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APPLICATION OF INTELLIGENT TRANSPORT SYSTEM FOR URBAN ROADS

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3	Secretary General, Indian Roads Congress	Nirmal, Sanjay Kumar

ABBREVIATIONS

ACC	-	Adaptive Cruise Control
ACN	-	Automatic Collision Notification
ANPR	-	Automatic Number Plate Recognition
APC	-	Automatic Passenger Counter
APTS	-	Advanced Public Transportation Systems
ATC	-	Advance Transportation Controller
ATC	-	Area Traffic Control
ATIS	-	Advanced Traveller Information System
ATM	-	Active Traffic Management
ATMS	-	Advanced Traffic Management System
ATSC	-	Adaptive Traffic Signal Control
AVCS	-	Advanced Vehicle Control Systems
AVI	-	Automatic Vehicle Identification
AVL	-	Automated Vehicle Location
AVO	-	Automated Vehicle Operations
BRTS	-	Bus Rapid Transit System
CAD	-	Computer Aided Dispatch
CBD	-	Central Business District
CCC	-	Central Control Centre
CCTV	-	Closed Circuit Television
CEC	-	Commission of European Communities
CPU	-	Central Processing Unit
CWS	-	Collision Warning Systems
DMS	-	Dynamic Message Signs
DRIVE	-	Road Infrastructure for Vehicle Safety in Europe
DSP	-	Digital Signal Processing
DSRC	-	Dedicated Short Range Communications
EMS	-	Emergency Management Services
EPC	-	Electronic Product Code
ERP	-	Electronic Road Pricing
ETC	-	Electronic Toll Collection
ETCS	-	Electronic Toll Collection System
EU	-	European Union
EUREKA	-	European Research Coordination Agency
EVM	-	Emergency Vehicle Management
eVMS	-	Electronic Variable Message Signs
FHWA	-	Federal Highway Administration
GIS	-	Geographic Information System
GNSS	-	Global Navigation Satellite System

GPS	-	Global Positioning System
GSM	-	Global System for Mobile Communication
HOT	-	High Occupancy Toll
HOV	-	High Occupancy Vehicle
HSS	-	Highways Specifications and Standards
IPT	-	Informal Public Transport
IR	-	Infra Red
IRC	-	Indian Roads Congress
ISA	-	Intelligent Speed Adaptation
ITS	-	Intelligent Transport System
JPO	-	Joint Program Office
LCSs	-	Lane Control Signs
LED	-	Light Emitting Diode
MHZ	-	Megahertz
NETC	-	National Electronic Toll Collection
NHAI	-	National Highways Authority of India
OCR	-	Optical Character Recognition
PIR	-	Passive Infra Red
PROMETHEUS	-	Program for European Traffic with Highest Efficiency Unprecedented Safety
P-Spec	-	Process Specification
PWD	-	Public Works Department
RF	-	Radio Frequency
RFID	-	Radio Frequency Identification
RTC	-	Regional Traffic Control
RTI	-	Road Transport Informatics
RTTI	-	Real Time Traffic Information
RWIS	-	Road Weather Information System
SP	-	Signal Priority
SP	-	Special Publication
TFL	-	Transport for London
TMC	-	Traffic Management Centre
TMS	-	Traffic Management System
TOC	-	Traffic Operation Centre
UHF	-	Ultra High Frequency
USDOT	-	U.S. Department of Transportation
VICS	-	Vehicle Information Communication System
VKT	-	Vehicle Kilometres Travelled
VMS	-	Variable Message Signs
VVD	-	Video Vehicle Detection
WPC	-	Wireless Planning & Coordination

APPLICATION OF INTELLIGENT TRANSPORT SYSTEM FOR URBAN ROADS

1 INTRODUCTION

1.1 Rapid Growth in population in India along with commensurate economic upturn and urbanization, has resulted in tremendous increase in mobility by all modes of transportation especially Automobile. This has also given rise to environmental and traffic control management issues on roads, in towns and major cities. Intelligent Transportation System (ITS) is now the established technology for resolving and mitigating these issues. Different countries have adopted their own strategies to use this technology depending upon their local socioeconomic culture and environment status. Therefore, need was felt to frame a separate document on this subject for road sector to bring uniformity and for guidance of professionals. The initial draft was prepared by the sub-group under chairmanship of Prof. P.K. Sarkar comprising Shri D.P. Gupta, Prof. M. Parida, Dr. Ch. Ravi Sekhar, Shri Pawan Kumar Singh and Shri Namit Kumar as members. The document was deliberated in several meetings of Urban Roads and Streets (H-8) Committee and finally it was approved in its meeting held on 14th October, 2016.

The Composition of H-8 Committee is as given below:

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The Highways Specifications & Standards Committee (HSS) considered and approved the draft document in its meeting held on 23rd June, 2017. The Executive Committee in its meeting held on 13th July, 2017 considered and approved the same document for placing it before the Council. The Council in its 212th meeting held at Udaipur on 14th July, 2017 considered and approved the draft IRC:SP:110 "Application of Intelligent Transport System (ITS) for Urban Roads" for printing.

1.2 Urbanization

Urbanization is central to achieving faster and more inclusive growth because agglomerations and densification of economic activities in urban conglomerates, stimulates economic efficiencies and employment opportunities. Number of urban agglomerations in India has increased from 1827 in 1901 to 7935 in 2011. Population living in urban areas has increased from 25.8 million in 1901 to 377 million (representing 31.2 percent of total population) in 2011. The number of metropolitan cities with a million plus population has increased from thirty five in 2001 to fifty three, in the year 2011. And over two-thirds of urban population lives in class 1 towns (population above 100,000). There is continuing increase in their numbers, especially those with population above one million. Eight cities viz. Mumbai, Delhi, Kolkata, Chennai, Hyderabad, Bangalore, Ahmedabad, and Pune have population over five million. The sharp increase in population in these cities has implications for urban transport management.

1.3 Transportation Issues

i. *Traffic jam and parking:* Congestion and insufficient parking spots are the foremost transport issues in large urban agglomerations, significantly connected with motorization and the dispersion of the automobile that has expanded the demand for transport infrastructure. The provision of transport infrastructure has not kept pace with the traffic demand. Motorization has created significant demand for parking areas.

ii. *Long commutation:* Besides experiencing congestion, people are spending an increasing amount of time to travel between their residence and workplace. A vital element behind this pattern is the thought with the trend related to residential affordability, as housing located far away from central areas (where most of the employment remains) is less expensive. Along these lines, workers are exchanging time for housing affordability.

iii. *Public transport inadequacy:* Many transit systems or parts of them, are either over or under used. Uneasiness for users created by crowdedness in peak hours shaped low ridership that makes several services financially unsustainable, significantly in urban areas. Disregarding essential endowments and cross financing (e.g. tolls) virtually, not every transit system can prove adequate to cover its operational and capital expenses.

iv. *Lack of concern for non-motorized transport:* As a result of the intense traffic, the flexibility of walkers, bikes and vehicles is impaired. An absence of consideration for walkers and bikes while undertaking the physical design of road infrastructure in urban areas is leading to traffic management challenges.

v. *High maintenance costs:* Financial deficit is being faced for ageing transport infrastructure, for both maintenance and upgradation to modern infrastructure, demand.

vi. *Environmental impacts and energy consumption:* Pollution, as well as noise, generated by traffic circulation is becoming a major impediment to the quality of life and even the health of urban populations.

vii. *Accidents and safety:* Growing traffic in urban areas is leading to growing range of accidents and fatalities.

1.4 Need for Intelligent Transport System

In India, a fast developing economy, the problem of road traffic congestion is getting aggravated in every major city. Infrastructure growth isn't enough as compared with growth in number of vehicles, due to space and expense imperatives. Further; increasing transportation capacity by building new roads and upgradation of existing infrastructure may not be a suitable solution in many urban areas as a result of the high costs as well as environmental and associated social issues. In such situation, there would be need to adopt traffic management measures to improve the quality of service and safety for the users of both public transport and personalized vehicles. The Intelligent Transportation System has emerged as an effective traffic management tool, based on a combination of information and communication technologies. The information technologies allow components within the transportation system (vehicles, roads, traffic lights, message signs, etc) to become intelligent by embedding them with microchips and sensors and empowering them to communicate with one another through wireless technologies. This manual focus on ITS system architecture, sensors and their applications in ensuring the safe and efficient movements of urban road traffic.

2 ROLE OF ITS

2.1 What is ITS?

Intelligent Transportation System (ITS) is the application of computer, electronics, and communication technologies and management strategies in an integrated manner to provide traveller knowledge to extend the safety and efficiency of the surface transportation systems (Mathew, 2014). These systems involve vehicles, drivers, passengers, road operators, transportation system manager, all interacting with each other and the surroundings, and linking with the advanced infrastructure systems to boost the security and capacity of road systems (**Fig. 1**). ITS have evolved with applications, as well as collision warning systems, ramp meters, advanced signal control systems, transit and emergency vehicle management systems, and others.

Fig. 1 Intelligent Transportation System (ETSI, 2012)

The purpose of ITS is to improve transportation safety and efficiency, and also advance capability of road systems. In the leading nations in the world, ITS has brought vital improvements, in transportation performance, as well as reduced congestion and pollution besides enhanced safety and traveller convenience. Thus, the main key categories of benefits delivered by ITS are increasing safety, mobility and operational performance, reducing congestion and pollution.

ITS can impact transportation performance in five key areas that address safety, mobility, productivity, energy and environment, and customer satisfaction. Different performance measures are used to assess ITS performance for each of these areas. Safety is measured through changes in crash rates or different surrogate measures like vehicle speeds, traffic conflicts, or traffic law violations. Mobility enhancements are measured in savings in delay, travel time budget savings, and on-time performance. Productivity enhancements are usually documented in cost savings to transportation providers, travellers, or shippers. Advantages accrued from ITS area with respect to energy and environment are generally documented through fuel savings and reduced pollutant emissions.

2.2 ITS Architecture

An ITS architecture is the framework inside which a system of ITS projects is designed. It defines the components of the system and therefore it allows interconnections and information flow between the elements. The first parts of ITS architecture are subsystems and information flows.

Subsystems: Subsystems are individual items of the general ITS that perform specific functions like managing traffic, providing traveller's information, or responding to emergencies. Subsystems can be related to explicit organizations like public safety agencies, transportation services, emergency management agencies, or transit providers. They are the sources and/or users of knowledge provided by different subsystems inside the boundary of ITS architecture. Subsystems embrace centre systems, wayside equipment, vehicle equipment and traveller devices that are associated in ITS.

Information Flows: Information flows of the data is changed/processed between subsystems like traffic information, or surveillance and sensor control data. They depict ITS integration by illustrating the information links between subsystems. In ITS, this integration is technical as well as institutional.

ITS architecture can be defined as comprehensive image of functions that has got to be performed (user services), physical entities wherever these functions reside (subsystems), interfaces between subsystems (information flows), communications requirements for interfaces and stakeholder roles.

2.3 Need of ITS Architecture to resolve issues in urban areas

ITS architecture could be a useful tool for integrating ITS technique into planning process. The ITS architecture defines the comprehensive set of data that ought to be shared by numerous agencies of transportation network. With the information of what knowledge should be changed between subsystems, these agencies develop a standard interest in cooperating planning efforts between all transportation projects. As Vehicle Kilometres Travelled (VKT) and congestion has systematically gone up unabated, preciseness technology has become essential to capture the details of the updated status of traffic for efficient transportation planning programmes. As urban areas expand and more roadways are interlinked with each other, operations and maintenance of this technology is imperative. Therefore ITS architecture has emerged as the best way through which to oversee the physical and virtual networks interacting with ITS.

2.4 Logical Architecture

Fig. 2 shows the interaction of management of traffic with different processes. Every method is broken down into additional sub processes. The sub process is further broken down into next level of sub process that are known as process specifications (P-specs) lowest level. These p-specs are needed to be performed to meet the necessities of user services.

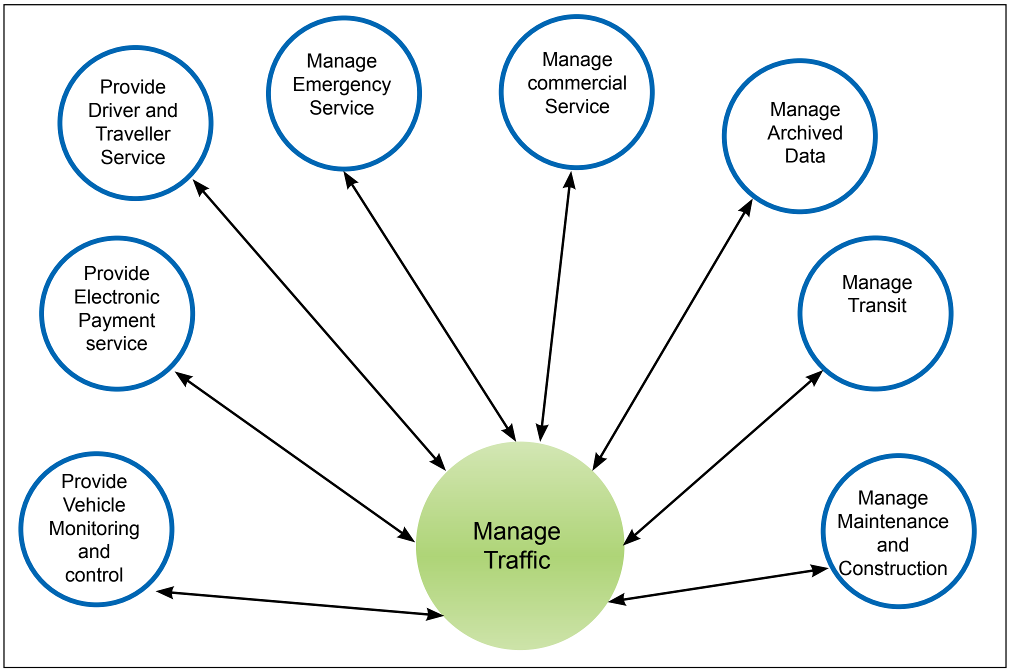

Fig. 2 Logical Architecture framework (US DoT, 1998)

2.5 Physical Architecture

The functions from logical design that serve a similar need are classified into sub systems. With these subsystems, a physical entity is developed to deliver functions. The info flow of logical architecture is combined to define interface between subsystems. **Fig. 3** shows the functions A and B of logical architecture assigned to system in physical architecture. Both the architecture forms the core of ITS.

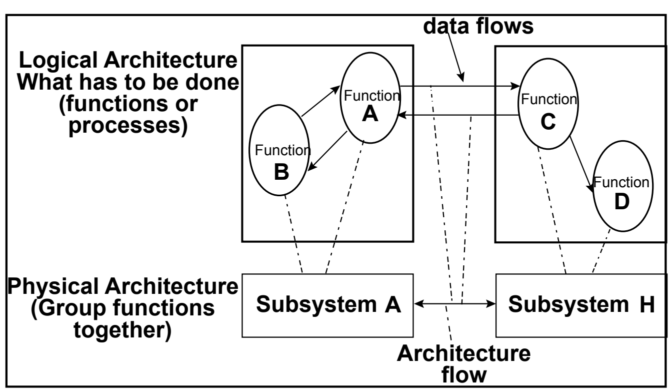

Fig. 3 Physical Architecture (US DoT, 1998)

The physical architecture of ITS, defines the physical subsystems and architectural flows based on the logical architecture. The subsystems are generally classified in four groups as centres, field, vehicle, and travellers. **Fig. 4** shows the subsystems and communications that comprise the physical architecture. The system represents aggregation of functions that serve a similar transportation need and closely correspond to physical components of transportation management system. Vehicle cluster consists of five differing kinds of vehicles. The traveller group represents other ways a traveller will access information on the status of the transportation system. There are four differing types of communication systems.

- Fixed point to fixed point
- Wide area wireless
- Vehicle - vehicle communication
- Field - vehicle communication

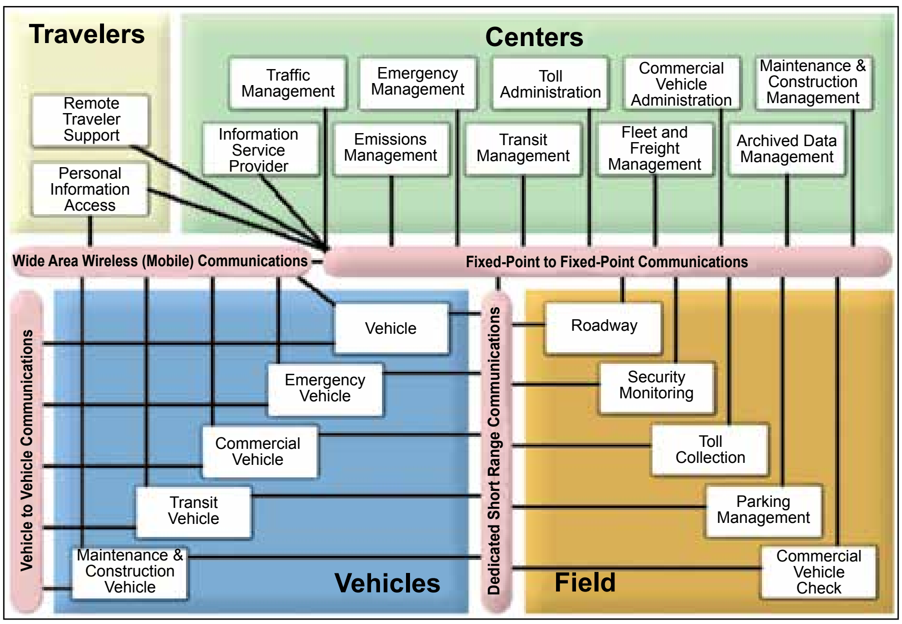

Fig. 4 ITS Architecture (TRB, 2000)

Traffic management system is connected to communications which gets real time information of the transportation system through roadway subsystem that comprise of signal control, detectors, camera, RFID Tags/ Readers (Compatible to open Road Tolling), ANPR Cameras and VMS (smart / eVMS) etc. These Smart / Connected/ eVMS shall aggregate the data from multiple subsystems and display location specific dynamic real time information.

2.6 Organizational Architecture

Organizational architecture refers to the engagement of various organizations/ stakeholders associated to be a part of the Traffic Management Centre (TMC) or Central Control Centre(CCC) such as NHAI, Traffic Police, Municipal Corporation, PWD, Mobile/ WiFi Service providers, Utility service provider companies, etc. for the control and management of traffic movement, incident management, maintenance of street lights, traveller information service, commercial vehicle management, Electronic payment systems, Safety services, Emergency management services, etc. The organizational architecture also defines and divides the involvement and role of various agencies in a system. When the works are distributed amongst all the agencies involved, it is also easy to find out the reasons for the failure of the system.

2.7 Equipment Packages

In order to provide additional preparation and oriented perspective to the ITS architecture, an equipment package is developed. Similar functions of a particular subsystem are grouped together and implemented by a package of hardware and software system facilities. For example, TMC equipment package enables traffic managers to monitor and manage the traffic flow at signalized intersections. It analyzes and reduces the collected data from traffic surveillance equipment and implements control plans for signalized intersections. TMC signal control equipment package contains five P- specs:

- Traffic operation personnel traffic interface
- Method traffic data
- Choose strategy
- Confirm indicator state for road management
- Output control data for roads

2.8 Market Package

The market package defines a set of equipment packages that are required to work together to provide a given transportation service. Most market packages are created from instrument packages from two or additional subsystems. These are designed to deal with specific transportation issues and desires. This package offers the central control and monitoring equipment, communication links and therefore the signal control equipment that support local street control or arterial traffic management. The various signal control systems are dynamically adjusted control plans and strategies based on current traffic conditions and priority requests.

2.9 User Services Bundles and User Services

A number of functions are required to accomplish the user services. These functional statements are known as user services requirements. For all the user services, the necessities are specified. If any new operation is added, new requirements are to be outlined. An illustration of user service requirements for traffic control user service is provided below:

Traffic Control provides the capability to efficiently manage the movement of traffic on streets and highways. Four functions are provided. These are:

- Traffic flow optimisation
- Traffic surveillance
- Control
- Provide information

There are eight users associated with ITS architecture as indicated below:

(i) Travel and Traffic Management (User Services Bundle) User Services:
- Pre-trip Travel Information
- En-route Driver Information
- Route Guidance
- Ride Matching and Reservation
- Traveller Services Information
- Traffic Control
- Incident Management
- Travel Demand Management
- Emissions Testing and Mitigation
- Highway Rail Intersection

(ii) Public Transportation Management (User Services Bundle) User Services:
- Public Transportation Management
- En-route Transit Information
- Personalized Public Transit
- Public Travel Security

(iii) Electronic Payment (User Services Bundle) User Services:
- Electronic Payment Services

(iv) Commercial Vehicle Operations (User Services Bundle) User Services:
- Commercial Vehicle Electronic Clearance
- Automated Roadside Safety Inspection
- On-board Safety and Security Monitoring
- Commercial Vehicle Administrative Processes
- Hazardous Materials Security and Incident Response
- Freight Mobility

(v) Emergency Management (User Services Bundle) User Services:
- Emergency Notification and Personal Security
- Emergency Vehicle Management
- Disaster Response and Evacuation

(vi) Advanced Vehicle Safety Systems (User Services Bundle) User Services:
- Longitudinal Collision Avoidance
- Lateral Collision Avoidance
- Intersection Collision Avoidance
- Vision Enhancement for Crash Avoidance
- Safety Readiness
- Pre-crash Restraint Deployment
- Automated Vehicle Operation

(vii) Information Management (User Services Bundle) User Services:

- Archived Data

(viii) Maintenance and Construction Management (User Services Bundle) User Services:

- Maintenance and Construction Operations.

