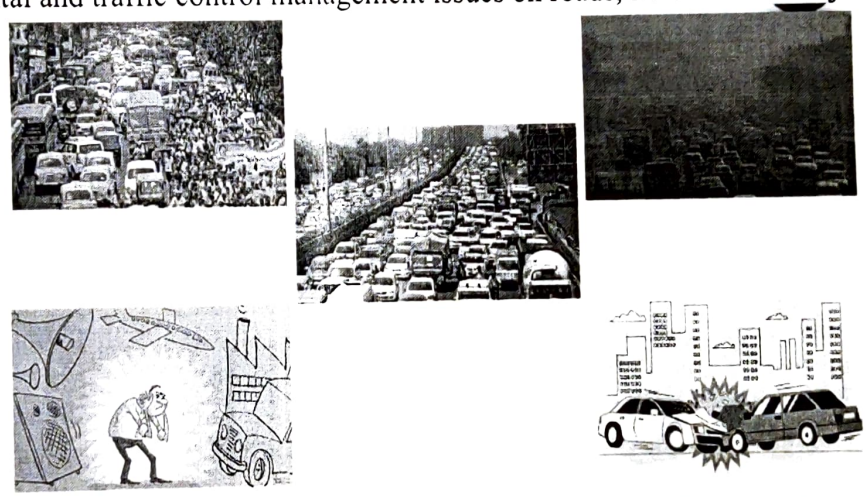
Module 1
INTRODUCTION

1.1 Introduction

Urbanization is central to achieving faster and more inclusive growth because it 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. This Rapid Growth in population in India 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.



A total number of 4,12,432 road accidents have been reported by States and Union Territories (UTs) during the calendar year 2021, claiming 1,53,972 lives and causing injuries to 3,84,448 persons. 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.

1.1.1 Transportation Issues

The following are the various problems in the field of transportation:

- *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.

- *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.
- *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.
- *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.
- *High maintenance costs*: Financial deficit is being faced for aging transport infrastructure, for both maintenance and upgradation to modern infrastructure, demand.
- *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 population.
- *Accidents and safety:* Growing traffic in urban areas is leading to growing range of accidents and fatalities.

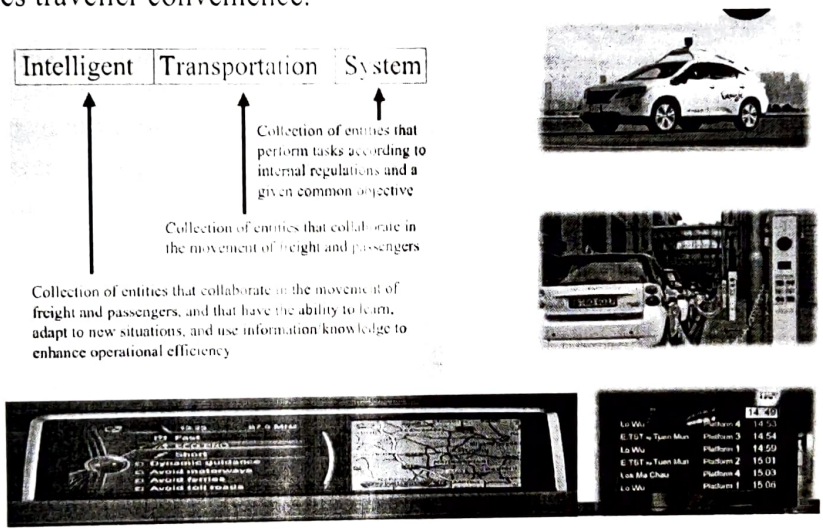
1.1.2 Need for Intelligent Transport System

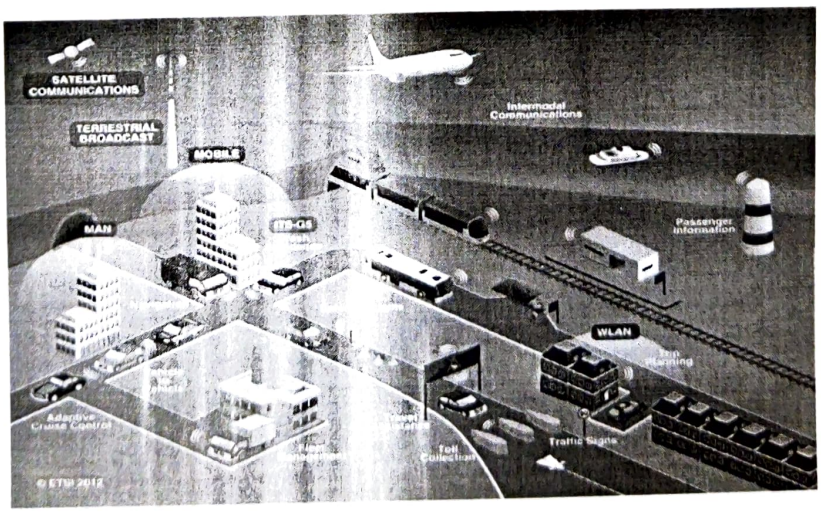
The following reasons describe the necessity of using ITS in India:

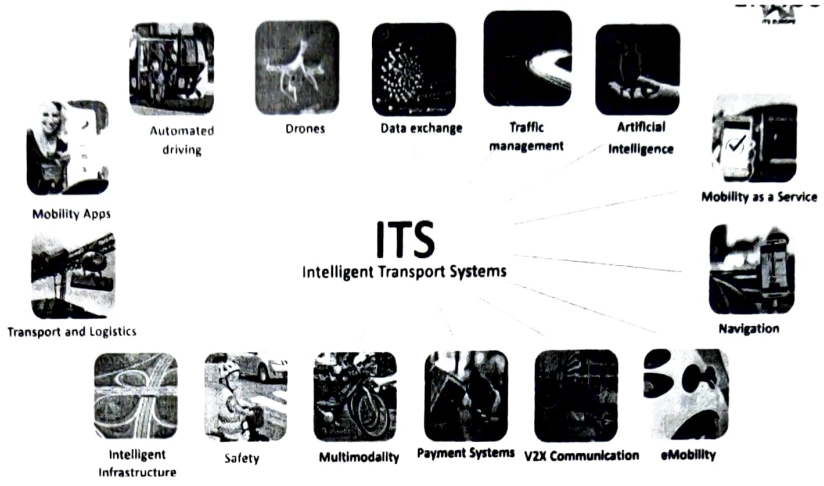
- Smart transportation is the need of the citizens of modern cities.
- In India, a fast-developing economy, the problem of road traffic congestion is getting aggravated in every major city.
- Infrastructure growth isn't enough as compared with growth in number of vehicles, due to space and expense imperatives.
- 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.
- ITS focusses on its system architecture, sensors and their applications in ensuring the safe and efficient movements of urban road traffic.

