INTELLIGENT TRANSPORATION SYSTEM

MODULE 1

OVERVIEW

Intelligent Transportation Systems (ITS) is the application of computer, electronics, and communication technologies and management strategies in an integrated manner to provide traveller information to increase the safety and efficiency of the road transportation systems. This paper mainly describes ITS user services, ITS architecture and ITS planning. The various user services offered by ITS have been divided in eight groups have been briefly described. The ITS architecture which provides a common framework for planning, defining, and integrating intelligent transportation systems is briefly described emphasizing logical and physical architecture

1.1 INTRODUCTION TO ITS

ITS (Intelligent Transportation Systems) has been defined as a combination of leading-edge information and communication technologies used in transportation and traffic management systems to improve the safety, efficiency, and sustainability of transportation networks, to reduce traffic congestion and to enhance drivers' experiences. ITS is an advanced application which aims to provide innovative services relating to different modes of transport and traffic management thus enabling users to be better informed and make safer, more coordinated, and 'smarter' use of transport networks.

Additionally, ITS is an integrated set of technologies, communication systems, and management strategies designed to improve the efficiency, effectiveness, safety, and sustainability of transportation networks. It encompasses a wide range of applications and solutions aimed at addressing the contemporary challenges associated with transportation in urban and rural areas.

1.2 Basic Elements of Intelligent Transportation Systems (ITS)

1. Technological Aspects

2. Systems Aspects

3. Institutional Aspects

1.2.1. **TECHNOLOGICAL ASPECTS**

- Sensing and Detection Technologies:
- Communication Systems:
- Data Processing and Analytics:
- Control Systems
- Human-Machine Interfaces:
- User Interfaces and Information Systems
- Safety and Security Systems

- Autonomous and Connected Vehicles
- Sustainable Transport Technologies

1.2.1.1 Sensing and Detection Technologies

These include various sensors and detectors that monitor traffic conditions, vehicle speeds, and environmental factors. Examples include inductive loop sensors, radar, and LIDAR.

- Traffic Sensors: Measure real-time traffic data, including vehicle speed, density, and flow. Examples include inductive loops, radar, and infrared sensors.
- Environmental Sensors: Monitor weather conditions (rain, fog, etc.) and road surface conditions to inform traffic management systems.
- Surveillance Cameras: Monitor traffic flow, incidents, and security concerns.
- Vehicle Detection Systems (VDS): Detect the presence of vehicles to optimize signal timing and traffic flow**.**

1.2.1.2 Communication Systems

ITS relies heavily on robust communication systems for real-time data exchange between vehicles, infrastructure, and control centers. This includes wireless communication, GPS, and dedicated short-range communications (DSRC).

- Vehicle-to-Vehicle (V2V) Communication: Enables vehicles to exchange information (like speed, location, and direction) to prevent collisions and improve traffic flow.
- Vehicle-to-Infrastructure (V2I) Communication: Vehicles communicate with road infrastructure (e.g., traffic signals, toll booths) for smoother operations and safety enhancements.
- Dedicated Short Range Communication (DSRC): A key wireless technology used for V2V and V2I communications.
- 5G and Cellular Networks: High-speed data transmission for real-time communication between vehicles and control centers

V2I technology allows vehicles to communicate with roadside infrastructure, such as traffic signals and road sensors. This enables traffic management systems to provide real-time information to vehicles and receive data from them to optimize traffic flow. The Connected and Autonomous Vehicles (CAVs) enable vehicles to use sensors, communication systems, and AI algorithms to navigate safely and efficiently. ITS infrastructure can support CAVs by providing essential data and connectivity.

Vehicle-to-everything communication (V2X) is crucial in successful implementation of an ITS system. V2X refers to the communication between vehicles and any entity that impacts, or may be impacted by, the vehicle. This includes vehicle-to-vehicle communication (V2V), vehicle-to-infrastructure communication (V2I), vehicle-to-pedestrians communication (V2P), and vehicle-to-network communication (V2N). These are part of a system that works to improve road safety and traffic conditions. As a key enabler of ITS, V2X is linked to several co-existing benefits such as an improved exchange of safety-critical information, the ability for drivers to make more informed decisions, optimization of the performance of a transportation system, and reduced consumption of fuel.