3 DETECTION AND DATA COLLECTION METHODS

3.1 Detection Methods

Detection methods or sensors are the techniques/components to sense a vehicle or pedestrian moving on the road and then to take necessary action accordingly. Various types of detection systems for vehicles and pedestrians are briefly described in this section.

3.1.1 *Automatic Pedestrian Detection Method*

In this method, sensors detect the presence of pedestrians and take pre-defined actions for traffic signal control. In this method, the pedestrian does not have to press any button as the system takes care of signal timing automatically and works on the principle of infrared red wave or pedestrian pressure sensitive mat. Moreover, if pedestrian takes more time to cross the road (may be due to age or any other reason), the pedestrian green light is adjusted accordingly to facilitate the movement of such pedestrians. **Fig. 5** illustrates the Automatic Pedestrian Detection System.

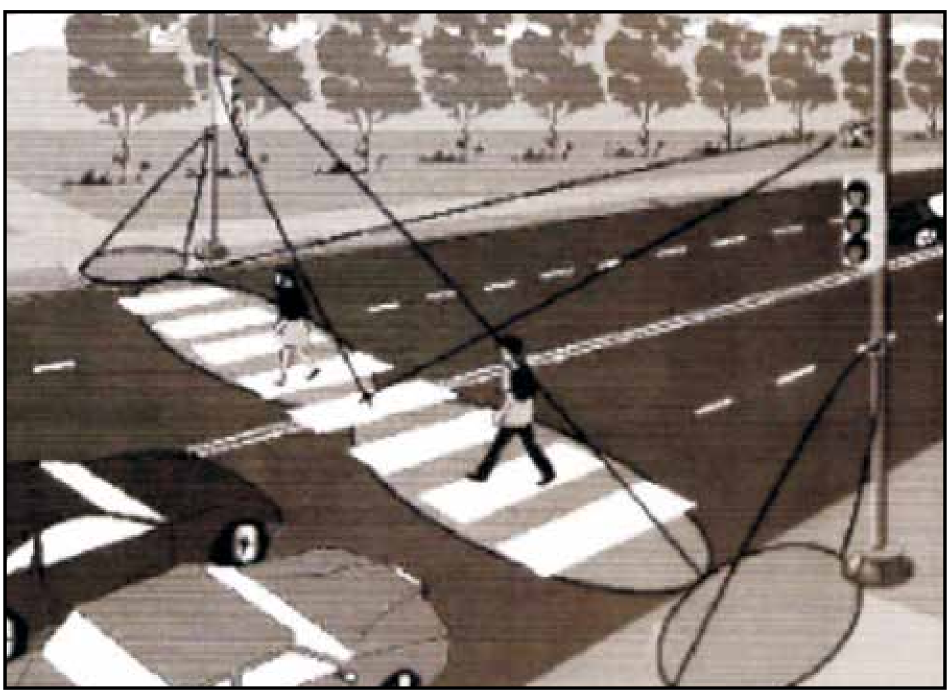

Fig. 5 Automatic Pedestrian Detection System (FHWA, 2001)

There are a few other types of Pedestrian Detection Systems as mentioned under:

(a) Traffic light as a permanent feature: The traffic lights in this scenario are provided for pedestrian crossings at intersections as a part of traffic signal for vehicular traffic. A specific cycle time is allotted for pedestrian signal. This type of arrangement is usually provided where there is continuous flow of pedestrian traffic. The green light for pedestrian crossing is designed on the basis of vehicular flow and pedestrian flow so that both get reasonable time to cross the intersection safely. The advantage of this system is that the pedestrian knows that he will get his time to cross the road and his needs are inbuilt in the traffic signal system. Usually the signal timing is fixed (even in ATC system, the signal timings for vehicles may increase or decrease as per load on network), but the green time for pedestrian is provided with some minimum fixed values.

(b) Traffic light but on request based: In this scenario, the traffic lights are provided for pedestrian crossings at intersections as a part of traffic signal for vehicular traffic, but the green light system for pedestrian is not automatic part of vehicular traffic signal system. In this case, at a road side traffic light pole (or special pole is placed), a button is provided. As soon as any pedestrian arrives, then he can press the button (pedestrian crossing button), called Pelican Crossing. After a small period of time, the pedestrian gets a green signal to cross the road. These signal timings are adjusted in a way that the drivers get sufficient time to stop his vehicle. This facility is provided where the pedestrian flow is irregular (not continuous). The advantage of this method is that the vehicular traffic will only be stopped when there is any pedestrian. If there is no pedestrian, there is no red light signal for driver. This type of system is mostly installed on mid block of the roads.

3.1.2 *Red Light Violation Detection System*

Motorists driving through an intersection after the traffic signal has turned red confronted with safety hazard. A Red Light violation can be considered as the violation when a motorist enters an intersection after the signal light has turned red.

The process of identifying a driver running during a red light and enforcing the violation is the time, generally consumed using traditional police methods. Although enforcing red light violations is a high priority for many police departments, the actual enforcement of the violation is difficult for several reasons. A single officer on patrol to stop an individual observed running a red light, the officer has to have a direct view of the traffic signal so that the decision can be quickly made, whether the suspected vehicle running during the red light was at he intersection before the light turned red.

By imposition of the enforcement, the officers should have the same view of the traffic signal as the violator. Officers who observe violations from cross streets or the opposing direction of traffic cannot enforce the violation. If an officer does observe a violation while viewing the same face of the traffic signal, the police officer will have to follow the violator through the flow of cross traffic that has the green signal, creating a dangerous situation for both the officer and the crossing vehicles. These factors make it difficult for an officer on patrol to enforce red light violations and force officers to position themselves in a stationary spot to view violations. Heavy manpower and resources are required to enable police departments to enforce violations for a long period of time. Automation of traffic Violation Detection would help in improved enforcement.

Automated enforcement systems designed to detect red light violations must have the ability to detect and record violations under varying field conditions and also to produce clear images that are easily retrieved and stored. Gary Erickson of Eastman Kodak Company, a manufacturer of automated enforcement technology, cites the ten following requirements that automated enforcement systems should include:

(i) The ability to capture, transmit, process, store and recover captured images so that data may be managed in an efficient manner;

(ii) Sufficient resolution to satisfy court standards for the image-reading of vehicle license plates, clear detail of the vehicle, and identification of the vehicle operator (if necessary);

(iii) The capability to prevent the spreading of over exposed portions of an image (anti-blooming) that may result from vehicle headlights or sunlight from highly reflective surfaces;

(iv) Adequate differentiation of light to dark areas within an image to provide necessary details (also referred to as contrast latitude);

(v) The ability to provide blur-free images of moving vehicles;

(vi) The ability to detect at varying levels of light;

(vii) Image enhancement circuitry to eliminate major sensor defects such as bright or dark columns which detract from the visible presentation of an image;

(viii) Continuous read-out of images to support monitoring along with single fame capture capability for recognising several successive vehicles committing a violation;

(ix) The ability to be moved to different locations or to be mounted into a permanent position; and

(x) Components should be environmentally friendly.

This ITS based solution of red light violation detection system may help reduce the accidents as it creates a sense of psychological fear among users not to violate the traffic rules . It also helps the driver to respect the law and provides visual and documentary evidences of violation and capturing regular offenders. There are three types of systems available namely Inductive Loop Sensor, Above Ground Sensors like Radar and Microwave based sensors techniques and ANPR cameras.

Inductive Loop Sensor consists of sensor loops (inductive type) detection system (single loop and two loop configuration depending on system design), Video camera and still camera with flash light and controller equipment's and communication system. In the above ground sensors system, functioning is almost same as the inductive loop except that the system uses above ground based detection system like laser system, which makes it simple and there is no need to dig the road or reroute the traffic at the time of installation.

ANPR (Automatic Number Plate Recognisation) cameras having a combination of IR (Infra Red) and Visual Spectrum Camera are used as part of an automated Red Light enforcement program. This will enable system to perform Automatic Vehicle Identification (AVI) with the help of a central processing unit, and a storage subsystem to record information such as date, time and location. This will enable enough documentary evidence for the offenders to be booked for violation and also instill a sense of discipline for Traffic Signal in road users. This will help to reduce the junction crashes due to red light violation.

3.1.3 *Automatic Number Plate Recognition Techniques*

The classical means to capture traffic density and speed of vehicular traffic depend on local measurements from induction loops and other on site instruments. This information does not give the whole picture of traffic situation. In order to collect data on the traffic flow of a large area, only airborne cameras or cameras positioned at very high locations (towers, etc.) can provide an up-to-date image of all roads covered. The method for measuring several traffic parameters for single vehicles and vehicle groups involve recording and evaluating a number of digital or analogue aerial images from high altitude and with a large total field of view. This can be carried out as non real time (Video recording and manual search). and real time methods such as Automatic Number Plate Recognition (ANPR), real time Optical Character Recognition (OCR) based vehicle monitoring system for tracking.

3.2 Data Collection Methods

Sensing Technologies: Sensing systems for Intelligent Transportation System are vehicle and infrastructure based networked systems, e.g., intelligent vehicle technologies. Pavement loops (**Fig. 6**) are used to sense the presence of vehicle demand at intersections and parking lot entrances. Pressure pads are used to sense the presence of pedestrians waiting to cross a roadway.

Inductive Loop Detection: One or more loops of wire are embedded under the road and connected to a control box. It is an established technology and not impacted by environmental conditions. Accurate in detecting vehicle presence and also performs well in both high and low volume traffic. A set-up of inductive loop detection system is shown in **Fig. 6**

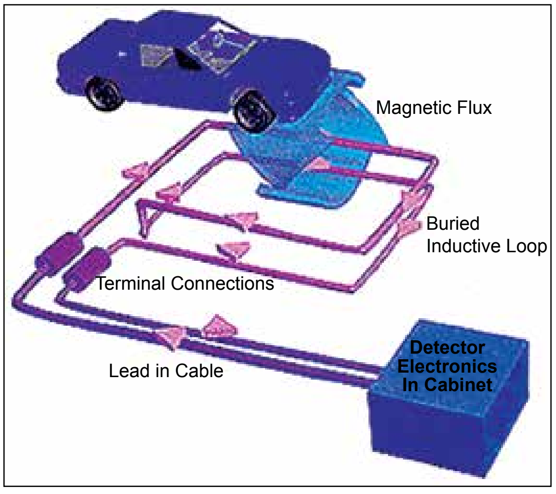

Fig. 6 Inductive Loop Detection System (FHWA, 1998)

Automated Number Plate Recognition (ANPR): The use of ANPR technology has grown rapidly, seeing widespread adoption worldwide as a means to providing more accurate and timely information in making critical business and enforcement decisions. The advancements include numerous capture technologies with an integrated dual lens camera and ANPR processor in one compact housing. It is seen as critical that the camera processor have in-house OCR algorithm mechanism. Plate detection and plate character recognition happen inside camera hardware thereby ensuring low bandwidth usage as well as speed of transmission and therefore preventive/corrective action is possible. Detection is possible for plates (reflective plates) even at high speeds of 120-150 kmph. Key of these camera systems are their feature of seamless sharing of hotlists, reads and alerts (Remote notification via email or text messaging) between agencies when ANPR captures vehicles matching details in hotlists. ANPR is an attractive product to complement or validate RFID or Digital Short-Range Communications.

Radar and acoustic sensors (**Fig. 7**) are also used for detecting vehicles in the roadway. It works along with transmission of radar pulses. A portion of the energy is reflected or scattered from the vehicle and roadway back toward the sensor and this energy is received and interpreted. The major benefits of this are low power, most accurate technology for detecting speed, traffic count accuracy and easy installation.

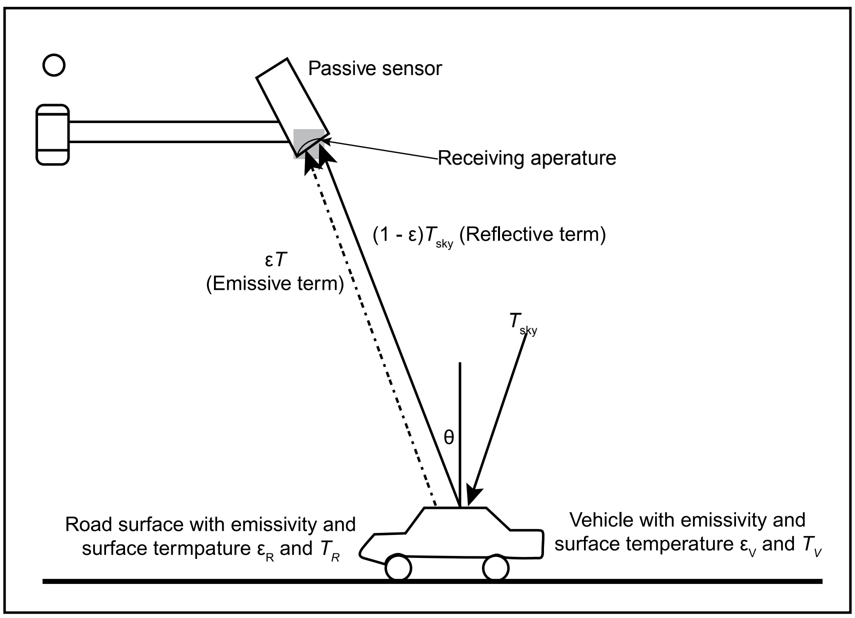

Fig. 7 Functioning of Sensor Technology
(FHWA, 1998)

Video Vehicle Detection: Video Vehicle Detection (VVD) is one of the most widely used methods (**Fig. 8**). Video detection is an image processor. It consists of a microprocessor-based CPU and software that analyzes video images. Using a mouse and interactive graphics, the user places virtual “detectors” on the video image displayed on a monitor Information/ data can be progressively transmitted to a server for real-time analysis.

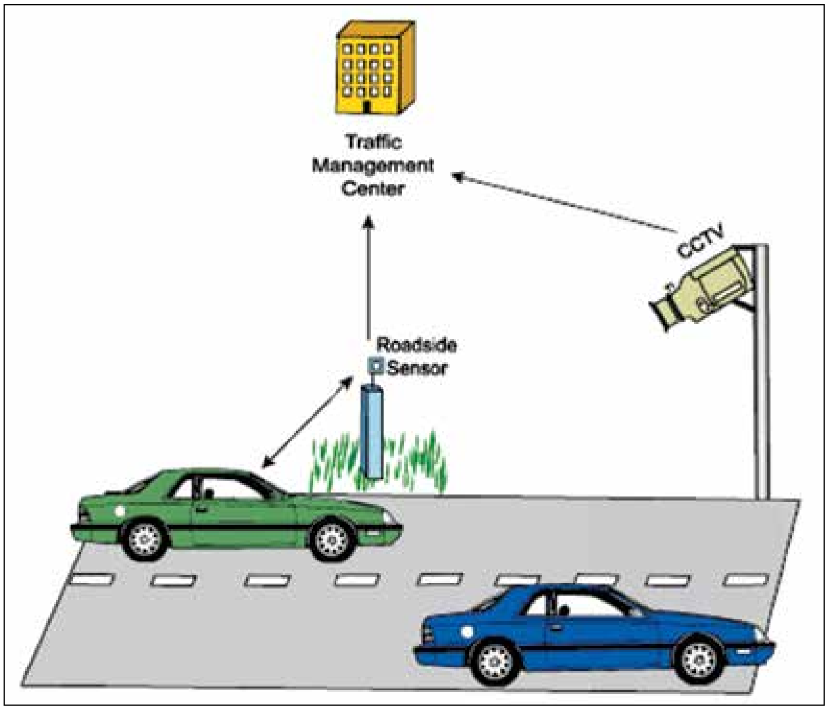

Fig. 8 Video Vehicle Detection System (Bachani, 2013)

Bluetooth Detection: Bluetooth is an accurate and inexpensive way to measure the travel time and undertake analysis of origin and destination pattern of trips. Bluetooth is a wireless standard used for communication between electronic devices such as mobile phones, smart phones, headsets, navigation systems, computers, etc. Bluetooth road sensors are able to detect Bluetooth MAC addresses of Bluetooth devices in vehicles passing. These sensors are able to calculate the travel time and provide data for origin and destination matrices if they are interconnected. Compared to other traffic measurement technologies, Bluetooth measurement has some differences.

- Accurate measurement points with absolute confirmation to provide to the second travel times.
- Is non-intrusive, which can lead to lower-cost installations for both permanent and temporary sites.
- Is limited to how many Bluetooth devices are broadcasting in a vehicle , therefore the counting and other applications are limited.
- Systems are generally quick to set up with little to no calibration needed.

Radio-Frequency Identification (RFID): Radio-Frequency Identification (RFID) is the wireless use of electromagnetic fields to transfer data, for the purposes of automatically identifying and tracking tags attached to objects. The tags contain electronically stored information. It is widely used in industries and transportation and communication purposes. For example, RFID placed in the road infrastructure can identify and communicate with the vehicles plying on the road through the following RFID system. **Fig. 9** shows the operation of RFID.

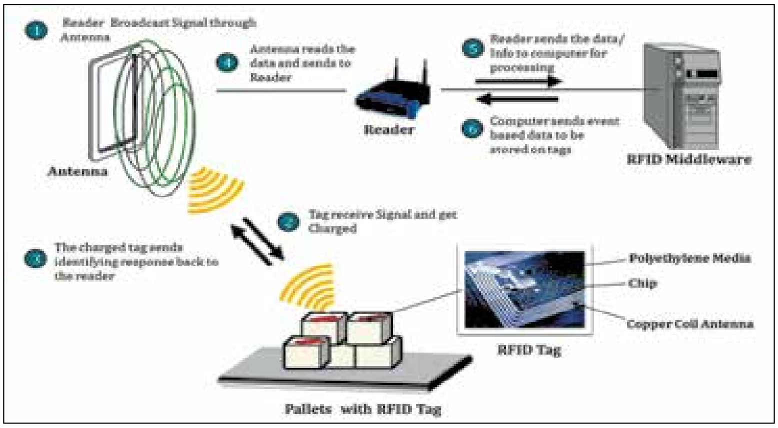

Fig. 9 Operation of RFID (RFIDHY Technology, 2016)

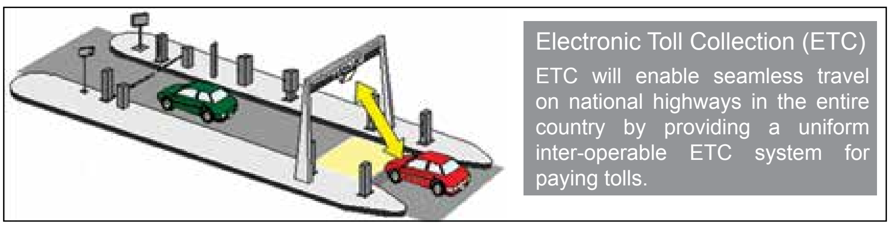

Fig. 10 RFID Based Electronic Toll Collection System (ETCS) (Bizlogics, 2016)

RFID protocol to be used for the ITS infrastructure shall conform to EPC Gen 2, ISO 18000-6C. RFID Frequency range used shall be UHF 865 MHZ to 867 MHZ* (*is the wireless license free band for RFID use in India). Typical existing product(s) for 'RFID-based-ETC' operates in the 865 MHZ – 868 MHZ bang. The used devices shall comply with the general conformance requirements of ISO 18000-6C standard and India specific requirements for WPC Type Approvals authority. Any offered device shall also support the future Gen2 V2 version with the antenna having linear polarised less than 25° Beam width having Operating Temperature between -20°C and 55°C and Storage Temperature varying between -40°C and 85°C. Critical for RFID Devices will be able to read Tag & EPC memory for at least 2 Tags per second for a moving vehicle with a speed limit of 75 Kilometers/ hour and to have a rich array of diagnostic and statistical reporting tools, user-configurable system, and a host of management features based on industry standard protocols. Air Interface with High Performance radio, a modem subsystems employing sophisticated DSP technology, an advanced singulation algorithms that optimize read rates in a wide range of end-user applications.

Infrared: It is a wireless used in wireless technology devices or systems that transfer data through infrared (IR) radiation. Infrared is electromagnetic energy at a wavelength or wavelengths somewhat longer than those of red light. The operation is more or less similar to RFID. It works with passive working mechanism with electric sensor that measures IR light radiating from all objects with temperature above absolute zero. It means that a Passive Infra Red (PIR) device does not generate or radiate any energy for detection purposes. In this case, IR light is being generated from vehicles plying on the road. It can classify vehicles, speed and density of vehicles. It is easy to install with probability of detection along with good resistance to rain, fog, dust and snow.