1.2 Intelligent Transport System

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 (Figure). The purpose of ITS is to improve transportation safety and efficiency, and enhances global connectivity by improvements achieved through the integration of advanced communications technologies into the transportation infrastructure and in vehicles. ITS, is part of the Internet of Things (IoT), includes vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) technology and incorporates both wireless and wire line communications-based information and electronics technologies. In the leading nations in the world, ITS has brought vital improvements, in transportation performance, as well as reduced congestion and pollution besides traveller convenience.







The following are the **Benefits of ITS applications**:

- Improved safety
- Reduced rush hour congestion and delay
- Reduced emissions
- Reduced travel times
- Enhanced access and quality of life
- Crash prevention
- Cost savings for commercial vehicle operations
- Enhanced travel options
- Improved customer service and reduced frustration
- Enhanced economic productivity.

1.3 Components of ITS

In order to deploy ITS, a framework is developed highlighting various services the ITS can offer to the users. A list of 33 user services has been provided in the National ITS Program Plan. The number of user services, keep changing over time when a new service is added. All the above services are divided in eight groups. The division of these services is based on the perspective of the organization and sharing of common technical functions. The eight groups are described as follows:

1. Travel and traffic management
2. Public transportation operations
3. Electronic payment
4. Commercial vehicle operations
5. Advance vehicle control and safety systems
6. Emergency management
7. Information management
8. Maintenance and construction management

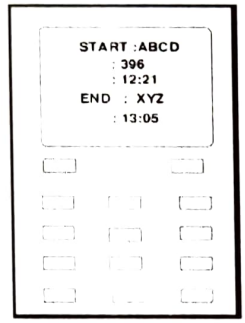
Bundle	User Services
1. Travel and Traffic Management	1.1 Pre-Trip Travel Information
	1.2 En-Route Driver Information
	1.3 Route Guidance
	1.4 Ride Matching and Reservation
	1.5 Traveler Services Information
	1.6 Traffic Control
	1.7 Incident Management
	1.8 Travel Demand Management
	1.9 Emissions Testing and Mitigation
	1.10 Highway-Rail Intersection
2. Public Transportation Operations	2.1 Public Transportation Management
	2.2 En-Route Transit Information
	2.3 Personalized Public Transit
	2.4 Public Travel Security
3. Electronic Payment	3.1 Electronic Payment Services
4. Commercial Vehicle Operations	4.1 Commercial Vehicle Electronic Clearance
	4.2 Automated Roadside Safety Inspection
	4.3 On-board Safety Monitoring
	4.4 Commercial Vehicle Administrative Processes
	4.5 Hazardous Material Incident Response
	4.6 Commercial Fleet Management
5. Emergency Management	5.1 Emergency Notification and Personal Security
	5.2 Emergency Vehicle Management
6. Advanced Vehicle Safety Systems	6.1 Longitudinal Collision Avoidance
	6.2 Lateral Collision Avoidance
	6.3 Intersection Collision Avoidance
	6.4 Vision Enhancement for Crash Avoidance
	6.5 Safety Readiness
	6.6 Precrash Restraint Deployment
	6.7 Automated Vehicle Operation
7. Information Management	7.1 Archived Data Function
8. Maintenance and Construction Management	8.1 Maintenance and Construction Operations

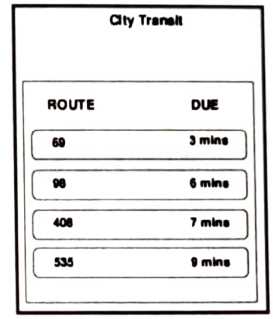
1.3.1 Travel and traffic management

The main objective of this group of services is to **use real time information on the status of the transportation** system to improve its efficiency and productivity and to mitigate the adverse environmental impacts of the system. This group of user service is **further divided in 10 user services**. Most of these services **share information with one another** in a highly

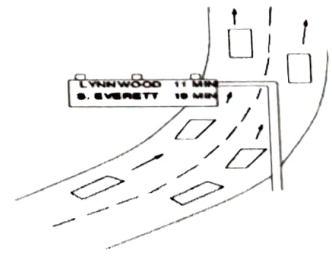
integrated manner for the overall benefit of the road transportation system. These services are described as below:

i. **Pre-trip information**: This user service provides information to the travelers about the transportation system before they begin their trips so that they can make more informed decisions regarding their time of departure, the mode to use and route to take to their destinations. The travelers can access this information through computer or telephone systems at home or work and at major public places. Pre-travel information can be accessed through mobile phones. Different routes and respective travel time durations indicated on VMS. The information include real time flow condition, real incidents and suggested alternate routes, scheduled road construction and maintenance tasks, transit routes, schedules, fares, transfers, and parking facilities.





ii. **En-route driver information**: This user service provides travel related information to the travelers en route after they start their trips through variable message signs (VMS), car radio, or portable communication devices. Figure shows the various congested and non-congested routes shown on display screen. VMS indicating different routes and travel time is shown in Figure. This helps the travelers to better utilize the existing facility by changing routes etc to avoid congestion. This also provides warning messages for roadway signs such as stop signs, sharp curves, reduced speed advisories, wet road condition flashed with in vehicle displays to the travelers to improve the safety of operating a vehicle. The information can be presented as voice output also.

