40% of the domestic tourists travelled to Mysore via Bengaluru and 60% took other routes. The majority of the international tourists visited from other places, not via Benaluru. Those who answered via other places came from other south Indian states such as Kerala and Tamilunadu states. It is inferred that many of the international tourists visit Mysore as one of their destinations, visiting other tourist places in neighbouring states in South India.

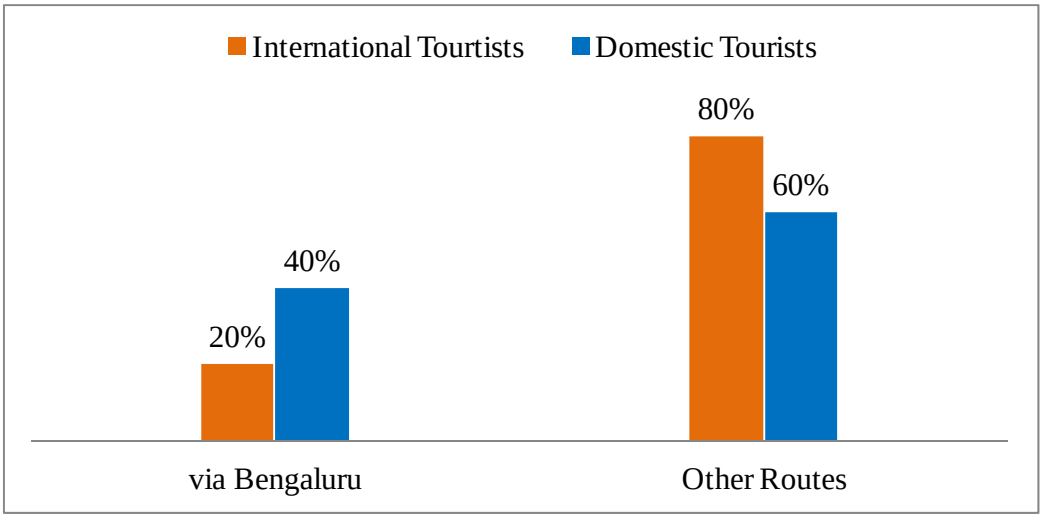


Figure 3.29 Route to Travel to Mysore

(Source: JICA Study Team)

(g) Transport Mode Taken by Tourists

The interviews were made to know about the characteristics of transport mode taken by the tourists. They were asked (i) transport mode to visit Mysore from other places, (ii) transport mode used for sightseeing in Mysore, and (iii) local transport experienced by the tourists as additional question.

1) Transport Mode to Visit Mysore

Many domestic tourists use either tour bus arranged by travel agency or their private vehicles. The majority of the international tourists come to Mysore by taxi. It was found that the use of public bus was much less than other transport mode. In regard of airplane usage, it shall be noted that the tourists who fall into this category arrive at Bengaluru airport from other places in India at first and travel to Mysore by such transport as taxi, car, and etc. due to limited air service of Mysore airport at the moment.

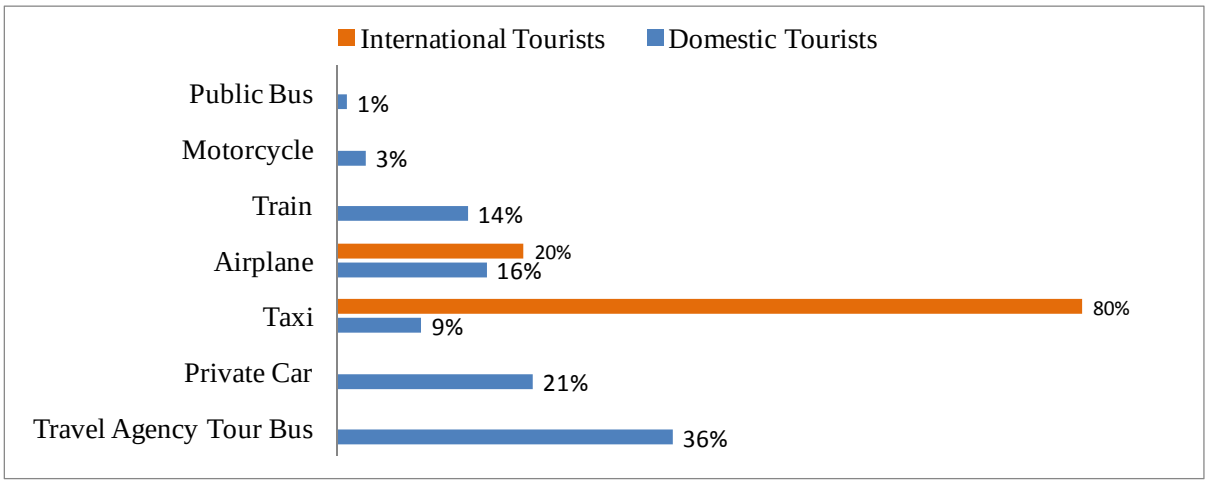


Figure 3.30 Transport Mode Taken by Tourists to Visit Mysore

(Source: JICA Study Team)