Microwave Sensors: It is also known as Dopplers sensors or Radar or RF that help detect walking, running, human targets etc. It produces electromagnetic wave (RF) field between transmitter and receiver that help to create an invisible volumetric detection zone, if anybody enters into that zone, change in field is recognized giving rise to sound of alarm. This sensor can also be effectively used for recording traffic data. **Fig. 11** demonstrates the concept of Infrared sensor technology.

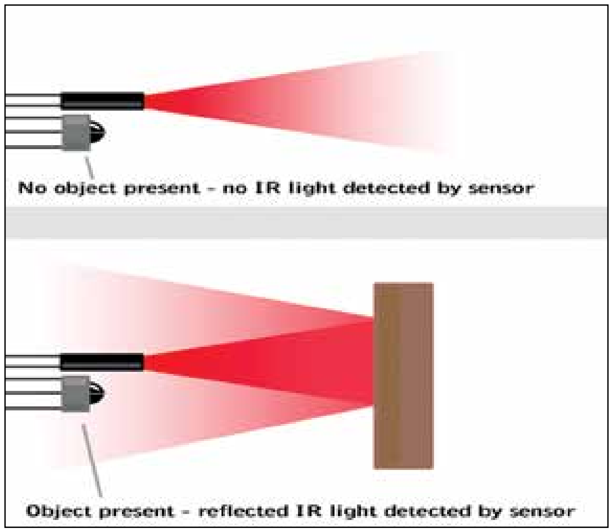

Fig. 11 : Concept of Infrared Sensor Technology (http://education.rec.ri.cmu.edu)

3.3 Route Travel Time Estimation Models

Travel time estimation models can be used in on line and offline application. Online application models are mainly focused on real-time application (Ravi Sekhar et.al 2012). Whereas offline application models are useful to the system planners and managers to estimate travel time for monitoring the performance of the road network overtime. These models are briefly discussed:

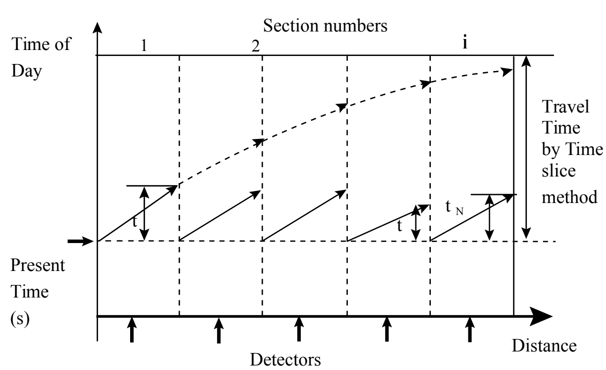

Fig. 12 Route Travel Time Estimation models (Ravi Sekhar 2008)

i) ***Instantaneous method:*** This is the simplest method of estimating the travel time of route. This method accumulates simply the section travel time for the same time period, regardless of whether vehicle traversing the freeway section will actually be in that section during the period. Mathematically, this can be explained in equation (3.1).

$$T(s) = \sum_{i=1}^{N} t_i(s) \tag{3.1}$$

Where $t_i(s)$ denotes the travel time of section "i" at present time "s".

This method generates an instantaneous travel time in which vehicle traverse the route instantaneously. In this method travel time calculations have a strong underlying assumption that the speeds will not change over time, means that travel time remain same in all the sections. This assumption may be valid in free flow conditions but as congestion starts building up, the instantaneous travel time starts lagging. The travel time estimation from these models is reliable when there is a small variation in travel time. In practical, speed will vary over the section at different time periods. Therefore these models fail to observe the dynamic behavior of traffic flow. The main advantage of these models is that they require less computational effort and can be used online to provide real time traffic information.

ii) ***Time slice method:*** Time slice method considers the variation of speed over time by constructing the vehicle trajectory. Travel Time obtained from this method is sufficiently close to the actual travel time. When a traffic condition is unstable and travel speed is varying, the travel time may be different from the instantaneous travel time, is called as the time slice method, in which the section travel times are accumulated successively with the delay of the section travel time. This is expressed mathematically in equation (3.2) and (3.3)

$$T(s) = \sum_{i=1}^{N} t_i\big(s + \tau_i(s)\big) \tag{3.2}$$

Where $t_i(s)$ denotes the travel time of section "i" to section i-1 can be written as

$$\tau_i(s) = \sum_{i=1}^{i-1} t_i\big(s + \tau_i(s)\big) \tag{3.3}$$

This model produces better results than the Instantaneous method but this method needs extensive data covering more time periods than the previous model. This method is more suitable for offline application rather than on line application.

iii) ***Linear method:*** In linear method, vehicles change their speeds gradually within the link. The speed of the vehicle at time 't' in section 'i' is not only a function of the speeds collected from upstream side and downstream detectors, as like in the preceding methods but also a function of distance of the vehicle to the end points of the section.(Lint and Vander Zijpp, 2003).

$$v(i,t) = v(i_a,t) + \frac{x(i,t) - X(i_a)}{l_i}\big[v(i_b,t) - v(i_a,t)\big] \quad (3.4) \tag{3.4}$$

Where x (i, t) is the location of the vehicle at time t in section i; $X(i_a)$is the location of the upstream detector for section i ; and $v(i_b, t)$ and $v(i_a, t)$ are the measured speeds at the extremities of the section i at time t.

4 ITS FOR TRAFFIC MANAGEMENT SYSTEM

4.1 Issues in Traffic Management System

The major issues of Traffic Management System (TMS) are optimizing capacity, minimize journey time by ensuring safety. In implementing any traffic management solution, the authorities face challenges to address concerns related to safety, efficiency and capacity. The main reasons resulting in challenges are :-

- Rapid increase in number of vehicles on the network
- Narrow roads, close intersections, encroachment on roads and haphazard on-street parking
- High density area not according to master plan
- Chronic congestion on major roads especially in the Central Business and the old city area
- Heterogeneous traffic, old (poorly maintained) vehicles
- Non-availability of proper maps and network inventory
- Non-availability of traffic data, inadequate power supply to traffic signals – manual management of traffic at corridor, area level
- Lack of coordination among related agencies
- Poor intersection geometry, roadside obstructions
- Lack of proper signage, information display system
- Lack of public awareness, driver behaviour
- Misuse (encroachment) on side roads
- Lack of facilities for pedestrian, pedestrian crossing, poor maintenance of foot over bridge, and footpaths
- Poorly designed road-side infrastructure that is unable to handle weather events such as heavy rains.
- Lack of interoperability in systems / no data standardisation for TMS.

4.2 ITS Tools for Traffic Management

It is extremely important to manage and regulate traffic safely and efficiently. Therefore, the most important part is to collect all kinds of traffic data from all sources including primary and secondary for using as real time data in order to work out an optimal solution for traffic problems. Advance Traffic Management in urban area appears to be one of the best options in this regard.

4.3 Advanced Traffic Management System

The ATMS view is a top-down management perspective that integrates technology primarily to improve the flow of vehicle and improve safety. Real-time traffic data from cameras, speed sensors, etc. traffic flows with respect to passenger and goods vehicles into a Traffic Management Centre (TMC) where it is integrated and processed (e.g. for incident detection), and may result in actions taken (e.g. traffic routing, DMS messages) with the goal of improving traffic flow.

This service deals with the issue related to road network based traffic management. Most of the time, ATMS provides most economic benefits to the traffic management of the city. It helps in optimising the use of road capacity for different modes and users. It helps in reducing travel time. The efficient use of traffic signals at intersection reduces queue length at traffic signals, while its use at area level or corridor level helps in reducing overall delays and decrease in journey time of most of the vehicles using that area or corridor. This ultimately helps in reducing vehicle operating cost as well as reducing fuel consumption and air pollution.

The ATMS also helps in managing the traffic demand on various corridors. ATMS is of great help in optimising the budget meant for providing solutions to the congested traffic. It also helps in maintaining the various transport related infrastructure for better services. **Fig. 13** shows the ATMS architecture while **Fig. 14** shows the functioning of ATMS.

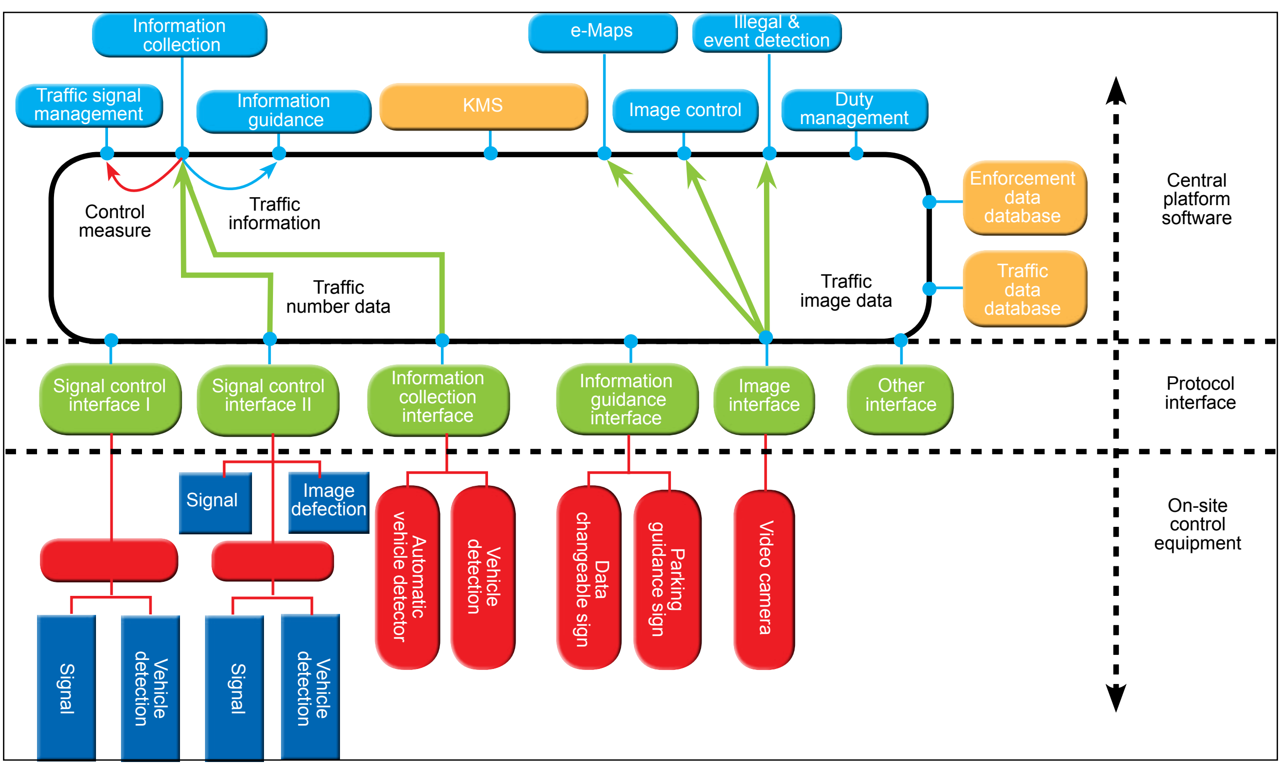

Fig. 13 ATMS Architecture

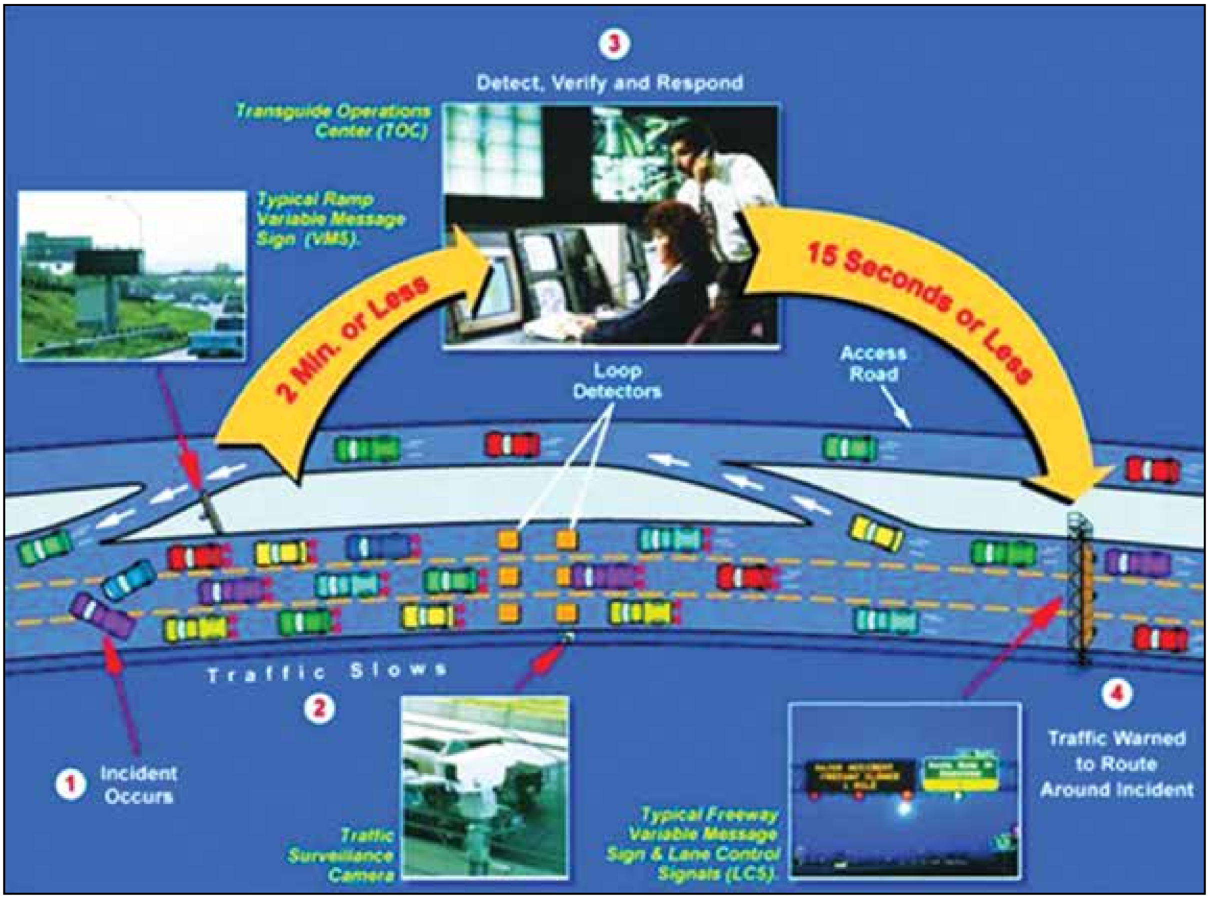

Fig. 14 ATMS Working Diagram (SWRI)

4.4 ATMS Functional Areas

- Real-time traffic monitoring
- Dynamic message sign monitoring, regulate and control traffic
- Incident monitoring
- Traffic camera monitoring and control
- Active Traffic Management (ATM)
- Chain control
- Ramp meter monitoring and control
- Arterial management
- Traffic signal monitoring and control
- Automated warning systems
- Road Weather Information System (RWIS) monitoring
- Highway advisory radio
- Urban Traffic Management and Control

The other important aspects of traffic management are that the reduction of traffic rule violations as far as possible. This system has an impact on the mobility of the road users.

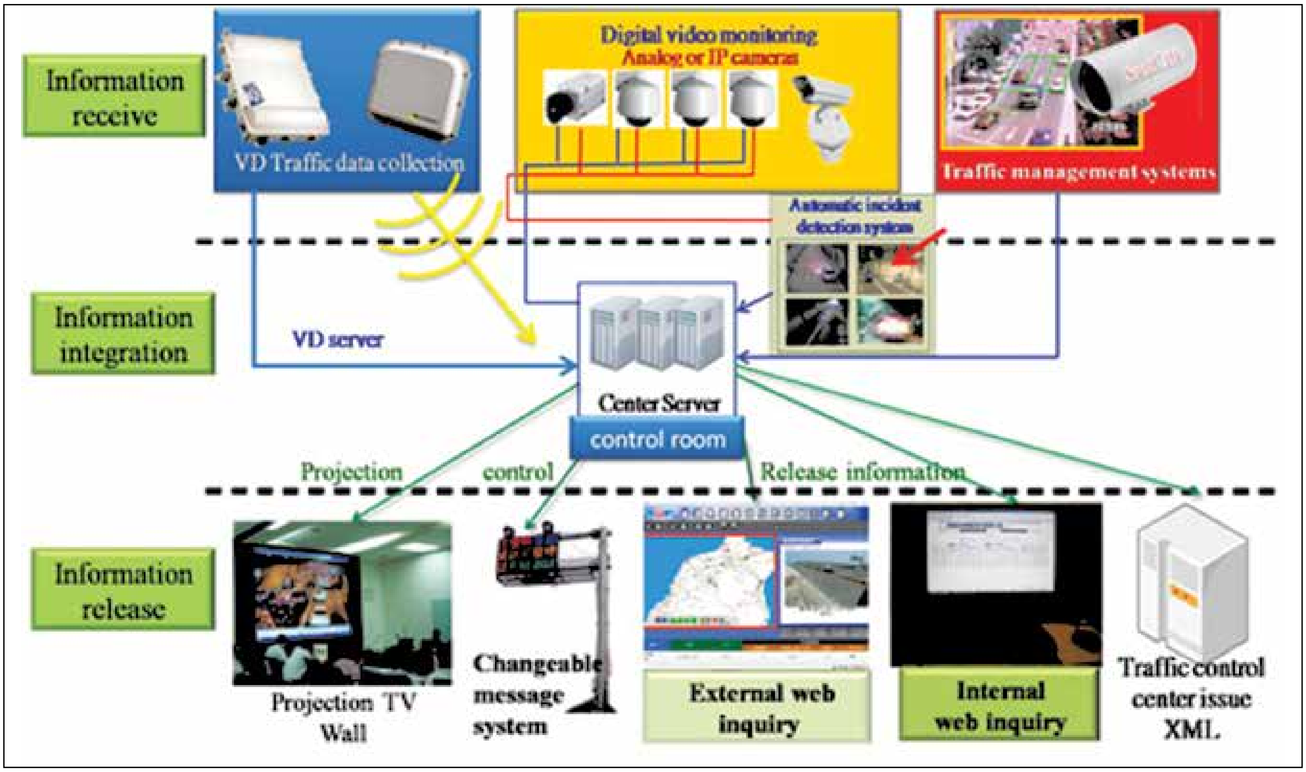

Fig. 15 ATMS Data Collection System (ITS, 2008)

In order to ensure safe and efficient advanced traffic management using various sources of data as shown in **Fig. 15,** one has to develop Traffic Management Control Centre as discussed below.

4.5 Traffic Management Centre

TMC is the hub of transport administration, where data is collected, and analyzed and combined with other operational and control concepts to manage the complex transport management network. It is the focal point for communicating transportation-related information to the media and the motoring public, a place where agencies can coordinate their responses to transportation situations and conditions. Typically, several agencies share the administration of transport infrastructure, through a network of traffic operation and management centres. There is localized distribution of data and information, communication with traffic management centre which adopts different criteria to achieve the goals of traffic management. This inter-dependent autonomy in operations and decision-making is essential because of the heterogeneity of demand and performance characteristics of interacting subsystems.

When it is not possible to develop a comprehensive Traffic Management Control Centre due to paucity of funds, traffic management measures for a single location or for a set of locations are commonly provided with ANPR, Red Light Camera, Speed/Detection/Enforcement Camera, VMS in urban areas. The following are some demonstrations as a part of ITS driven applications for Traffic Management. **Fig. 16** shows a concept of Traffic Management Control Centre.

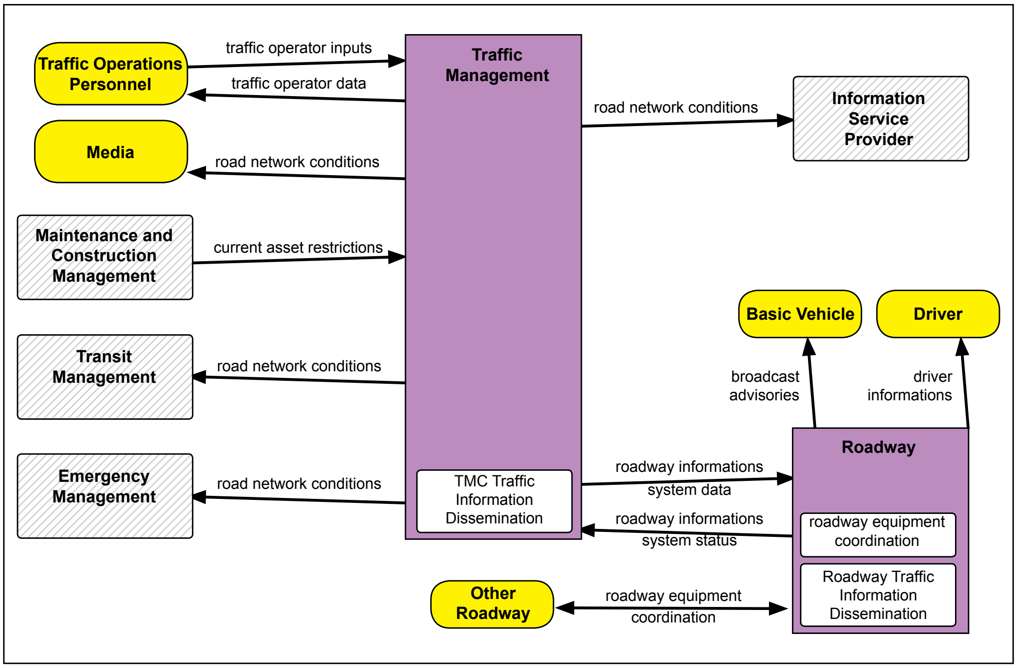

Fig. 16 A Concept of Traffic Management Control Centre (ITS, 2008)

Arterial Management: Arterial management systems manage traffic along arterial roadways, employing traffic detectors, traffic signals, and various means of communicating information to travellers. These systems make use of information collected by traffic surveillance devices to ensure smooth flow of traffic along travel corridors.