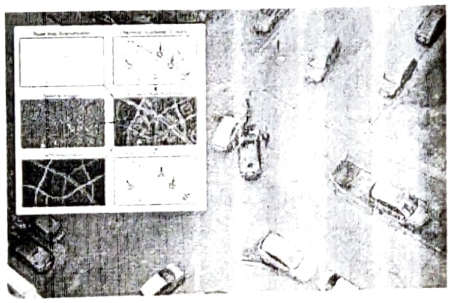


iii. **Route guidance**: This service provides information to the travellers with a suggested route to reach a specified destination, along with simple instructions on upcoming turns and other manoeuvres. This also provides travellers of all modes the real-time information about the transportation system, including traffic conditions, road closures, and the status and schedule of transit systems. The benefits of this service are reduced delay and drivers stress levels particularly in an unfamiliar area.

iv. **Ride matching and reservation**: This user service provide real-time ride matching information to travellers in their homes, offices or other locations, and assists transportation providers with vehicle assignments and scheduling. Travellers give information to the service center and get number of ride sharing options from which they can choose the best.

v. **Traveler Services Information**: This service provides a business directory of information on travel-related services and facilities like the location, operating hours, and availability of food, lodging, parking, auto repair, hospitals, gas stations and police facilities. This also makes reservations for many of these traveler services. The traveler services information are accessible in the home, office or other public locations to help plan trips. These services are available en-route also.

vi. **Traffic Control**: This service collects the real time data from the transportation system, processes it into usable information, and uses it to determine the optimum assignment of right-of-way to vehicles and pedestrians. This helps in improving the flow of traffic by giving preference to transit and other high occupancy vehicles or by adjusting the signal timing to current traffic conditions. The information collected by the Traffic Control service is also disseminated for use by many other user services.



vii. **Incident Management**: This service aims to improve the incident management and response capabilities of transportation and public safety officials, the towing and recovery industry, and others involved in incident response. Advanced sensors (close circuit TV cameras), data processors and communication technologies are used to identify incidents quickly and accurately and to implement response which minimizes traffic congestion and the effects of these incidents on the environment and the movement of people and goods.

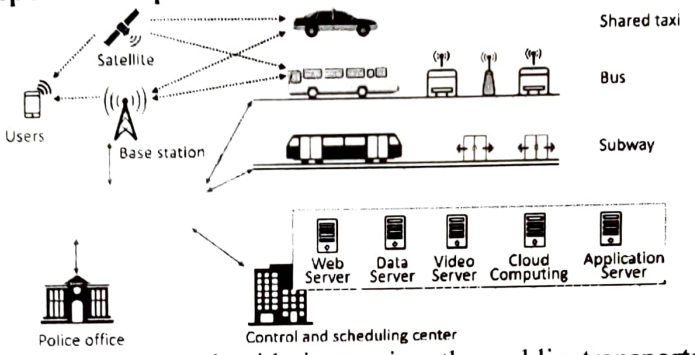
viii. **Travel Demand Management**: This user service develops and implement strategies to reduce the number of single occupancy vehicles while encouraging the use of high occupancy vehicles and the use of more efficient travel mode. The strategies adopted are:

   i. Congestion pricing
   ii. Parking management and control
   iii. Mode change support
   iv. Telecommuting and alternate work schedule.

ix. **Emissions Testing and Mitigation**: The main objective of this service is to monitor and implement strategies to divert traffic away from sensitive air quality areas, or control access to such areas using advanced sensors. This also used to identify vehicles emitting pollutants exceeding the standard values and to inform drivers to enable them to take corrective action. This helps in facilitating implementation and evaluation of various pollution control strategies by authorities.

x. **Highway Rail Intersection**: This service is to provide improved control of highway and train traffic to avoid or decrease the severity of collisions between trains and vehicles at highway-rail intersections (HRI). This also monitors the condition of various HRI equipments.

1.3.2 Public transportation operations



This group of service is concerned with improving the public transportation systems and encouraging their use. This group is divided in four services which are described as below:

i. **Public Transportation Management**: This user service collects data through advanced communications and information systems to improve the operations of vehicles and facilities and to automate the planning and management functions of public transit systems. This offers three tasks:
   a. To provide real-time computer analysis of vehicles and facilities to improve transit operations and maintenance by monitoring the location of transit vehicles, by identifying deviations from the schedule, and offering potential solutions to dispatchers and operators.
   b. To maintain transportation schedules and to assure transfer connections from vehicle to vehicle and between modes to facilitate quick response to service delays.
   c. To enhance security of transit personnel by providing access management of transit vehicles.

ii. **En-Route Transit Information**: This service is intended to provide information on expected arrival times of t vehicles, transfers, and connections to travellers after they begin their trips using public transportation. This also provide real-time, accurate transit service information on-board the vehicle, at transit stations and bus stops to assist travellers in making decisions and modify their trips underway.

iii. **Personalized Public Transit**: The aim of this service is to offer public transport facility to travellers by assigning or scheduling vehicles by
   - diverting flexibly routed transit vehicles.

- assigning privately operated vehicles on demand which include small buses, taxicabs, or other small, shared-ride vehicles.

Under this service, travellers provide information of their trip origin and destination to service station. The center then assigns the closest vehicle to service the request and to inform the travellers regarding arrival of such vehicles well in advance to reduce their anxiety.

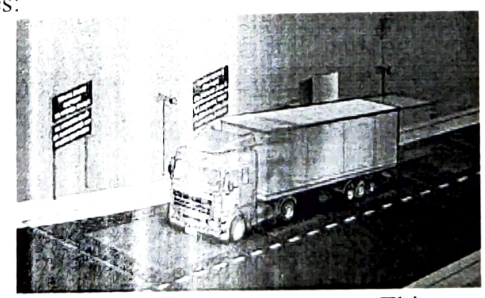
iv. **Public Travel Security**: This user service creates a secure environment for public transportation operators and support staff and monitors the environment in transit facilities, transit stations, parking lots, bus stops and on-board transit vehicles and generates alarms (either automatically or manually) when necessary. It also provides security to the systems that monitor key infrastructure of transit (rail track, bridges, tunnels, bus guide ways, etc.).