2) Transport Mode Used for Sightseeing in Mysore

It was found that the taxi was outstandingly preferred mode for sightseeing by international tourists, indicating those who came to Mysore via Bengaluru airport also using taxies for sightseeing in Mysore. Although the city bus operated by KSRTC is fairly available in Mysore, none of the tourists (both domestic and international) used for sightseeing.

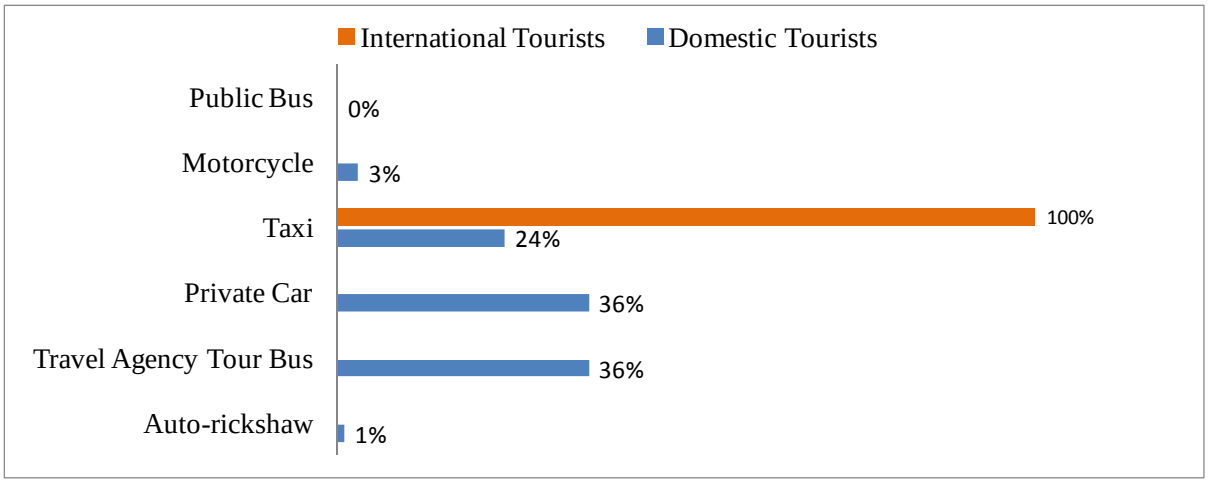


Figure 3.31 Transport Mode Used by Tourists for Sightseeing in Mysore

(Source: JICA Study Team)

3) Experience of Local Transport

The 'experience' by tourista means the transport used for moving around for such purposes as shopping, going dinner, moving to the tourist spots and etc. other than sightseeing presented above. None of the international tourists used 'Tonga', a traditional horse-drawn carriage, whereas nearly half the domestic tourists used. Here again, none of the tourists used the city bus.