Freeway Management: Motorists are now able to receive relevant information on location specific traffic conditions in a number of ways, including dynamic message signs, highway advisory radio, in-vehicle signing, or specialized information transmitted only to a specific set of vehicles.

Transit Management: Transit ITS services include surveillance and communications, such as Automated Vehicle Location (AVL) systems, Computer-Aided Dispatch (CAD) systems, and remote vehicle and facility surveillance cameras, which enable transit agencies to improve the operational efficiency, safety, and security of the nation's public transportation systems.

Traffic Incident Management: These systems can reduce the effects of incident-related congestion by decreasing the time to detect incidents, the time for responding vehicles to arrive, and the time required for traffic to return to normal conditions.

Emergency Management: ITS applications in emergency management include hazardous materials management, the deployment of emergency medical services, and large and small-scale emergency response and evacuation operations.

Electronic Payment for Congestion and Road Pricing: These systems employ various communication and electronic technologies to facilitate monetory transaction between travellers and transportation agencies, typically for the purpose of paying tolls and transit fares. Pricing refers to charging motorists a fee or toll that varies with the level of demand or with the time of day.

Traveller Information: Traveller information derived from real life data transmission from the traffic management centre to help road users to take appropriate travel decision, use a variety of technologies, including Internet websites, telephone hotlines, as well as television and radio, to enable users to make more informed decisions regarding trip departures, routes, and mode of travel.

Information Management: ITS information management supports the archiving system and retrieval of data generated by other ITS applications and enables ITS applications that use archived information. Decision support systems, predictive information, and performance monitoring are some ITS applications enabled by ITS information management. In addition, ITS information management systems can assist in transportation planning, research, and safety management activities.

4.6 Crash Prevention and Safety and Efficiency of Commercial Operations

4.6.1 Crash prevention and safety systems detect unsafe conditions and provide warnings to travellers to take action to avoid crashes. These systems provide alerts for traffic approaching at dangerous curves, off ramps, restricted overpasses, highway-rail crossings, high-volume intersections, and also provide warnings about the presence of pedestrians, and bicyclists, and even animals on the roadway.

Roadway Operations and Maintenance: ITS applications in operations and maintenance focus on integrated management of maintenance fleets, specialized service vehicles, hazardous road conditions remediation, and work zone mobility and safety. These applications monitor, analyze, and disseminate roadway and infrastructure data for operational, maintenance, and managerial uses. ITS can help secure the safety of workers and travellers in a work zone while facilitating traffic flow through and around the construction area.

Road Weather Management: Road weather management activities include Road Weather Information Systems (RWIS), winter maintenance technologies. ITS applications assist in monitoring and forecasting of roadway and atmospheric conditions, dissemination of weather-related information to travellers, weather-related traffic control measures such as variable speed limits, and both fixed and mobile winter maintenance activities, in high attitude areas.

Collision Avoidance Systems: To improve the ability of drivers to avoid accidents, vehicle-mounted Collision Warning Systems (CWS) continue to be tested and deployed. These applications use a variety of sensors to monitor the vehicle's surroundings and alert the driver of conditions that could lead to a collision. Examples include forward collision warning, obstacle detection systems, and road departure warning systems.

Driver Assistance Systems: Numerous intelligent vehicle technologies exist to assist the driver in operating the vehicle safely. Systems are available to aid with navigation, while others, such as vision enhancement and speed control systems, are intended to facilitate safe driving during adverse conditions. Other systems assist with difficult driving tasks such as transit and commercial vehicle docking.

Collision Notification Systems: Collision notification systems have been designed to detect and report the location and severity of incidents to agencies and services responsible for coordinating appropriate emergency response actions. These systems can be activated manually (May day), or automatically with Automatic Collision Notification (ACN), and advanced systems may transmit information on the type of crash, number of passengers, and the likelihood of injuries.

4.6.2 The ITS also helps in improving efficiency of commercial vehicle operation and freight movement:

Commercial Vehicle Operations: ITS applications for commercial vehicle operations are designed to enhance communication between motor carriers and regulatory agencies. They include electronic registration and permitting programs, electronic exchange of inspection data between regulating agencies for better inspection targeting, electronic screening systems, and several applications to assist operators with fleet operations and security.

Intermodal Freight: Intermodal Freight ITS can facilitate the safe, efficient, secure, and seamless movement of freight. Applications being deployed provide for tracking of freight and carrier assets such as containers and chassis, and improve the efficiency of freight terminal processes, drayage operations, and international border crossings.

4.7 ITS Tools for Safety

The objective of the transportation system is to improve seamless travel with safety of travel. Crashes and fatalities are undesirable occurrence of the transportation system. Intelligent Transportation System helps to minimize the risk of occurrences of accident.

Advanced Vehicle Control & Safety Systems: The aim of the user service is to improve the safety of transportation system by improving the drivers' abilities with respect to maintaining vigilance and control of the vehicle through enhancing the accident avoidance capabilities of vehicles. Following user services are included in this group.

Longitudinal Collision Avoidance: The user service can provide assistance to vehicle operators in avoiding collisions to the front and/or rear of the vehicle longitudinally. This is achieved by implementing rear-end collision control and warning, Adaptive Cruise Control (ACC), head-on collision control and warning, and backing collision warning to the drivers.

Lateral Collision Avoidance: This helps drivers in avoiding accidents that result when a vehicle goes out of lane of travel, by warning drivers and by assuming some control of the vehicle. This service assists the drivers through the blind spot situation display/lane change, lane departure warning and control, and collision warning control.

Intersection Collision Avoidance: The aim is to provide assistance to the vehicle operators in avoiding collisions at intersections. With this system, the position of vehicles within the intersection area through the use of vehicle-to-vehicle communications or vehicle to infrastructure communications can be tracked.

Vision Enhancement for Crash Avoidance: This service helps in reducing the number of vehicle accident that occur during periods of poor visibility. Vehicle sensors capable of capturing an image of driving environment and providing a graphical display of the image help the drivers to enhance the road safety.

Safety Readiness: With the help of this, warnings regarding their own driving performance, the condition of the vehicle, and the condition of the roadway as sensed from the vehicle can be provided to drivers.

Pre-Crash Restraint Deployment: This service helps in reducing the number and severity of injuries caused by vehicle collisions by anticipating an imminent collision and by activating passenger safety systems prior to the actual impact.

Automated Vehicle Operations (AVO): This service provides a fully automated vehicle-highway system in which instrumented vehicles operate on instrumented roadways without operator intervention.

4.8 Emergency Notification and Personal Security

This user service consists of two sub parts i.e., (i) driver and personal security (user-initiated distress signals), and (ii) automated collision notification (automated notification of emergency personnel of the location, nature, and severity of the serious crashes). For personnel security subservice, GPS is used to transmit the location for help and provides assistance to the emergency personnel, repair service or the vehicle towing centre. Now vehicles which are pre-fitted with the GPS trackers and sensors and connected to cloud data are easily being operated on this system.

Private vehicles are normally not connected/not installed with GPS. However, the RFID Tags pre-installed in vehicles and the advent of e-tolling ensuring existing vehicles to get tagged; it shall be easier to track and find vehicles through a network of RFID Readers across the city for surveillance using the unique and pre-programmed yet open to all TID field in the tags.

For the Automated Collision Notification subservice, this is automatically used by the installed sensors in the vehicle to the emergency helpline about the location of the vehicle where it meets with accident. Additional information about the condition and severity of the accident also get transmitted based on the technology. This emergency notification requires crash-sensing and GPS technology.

Performance requirements for Emergency Notification and Personal Security include continuous real-time communications from appropriately equipped vehicles to at least one response unit from any location nationwide, there should be minimum time taken for transmission and GPS tracker. This system should be both manual and automatic depending upon the severity of the crash or the requirement of the user. The system should monitor vehicle component conditions from inside the vehicle every few seconds and, for critical emergency condition cases, this automatically sends the appropriate distress signal.

To have this system in use, the main elements of the operation are in-vehicle GPS device for vehicle position/location, a two way communications link between the vehicle and the control centre using commercially available smart phone service, and control centre equipment for processing vehicle location, type of assistance required, and routing of the request to the appropriate response agency. The motorist will be notified of the action taken and the anticipated response time.

Private aggregators also have launched disaster reporting apps which can be connected to central systems. User shall be able to also see in real time, the action taken and the time / route taken by the first responders on his registering the issues.

4.9 Emergency Vehicle Management

The EVM service will provide for more efficient management and assignment of emergency response vehicles. Its intent is to reduce the amount of time between a public safety operator's notification of an incident and the arrival of emergency personnel on the accident location. This service will provide public safety agencies with fleet-management capabilities, route guidance, and signal priority and pre-arrangement for emergency vehicles.

This service consists of three sub divisions

- Emergency vehicle fleet management
- Route guidance
- Signal priority

The primary users of all these services are police, fire, and hospitals. Real time reliable transportation and traffic information is required by this service in order to provide travel alternatives for the arrival of the emergency vehicle at the emergency site; location of the incident and of emergency vehicles in the fleet is essential at the dispatch centre. Emergency Vehicle Management will identify the closest and most appropriate response vehicle, and transfer complete, accurate information on the nature and location of the incident to it.

Performance requirements developed to date indicate that EVM should provide real-time emergency vehicle fleet management, offer vehicle identification with 99.9% accuracy within one minute of initiation, and vehicle location with position accuracy within the range of 6-15 m. The system should also provide real-time traffic signal prioritization by maintaining current information on signal timing, vehicle's location which is in emergency, and its routing.

5 ITS FOR PUBLIC TRANSPORT SYSTEM

5.1 Introduction

The public transport modes include buses, trains, rapid transit (metro/subways/undergrounds) etc. The public transport between cities is mostly dominated by intercity rails, airplanes and coaches. Few examples, transport management systems include GPS based operation of public transport, computerized traffic signalling, information systems such as e-ticketing, e-information etc. Such systems increase the efficiency, safety, reliability and quality of transport systems. An increase in the efficiency of the transport system also leads to reduction in the GHG emissions. It includes using the real-time information of public transport for passengers such as real time passenger information systems, prioritization of public transport, estimation of arrival time of bus at stops, transit priority of public transport etc. When ITS is used for operation of Bus Rapid Transit System (BRTS) , it has to develop the mechanism for integrations with various components of the system as shown in flowchart as shown **Fig 17**. It illustrates how the various ITS elements can work together in a BRTS context and groups the elements into those for the customer, operator and vehicle. The three major implication of ITS in integration with public transport are fleet Operation and Management, Fare Collection and Customer Information (**Fig. 18**)

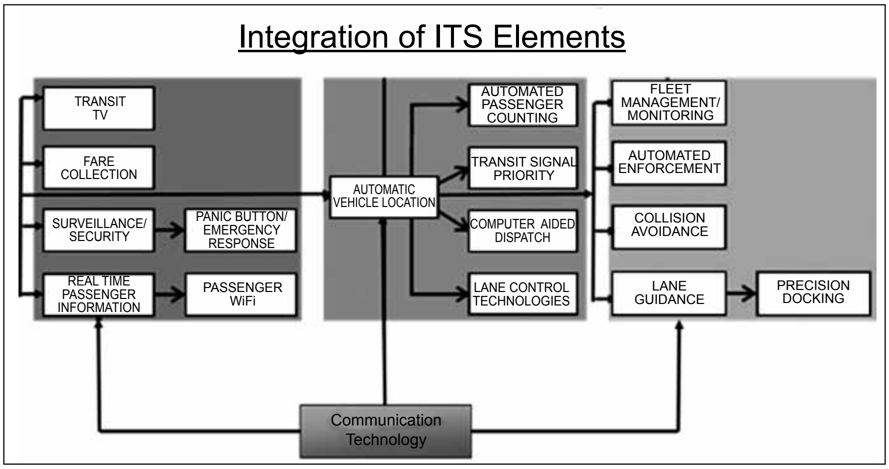

Fig. 17 Integration of ITS Elements in Public Transport System

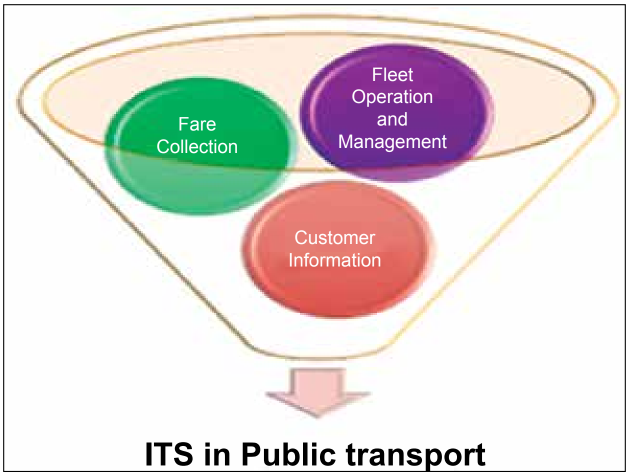

Fig. 18 ITS in Public Transport

5.2 Fleet Management and Operations

Fleet Management and Operation includes five different technologies, as follows: Automatic Passenger Counters (APC), Automatic Vehicle Location (AVL), Scheduling and Dispatching (S&D), Geographic Information Systems (GIS), and Signal Priority (SP). These technologies are often combined in various software packages, which allow for the integration of many different transit functions. The computer applications allow better resource utilization so as to meet service demands, which help make public transportation more appealing to the people.

5.2.1 *Automatic Passenger Counter*

The APC automatically records the number of passengers, time and location of each stop as passenger board and alight the bus. The APC can collect data which is collected manually or with a hand-held device or electromagnetic spectrum (infrared beam). With the help of infrared beams at the doors or pressure sensitive mats on the steps, the APC accurately records the time, location, and the number of passengers as they enter or exit the bus as shown in **Fig. 19**. With the information provided by the APCs, transit planners can make changes to routes and schedules that better serve the transportation needs of their community.

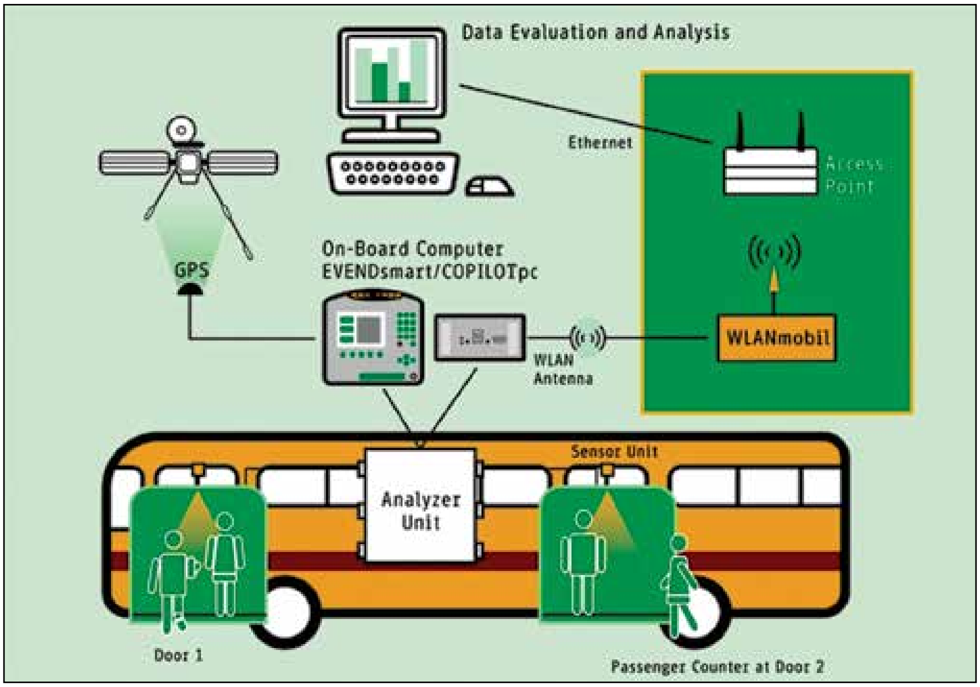

Fig. 19 Working of Automatic Passenger Counter (Innovation in Traffic Systems)

5.2.2 *Automatic Vehicle Location*

Satellite geo-positioning technology tracking vehicles is one of the most common AVL systems, which is another ITS technology that involves daily operations and management. The location of buses can be determined at any given time with AVL of the vehicles that are equipped with the technology. Access to this type of information, is especially significant in an emergency situation, when either passenger or driver safety may be threatened. Moreover, the bus location information can be given to customers to assist them in planning an itinerary based on the most up-to-the minute information. Finally, this information can be used to determine whether buses are running on their schedule and, if necessary, to reroute buses around problem areas. Many transit agencies have found that automatic vehicle location has been increasing their on time performance while at the same time it has been decreasing the number of buses necessary for a route. **Fig. 20** shows the Bus Management Architecture.

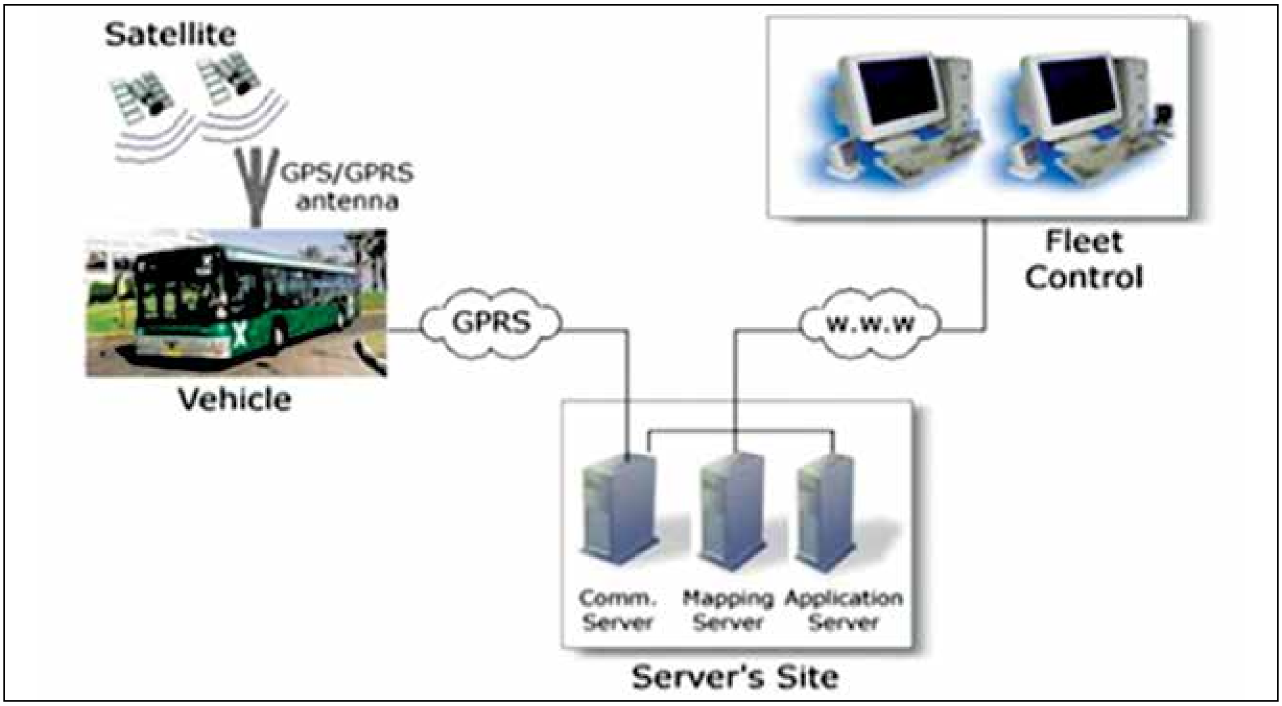

Fig. 20 Bus Management Architecture

5.2.3 *Geographic Information Systems*

A Geographic Information System (GIS) enables a transport agency in collection, storage, and analysis and displays the data by location. GIS can deliver transportation agencies with detailed information regarding mobility issues. With the help of GIS software, a spatial analysis can be used to determine about job opportunities, day-care centres, and public transportation, etc. Transit planners also can use the information provided by GIS to revise, improve, or add new services.