1.3.3 Electronic payment

This user service allows travellers to pay for transportation services with a common electronic payment medium for different transportation modes and functions. Toll collection, transit fare payment, and parking payment are linked through a multi-modal multi-use electronic system. With an integrated payment system, a traveller driving on a toll road, using parking lot would be able to use the same electronic device to pay toll, parking price and the transit fare. Figure shows the electronic payment facility by radio car tag.

1.3.3 Commercial Vehicle operations

The aim is to improve the efficiency and safety of commercial vehicle operations. This involves following services:



i. **Commercial Vehicle Electronic Clearance:** This service allows enforcement personnel to electronically check safety status, vehicle's credentials, and size and weight data for the commercial vehicles before they reach an inspection site. The

authorities send the illegal or potentially unsafe vehicles only for inspection and bypass safe and legal carriers to travel without stopping for compliance checks at weigh stations and other inspection sites.

ii. **Automated Roadside Safety Inspection:** At inspection station the safety requirements are checked more quickly and more accurately during a safety inspection using automated inspection capabilities. Advanced equipments are used to check brake, steering and suspension performance and also the driver's performance pertaining to driver alertness and fitness for duty.

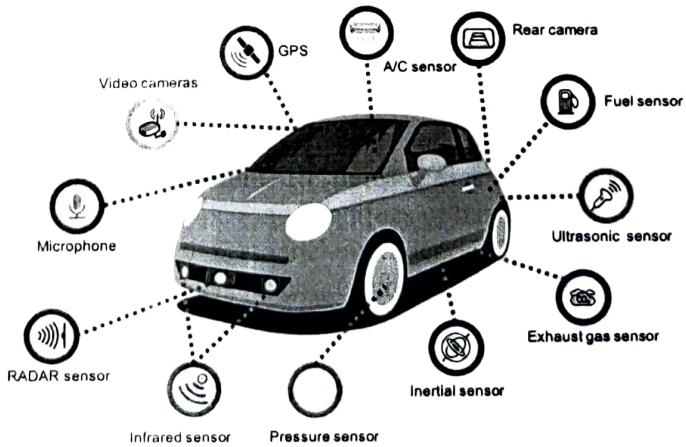
iii. **On-board Safety Monitoring:** This service monitors the driver, vehicle, and cargo and notify the driver, carrier, and, also to the enforcement personnel, if an unsafe situation arises during operation of the vehicle. This is user service also assures freight container, trailer, and commercial vehicle integrity by monitoring on-board sensors for a breach or tamper event.

iv. **Commercial Vehicle Administrative Processes:** This service allows carriers to purchase credentials such as fuel use taxes, trip permits, overweight permit, or hazardous material permits automatically. The mileage and fuel reporting and auditing components are provided to the carriers automatically which reduce significant amount of time and paperwork.

v. **Hazardous Materials Incident Response:** This user service provides immediate information regarding the types and quantities of hazardous materials present at incident location to the emergency personnel in order to facilitate a quick and appropriate response. The emergency personnel are informed regarding shipment of any sensitive hazardous materials so that timely action could be taken in case of accidents.

vi. **Freight Mobility:** This service provides information to the drivers, dispatchers, and inter-modal transportation providers, enabling carriers to take advantage of real-time traffic information, as well as vehicle and load location information, to increase productivity.

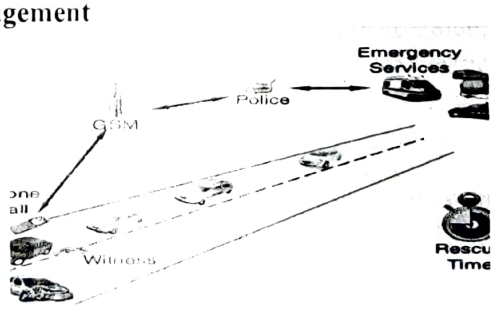
1.3.4 Advanced vehicle control and safety systems



This user service aims to improve the safety of the transportation system by supplementing drivers' abilities to maintain vigilance and control of the vehicle by enhancing the crash avoidance capabilities of vehicles. Following user services are included in this group:

i. **Longitudinal Collision Avoidance**: This user service provides assistance to vehicle operators in avoiding longitudinal collisions to the front and/or rear of the vehicle. This is achieved by implementing rear-end collision warning and control, Adaptive Cruise Control (ACC), head-on collision warning and control, and backing collision warning to the drivers.
ii. **Lateral Collision Avoidance**: This helps drivers in avoiding accidents that result when a vehicle leaves its own lane of travel, by warning drivers and by assuming temporary control of the vehicle. This service provides to the drivers the lane change/blind spot situation display, collision warning control and lane departure warning and control.
iii. **Intersection Collision Avoidance**: This user service is specifically aimed at providing vehicle operators with assistance in avoiding collisions at intersections. The system tracks the position of vehicles within the intersection area through the use of vehicle-to-vehicle communications or vehicle to infrastructure communications.
iv. **Vision Enhancement for Crash Avoidance**: This service helps in reducing the number of vehicle crashes that occur during periods of poor visibility by in vehicle sensors capable of capturing an image of driving environment and providing a graphical display of the image to the drivers.
v. **Safety Readiness**: This helps to provide drivers with warnings regarding their own driving performance, the condition of the vehicle, and the condition of the roadway as sensed from the vehicle.
vi. **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.
vii. **Automated Vehicle Operations (AVO)**: This service provides a fully automated vehicle-highway system in which instrumented vehicles operate on instrumented roadways without operator intervention.

1.3.5 Emergency management

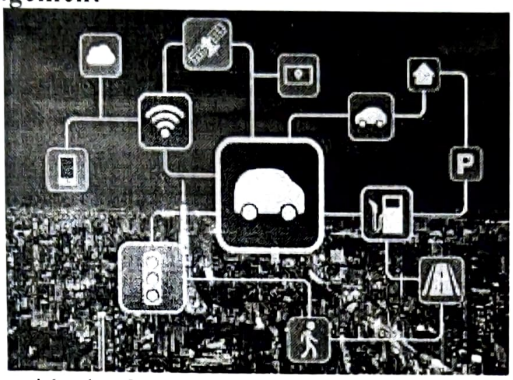


This service has two functions:

- **Emergency notification and personal security** - This is to provide travellers the ability to notify appropriate emergency response personnel regarding the need for assistance due to emergency or non-emergency situations either by manually or automatically from the vehicle on the occurrence of an accident.