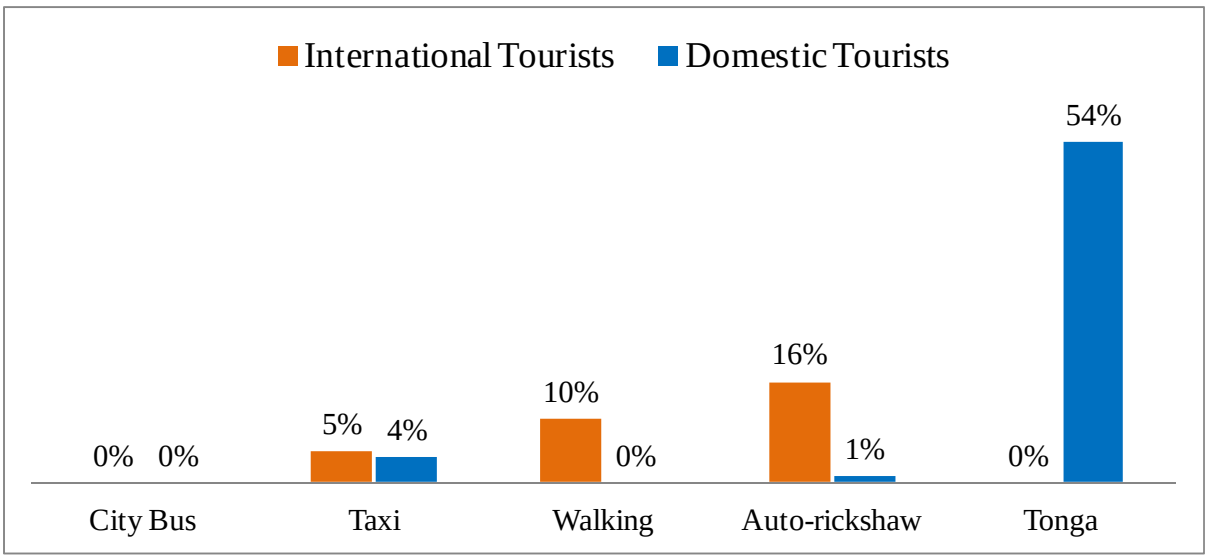


Figure 3.32 Local Transport Experienced by Tourists

(Source: JICA Study Team)

(h) Traffic Problems Faced by Tourists

Figure 3.33 shows the traffic related problems faced by the tourists. For the domestic tourists, the major problems are lack of route guidance information and traffic congestion with some response of

bad road condition. The issues faced by the international tourists were different from the domestic tourists. More international tourists worry about the pedestrian infrastructures and road condition. A certain number of the international tourists also raised the issue of lack of route guidance information.

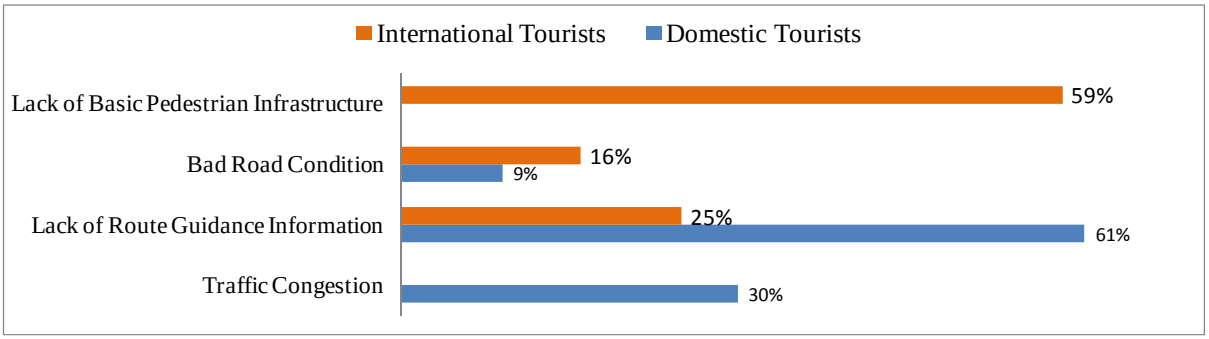


Figure 3.33 Traffic Problems Faced by Tourists

(Source: JICA Study Team)

(i) Information Source and Opinions on Facilities

The information source for Mysore tourism and opinions of the facilities were asked. The website was a major source of pre-trip information for the domestic tourists but it was used by fewer international tourists. All tourists depended on the local people in Mysore to find out the locations of tourist spots.

As to the parking facilities, relatively small number of the tourists responded that it was difficult to find the parking places. However is shall be noted that this survey was carried out on weekdays and the result may vary on weekends and holidays when number of the tourists increase.

As to ticketing system, a majority of the tourists expressed difficulty in purchasing ticket because they were required to stand and wait on the queue for a long time. Many wished that the ticketing system be improved to e-ticketing to avoid standing in a queue.

Table 3.19 Information Source and Opinion on Facilities

Items	Domestic Tourists		International Tourists	
Pre-trip information source	Website	Other Source (*)	Website	Other Source (*)
	66%	34%	10%	90%
Route navigation media	Map	Asking people	Map	Asking people
	0%	100%	0%	100%
Difficulty in finding parking place near tourist spot	Yes	No	Yes	No
	33%	67%	15%	85%
Difficulty in purchasing ticket at tourist spot	Yes	No	Yes	No
	57%	43%	70%	30%

Note (*): Friends, relatives, travel agencies and etc.

(Source: JICA Study Team)

(j) Inconvenience for Tourist

Inconveniences faced by the tourists were asked and the result is summarised below. Lack of tourist spot guidance information and local language communication were two major issues faced by the domestic tourists. A majority of the international tourists expressed inconveniences of insufficient tourism information and bad attitude of shop employees.