1.2.1.3 Data Processing and Analytics

ITS systems use advanced algorithms and machine learning to process and analyze large volumes of data, enabling real-time decision-making and predictive analytics.

- **Traffic Management Centers (TMCs):** Centralized systems that gather, analyze, and manage real-time traffic data to optimize traffic flow and incident response.
- **Big Data Analytics:** Analyzes large amounts of traffic data to predict patterns, optimize routes, and reduce congestion.
- **Cloud Computing:** Provides scalable data storage and processing for real-time transportation management

1.2.1.4 Control Systems

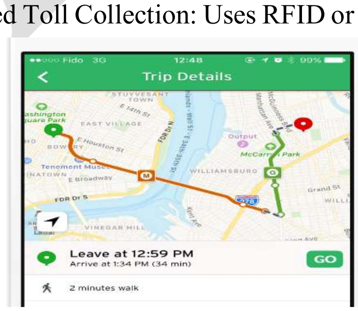
- Adaptive Traffic Signals: Adjust signal timing based on real-time traffic conditions to reduce congestion and improve traffic flow.
- Ramp Metering: Controls the rate of vehicles entering highways to prevent bottlenecks.
- Dynamic Message Signs (DMS): Display real-time information such as traffic conditions, accidents, and weather warnings to drivers.
- Autonomous Vehicle Systems: Uses AI, sensors, and control systems to allow vehicles to navigate without human intervention.

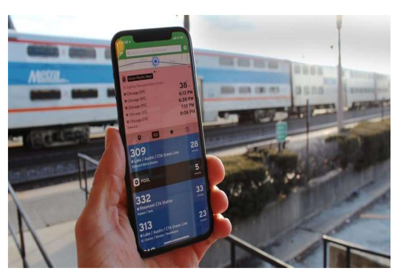
1.2.1.5 Human-Machine Interfaces

- Interfaces that allow communication between users and the ITS, such as in-vehicle displays, mobile apps, and traffic management centers.
- Control Systems:

1.2.1.6 User Interfaces and Information Systems

- Traveller Information Systems: Provide real-time information to drivers via apps, websites, or onboard systems (e.g., GPS navigation) about traffic conditions, road incidents, and optimal routes.
- Smartphone Applications: Integrated apps for real-time navigation, public transit tracking, and shared mobility options.
- Automated Toll Collection: Uses RFID or other sensors to automatically charge tolls without stopping





1.2.1.7 Safety and Security Systems

- Incident Detection and Management Systems: Automatically detect accidents or other road incidents and dispatch emergency services while informing other drivers.
- Collision Avoidance Systems: Uses sensors and V2V communication to warn or prevent vehicles from colliding.
- Emergency Notification Systems: Provide quick response capabilities by alerting authorities during crashes or breakdowns

1.2.1.8 Autonomous and Connected Vehicles

- Advanced Driver Assistance Systems (ADAS): Technologies like adaptive cruise control, lane departure warning, and automatic emergency braking improve vehicle safety.
- Self-driving Vehicles: Autonomous cars use sensors, AI, and communication systems to navigate without human drivers, integrating with ITS for traffic optimization.

1.2.1.9 Sustainable Transport Technologies

- Electric Vehicle (EV) Charging Stations: Integrated into transportation networks, often with real-time data available on availability and location.
- Eco-Driving Assistance: Systems that help drivers optimize fuel efficiency through real-time feedback on driving habits.

1.2.2. **SYSTEMS ASPECTS**

1.2.2.1 Traffic Management Systems:

These systems manage and control traffic flow, including traffic signals, ramp metering, and dynamic message signs. The sensors and cameras are used to collect real-time data on traffic conditions, such as speed, volume, and congestion. This data is then used to optimize traffic flow and reduce congestion.

- **Integrated Traffic Control:** Centralized or distributed systems that monitor and control the flow of traffic in real-time. They coordinate traffic signals, freeway ramp meters, and dynamic message signs based on real-time data.
- **Incident Management Systems:** Detect accidents or breakdowns and coordinate the appropriate emergency response, while updating other drivers to reduce secondary incidents.
- **Congestion Management:** Systems that monitor traffic density and implement congestion-reduction strategies such as dynamic lane management, congestion pricing, and alternative routing.