- **Emergency vehicle management** - This user service is to reduce the time from the receipt of an emergency notification to the arrival of the emergency vehicles at incident location thereby reducing the severity of accident injuries.

1.3.6 Information management

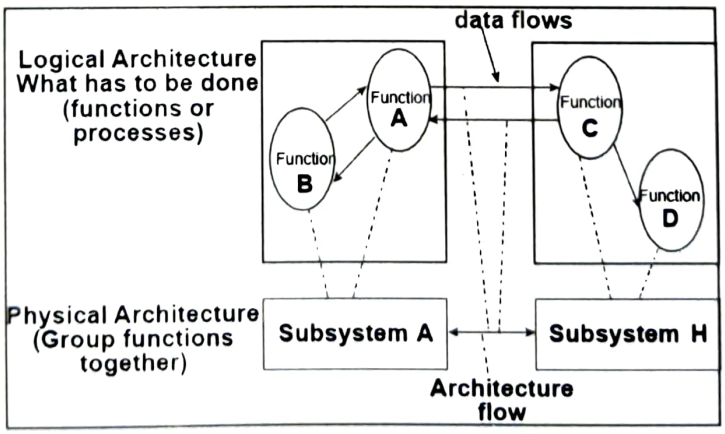


This service is aimed to provide the functionality needed to store and archive the huge amounts of data being collected on a continuous basis by different ITS technologies.

1.3.7 Maintenance and construction management

This user service is aimed to provide the functionality needed for managing the fleets of maintenance vehicles, managing the roadway with regards to construction and maintenance and safe roadway operations.

1.4 ITS Architecture

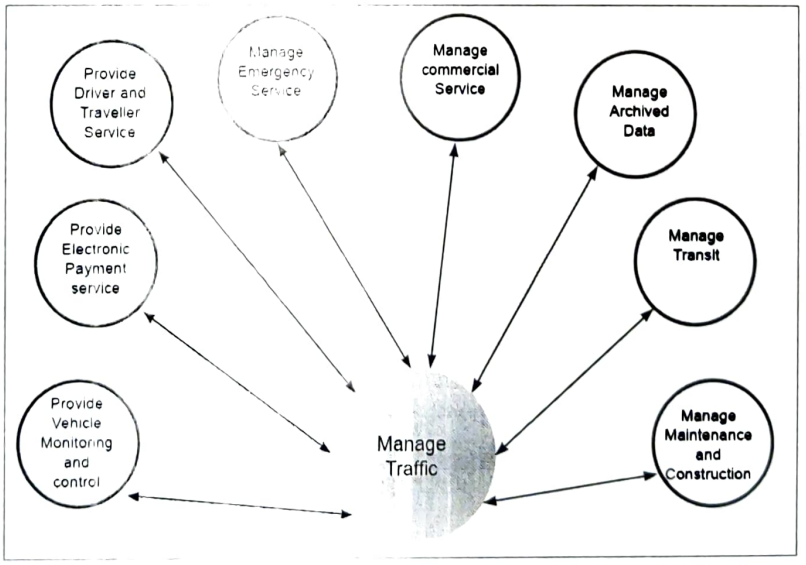


An ITS architecture is the framework inside which a system of ITS projects is designed. It defines the components of the system and therefore it allows interconnections and information flow between the elements. The first parts of ITS architecture are subsystems and information flows.

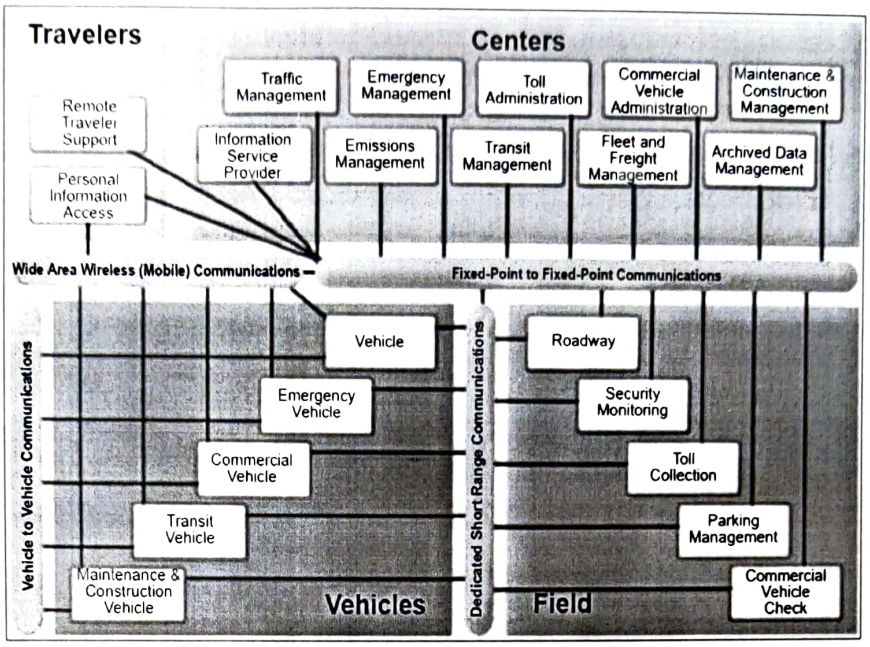
- **Subsystems:** Subsystems are individual items of the general ITS that perform specific functions like managing traffic, providing traveller's information, or responding to emergencies. Subsystems can be related to explicit organizations like public safety agencies, transportation services, emergency management agencies, or transit providers. They are the sources and/or users of knowledge provided by different subsystems inside the boundary of ITS architecture.
- **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. Both logical and physical architectures form the core of ITS.

i. **Logical Architecture:** Figure 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). These p-specs are needed to be performed to meet the necessities of user services.



ii. **Physical Architecture:** 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. Figure shows the subsystems and communications that comprise the physical architecture.