5.2.4 *Scheduling and Dispatch*

The scheduling/dispatch software helps in aiding the design and modifying the transit routes. It can also be used to route, schedule, and dispatch vehicles in demand response operations, when it is combined with GIS and AVL in order to coordinate different transit operations as shown in the **Fig. 21**. Combined technologies like, computer-aided dispatching and AVL helps in increasing the efficiency of transit operations, improve service, enhance safety and cut costs. For example, systems integrated with automated scheduling and dispatching and AVL allow a dispatcher to know the exact location and status of each bus under control. This real-time information allows the dispatcher to address any problems with service or to respond to any emergency. In addition, automated dispatching software and AVL allow the coordination of services among many separate transportation agencies to meet the employment transportation gaps.

Fig. 21 Comprehensive Scheduling & Dispatch Centre

5.2.5 *Traffic Signal Priority*

Traffic Signal Priority is a technology that aims to ensure a continuous traffic light green wave or turns it green earlier than it would do without priority as shown in the **Fig. 22.** Signal Priority is implemented primarily by emergency vehicles, but now can be used by buses and streetcars. A signal priority system is combined with AVL technology, which allows the system to provide priority only when needed (i.e., when a bus is running behind schedule). The benefits of a signal priority system are that these keep transit vehicles on schedule and improves on-time performance. As a result, fewer vehicles are necessary for serving a route. This can mean good savings for a transit agency.

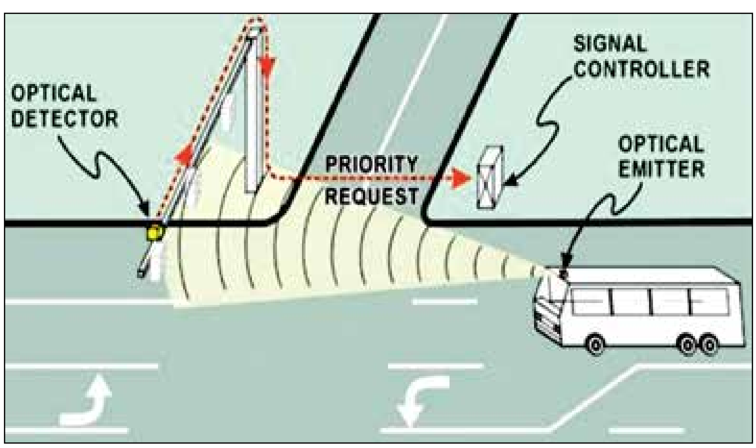

Fig. 22 Transit Signal Priority using Optical Detection System (Transit Signal Priority)

5.3 Traveler Information Systems

Traveller information systems provide road users with information for planning their trips as well as while they are travelling. Transit information may be static, like route maps, or dynamic information such as route delays and any other real-time information. Travellers are able to access information from different locations such as home, work, wayside areas, transportation terminals and on-board vehicles. Information can be accessed through various means, such as automated trip itineraries, in-vehicle announcers; variable message signs, monitors, and interactive kiosks. These technologies also help individuals better plan their trips and help decrease hindrances by providing required information.

5.4 Automated Trip Itineraries

Automated trip itineraries help in assistance to the customers with the information necessary to plan a trip from its point of origin to its final destination. Automated trip itineraries include a broad range of data, like modes of travel, travel time, fares, tourist information, transfers, schedules and weather. When these are combined with AVL technology, real-time information regarding traffic congestion, possible delays can be reported. Since automated trip itineraries are electronic, they can be accessed by various means, such as touch-tone telephones, kiosks, and Internet, fax machines, personal computers, pagers, hand-held devices, cable and interactive television. The benefits of automated trip itineraries are that they provide accurate and timely information for customers through a variety of means.

5.5 In-Vehicle Announcers

In-vehicle announcers usually are audio and visual systems, used en-route, to provide passengers with next stop information. A sign placed in the front, and sometimes in the middle of each vehicle, displays next stop information and a pre-recorded message simultaneously announces the same information as shown in **Fig. 23**. The working system of vehicle announcer is also shown in **Fig. 24**. In-vehicle announcers help the passengers to either visualize or hear the information which helps to recognize their stop. Moreover, they help new customers, unfamiliar with a route, as well as existing customers who may be , inattentive to their surroundings, to find their stop.

Fig. 23 In-Vehicle Announcers System
(Scheidt & Bachmann System Technic)

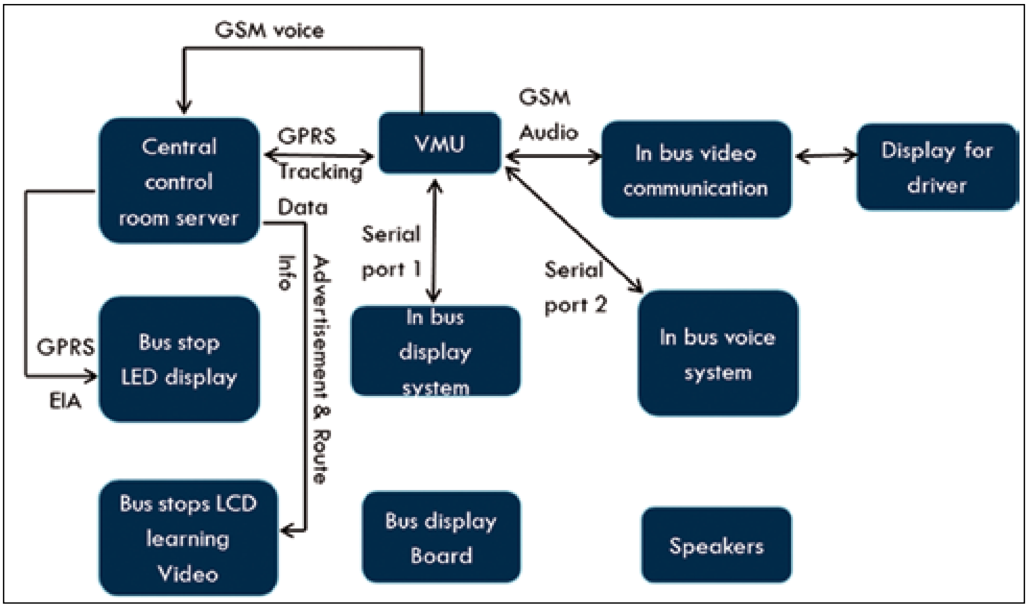

Fig. 24 Working of In-Vehicle Announcers

5.6 Interactive Kiosks

Interactive Kiosks are computer-like terminals or larger machines that display the travel information as shown in **Fig. 25.** These are generally found in malls, businesses, hotels, airports and transit centres. Interactive kiosks are accessed easily by means of a computer-mouse, touch screen, or keyboard. Kiosks can also deliver a wide range of travel information, like routes and schedules, traffic congestion, and weather, etc. When combined with automatic vehicle location information, kiosks provide the customers with real-time information, like on time status of their transit vehicle.

Fig. 25 Kiosks (Urban Transport)

Interactive kiosks promote transit services by providing easily accessible information about various services for both new and existing customers. This contributes to greater customer convenience, satisfaction, and for the transit agency which are, potential for increased revenues.

5.7 Electronic Fare Collection

An electronic fare collection is a system in which cards are used in place of coins or tokens, to pay for transit rides as shown in **Fig. 26.** The purpose of an electronic fare collection system is to reduce the cost of handling and protecting transit revenues and to provide customer convenience. RFID based windshield tags issued by certified banks too could be used for the payments extending further applications other than only tolling alone; same could be used for parking as well as Fuel/Gas stations payments especially for commercial operators. Automated Congestion pricing implementation too can utilise the same pre-existing RFID Windshield tags.

Fig. 26 Electronic Fare Collection System

In an automated fare system different types of media devices can be used in a variety of ways which include magnetic stripe cards, credit cards, or smart cards that can be contact or contactless as shown in **Fig. 27.** For example, some systems may use these media for transit, retail purchases, and banking, while other systems may use them for transit only. One of the benefits of an electronic fare system is a reduction in the cost of handling and fare processing.

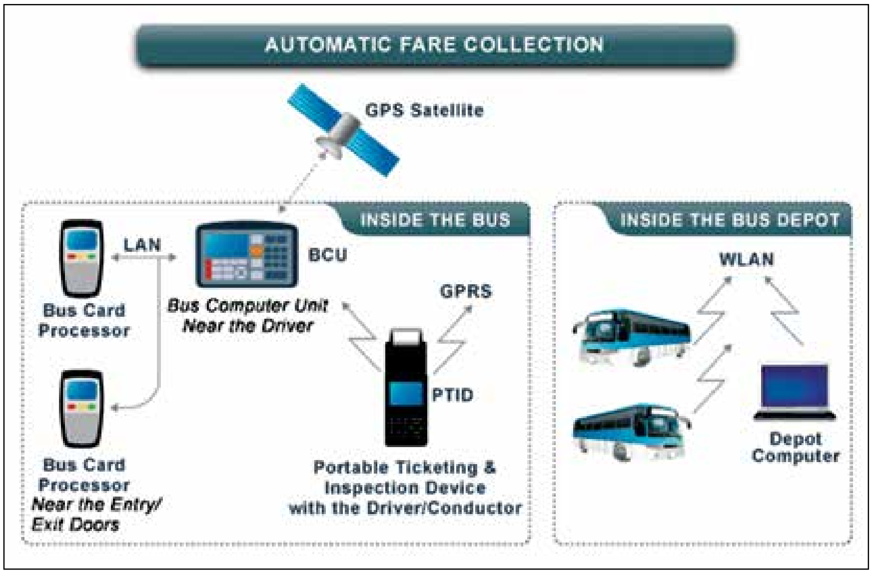

Fig. 27 Automatic Fare Collection (Prodigy Electronics, 2001)

6 APPLICATIONS OF ITS

6.1 General

ITS improves transportation safety and mobility and enhances global connectivity by means of productivity improvements achieved through the integration of advanced communications technologies into the transportation infrastructure and in vehicles. The major applications of ITS in road sector are discussed in this section. Given the wide range of intelligent transportation systems, it is useful to deliberate ITS applications through a taxonomy that arranges them by their primary functional intent. The major ITS application areas can be classified into the following functional groups:

- Advanced Traveller Information System (ATIS)
- Advanced Traffic Management Systems (ATMS)
- ITS Enabled Pricing Systems
- Advanced Public Transportation Systems (APTS)
- Advanced Vehicle Control Systems (AVCS)
- Traffic Control & Management
- Law Enforcement

6.2 Advanced Traveller Information System

Advanced travellers information systems (ATIS), a part of new technology applications in transportation, provide accurate and timely information that help travellers to select routes, times of travel and travel modes. They work even better with inclusion of geographic tourist guides and yellow pages that enable travellers to select destinations based on proximity to other places.

Fig. 28 GPS based Navigation System

Delivering data directly to travellers empower them to make better choices about alternate routes or modes of transportation. When archived, this historical data provides transportation planners with accurate travel pattern information, optimizing the transportation planning process. The following ITS applications are part of ATIS:

Real Time Traffic Information (RTTI) Provisions: The Real-time Traffic Information System is a technology for providing dynamic traffic information on real time basis to the users. The RTTI prototype uses advanced technologies (GPS, video cameras, wireless communication, traffic models and algorithms) to provide traffic information that is updated every minute. The following information is usually provided through RTTI system:

Information is provided on:

- Alternate Routes and Travel Times: Alternate routes and estimated travel times for user selected with respect to origins and destinations and modes.
- Congestion and speed maps: Speed and congestion levels on various roads.
- Maps for Delay of Vehicular Traffic: Traffic delays (in minutes) at various junctions and roads.
- Variable Message Signs (VMS): Snapshot images of information to be displayed on electronic sign boards about current traffic conditions, at key locations.
- Live Traffic Camera: Live traffic images from video cameras on the ITS platform.

Users can access this information from anywhere at any time via the web. Such information can help travellers in selecting better routes and departure times, which can lead to saving in travel time, reduction of travel cost, and avoidance of traffic congestion.

Route Guidance/Navigation System: A route-guidance system uses maps, arrows, and/or a voice interface to provide drivers turn-by-turn guidance to a destination. First-generation navigation systems primarily select routes on the basis of the shortest distance between a source and a destination. Recently, new advanced systems are capable of incorporating real-time congestion delays which allow the users to find the shortest travel time route instead of the standard shortest distance route, and enabling users to adapt to dynamic traffic conditions.

Parking Information and Management: It provides information about the current parking situation to the end-user via mobile application and navigate the end user to the vacant parking lot. The usage of the current Indian NETC Flagship RFID based FASTAG can be used for payment processing in the parking.

Road Side Weather Information: Road Weather Information Systems (RWIS) provide detailed roadside weather conditions and road surface temperature data. A complete RWIS combines the road side readings with standard meteorological data to provide precision road weather forecasts and pavement condition predictions.

6.3 Advanced Traffic Management System

ATMS are a fundamental part of intelligent transportation systems that has been used to improve the quality of traffic service and to reduce traffic delays as well. ATMS operates with a series of video and roadway loop detectors, variable message signs, network signal and ramp meter timing schedules, including roadway incident control strategies from one central location to respond to traffic conditions in real time.

The main ATMS elements are -

- Support systems - cameras, sensors, traffic light/ semaphore and electronic displays help system operators to manage and control real time traffic
- Real time traffic control systems - These systems use the information provided by the two previous elements, they can change semaphores/ traffic light, send messages to electronic displays and control highway access.

The following ITS applications are part of ATMS:

Traffic Operations Centres (TOC): TOCs serve as the control centre for city's major street and highway network. TOC monitors traffic signals, intersections, and roads and proactively deploys traffic management strategies to reduce congestion and coordinate state and local authorities during special events, emergencies, or daily stop-and-go traffic. Operators in TOC monitor a closed circuit television (CCTV) system and alert the proper authorities and approaching drivers (via dynamic message signs [DMS] or a website about problem areas, reducing crashes and saving in travel time to drivers, money, and fuel. Representatives of law enforcement, fire and emergency management services (EMS), and local transit agencies are often co-located at TOCs to improve multi agency response. Using a complete network picture, TOCs can proactively identify weak areas, suggest solutions to state or local agencies, and communicate solutions or information to drivers and transit riders in real time.

Adaptive Traffic Signal Control (ATSC): The conventional signal systems use pre–programmed, daily signal timing schedules. The Adaptive Traffic Signal Control technology adjusts the timing of red, yellow and green lights to accommodate changing traffic patterns and ease traffic congestion. The process is simple. The traffic sensors collect data, traffic data is evaluated and signal timing improvements are developed. ATSC implements signal timing updates. The process is repeated every few minutes to keep traffic flowing smoothly. On average ATSC improves travel time by more than 10 percent. In areas with particularly outdated signal timing, improvements can go up to 50 percent or more.

Variable Message Signs: VMSs are electronic traffic signs often used on roadways to give travellers information about special events. Such signs warn the road users of traffic congestion, accidents, incidents, roadwork zones, or speed limits on a specific highway segment. VMSs as shown in **Fig. 29** may suggest the road users to take alternative routes, limit travel speed, warn of location of the incidents or just inform of the traffic conditions. A common technology used in new installations for variable message signs are LED displays. In recent years, some newer LED variable message signs have the ability to display coloured text and graphics. They are commonly installed on an overhead gantry structure or a cantilever structure. It is fully-programmable, customizable solution specific to the location for the benefit of users.

The information displayed is real-time dynamic information as well as static information controlled automatically via a central server. It is designed to affect motorist's behaviour to improve traffic flow and enhance the driving experience of motorists on roads.

The information displayed include:

- Live travel time between destinations
- Live traffic congestion
- Weather Updates
- Alternate routes
- Pollution data
- Variable Speed limits
- Event notice and motorist instructions
- Accident updates
- Incident management via Emergency messages
- Directional signs
- Traffic Do's and Don'ts
- Warning / Public messages etc.

Smart Variable Message signs should be able to draw information from cloud based services as well as able to integrate with local road/ground based sensors to provide useful information to the motorists. The variable message signs should be able to work on a standalone basis and show real time information even in the event of a failure at the central server / during emergency situations.

Unlike the late 1990s when the most common technology used in new installations for variable message signs are LED display which are mostly single coloured displays showing static messages, today the technology has advanced and now these displays are fill coloured with better resolution, capable of displaying text and graphics both. A full-colour 10 mm pitch LED display having a brightness of 7500-8000 cd/m^2 is required for better visibility and readability.

Apart from Traffic Management system, Variable Message Signs can be used at bus stops to display the live journey time of buses, can be integrated with other ITS solutions to give driver feedback, ensure driver safety and enforce traffic rules.

VMS as shown in **Fig. 29** may suggest the road users to take alternative routes, limit travel speed, warn of duration and location of the incidents or just inform of the traffic conditions.

Fig. 29 VMS in working
(Smart Electronic Display Solutions)

Ramp Metering: Ramp metering can be defined as a method by which traffic seeking to gain access to a busy highway is controlled at the access point via traffic signals. This control prevents traffic flow breakdown and the onset of congestion. Ramp metering is the use of traffic signals to control the flow of traffic entering an expressway facility as shown in **Fig. 30**. Ramp metering, when properly applied, is a valuable tool for efficient traffic management on expressway

The objectives of ramp metering include:

a. Controlling the number of vehicles that are allowed to enter the expressway.
b. Reducing expressway demand.
c. Breaking up of the platoon of vehicles released from an upstream traffic signal.

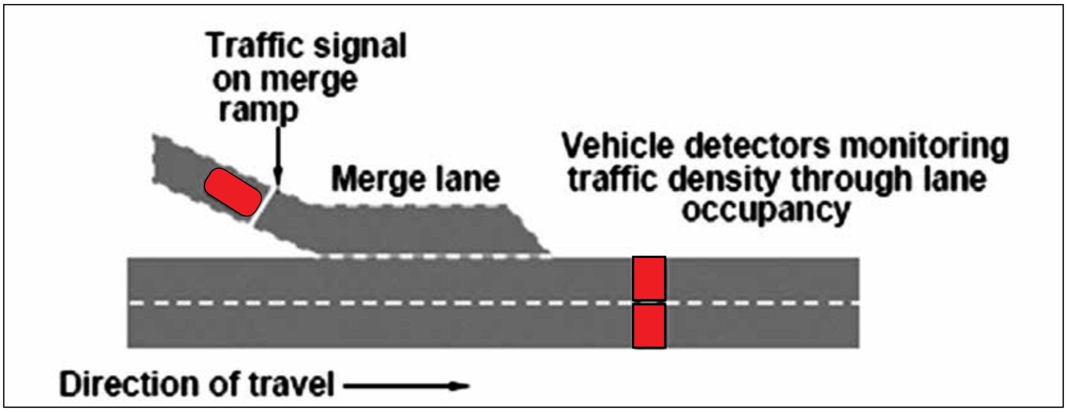

Fig. 30 Ramp Metering

Driver Feedback System

Over speeding is one of the major reasons for road accidents and fatalities. Authorities all over the world struggle with enforcement of speed limit with highways and city roads.

Enforcement of speed limits is conventionally imposed using speed radar guns coupled with cameras pointed at vehicles to measure the spot speed of vehicles and issue a challan in the event of over speeding. This method is largely dependent on availability of police patrol vans, manpower and specialized radar equipment. The Driver Feedback System aims to overcome these requirements by providing feedback to drivers on their speed relative to the speed limit on the lane. This has proved world over to be an effective mechanism to control speeds of lanes. As the driver slows down, vehicles behind him tend to slow down within the speed limit and this creates a snowball effect to slow down the entire lane.

A typical Driver Feedback system has a digital LED display showing the speed of the approaching vehicle on the lane along with an indication to the driver whether he is above or below the limit. Warnings are flashed if the driver is over speeding. A Doppler radar is mounted facing the lane to capture speed of the vehicle and relay the same to the processor which in turn feeds the display.

This system can be further enhanced to impose enforcement by coupling with ANPR cameras which can identify the number plate of the vehicle which is over speeding and relay the same to the authorities for appropriate fines / actions.

6.4 ITS Enabled Pricing Systems

With the advent of RFID based contact less smart card technology, there has been revolutionary changes in the transportation pricing (fares, tolls etc) system. The money can be automatically deducted from the smart card at collection centres without any manual transaction as toll, congestion prices, fares, parking fee etc.

The following ITS applications are a part of Transportation Pricing Systems:

Electronic Toll Collection: ITS have a central role to play in electronic toll collection (ETC), also commonly known internationally as "road user charging," through which drivers can pay tolls automatically via a DSRC-enabled on-board device or tag placed on the windshield (such as E-Z Pass in the United States). The most sophisticated countries, including Australia and Japan, have implemented a single national ETC standard as shown in **Figs. 31** and **32**, obviating the need to carry multiple toll collection tags on cross-country trips because of lack of interoperability of various highway operators' ETC systems.

Radio Frequency Identification is the usage of electromagnetic fields wirelessly to transfer and receive data from the tags mounted on the object being tracked and identified using the RFID transceiver. RFID tag and trans receiver are the heart of the system with RFID tag storing the information electronically. ETC (Electronic Toll Collection) using RFID tag consists of Electronic chip and antenna which are embedded together. RFID tags could be divided mainly into two classes, passive or active by design. Passive tags are powered by the reader emitted power. Active tags have small battery which helps them in emitting its ID signal periodically. RFID reader is a combination of transmitter and receiver. It emits signals continuously.