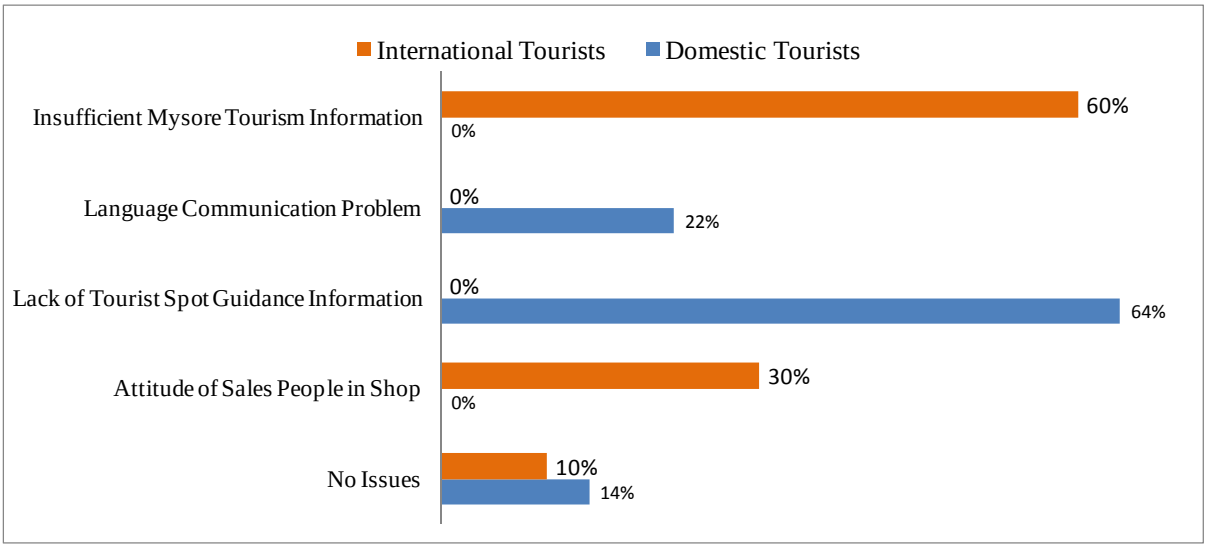


Figure 3.34 Inconveniences Faced by Tourists

(Source: JICA Study Team)

(k) Improvement Wanted by Tourists

The improvement wanted by the tourists was asked and the results are summarised below. It was found that improvement of site visit information was responded by the largest number of the tourist. Introduction of eco-friendly vehicles such as electric vehicle, bicycle sharing and etc. was responded by the second largest number of the tourists.

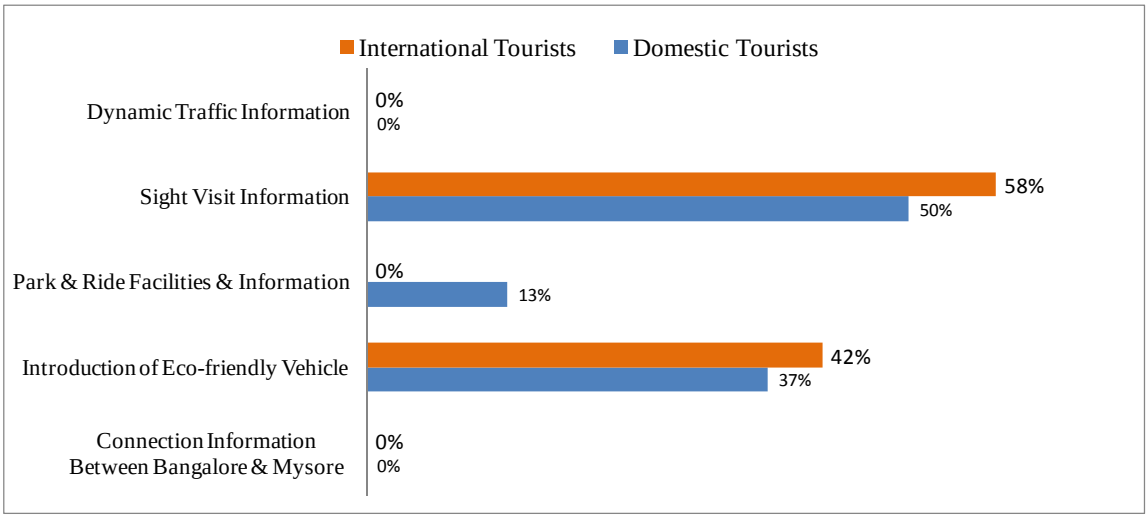


Figure 3.35 Improvement Wanted by Tourists

(Source: JICA Study Team)

(l) Tourist Opinions on Quality of Environment

As additional questions, the opinions on the quality of environment were asked to the tourists. The necessity of improvement in cleanliness and hygiene was stressed by nearly half of the international tourists.