An ITS Architecture is important for a number of reasons:

- it ensures an open market for services and equipment, because there are "standard" interfaces between components;
- an open market permits economies of scale in production and distribution, thus reducing the price of products and services;
- it ensures consistency of information delivered to end-users;
- it encourages investment in ITS since compatibility is ensured;
- it ensures inter-operability between components, even when they are produced by different manufacturers;
- it permits an appropriate level of technology independence and allows new technologies to be incorporated easily;
- it provides the basis for a common understanding of the purpose and functions of the ITS, thus avoiding conflicting assumptions.

1.5 Technologies used in ITS

The following are the various types of advanced technologies used in ITS:

i. **Global Positioning System (GPS):** Embedded GPS receivers in vehicles' on-board units (a common term for telematics devices) receive signals from several different satellites to calculate the device's position. This requires line of sight to satellites, which can inhibit use of GPS in downtown settings due to "urban canyon" effects. Location can usually be determined to within ten meters. GPS is the core technology behind many in-vehicle navigation and route guidance systems.

ii. **Dedicated-Short Range Communications (DSRC):** DSRC is a short- to medium-range wireless communication channel, operating in the 5.8 or 5.9GHz wireless spectrum, specifically designed for automotive uses. Critically, DSRC enables two-way wireless communications between the vehicle and roadside equipment (RSE). DSRC is a key enabling technology for many intelligent transportation systems, including vehicle-to-infrastructure integration, vehicle-to-vehicle communication, adaptive traffic signal timing, electronic toll collection, congestion charging, electronic road pricing, information provision, etc. DSRC is a subset of radio frequency identification (RFID) technology.

iii. **Wireless Networks:** Similar to technology commonly used for wireless Internet access, wireless networks allow rapid communications between vehicles and the roadside, but have a range of only a few hundred meters. However, this range can be extended by each successive vehicle or roadside node passing information onto the next vehicle or node.

iv. **Mobile Telephony:** ITS applications can transmit information over standard third or fourth generation (3G/4G/5g) mobile telephone networks. Advantages of mobile networks include wide availability in towns and along major roads. However, additional network capacity may be required if vehicles are fitted with this technology, and network operators might need to cover these costs.

v. **Radiowave or Infrared Beacons:** Vehicle Information Communications System (VICS) uses radio wave beacons on expressways and infrared beacons on trunk and arterial roadways to communicate real-time traffic information. VICS uses 5.8GHz DSRC wireless technology.

vi. **Roadside Camera Recognition:** Camera- or tag-based schemes can be used for zone-based congestion charging systems, or for charging on specific roads. Such systems use cameras placed on roadways where drivers enter and exit congestion zones. The cameras use Automatic Number Plate Recognition (ANPR), based on Optical Character Recognition (OCR) technology, to identify vehicle license plates; this information is passed digitally to back-office servers, which assess and post charges to drivers for their use of roadways within the congestion zone.

1.6 Data collection techniques

Real time observation and strategic planning needs precise, extensive and prompt data collection through verified hardware and competent software, that lays the foundation of further ITS functions.The overall application of ITS consist of data

collection analysis, and using the results of the analysis in the operations, control and research concepts for traffic management. The following are the various data collection methods used in ITS:

i. **Detector:** Over the last decade, sensor technology has become ubiquitous and has attracted a lot of attention. In transportation, sensor technology supports the design and development of a wide range of applications for traffic control, safety, and entertainment. In recent years, sensors, and actuators such as tire pressure sensor and rear-view visibility systems have become mandatory. Other sensors are optionally installed by manufacturers to monitor the performance and status of the vehicle, provide higher efficiency and assistance for drivers. Currently, the average number of sensors in a vehicle is around 60–100, but as vehicles become "smarter", the number of sensors might reach as many as 200 sensors per vehicle. Classification of three categories of sensors based on the place of deployment in the vehicle:
    - powertrain,
    - chassis, and
    - body.

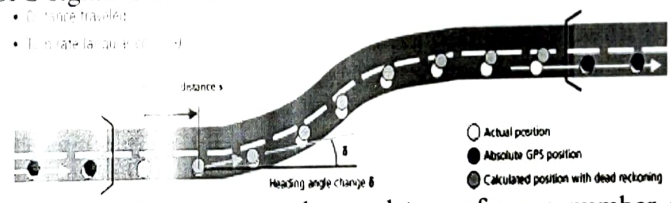
    Another classification of sensors in a vehicle based on the type of application as described below

Category of Sensors	Description	Example
Safety	Form the basis of safety systems and focus on recognizing accident hazards and events almost in real- time.	Micro-mechanical oscillators, speed sensors, cameras, radars and laser beams, inertial sensors, ultrasonic sensors, proximity sensors, night vision sensors.
Diagnostic	Focus on gathering data for providing real-time information about status and performance of the vehicle for detecting any malfunction of the vehicle.	Position sensor, chemical sensors, temperature sensors, gas composition sensors, pressure sensor, airbag sensor.
Traffic	Monitor the traffic conditions in specific zones, gathering data that improves the traffic management.	Cameras, radars, ultrasonic, proximity.
Assistance	Responsible for gathering data that provide support for comfort and convenience applications.	Fuel composition sensor, humidity sensors, temperature sensors, position sensors, torque sensors, image sensors, rain sensors, fogging prevention sensors, distance sensors.
Environment	Monitor the environment conditions, offering drivers and passengers alert and warning services that are used to enhance their trips.	Pressure sensors, temperature sensors, distance sensors, cameras, weather conditions.
User	Focus on gathering data that support the detection of abnormal health conditions and behavior of the driver that can deteriorate the driver's performance.	Cameras, thermistors, Electrocardiogram (ECG) sensors, Electroencephalogram (EEG). sensors, heart rate sensor.

ii. **Automatic vehicle location:** Automatic Vehicle Location Systems (AVL) are technologies that can be used by transport operators to provide a direct link between vehicles, operation control centres and real-time passenger information systems. These systems allow for real-time tracking of services that provides the ability to improve service efficiency, asset utilisation and customer service. Interface with AVL systems tends to be provided for the driver as part of a driver's console and for the operator at a control centre. The primary navigational technologies utilised in AVL systems include GPS, dead-reckoning systems, station or roadside detectors, sub-surface detector loops and wireless triangulation.