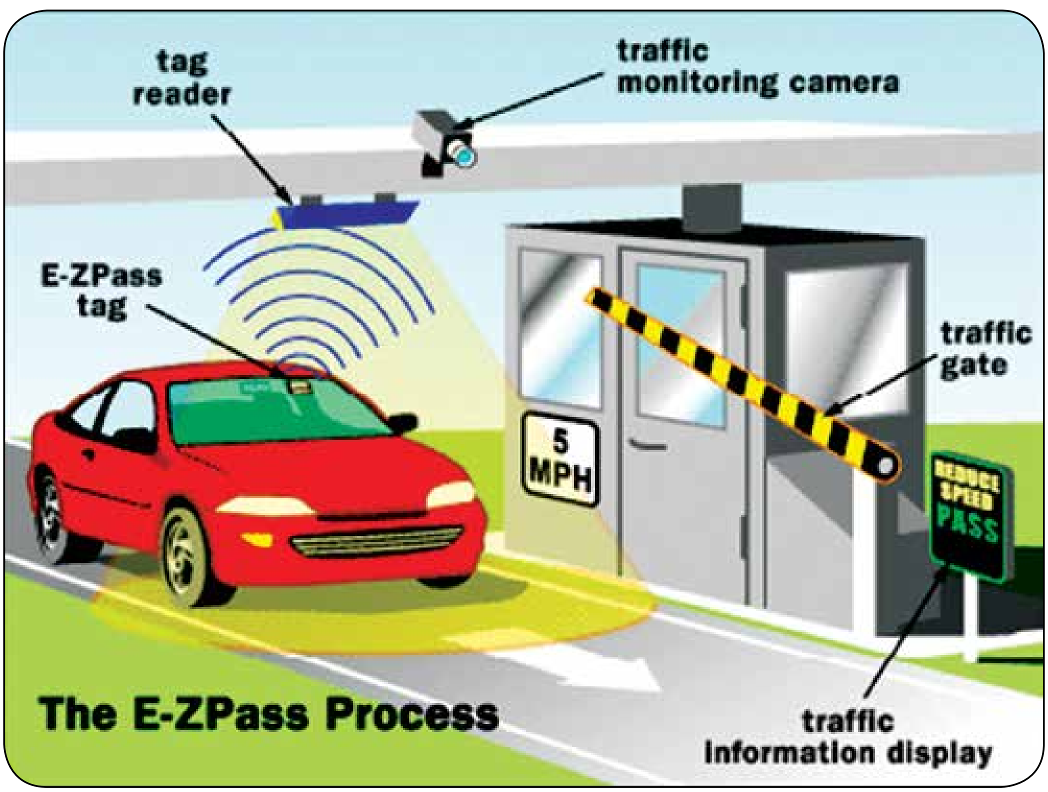

Fig. 31 Electronic Toll Collection via E-Z Pass (E-Z Pass)

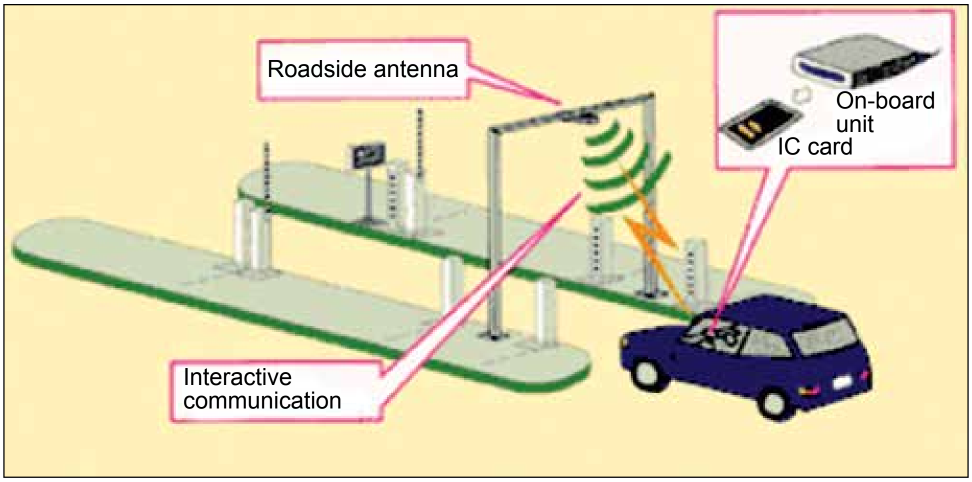

Fig. 32 Conceptual Image of ETC (ITS, 2012)

As per the Government of India mandate, UHF RFID readers need to be installed at lanes to process the vehicle coming with tags automatically at individual lanes. Readers and tags are tuned to 865-868 MHz frequency which is UHF frequency band used in India as per the Government regulations. The tags are mapped with the individual vehicles with number of trips or money which could be deducted per trip when the vehicle passed the toll plaza. RFID readers could be mounted at the height of 5-6 meters at middle of the lane or mounted on the island of individual lanes. RFID reader reads the EPC and User data memory bank of the RFID tag to successfully validate the transaction.

As per the Government mandate, individual lanes at the plaza need to have individual readers and antenna combination. Overall plaza requires multiple readers (As many as number of lanes) and antennas. These readers working together produce very high RF radiations which at times can reflect and refract in the plaza causing undesirable results i.e. tag not getting scanned, tag reading from other lanes etc. Considering these constraints, plaza needs a stable technology which can mitigate these issues and perform optimally to get desired results. Following points shall be kept in mind:

- **Antenna –** Antenna should be selected based on the beam width of radiation it emits.

  Antenna could be broadly classified under two categories:
- **Linear Antennas –** Linear Antennas has lower beam width compared to circular antennas. This helps in defining shorter, thinner read zones subsequently helps in enhanced accuracy levels and less cross-talks between adjacent lanes compared to circular antennas.
- **Circular Antennas –** Circular Antenna has wider beam width. It covers wider area read zone but tends to penetrate into unwanted read zoned which introduces signal reflection and unwanted reading of tags from undesired zones. Globally, Linear antenna is preferred antenna for ETC system. Circular antenna is preferred in parking and supply chain applications where readings and read zone are not constraints.

- It is critical for RFID Devices to be able to read tag and EPC memory for at least 2 tags per second for moving vehicle with a speed limit of 75 kilometers/ hour. It should also have a rich array of diagnostic and statistical reporting tools, user-configurable alarms, and a host of management features based on industry standard protocols.
- **Mounting height of Antenna –** Height of Antenna is crucial as the beam width of the antenna coming from a distance increases the reading zone. Reading zone has to be defined in a way that readers captures the tag in the desired lane.
- **Zone mapping –** Reading zone of the reader should be defined during the installation and commissioning.
- Site interference – Presence of metal at the plaza reflects and refract RF radiations across the lanes. As the plaza was not designed originally for RFID system implementation, there will be certain issues which will be part of the overall RFID implementation.
- **RFID tags –** ISO 18000-6C tags needs to be utilized as per the mandate. Only approved tags shall be used.

Electronic Road Pricing (ERP): ERP is electronic means of collecting congestion charges which are usually collected from the road users in the congested parts of the cities as a part of traffic management strategies. Based on a pay-as-you-use principle, motorists are charged when they use priced roads during peak hours. It uses a dedicated short-range radio communication system to get ERP charges deducted from smart-cards inserted in the in-vehicle units of vehicles each time they pass a pricing point when the system is in operation. The pay-as-you-use principle helps make motorist more aware of the true cost of driving. Singapore is one of the foremost countries to implement the ERP as a part of congestion management programs as shown in **Fig. 33.**

Fig. 33 ERP in Singapore (ERP, Singapore)

Fee Based Express – High Occupancy Toll (HOT) Lanes: A high-occupancy toll lane (or HOT lane) is a type of traffic lane or roadway that is available to high-occupancy vehicles and; other vehicles being required to pay a variable fee that is adjusted in response to demand. Unlike toll roads, drivers have an option to use general purpose lanes, on which a fee is not charged. HOT lanes allow lower occupancy cars access to High Occupancy Vehicle (HOV) lanes. Admission to these managed lanes is based on a fee paid by the driver. Those in the HOT lanes are assured of a high-speed and reliable trip time; the toll is adjusted to maintain free-flow conditions. The IT based electronic payment mechanism is used to collect the user fee to use HOVs. Existing Fastags (mandated by Govt. of India) can be utilised to be incorporated in the HOV Lanes for charging of variable fees.

Vehicle Kilometers Travelled (VKT) Usage Fees: VKT fees are distance-based fees levied on a vehicle user for use of a roadway system. In a broad sense, VKT fees' application is envisioned through the use of an onboard vehicle device to capture the distance driven by a vehicle through GPS or other technology and relate that to a method of charging, which could range from manual cash payment to automatic deduction for a prepaid customer account through Credit Cards/Fastag mandated by Govt. of India etc.

Variable Parking Fees: Variable parking pricing is a tool for managing the parking supply in a particular area. The concept is to increase parking fees during heavily used times, days, during event or in particular areas, and lower fees when demand is low. It is a mechanism to better manage the parking supply to reach a particular performance target. Within variable pricing, prices can vary based on duration of stay, day of week, time of day or location. In the parking lots, the sensors that report the occupancy of each lot and parking meters that charge variable prices according to the time of day. Using this new technology, the city adjusts parking prices in response to the occupancy rates.

6.5 Advanced Public Transportation Systems

Advanced Public Transportation Systems (APTS) include applications such as Automatic Vehicle Location (AVL), which enable transit vehicles, whether bus or rail, to report their current location, making it possible for traffic operations managers to construct a real-time view of the status of all assets in the public transportation system. APTS help to make public transport a more attractive option for commuters by giving them enhanced visibility into the arrival and departure status (and overall timeliness) of buses and trains. This category also includes electronic fare payment systems for public transportation systems, such as Suica in Japan or T-Money in South Korea, which enable transit users to pay fares contactless from their smart cards or mobile phones using near field communications technology.

The following ITS applications are part of APTS system:

- Real Time information of Public Transit System (e.g. Bus, Metro, Rail)
- Real-time information means any information available to transit providers or customers about the current status of vehicles, including approximate locations and predictive arrival times. Most real-time information relies on Automatic Vehicle Location (AVL) and Global Positioning Systems (GPS) in order to estimate approximate arrival times for passengers and transit system

operators. Passengers access real-time arrival and departure information through dynamic signs at stops and stations or through the Internet at home or on smart phones. As smart phones become more prevalent, they have made access to third-party scheduling information and apps highly accessible for passengers.

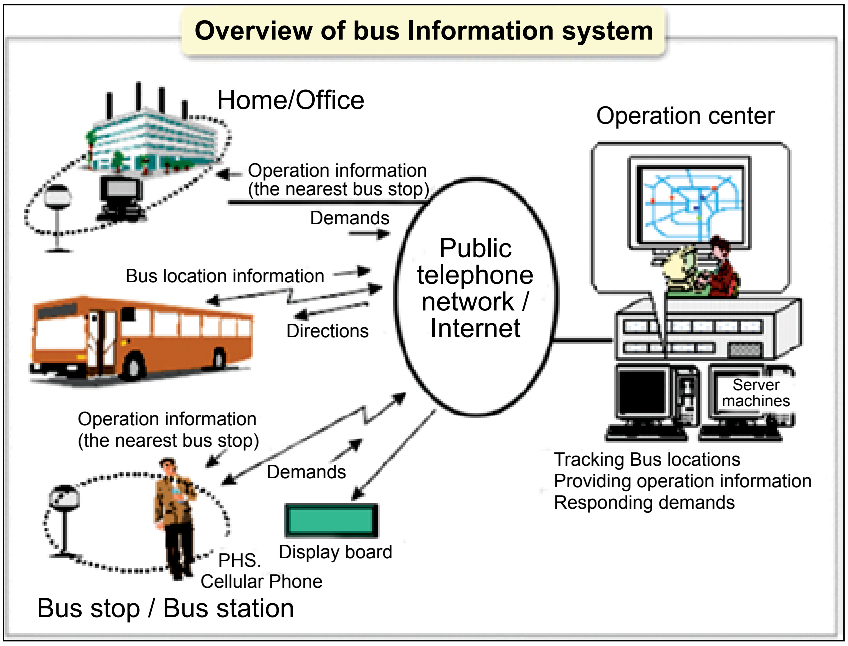

Fig. 34 Bus Information System
http://www.oki.com/jp/SSC/ITS/eng/businfo.html

Automatic Vehicle Location (AVL): The Automatic Vehicle Location (AVL) systems enable transit agencies to easily monitor and collect data on their fleet's location and performance. This data is translated into real-time bus arrival information for passengers, and an improved perception of transit reliability as shown in **Fig. 34.** The system is practical, time-saving, and increases schedule adherence. If the system was linked to other systems, potential uses may include tracking where traffic delays happen to occur on highways since multiple transit vehicles use the transport network.

Electronic Fare Payment: Electronic Fare Payment system allows integration of fare for various modes of transport. The integrated fare product (Usually a smart card) can be used across all or most of the modes of public transport in a city and promotes the use of public transport.

6.6 Advanced Vehicle Control Systems

Vehicle Information and Communication System is a digital data communication system, which promptly provides the latest necessary road traffic information to drivers via car navigation systems. Information is transmitted in the direction of traffic flow to the drivers to suit their needs, from beacons installed on the roadside via on-board car navigation equipment. There are over 2 million AVCS units already in use. The benefit of this system is that, the road traffic conditions informed in advance makes a driver more relaxed and comfortable. It also offers alternative choice on routes to avoid traffic congestion. This ensures that AVCS changes from a “Luxury” to a “Necessity” once people start using it.

One of the areas having the greatest potential payoff for electronics in automobiles is in the relationship of the car and driver to the road. Seemingly, the key feature of automatic intelligent transportation network is precise and real-time interaction between vehicles and a network. Improvements in traffic flow in congested areas might be possible if the drivers are updated with real time information concerning traffic problems on the road ahead. The two most popular means of communication between the vehicle and the driver are given in **Fig. 35** and **Fig. 36**.

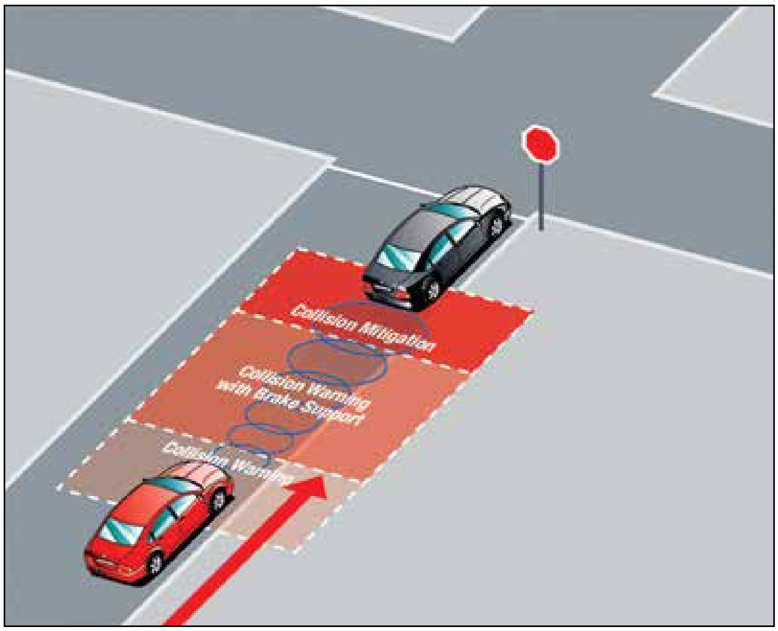

Fig.35 Vehicle to Vehicle Integration
(http://www.utires.com/blog/road-safety-overview)

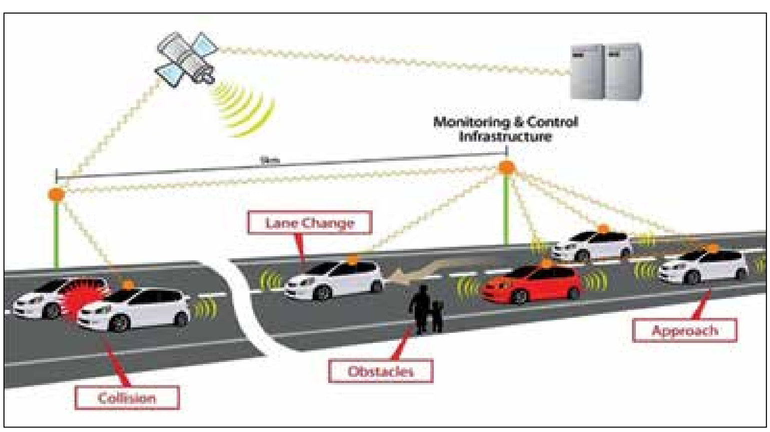

Fig. 36 Vehicle to Infrastructure Integration
(Automobile Innovations Website, 2013)

6.7 Traffic Control and Management

The Traffic Control and Management system using ITS helps in efficient control and management of the traffic. Depending upon the geographical reach, the Traffic Control and Management system can be divided into following categories:

Surface Street Control: Surface Street Control refers to the monitoring, control and management of traffic operations on municipal streets and arterials. The primary application of ITS within Surface Street Control is the management of signalized intersection control and the assignment of right-of-way for all users of the transportation network including vehicles (e.g., passenger cars, trucks, transit vehicles, emergency response vehicles, maintenance vehicles, etc.), cyclists and pedestrians. This section describes surface street control systems from a network perspective addresses signal coordination techniques, system types and vehicle priority systems. A range of traffic signal control systems are represented ranging from static pre-timed control systems to fully traffic-responsive systems that dynamically adjust control plans and strategies based on current traffic conditions and priority requests. The major objectives of Surface Street Control Systems are to

- Maximize the capacity of the existing road network through the optimization of traffic signal operation;
- Improve safety for all road users, including vehicles, cyclists and pedestrians;
- Reduce delays, stops and fuel consumption associated with the operation of traffic signals for all road users;
- Monitor the operation of traffic signal equipment and report malfunctions to minimize equipment “down time” and maximize maintenance efficiency.

A typical Surface Street Control System consists of intersection control equipment (i.e., intersection controller, signal heads, etc.), detection equipment (i.e., vehicle detector, pedestrian detector, bicycle detector, etc.), communications network and a computer system to provide central control and monitoring functions of the field equipment. Multiple Surface Street Control Systems in a region should be capable of sharing data with each other electronically. The objective of this information exchange is to allow adjacent jurisdictions to provide area-wide signal coordination along major corridors and road networks regardless of jurisdictional boundaries.

The primary objective of a traffic signal is to safely assign right-of-way to vehicles, cyclists and pedestrians, competing for the use of the same road space at intersecting roadways. Typically, this is achieved using intersection control equipment with right-of-way assigned, based on the presence of vehicles, pedestrians and bicycles. Priorities between road users and vehicle types can vary, and for this reason many traffic signal systems offer a method of providing priority service to accommodate transit vehicles, emergency response vehicles and operation of at-grade rail crossings located in close proximity to signalized intersections. Both local and centralized methods of priority control are available.

A secondary application of ITS within Surface Street Control is lane management, which involves the restriction of specific lanes of a roadway to designated vehicle types, direction of travel or other purposes. It involves the use of Lane Control Signs (LCSs) and a central control and monitoring system. Lane management systems are commonly used for reversible lane operation on urban arterials as well as bridges and tunnels, for High Occupancy Vehicle (HOV) / High Occupancy Toll (HOT) lane management, and have also been applied for traffic management purposes through construction zones. Typically, they are applied to traffic bottlenecks where roadway expansion is difficult due to right-of-way or cost restrictions. Their primary objective is to maximize the capacity of existing roadway infrastructure for specific vehicles or to alter a direction of travel.

Highway Control: Highway control uses roadside equipment and communications to monitor traffic conditions on the highway network for traffic management, incident detection and management, ramp metering and access control. Typically, it is applied to high-volume; access-controlled highways located within or in close proximity to large population centres. Highway control employs monitoring techniques and adaptive control strategies to maximize the efficiency of traffic movement and better manage traffic congestion. It is widely recognized that the occurrence of an incident and the resultant blockage of traffic lanes and/or shoulders has a dramatic effect on the capacity of the roadway. It therefore follows that the faster an incident can be cleared, the less impact it will have on the operation of the highway network. Incident management refers to the timely detection of incidents and the dissemination of relevant information to emergency response agencies, maintenance personnel, traffic management staff and motorists in order to minimize the duration and impact of the incident on the transportation network.

Regional Traffic Control (RTC): RTC enhances the surface street control and highway control by adding the communications links and integrated control strategies that enable integrated inter-jurisdictional traffic management. Regional traffic control can be applied to an expressway or an arterial corridor consisting of an expressway, arterial road or combination of both. A typical Regional Traffic Control System consists of traditional traffic control such as regulation, warning and guidance of traffic, as well as expressway management activities such as vehicle monitoring, incident detection and management, provision of motorist assistance and traffic information dissemination. The major objectives of Regional Traffic Control Systems are to:

- Monitor traffic flow and other environmental conditions on the expressway/ arterial corridor;
- Reduce delays and collision risks due to non-recurrent congestion through rapid detection and appropriate management of incidents;
- Determine and identify actions to alleviate recurrent of traffic congestion;
- Disseminate information to motorists about the expressway/arterial corridor condition to improve safety and mobility, and enable diversion of traffic if required; and
- Maintain the expressway/arterial corridor at an operating level by efficient implementation of traffic control strategies (including ramp metering, active/ passive diversions, etc.)