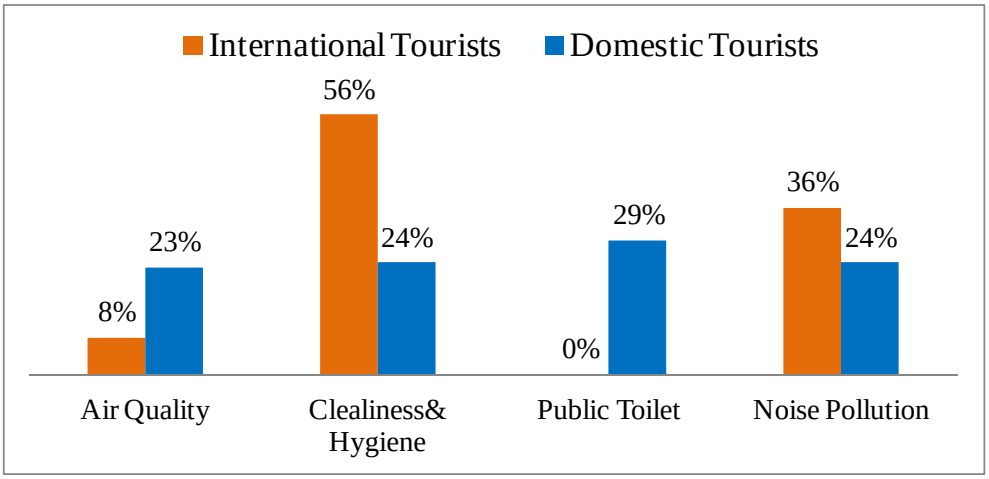


Figure 3.36 Opinions on Quality of Environment

Note (*): The figure above shows the percentage of the tourist who answered that improvement was necessary.

(Source: JICA Study Team)

3.1.9 Summary of Issues in Mysore

According to the studies so far, the issues in Mysore are identified and summarised in Table 3.20.

Table 3.20 Identified Issues in Mysore

Category	Issues \ Source of Issues	CTTP	Master Plan	Opinion Survey	Others (*1)	Observed by JICA Team (*2)
Road Traffic	Heterogenerous traffic condition	●				
	Rapid increase of vehicles		●	●		
	Traffic congestion in core area	●				
	Increasing number of accidents	●			●	
Road Infrastructure	Insufficient road infrastructure to accommodate traffic demand	●	●			
	Insufficient road surface conditions such as Ill-paved, speed breakers, unclear lane markings	●		●		
	On road parking occupying road spaces	●				
	Limited off road parking facilities	●				
	Improper road and intechange structure					●
	Absence of vulnerable-friendly spaces such as separate sidewalks, crash barriers, slopes, narrow space of footpath etc	●		●		
Public Transport	Inefficient connectivity between different transport modes	●				
	Absence of facilities for pedestrians and passengers to avid conflict between pedestrian and vehicles	●				
	Inconvenience to purchase ticket due to lack of efficient ticketing system			●		
	Consequently high demand of road traffic	●				
Traffic Manner	Lack of traffic discipline	●				
	Lack of awareness of importance of traffic discipline	●				
Facilities	Number of broken roadside facilities					●
	Improper cycle of traffic signal at major interchanges					●
	Absence of systems and data to support traffic and road management					●
	Absence of dynamic traffic information					●
	Lack of parking facility	●				
Tourism	Lack of tourist spot guidance information			●		
	Insufficient tourism information			●		
	Lack of route guidance information			●		
Administration	Uncoordinated manner amongst concerned agencies for infrastructure planning, traffic management and road management	●				
	Haphazard road works and planning due to above	●				
	Lack of sufficient engineering expertise and knowledge and capacity	●				

*1: Others means other materials collected by JICA Study Team including new paper article and interview to Indian authority.
*2: Obeservations by JICA Study Team on the items which are not covered by above listed sources.

(Source: JICA Study Team)

3.2 Policy for ITS for Mysore

3.2.1 Visions of ITS Master Plan

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

- **Enhance quality of life and convenience of tourists by utilising latest technologies**
- **Achieve better environmental friendly mobility through integrated manner for urban transport**
- **Optimize efficiency to achieve sustainable urban growth by protecting heritage value of the city**

(1) Goals of ITS for Mysore

Under the visions of ITS for Mysore, the goals are further set out to be achieved. They are accessibility, efficiency, safety and reduced environmental impact. The goals and their descriptions are as shown in Table 3.21.

Table 3.21 Goals of ITS

Goal	Description
Accessibility	To reduce travel time and cost To provide travel/traffic information To provide tourist information
Efficiency	To enhance road management To enhance Pedestrian and NMT connectivity To enhance efficiency of road use
Safety	To reduce traffic accidents To enhance response for emergency
Environment and Energy	To reduce air pollution To reduce CO_2 emissions To reduce energy consumption

(Source: JICA Study Team)

3.2.2 Strategies and ITS Components

(1) Strategies

In order to achieve the goals, the following eight (8) strengthen areas shall be realised by the ITS in Mysore.