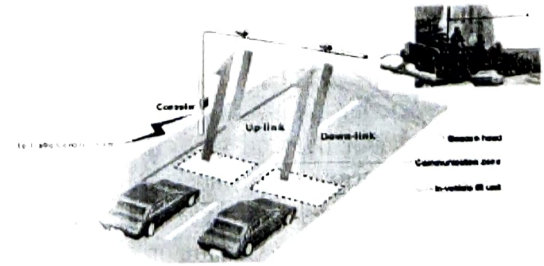
a. **Global Positioning System (GPS)** is a technology that allows receiver devises (GPS receivers) to self-determine their location. This is based on accurate real-time location information from satellite signals for the purposes of navigation.

b. **Dead Reckoning:** The method of using gyroscopes and odometers for vehicle location is termed 'dead-reckoning' and is form of inertial navigation. This navigational method is most commonly used in conjunction with GPS as part of an integrated in-vehicle system, but it could also be used with other vehicle location systems such as roadside detectors. In most cases a dead-reckoning system is used to provide back-up vehicle location information to a GPS system, when the GPS signal is unavailable.



c. **Station or roadside detectors** can be used to perform a number of different functions including access control, priority routing, vehicle tracking, performance monitoring and real-time passenger information. There are a variety of different systems available with different capabilities and levels of complexity.

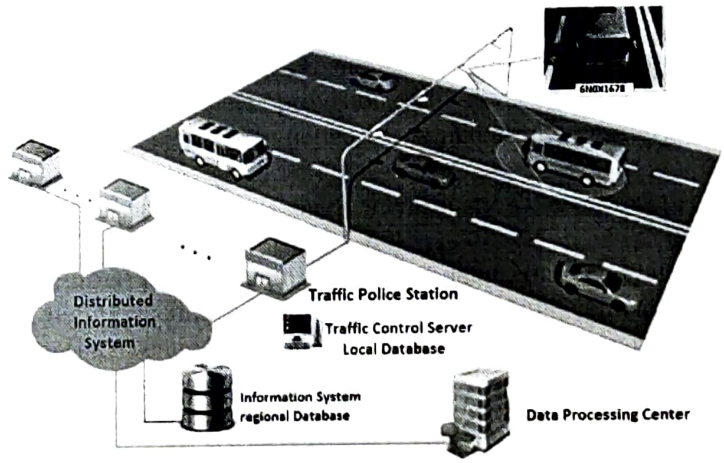
d. **Sub-surface detector loops**, also known as inductive loop detectors, are used to detect the passage of vehicles in a given location. This technology can detect both stationary and moving vehicles and can be installed across single or multiple lanes of traffic. A range of outputs are possible from the system depending on its complexity and integration with other systems, including the number of vehicles passing, vehicle speed and junction control.



e. **Wireless triangulation** is a Wi-Fi based technology that aims to pinpoint vehicle/user location more accurately than GPS technology. This technology is particularly suited to use in dense urban areas where GPS may not perform well in terms of consistent service provision. This system is dependent on the availability of multiple wireless networks, which is increasingly a feature of urban areas.

iii. **Automatic vehicle identification:** The Vehicle Identification cluster has two associated Technology types:

a. **Automatic number plate recognition:** Automatic Number Plate Recognition (ANPR) is a highly accurate system capable of reading vehicle number plates without human intervention through the use of high speed image capture with supporting illumination, detection of characters within the images provided, verification of the character sequences as being those from a vehicle license plate, character recognition to convert image to text; so ending up with a set of metadata that identifies an image containing a vehicle license plate and the associated decoded text of that plate.

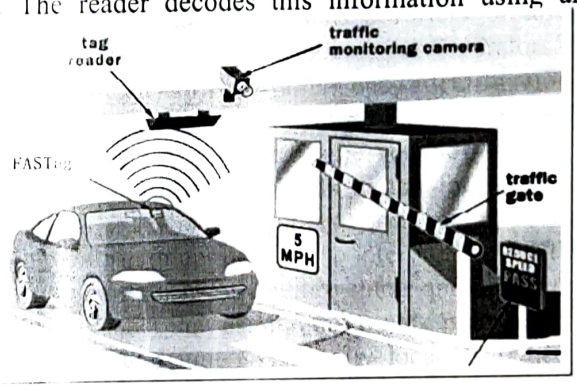


ANPR is therefore the underlying technology used to find a vehicle license/number plate and it, in turn, supplies this information to a next stage of computer processing through which the information can be interpreted, stored or matched to create an ANPR based application. Examples of this are the use of ANPR in:

- Car Park Management
- Journey Time Analysis
- Traffic Management
- Retail Park Security
- Weighbridges
- Tolling
- Bus Lane Enforcement

ANPR is a technological tool, which is used in providing assistance to the enforcement of the law as well ensuring the continued safety of all road users.

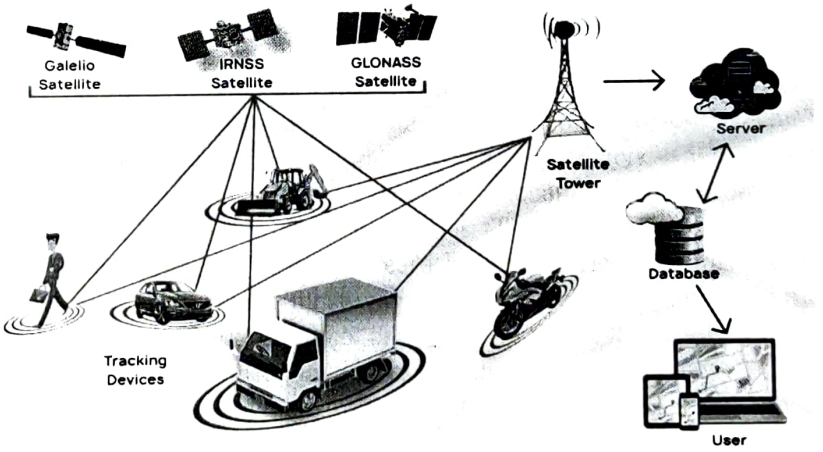
b. Vehicle intelligent tag/transponder: There is a variety of different vehicle intelligent tag transponder types available to transport operators, but these all generally fall under the category of Radio Frequency Identification (RFID) tags which are very similar technology to smartcards. This technology is primarily used for access control and to provide real-time vehicle location information. The system consists of hardware components in the form of the RFID tags themselves, roadside RFID readers/transmitters and a central computer system, as well as software in the form of applications to interpret the RFID information. In this system RFID tags can be encoded with vehicle and/or driver information which is read by an RFID reader unit using radio waves, potentially from several metres away. The RFID reader unit is generally located at the roadside, for example at a bus stop, or at an access point, such as a restricted access road with an electronic gate. The reader unit continuously emits a radio signal of a specific frequency, and when a recognised RFID tag comes into range the encoded information on the tag is transmitted via the radio signal to the reader in an encrypted format. The reader decodes this information using an embedded processing unit.