1.2.2.2 Public Transportation Management:

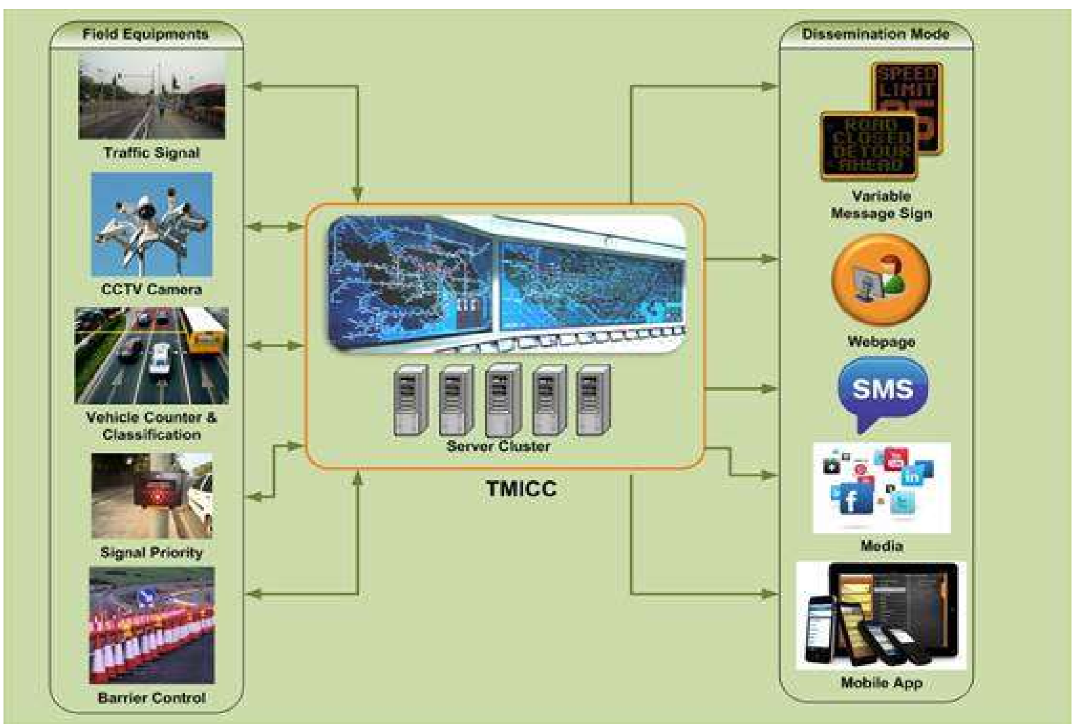
ITS enhances public transit systems through real-time tracking, scheduling, and passenger information systems. ITS technologies can be used to improve the efficiency and reliability of public transportation systems. For example, real-time information on bus and train arrival times can help passengers to plan their trips more effectively

- **Real-Time Transit Monitoring:** Provides real-time updates on bus or train locations, expected arrival times, and any delays, making public transportation more reliable and efficient.
- **Transit Signal Priority (TSP):** Gives buses or trains priority at traffic signals to improve transit times and service reliability.
- **Fleet Management:** Systems that manage public transportation fleets, optimizing vehicle assignments, routes, and schedules based on real-time data.

1.2.2.3 Traveller Information Systems:

These systems provide real-time information to travellers regarding traffic conditions, travel times, and alternate routes. The systems provide travellers with real-time information on traffic conditions, public transportation schedules, and other relevant information. This information can help travellers to make better travel decisions and avoid congestion.

- **Real-time Information Dissemination:** Provides current traffic, road, and weather conditions to travellers through apps, websites, message boards, and radio systems.
- **Route Guidance:** Offers dynamic navigation that adapts to changing traffic conditions, giving users optimized routes.
- **Multimodal Travel Information:** Displays integrated travel options across multiple modes (cars, buses, trains, bikes), supporting seamless transitions between them.