The strengthen area are explained as follows:

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

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

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

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

(c) Centrally Coordinated Administrative Structure to Realise Proper Coordination

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

(d) Proper Decision Making on Urban Transport

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

(e) Proper Traffic Control and Management

A mechanism which enables to properly control traffic shall be in place. For example, the road traffic needs to be controlled according to the traffic condition which continuously changes. In order to realise this, for example, such facilities as dynamic real time traffic monitoring and advanced traffic signal system are important. Furthermore in broader sense of controlling traffic, traffic measures such as traffic demand management need to be properly carried out.

(f) Proper Road Management

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

(g) Efficient Public Transport Connectivity

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

(h) ITS Promotion and Coordination with ITS National Policy

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

(2) ITS Focus Area and ITS Component for Strategies

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

In order to execute the strategies, ITS focus areas are defined. ITS Components to realise the ITS focus areas are then identified as shown in Table 3.22.

Table 3.22 ITS Components by ITS Focus Areas

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

ITS Focus Area	ITS Component (*1)
13) Assisting Commercial Activities	Traffic Information Provision System Area Traffic Signal Control System Commercial Vehicle Management System
14) Assisting Emergency Vehicle Activities	Area Traffic Signal Control System
15) Assisting Efficiency in Public Transport Operation	Public Transport Operation Management System Public Transport Fare Payment System Common Smartcard System

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

(Source: JICA Study Team)

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

The outline of the ITS Components listed in Table 3.23 on the previous page and their current situations in Mysore are summarised in Table.

Table 3.23 Outline of ITS Component and Current Situation

	ITS Component	Outline and Current Situation in Mysore
A	Traffic Data Collection System	**1) Outline** This system is for collecting quantitative data on traffic. The system comprises "Probe Car Based Traffic Monitoring System" and "Traffic Volume Measurement System".
		2) Current Situation in Mysore • Probe Car Based Traffic Monitoring System KSRTC is operating bus service in city of Mysore and introduced bus location system, installing GPS devices on city buses. In addition, KSRTC is providing passenger information to users at bus terminals and major bus stops. The collected probe data will be used for the purpose of bus location system of KSRTC. However, utilisation of probe data for providing traffic information is not planned in Mysore. • Traffic Volume Measurement System The system that quantitatively measures traffic volume does not exist nor is planned in Mysore.
B	Traffic Condition Monitoring System	**1) Outline** This system is for monitoring traffic condition by image at traffic control centre. It uses CCTV camera.
		2) Current Situation in Mysore The traffic condition is monitored by Mysore Traffic Police. They monitor the condition at major junctions by CCTV cameras in Mysore.

	ITS Component	Outline and Current Situation in Mysore
C	Traffic Information Provision System	**1) Outline** This system is for disseminating dynamic traffic information to road users. The dynamic traffic information is generated by realtime traffic data. The information is disseminated through such media as Variable Message Sing Board (VMS), Internet, SMS, and etc.
		2) Current Situation in Mysore Such system does not exist nor is planned in Mysore. Traffic management centre of Mysore Traffic Police is monitoring major junctions through CCTV but dynamic traffic information is not provided.
D	Traffic Accident Management System	**1) Outline** This system is for managing traffic accident information and data. The system comprises data base, user interface, retrieving/statistic functions, and etc.
		2) Current Situation in Mysore The traffic accident is manually recoded by Mysore Traffic Police and introduction of the system is under consideration.
E	Parking Management System	**1) Outline** This system is for managing parking and providing parking availability information. The system comprises parking payment system, parking sensors, database, Variable Message Sign Board/Internet and etc.
		2) Current Situation in Mysore There is no parking management system in Mysore. Currently drivers cannot recognize available parking space until driver reach parking lots.

	ITS Component	Outline and Current Situation in Mysore
F	Area Traffic Signal Control System	**1) Outline** This system is for optimising signal phase in area wise according to traffic condition to realise smooth traffic flow. It also assists smooth pass of emergency vehicle. The system comprises roadside sensors, traffic signal, centre system, and etc
		2) Current Situation in Mysore The existing signals in Mysore are manually controlled. Introduction of area traffic signal control is proposed by CTTP but the proposal remains a broad description.
G	Traffic Regulation Violation Enforcement System	**1) Outline** This system is for enforcing violation of traffic regulation. Major examples are speed violation enforcement system, signal violation enforcement system, and etc. The speed violation enforcement system detects over-speeding. The signal violation enforcement system detects red-signal violation at junction.
		2) Current Situation in Mysore The over speed enforcement is implemented by Mysore Traffic Police, using mobile laser gun. The red-signal violation enforcement is implemented by Mysore Traffic Police, using the red light camera that takes photo of violated vehicle.
H	Overloaded Vehicle Monitoring System	**1) Outline** This system is for measuring weight of large sized vehicle for enforcement of overloading. There are generally two types of measurement; axle weight measurement and vehicle weight measurement. The system comprises weight measurement sensors, CCTV camera, functions for recording the measured weight/overloaded vehicle information, and etc.
		2) Current Situation in Mysore Introduction of overloaded vehicle monitoring is already under consideration by the authorities.