In access control applications, the reader may hold information relating to allowed vehicles and provide access based on this. In other systems, where RFID technology is used to provide vehicle location information, the roadside reader unit also includes an embedded wireless radio transmission device, typically a GPRS device, to transmit vehicle information, stop number and a time and date stamp to a central location such as a control centre. This type of system may also operate in an alternative way with the RFID tag located at the stop and the reader unit located on-board the vehicle. Whichever way the system is implemented, once the data is received at the control centre it is interpreted using a software application on the central computer system. This software can match the stop number to a predefined GPS stop location to determine real-time vehicle location information. This data can be used to provide real-time passenger information (RTPI) using estimated time of arrival information based on route distance and average vehicle speed. However, because this system does not continuously track vehicles, accurate speed information is not available and congestion cannot be detected, and this may result in RTPI inaccuracies.

iv. **Geographic information system:** Global Positioning System (GPS) is a technology that allows receiver devices to self-determine their location. This is based on accurate real-time location information from satellite signals for the purposes of navigation. The system is developed and operated by the United States Government, having been originally developed for military purposes by the Department of Defence. It was made available for public use in 1991. In the context of transportation, GPS technology is primarily used to support the maximisation of service efficiency and performance, through the provision of accurate vehicle and route location information to both in-vehicle and external ITS devices and applications. The GPS receiver can be a free-standing device, or it can be an embedded card in other devices such as the on-board computer. Currently, it is by far the most widely utilised technology for the purposes of automatic vehicle location.The technology operates using three key segments:

- Satellites, of which there are 27 orbiting the earth twice a day.
- Monitoring stations, which are located at various points across the world and are used to monitor the satellites, to correct errors and to update the satellites navigational message.
- A GPS receiver, which is the device providing user access to the system.



GPS requires signals from a minimum of three satellites to determine the position of a given GPS receiver. Signals are sent out continuously by each satellite. The signals contain information relating to the location of the satellite and the time at which the signal was sent. The GPS receiver compares the time the satellite signal was received to the time that it was sent, to determine the receiver distance from that satellite. By calculating this distance for a minimum of three satellites, the receiver position can be found. The basic system is accurate to approximately 15 metres. Generally, the location information from GPS equipped vehicles is transferred to an operations control centre or other system via dedicated wireless networks (cellular networks, satellite or terrestrial radio). Location information can be displayed on board the vehicle and to the transport user via internet, smartphones, SMS or on information displays at transport stops in various formats and in real-time.

v. **Video data collection:** Many of today's ITS systems already make use of the advantages of video-based data acquisition. While these solutions only represent a small part of all sensor systems used in ITS, it is important to understand their working principles, main advantages and shortcomings. In the following subchapters more details are presented on the current use-cases of video sensors, by sorting them into different groups of applications and focusing on the common technologies used in these groups.

a. **Traffic analysis:** Current application in traffic engineering is the acquisition and offline analysis of traffic data in order to provide valuable information for planning new roads, to increase the capacity of the already used infrastructure and to increase the safety of road users by fast detection of incidents.

- **Automatic Incident Detection (AID):** The application of incident detection is of great importance in video sensor technology as it specifically focuses the safety of road users. The goal of this technological solution is the automatic detection of dangerous traffic situations such as the presence of a vehicle driving in opposite direction, slowly moving or stopped vehicles.
- **Traffic count:** In order to be able to effectively plan and manage road infrastructure, a large quantity of traffic data is required. Currently several different methods exist to gather this data, but in general they all are mobile and flexible solutions due to the fact that the considered locations only need to be analyzed for a short period of time. Thus, the techniques used for data acquisition include mobile radar equipment, floating vehicle data measurement and even manual counting.
- **State recognition**: Another currently considered application covered by video analysis is the traffic state recognition. This application can actually be covered by traffic counting with an additional step of classifying the parameters into traffic state groups like congestion, slow traffic and dense traffic.

b. **Traffic management:** Additionally, to collecting traffic data for offline analysis and post-measurement management decisions, many of today's applications are online systems which are used to make fast decisions. Examples are conferring right to hard shoulder use, or to make hardware in the loop-based management systems possible, like adaptive traffic lights, which consider the presence of vehicles in the crossing

- **Temporary hard shoulder use**: In many countries, freeway traffic capacity is limited and dense traffic is already overburdening traffic infrastructure. In order to cope with this issue, the hard shoulder lane is often used in order to increase capacity of the freeway. The main problem with making use of hard shoulder is ensuring that no objects are present on the lane, so that safety of road users can be guaranteed. Video detection systems are currently implemented at some of these locations to provide useful information about the state of the hard shoulder lane. This helps operators in their decision by

not only ensuring a better detection of dangerous objects on the freeway but also shortening the decision time.

- **Closed loop sensor systems**: Another efficient way of using video sensor systems is the online use of sensor data to control other actuators of ITS systems. One example of such solutions are adaptive traffic lights, which do not behave periodically just based on the pre-programmed traffic light phases but also react to other parameters like the presence of vehicles, their number and also time period of vehicles being stopped at the intersection. Few information about video-based solutions is based on thermal imaging or loop-detectors.
- **Access control**: A parking lot monitoring and management system using ANPR to identify vehicles. This system helps to overcome manual work like controlling the authorization for reserved parking, monitoring vehicle damaging and vehicle parking lot retrieval.

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Note: Refer Textbooks.