6.8 Law Enforcement

The ITS can be effectively used to ensure enforcement of traffic laws by the road users.

Some of the most popular ITS applications for Law enforcement are given here:

Automatic Number Plate Recognition: This technology applies the concept of optical character recognition on images to read vehicle registration plates. It can be applied on existing closed-circuit television, road-rule enforcement cameras. The police forces around the world use it for law enforcement purposes. For the purpose of electronic toll collection on pay-per-use roads by local or urban body/highways agencies use this technique around the world. The images of the front vehicle including the colour, texture and text from the registration number plate are captured by the cameras with some configurable to store a photograph of the driver. Systems commonly work on the concept of infrared lighting to allow the camera to take the picture at any time of the day. Major concerns about these systems expose the privacy fears of government tracking citizens' movements. **Fig. 37** shows the application of ANPR.

Plate detection and plate character recognition happen inside camera hardware thereby ensuring low bandwidth usage as well as speed of transmission and therefore preventive/ corrective action is possible since now detection is possible for plates (reflective plates) even at high speeds ranging between 120-150 kmph. Keys of this camera system are their feature of seamless sharing of hotlists, reads, and alerts (Remote notification via email or text messaging) between agencies when ANPR captures vehicles matching details in hotlists. ANPR is an attractive product to complement or validate RFID or Digital Short- Range Communication.

Mobile ANPR

The Mobile ANPR on the other hand assists on-street patrol officers checking for criminal activity by capturing and analysing the license plates against known data basis thereby greatly increasing the chances of successfully finding the suspect. The ANPR system acts as a valuable force multiplier.

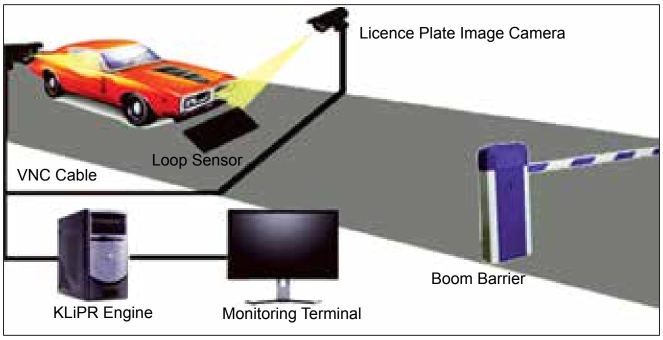

Fig. 37 Automatic Number Plate Recognition

Red Light Violation Detection System: The ITS based solution's red light violation detection system discussed in previous chapter may help reduce the accidents as it creates a sense of psychological fear not to violate the traffic rules.

Speed Violation Detection System: Speed violation detecting system using Global System for Mobile Communications (GSM) technology and Radio Frequency Identification (RFID) technology is adopted as a solution to the general problem of road speed violations and related accidents on the roads.

7 PHASES FOR IMPLEMENTATIONS OF ITS

7.1 General

All the challenges to minimize the transport problems mentioned in the preceding sections cannot be addressed completely using ITS tools alone for traffic and transport demand management tools. ITS tools combined with other engineering interventions can together create a successful traffic and transport management system plan for any city in India.

The TMS measures need to be implemented in a phased manner so that the experience from the earlier phases can be utilized in the later phases. Thus based on funds, available expertise, severity of the problem, and ground reality, the following suggested phases or components of ITS can be modified and adapted to suit the prevailing conditions in a city. Depending on actual needs, one can add or delete systems or subsystems described in this section.

It means that the ITS tools suggested in different phases can be added in earlier phases or postponed for future phases as per specific need for a city. For example, a city is not experiencing much traffic congestion, accidents, delays etc. but the public transport system is introduced in a city. In that case, in first phase itself, one can add passenger information system along with or without other tools as proposed in Phase I. The best examples are in new cities (like New Raipur) where the public transport system/BRT system is the first priority. The passenger information system is an appropriate ITS tool to start with for traffic management system in first phase.

7.2 Phase I

The first phase applies to cities where the problem of traffic congestion has not become acute, congestion is just starting to spread beyond the peak hours, and funds or trained/technical staff may also be a constraint. This phase is ideal to appreciate the benefits of ITS. It also constitutes the first step towards learning about the experiences or issues related to implementing and maintaining TMS in a city. This phase does not require a sophisticated control room or advanced level of infrastructure. Once cities understand and sort out the implementation and maintenance issues related to TMS and ITS, and become capable of analysing the field data on their own, then they can graduate to higher phases. Cities like Vijayawada, Amritsar, Pathankot, Karnal, and Meerut are good examples of cities that can start with Phase I immediately. Systems proposed in the first phase are listed in **Table 1**.

Table 1 Systems Proposed in Phase I

System Proposed	Objective
Intelligent signals/ coordinated signals	For smooth discharge of traffic at intersection /smooth flow of traffic on corridor
Area traffic control system (ATC)	Smooth flow of traffic in implemented network, minimum overall delay at red lights, and green signal throughout for emergency vehicles.

In order to implement this phase, the coordination among following agencies/organisations is required.

- Traffic Police
- Public Works Department(PWD)
- Municipality
- Development Authority

Authorities and agencies included in the organizational architecture are those that are responsible for providing and maintaining the road infrastructure along with the traffic police. A systems architecture diagram for each of the proposed phases has been prepared. The definition of a "System" as used in this report is "a set of methods or procedures or algorithms to perform a specific job". Usually the system consists of input, data processing or manipulation and output (desired/defined). The system architecture proposed for Phase I is shown in **Fig. 38**.

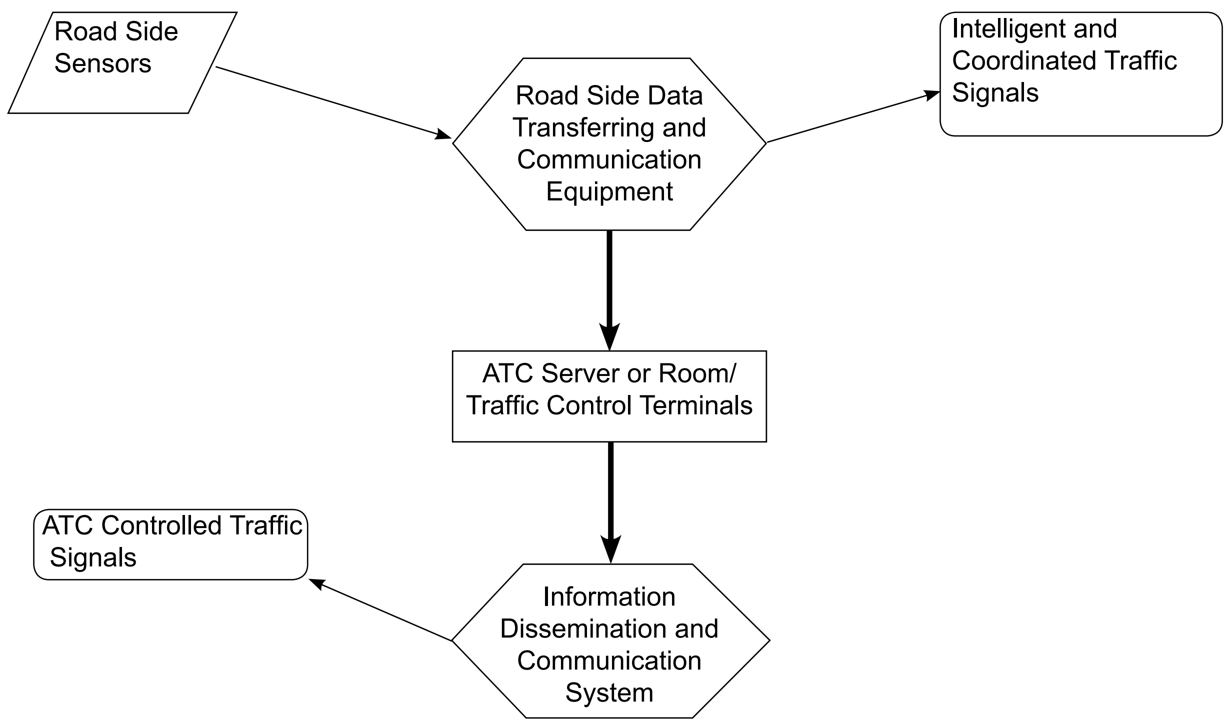

Fig. 38 System Architecture for Phase-I

7.3 Phase II

When a city is ready with a computerized database of vehicle owners/driving licenses/ commercial vehicle permits and also starts implementing smart driving licenses/permits/ registration certificates, etc., it is an indication that the city is prepared for Phase II. Further, if the road network in the city is also used by a lot of traffic and traffic violations show increasing trends (and disposing of the traffic violation cases takes more time), then that city could turn to Phase II.

This phase also assumes that the city has some basic infrastructure such as a traffic police control room and is ready to expand in terms of trained/ skilled staff, infrastructure, and advanced communication systems. Systems proposed for Phase II include all systems in Phase I along with the systems presented in **Table 2.**

Table 2 Additional Systems Proposed for Phase II

System Proposed	Sub-System (ITS – Tools)	Objective
Intelligent Traffic management and Electronic payment	• Speed control signage, hazard warning system (VMS) • Emergency road side phone system • Electronic road pricing system	• To inform the vehicle drivers about speed restrictions and about any obstruction (temporarily or permanent) in traffic flow • To reduce congestion by means of introducing congestion charges
Traffic rules enforcement system Transport authority enforcement system	• CCTV system, Automatic Speed detection system • Automatic number plate recognition system • Red light violation detection system • Wrong way vehicle detection system • e- Challan system • Smart card based driving licenses issue system • Smart card based permit and registration certificate issue system • Police patrol monitoring system • Traffic police (squad, post) Traffic interceptor vans	• To capture traffic rules offenders, and collect fines from them. • To book the traffic rules offenders, violation of permit rules, fake driving license holders, fake permits and RC holders, stolen vehicles in the law of court • Maintain the records of traffic rules offenders for giving severe punishment in law of court • Reduce accidents and increase safety • To collect congestion charges
Infrastructure maintenance and management system	• Maintain and manage road side ITS and non-ITS based infrastructure • Maintain roads, footpaths, FOBs, junctions • Maintain and manage communication system, control room • Maintain traffic signals, VMS, signage of different types	• To provide maintained road network for all road users for smooth flow of traffic and road users mobility. • To provide un-interrupted platform for ITS functioning
Data warehouse	• Automatic traffic counter and classifiers	• To maintain data of traffic, vehicles for forecasting, planning etc. • For demand management
Information dissemination system	• VMS, speed signage, hazard warning signage, SMS, Web sites, social sites, e-mail, FM radio	• It helps the traveller and vehicle driver to take corrective action in their trip as well as prepare themselves as per any traffic advisory or alert is issued

Organisation:

The urban transport departments of the city can be the main agency assisted by the Traffic Police, other stakeholders would be

- Public Works Department(PWD)
- Municipality
- Development Authority
- Planning departments/Research units

In the Organizational Architecture, some more departments are added due to their role in Phase II. Some more departments may also be required or some of the departments suggested above may be removed, depending on the jurisdictions and responsibilities assigned to them as per their State Constitution or by their State Assembly. The systems architecture diagram for Phase II is given in **Fig. 39**.

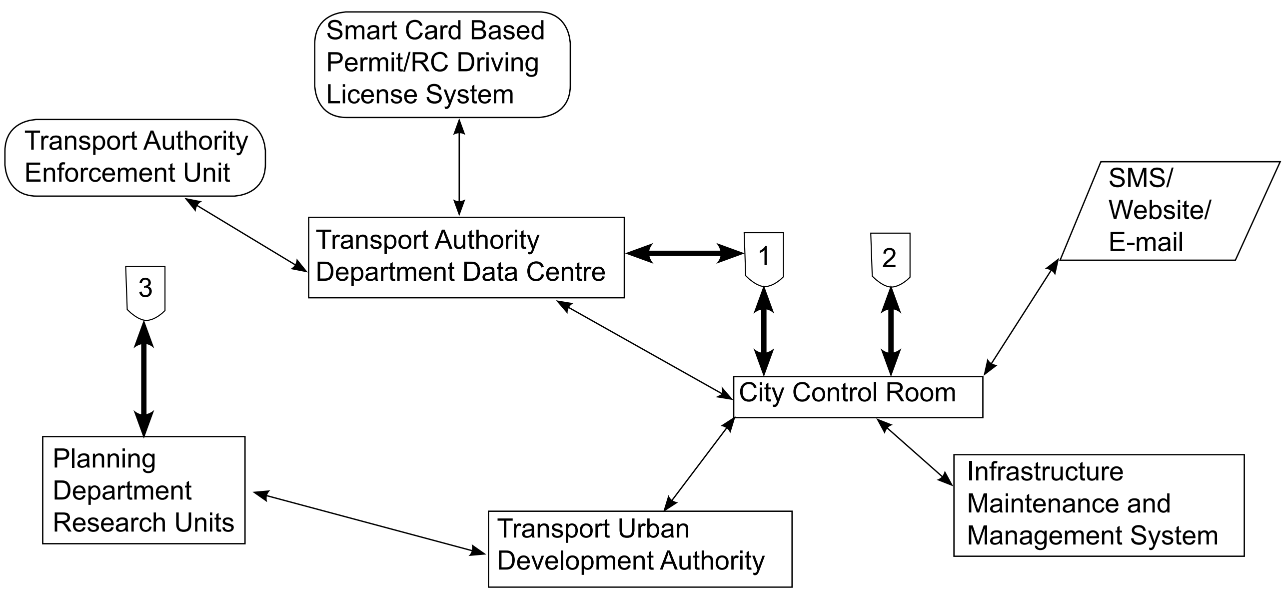

Fig. 39 System Architecture for Phase II

7.4 Phase III

When road accidents and road rage become everyday affair and fatalities are increased then the city should consider adopting Phase III. It is recommended that the city should begin to prepare for Phase III immediately after implementing Phase II. If the pollution level increases at a faster rate than stipulated, the city should also commence implementing phase III. This Phase requires that the city should have a trauma centre and ambulance system. All metropolitan cities and state capitals should implement components of Phase I, II and III.

System Proposed: Additional systems for Phase III are indicated in **Table 3** and its architecture is shown in **Fig. 40.**

Table 3 Additional Systems Proposed for Phase III

System Proposed	Sub-System	Objective
Traffic monitoring and surveillance system	• Automatic vehicle detection system (Image processing) • Towing system • Journey time monitoring system	• To clear the network in time of breakdown of vehicles for un-interrupted traffic flow • To take action after detecting any incidents and reduce casualties
Emergency and accident response system	• Transportation monitoring system (fleet monitoring system-public transport, ambulances) • Distress call response management system- emergency road side telephone system	• To provide immediate relief to road users • To help save life of road-side accident victims • To help road users in case of emergency
Automatic air pollution monitoring system – meteorological sensors		• To save the city and habitats from pollution • To book the vehicles for violation of pollution norm and collect fine and book them in law of court

Stakeholders:

The purpose of bringing various stakeholders at one ITS architecture platform is to collect, exchange and disseminate the relevant information so as to help travelers, operators to provide with real time information on travel for taking appropriate decision. There are a number of stakeholders to be included for effectively addressing the traffic management operation. These are namely:

- Traffic Police
- Public Works Department (PWD)
- Municipality
- Transport Authority
- Development Authority
- Planning departments/Research units
- Fire Brigade
- CAT-Ambulance system
- Hospitals
- Disaster Management Agency
- Environment-Pollution Control Department
- Courts

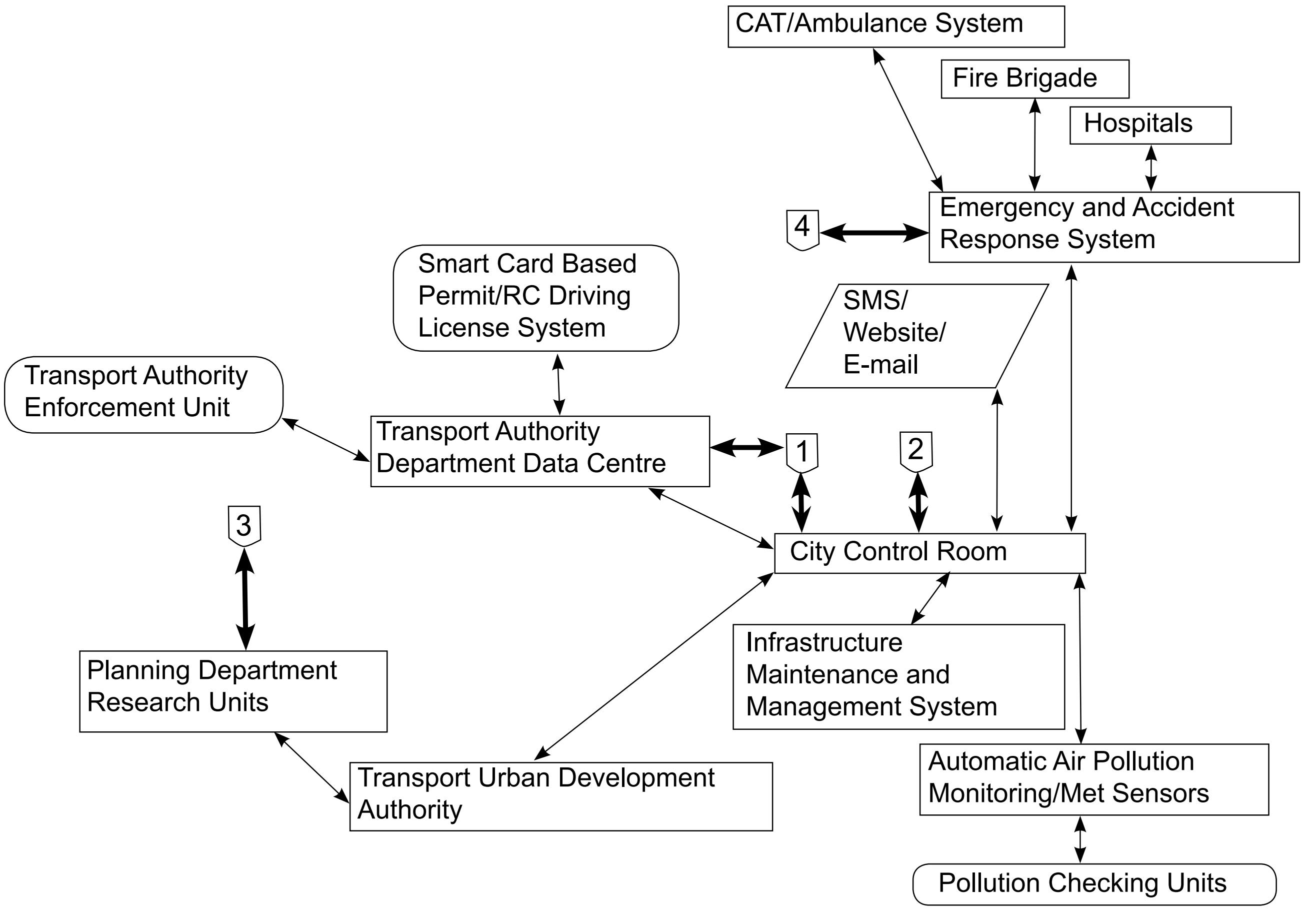

Fig. 40 System Architecture for Phase III

7.5 Phase IV

This phase is for those cities/areas where pedestrian or bicycle traffic is also an important component of the transportation system.