	ITS Component	Outline and Current Situation in Mysore
I	Road Inventory System	**1) Outline** This system is for managing road. The road inventory information, generally by road section, is recorded in the system and used for road management. The road inventory information includes road width, number of lane, design speed, completed/planned road work, and etc.
		2) Current Situation in Mysore The development of the road inventory system is already under consideration by the authorities.
J	Public Transport Operation Management System	**1) Outline** This system is for assisting efficiency in operation of public transport such as bus. The system comprises control centre, various managing functions and etc.
		2) Current Situation in Mysore The bus operation system has been developed in Mysore by KSRTC
K	Public Transport Fare Payment System	**1) Outline** This system is for collecting and managing public transport fare. It comprises ticketing machine/device, fare collection database, management functions, and etc. The payment is made by paper ticket issued by the system, token, smartcard and etc.
		2) Current Situation in Mysore The fare payment system of city bus is planned to introduce by KSRTC. The fare will be paid by paper ticket with handy terminal device.
L	Passenger Information Provision System	**1) Outline** This system is for providing information of public transport to passengers. The information to be provided includes operation status of the public transport, route, expected arrival time, and etc.

	ITS Component	Outline and Current Situation in Mysore
		2) Current Situation in Mysore The passenger information provision system of city bus is operated by KSRTC. The operation status and expected arrival time is provided by variable information board installed on the bus terminal and major bus stops.
M	Common Smartcard System	**1) Outline** This system is for enhancing convenience of public transport use by smartcard which can be commonly used for different transport mode. The transactions across different transport modes is calculated and settled by clearing house according to usage. The system comprises smartcard, card reader, card management system, clearing house, and etc.
		2) Current Situation in Mysore The common smartcard has not been introduced yet in Mysore nor planned.
N	Safety Assistance System for Vulnerable Road Users	**1) Outline** This system is for assisting safety and convenience for vulnerable road users. Major examples are warning system and walking route guidance system. The warning system alerts the driver in vehicle on existence of pedestrian or bicycle standing/passing behind the corner to avoid hitting. The walking route guidance system provides safe and shortest route to the destination to the pedestrian.
		2) Current Situation in Mysore The major car manufactures started embedding the warning system in cars in the world nowadays. The walking route guidance system on Internet or smart phone is increasingly available in the developed countries. However none of these are available yet in Mysore.
O	Commercial Vehicle Management System	**1) Outline** This system is for assisting operation of commercial vehicle for improving efficiency. It monitors the locations and operation of the vehicle and manages their operations. The system comprises GPS devices on vehicle, control centre together with various functions for operation, and etc.

	ITS Component	Outline and Current Situation in Mysore
		2) Current Situation in Mysore The commercial vehicle management systems are operated by private companies such as logistic service company, and etc.

(Source: JICA Study team)

(4) ITS Component for ITS Master Plan for Mysore

ITS Components to be planned in detail by ITS Master Plan for Mysore are selected by consideration shown in **Table 3.24** on the next page.

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

Table 3.24 ITS Component for ITS Master Plan for Mysore

Consideration for Selection \ ITS Component		**A) Traffic Data Collection System**	B) Traffic Condition Monitoring System	**C) Traffic Information Provision System**	D) Traffic Accident Management System	**E) Parking Management System**	**F) Area Traffic Signal Control System**	G) Traffic Regulation Violation Enforcement System	H) Overloaded Vehicle Monitoring System	I) Road Inventory System	J) Public Transport Operation Management System	K) Public Transport Fare Payment System	L) Passenger Information Provision System	**M) Common Smartcard System**	N) Safety Assistance System for Vulnerable Road Users	O) Commercial Vehicle Management System	Remarks
Reasons to Be Selected	Systems which collect quantitative data on traffic condition	●								●					●		
	Systems which significantly improve traffic flow			●			●										F): Contribute to improvement of traffic flow more directly than other systems.
	Sytems which require a centre to operate but the centre does not currently exist	●		●		●								●	●		
	Systems which provide dynamic information on traffic condition			●													
	Systems which ehnance convenience and reliability in time for users			●		●	●						●	●			C): Assist users to avoid congested route/time. E): Assist to guide to available parking F): Increase travel speed. L),M): Enhance convenience for public transport users.
	Systems which can be implemented at early stage	●	●	●	●		●	●	●	●	●	●	●	●		●	E): Requires parking N): Requires advanced technology and maturity of infrastructure
Reasons Not to Be Selected	Systems which are already implemented by agencies		●					●			●	●	●			●	B), G): Implemented by Traffic Police J), K), L): Implemented by KSRTC O): Implemented by private companies.
	Systems which are planned by agencies				●				●	●							D),H), I) : Planned and considered by relevant authorities
	Systems which are generally implemented by private sector (*)														●	●	
	Selected ITS Component	◎		◎		◎	◎							◎			**ITS components selected for ITS Master Plan are highlighted above**

(*) : ITS components which are generally implemented by private sector are not selected.

(Source: JICA Study Team)

3.2.3 Phasing Policy of ITS Master Plan

The phased development policies are set out in three phases for Mysore as shown in Table 3.25.

Table 3.25 Phased Development Policy

Phases	Year	Policies
Phase-1	2015 - 2017 (3 Years)	▪ To develop proposed ITS components for major target area, i.e. core area and major tourist spots ▪ To start operation of these ITS components
Phase-2	2018 - 2022 (5 Years)	▪ To expand and upgrade ITS components which are implemented in Phase-1as necessary ▪ To start operation of these ITS components
Phase-3	2023 - (After 8 years)	▪ To upgrade functions, adopting new technologies

<Phase-1>

The proposed ITS components will be introduced targeting important areas: i.e. core area and major tourist spots.

In addition, improvement of vehicle registration and standardisation of number plate is important to implement proper and effect enforcement by such ITS as e-challan system for traffic violation implemented by Mysore Traffic Police. It is recommended that these are improved in early stage.

<Phase-2>

According to the progress of improvement/development of infrastructure, increasing in number of vehicle and tourist and change in travel pattern, functions and coverage area of ITS component will be expanded as necessary.

<Phase-3>

A number of new technologies which do not exist as of 2015 are expected to be available in this period. The traffic conditions will also be different after improvement/change of infrastructure coupled with continuous urbanisation. Hence, reviewing the traffic conditions and introduced systems, and revising plans adopting newly available technologies will be required in this phase.

3.2.4 Implementation Schedule of ITS for Mysore

Based on considerations so far, ITS implementation schedule for the selected ITS components are set out in Table 3.26

Table 3.26 Implementation Schedule of ITS for Mysore

Technical Prerequisite for ITS and Major Event		Phase-1 2015	Phase-1 2016	Phase-1 2017	Phase-2 2018	Phase-2 2019	Phase-2 2020	Phase-2 2021	Phase-2 2022	Phase-3 2023-	Remark
Technical Recommendation	Improvement of Vehicle Registration										Recommended for Vehicle Registration implementation by mid of 2018
	Standardisation of Vehicle Number Plate										Recommended for vehicle number plate implementation by mid of 2018
Major Event in Mysore	Public Bicycle Sharing										It is planned to start from middle of 2016 (WB grants project)
	Completion of ORR, BRTS, and improvement of major radial roads										Concrete schedules are not clear, thus expressed in dotted-line.
	ITS Master Plan		▲Approval of ITS Master Plan				▲Revising ITS Master Plan			▲	Revising ITS Master Plan is recommended.

Selected ITS Components		Phase-1 2015	Phase-1 2016	Phase-1 2017	Phase-2 2018	Phase-2 2019	Phase-2 2020	Phase-2 2021	Phase-2 2022	Phase-3 2023-	Remark (*1)
Mysore Traffic Information System	Traffic Data Collection System (ATCC)										- It will be prepared as a component of Mysore Traffic Information System. - The coverage area/function will be expanded as necessary.
	Traffic Data Collection System (Probe)										- It will be prepared as a component of Mysore Traffic Information System. - The coverage area/function will be expanded as necessary.
	Traffic Information Provision System (Internet & Mobile Application)										- It will be prepared as a component of MysoreTraffic Information System. - The coverage area/function will be expanded as necessary.
	Traffic Information Provision System (VMS)										- It will be prepared as a component of MysoreTraffic Information System. - The coverage area/function will be expanded as necessary.
Traffic Management System (Existing)	Area Traffic Signal Control System				(Expansion)						- The area control signals will be installed in core area. - They will be prepared under existing Traffic Management System of Mysore Traffic Police. - The coverage area will be expanded in expansion stage as necessary.
Common Smartcard System											The service of common smartcard system in Mysore will participate in the clearinhouse scheme to be developed in Bengaluru.

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

: Operation

Note (*1): The details can be found in the next chapter.

(Source: JICA Study Tram)