System Proposed: Additional systems for Phase IV are indicated in **Table 4** and System Architecture is given in **Fig. 41.**

Table 4 Additional Systems Proposed for Phase IV

System Proposed	Sub-System	Objective
Parking management and information system	• Parking guidance system • Intelligent parking lot management system • Electronic parking charge payment system	• Guide the driver to particular parking sites among number of sites within an area • Guiding the drivers to park at particular parking bay • Help the drivers to locate particular location in city through unit fitted in car • Help the drivers or road users to locate particular location in city through system available on road side
Pedestrian / biker detection system		• To reduce and avoid pedestrian/biker casualty in road accidents

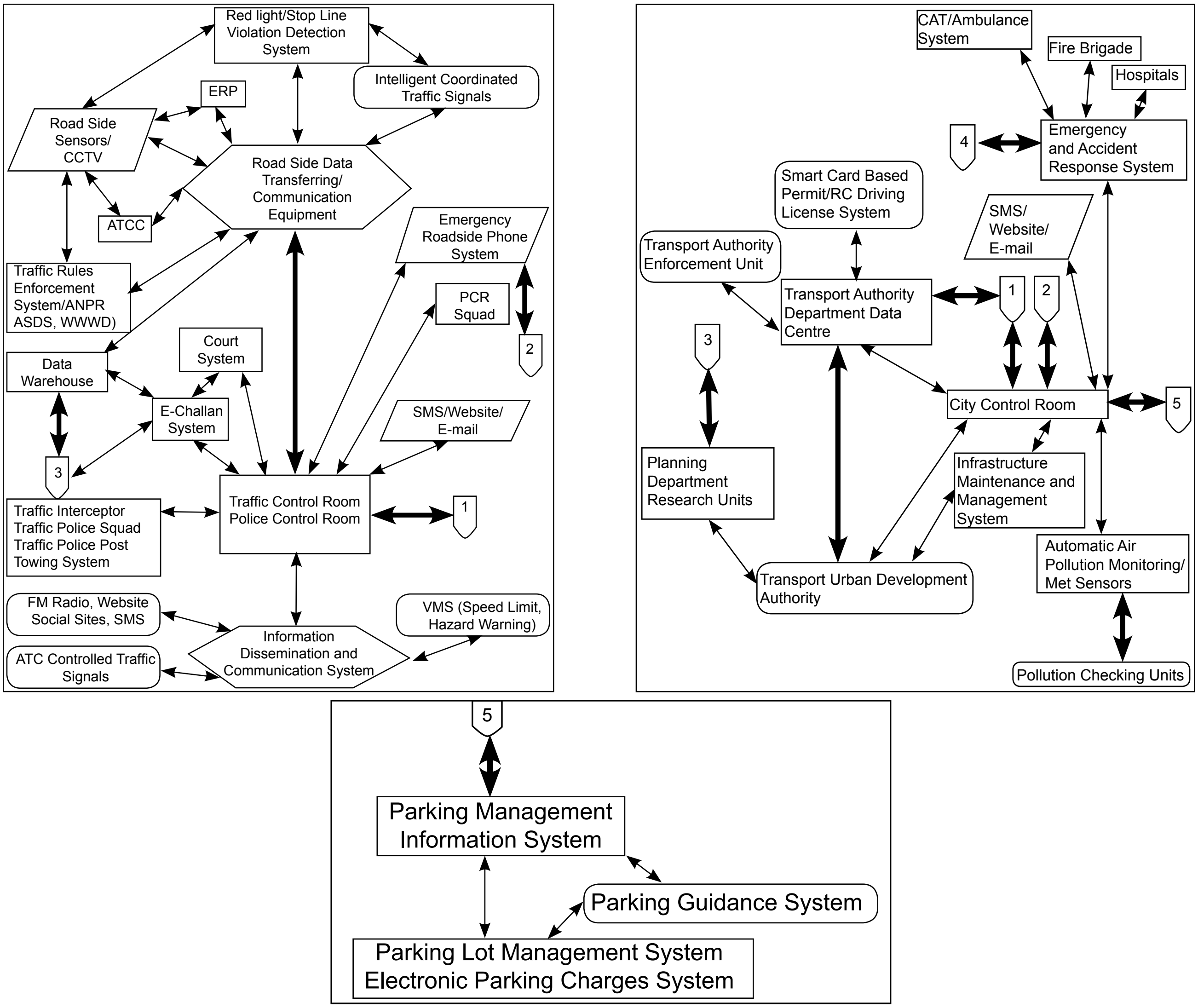

Fig. 41 System Architecture for Phase IV

7.6 Phase V

When the city wants to integrate public transport system with the traffic management system, Phase V is proposed.

System Proposed: Additional systems proposed for Phase V are indicated in **Table 5.**

Table 5 Additional Systems Proposed for Phase V

System Proposed	Sub-System	Aim
Advanced Traveller Information System (ATIS)	Passenger information system	To help the road user for information related to public transport/Informal Public Transport (IPT) at road side

Authority/agency involved: all agencies along with public transport authority and IPT service provider (If they exist).

Area covered: The whole network.

The suggested system architecture for Phase V, which is the fully built-out phase, is given in **Fig. 42.**

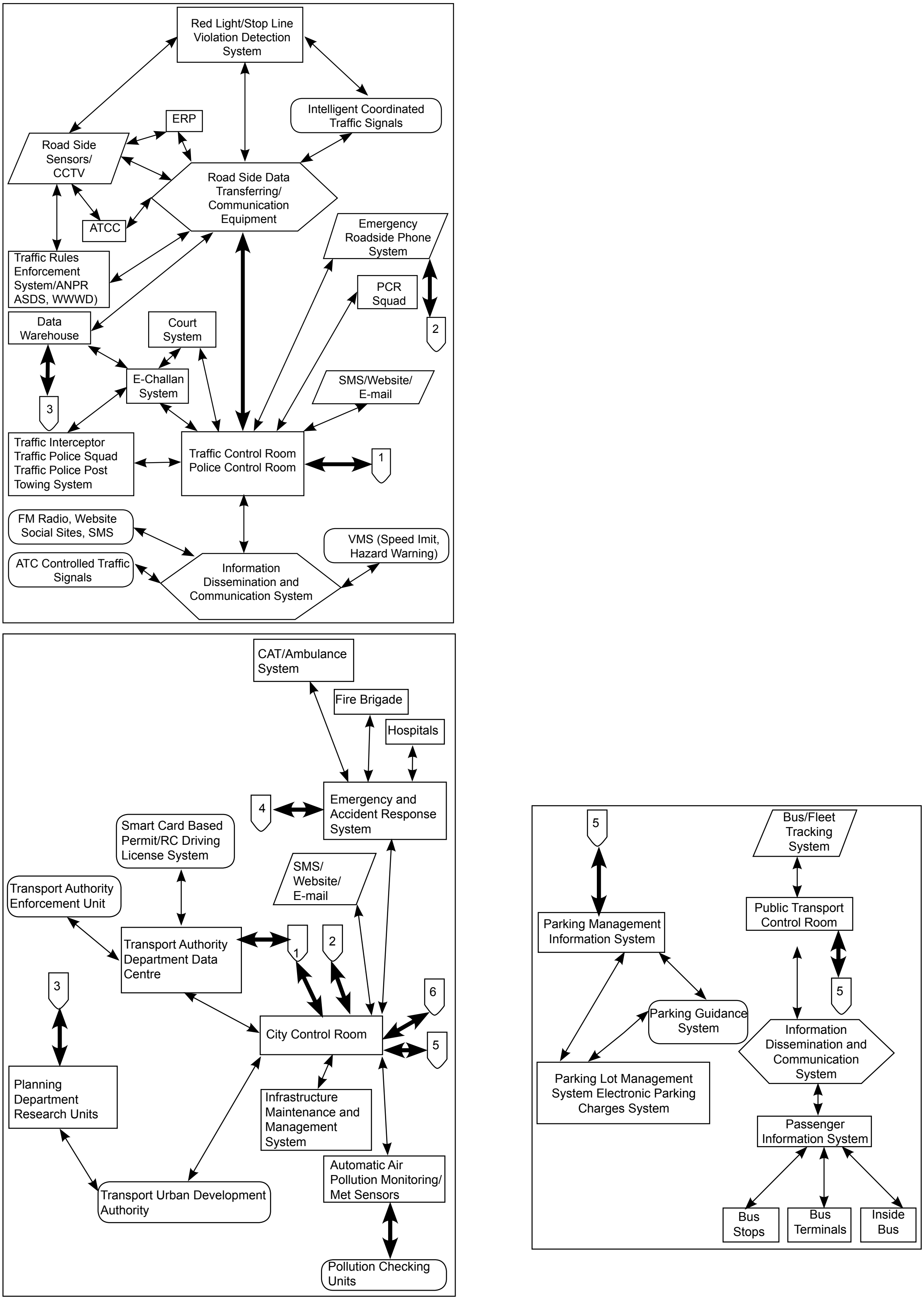

Fig. 42 System Architecture Diagram for All Phases

8 ITS AROUND THE WORLD

8.1 Introduction

A number of ITS applications have been developed by various organizations/institutions around the globe and tailored to offer transportation solution to meet their specific needs. In developed countries, road operators have become dependent on ITS for not only traffic congestion and travel demand management, but also for road safety and improved transport infrastructure. ITS employs modern communication, computer and sensor technology directly, and are also enabled indirectly by developments in terms of materials, technology and operations research, including network analysis and risk assessment. The vastness of the playing field makes the ITS a cooperative effort between the public sector, private sector, and academia. There is a substantial emphasis on the central and critical role of local public-sector partnership with knowledge input from academic circles. Substantial changes have been made in the core competencies and perspective of these organizations and relationships for developing programmes towards a successful ITS. Some implementations of ITS around the world are briefly described here.

8.2 United States of America

The U.S. Department of Transportation (USDOT) with the help of Intelligent Transportation Systems Joint Program Office (ITS JPO) conducts research on all major modes to advance transportation safety, mobility, and environmental sustainability through electronic and information technology applications. USDOT developed ITS strategic Plan for 2015-2019. This presents the strategic themes and programme categories under which ITS categories reflect modal and external stakeholder input about the areas where attention, focus and resources should be devoted. Los Angeles smart traveller project has deployed a small number of information kiosks in location such as office lobbies and shopping plazas.

8.3 Japan

Japan's ITS not only promotes the optimization of road traffic control, but also achieves reduction in traffic accidents and congestion, and aims to co-exist with energy saving society. Under cooperative project between Japanese government and private companies, "Grand Design of ITS Promotion" clarified nine development fields and twenty one utility services in July 1997, and led them into national projects. Research and Development of Japan's ITS, such as car navigation, VICS (Vehicle Information Communication System) and ETC (Electronic Toll Collection System) have progressed, and market of these systems has grown rapidly in Japan. In the second stage of ITS, "ITS Promotion Guide Line" as government/ private collaborating project promoted the practical applications of ITS, and assisted safe driving to realize "the world's safest road traffic environment". And hereafter, Japan's ITS activities are also expected as a better approach to "a sustainable mobile society", and solve the environmental issues and traffic issues. ITS tools in Japan used to resolve the problems such as traffic congestion, traffic accidents and environment degradation (**Fig. 43**). Due to implementation, 20% of CO_2 reduction in transport sector, saved 5 billion hours annually and reduced fatality accidents to 4400 (Year 2010). Practical application of VICS (**Fig. 44**) reduced annual CO_2 emission by 2.4 million tonnes in the year 2009. ETC eliminates almost all toll gate congestion on expressways. Japan Launched nationwide 1600 ITS spots on expressways to provide basic services such as dynamic route guidance, safety driving support and ETC. ITS spot transmit optimum speed and Headway Distance.

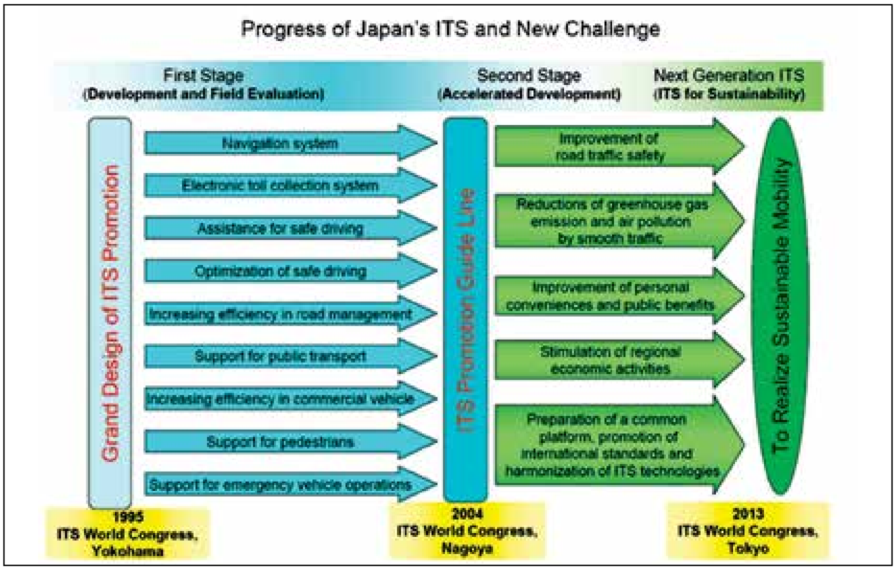

Fig. 43 Progress of Japan ITS and New Challenge (Wireless Technologies and Solutions of Japan, 2011)

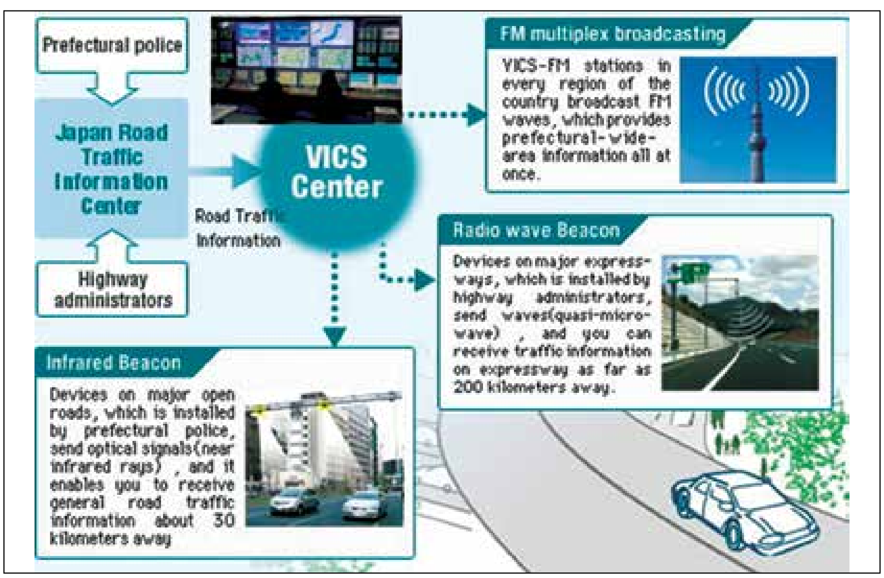

Fig. 44 Widely Developed ITS Services in Japan (VICS, 2013)

8.4 Europe

Mainland Europe's Intelligent Transport Systems falls under the umbrella of Road Transport Informatics (RTI). RTI focuses on two interacting programs - Road Infrastructures for Vehicle safety in Europe (DRIVE) and Program for European Traffic with Highest Efficiency and

Unprecedented Safety (PROMETHEUS). DRIVE falls under the control of the Commission of European Communities (CEC), and PROMETHEUS is part of the European Research Coordination Agency (EUREKA) platform, an industrial research initiative involving 19 countries and European vehicle manufacturers. Other European Union (EU) public-private partnership focusing on specific safety applications of ITS technologies initiatives are eSafety, INVENT, and PReVENT. The INVENT program works towards improving traffic flow and traffic safety by development of novel driver assistance systems, knowledge and information technologies, and solutions for more efficient traffic management, to prevent or minimise the severity of accidents. Traffic Impact, Legal issues and Acceptance evaluate the economic and business implications of the new technologies, as well as potential legal conflicts. The PReVENT programme integrates a number of safety functions in order to create a safety belt around the vehicle.

8.5 United Kingdom

In London, Internet based maps is aimed at facilitating the operation of freight transport. In London, “Transport for London” (TfL) have produced a digital map of all London’s speed limits which is available free of charge to anyone who wishes to use the map for personal use, or to create commercial applications. Various facilities developed to ensure smooth and safe flow of traffic are described as under:

- Information services to support travel planning - for towns, workplaces, other activity centres, and individuals.
- Toll collection and management. Electronic toll collection has been implemented in several regions of the country.
- Point to point speed enforcement has been ensured by use of multilane cameras.
- Automated information display for smoother and safer traffic flows.
- Two kinds of Intelligent Speed Adaptation (ISA) applications are being implemented.

London Congestion Pricing: London congestion pricing is one of the most talked about ITS applications. Transport for London has used thousands of ANPR cameras to identify vehicles entering into London CBD (Central Business District) to reduce congestion. Authorities implemented a unique solution of levying a hefty charge on Vehicles entering CBD areas during peak hours. ANPR cameras provide an efficient and accurate inventory of vehicles, which are visiting CBD areas during peak hours and automatically charging them through an account linked to License plate.

8.6 Middle EAST

Dubai Municipality started the implementation phase I for project ITS Dubai, which is considered to be the first comprehensive ITS project in the Middle East, and one of the most sophisticated ITS projects currently being implemented in the world. This ITS is expected to serve a rapidly growing population. Several integrated approaches are being implemented to achieve ITS in Dubai, such as constructing new roads and interchanges, promoting public transportation, and enhancing road network.

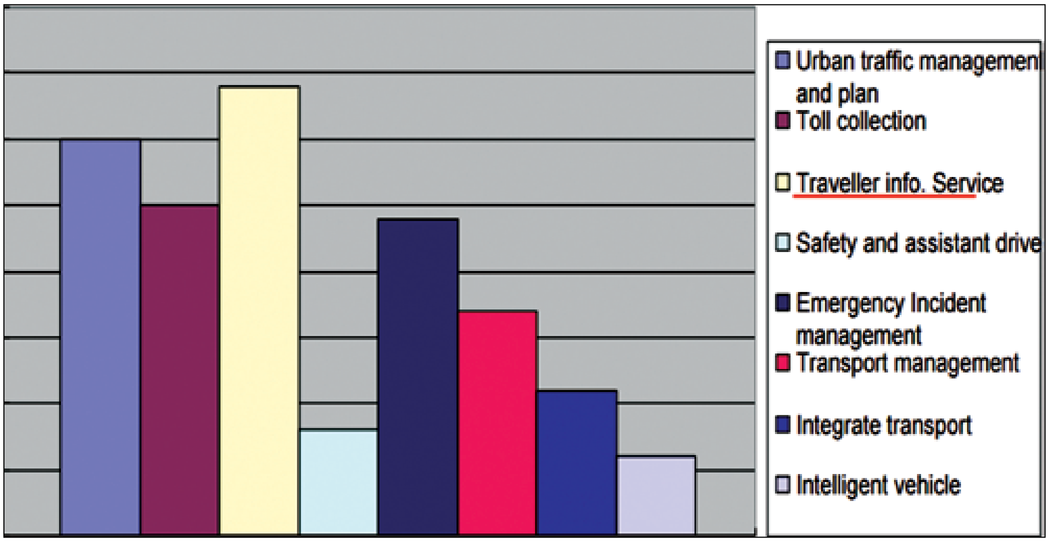

Fig. 45 Trend using ITS from 2003-2008 in China

8.7 ITS Development in China

In China, the National ITS strategy has been generated. This is mainly focused for development of ITS standard and Framework. Many ITS technologies have been applied in China and created new industries. National and local ITS application system promote safety, flexible, and environmentally safe movement of people and goods. The current status of ITS in China is as follows:

- Traffic Information Services: Become popular Smart Phone, Car-navigator, Website, VMS, Broadcast
- Car Navigator: Cumulative sales of on-board units: 65 million
- ETC: ETC cover the total national expressway network. More than 12,000 ETC lanes have been built.
- Network Reservation Taxi/Car Service; Taxi hailing, Express, Private car service,
- City Traffic Control Centre: Established in 256 Cities
- Smart Public Transport and Service: Smart Card: issued more than 430 million
- The Use of GNSS Big Data
- Commercial Vehicle Monitoring System
- Online Ticket booking System

8.8 ITS Initiatives in India

The ITS program in India is aimed at ensuring safe, affordable, quick, comfortable, reliable and sustainable access for the growing urban and rural population to jobs, education, recreation and such other needs. Some of the ITS initiatives in India are as follows:

- Electronic Toll Collection (ETC): Pilot projects on NH-5 and Ahmedabad Mumbai Highways
- ITS on BRT Corridors: Signal priority, Vehicle Tracking and Automatic Fare Collection in Ahmedabad, Indore and Bhopal BRT
- Advanced Parking Management: Parking lot at Palika Bazar in Delhi, Capacity to park 1050 cars and 500 two wheelers, Electronic Parking Guidance and VMS Smart Cards – Automated multi-level parking in Sarojini Nagar Market of Delhi implemented;
- City Wide ITS: Implemented in Mysore and planned in Naya Raipur

9 ISSUES AND CHALLENGES OF ITS IN INDIA

In India, there are not many comprehensive, fully developed ITS applications with traffic management centres. ITS concepts will be useful in the Indian scenario particularly in emergency management, enforcement for speed management and red light violation, electronic toll pricing, e-challaning, traffic congestion management, advanced traffic management systems, advanced traveller information systems, commercial vehicle operations, advanced vehicle control systems, etc. Full utilization of ITS on urban roads can be achieved only by implementation at network level rather than at corridor level. (Corridor level ITS can function well on inter-city expressways and highways). Some of the specific actions required to meet the challenges of ITS in India include:

- Availability of definite guidelines and regulations, standards and specification in physical implementation
- Integration of the ITS applications and development introduction of standards/ specifications of equipments
- High cost for ITS safety systems
- Setting up a citywide ITS implementation with fully functional Traffic Management Centres
- National level Data Centres and Maintenance of Archived data
- Online or offline data modelling methods to handle huge data
- Development of ITS architecture at city, regional and national level along formulation of ITS policies and programmes.

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(The Official amendments to this document would be published by the IRC in its periodical, 'Indian Highways' which shall be considered as effective and as part of the code/guidelines/manual, etc. from the date specified therein)