1.2.2.4 Automated vehicle systems:

These systems use sensors and artificial intelligence to enable vehicles to drive themselves or to communicate with each other and with the road infrastructure. This can help to improve safety and efficiency

- **Autonomous Vehicle Support:** Infrastructure systems to support autonomous driving, including vehicle-to-infrastructure (V2I) communication and dedicated lanes for autonomous vehicles.
- **Vehicle Platooning:** A system where groups of vehicles travel together in a convoy, closely spaced to reduce drag and improve road capacity, with minimal driver intervention.
- **Driver Assistance Systems (ADAS):** Vehicle systems integrated with ITS for functions like automated braking, lane keeping, and collision avoidance, improving driver safety and efficiency

1.2.2.5 Incident Management Systems:

ITS systems use sensors, cameras, and algorithms to detect and respond to incidents such as accidents, breakdowns, and road hazards. Rapid incident management helps improve safety and minimize traffic disruptions. In Environmental Monitoring, ITS can monitor air quality, noise levels, and other environmental factors related to transportation. This information can be used to implement strategies for reducing emissions and mitigating environmental impacts

1.2.2.6 Electronic Payment Systems:

Examples include electronic toll collection (ETC) and contactless payment systems for public transit.

- **Electronic Toll Collection (ETC):** Automates toll payments via RFID or other contactless systems, improving traffic flow at toll points without requiring vehicles to stop.
- **Congestion Pricing Systems:** Dynamically charge tolls based on the time of day or the level of traffic congestion, encouraging off-peak travel and reducing congestion.
- **Smart Parking Systems:** Monitor parking availability and allow for automatic fee payment, reducing the need for manual intervention and improving space utilization.

1.2.2.6 Safety and Emergency Systems

- **Automated Incident Detection (AID):** Systems that detect traffic incidents, stalled vehicles, or accidents automatically, triggering an immediate response.
- **Emergency Vehicle Presumption:** Traffic signals that can detect approaching emergency vehicles and give them priority at intersections, speeding up response times.
- **Road Weather Management Systems:** Monitor and predict road conditions due to weather (ice, snow, fog) and automatically alert drivers, reroute traffic, or activate safety measures like reduced speed limits.

1.2.3. INSTITUTIONAL ASPECTS

1.2.3.1 Policy and Regulatory Framework:

ITS implementation requires supportive policies and regulations that address issues such as data privacy, interoperability, and standards.

- **Legislation and Policy Development:** Establishes the legal framework for the deployment of ITS. This includes regulations related to privacy, data sharing, autonomous vehicles, communication standards, and environmental impact.
- **Standards and Protocols:** Ensures interoperability between systems and devices, promoting uniformity across different jurisdictions and vendors. Standardization is key for seamless communication between systems (e.g., V2V, V2I).
- **Safety and Security Regulations:** Develops policies related to public safety and cybersecurity for ITS, including standards for protecting transportation infrastructure from cyber threats.
- **Data Privacy and Management:** Creates laws and policies that protect the privacy of personal and travel data collected through ITS systems, balancing data usage with privacy concerns.

1.2.3.2 Funding and Investment:

Adequate funding from government and private sectors is crucial for the development and maintenance of ITS infrastructure

- **Government Funding:** National, regional, and local governments often provide the financial backbone for ITS projects. This includes investments in infrastructure, research and development, and operational support.
- **Private Investment:** Through public-private partnerships or private initiatives, private companies may contribute financially, especially in areas such as toll collection systems, autonomous vehicle development, or infrastructure technologies.
- **Grants and Incentives:** Governments may offer grants, tax incentives, or subsidies to foster innovation, research, and development in the ITS field, and to encourage the
- adoption of ITS solutions by municipalities and businesses.
- **User-Pay Models:** Implementing revenue models such as congestion pricing, electronic toll collection, or smart parking fees to fund ITS projects, ensuring sustainable financial resources over time.

1.2.3.3 Collaboration and Partnerships (Interagency Coordination):

Successful ITS deployment often involves collaboration among multiple stakeholders, including government agencies, private companies, and research institutions.

- **Collaboration Among Agencies:** ITS requires cooperation between multiple government entities such as transportation departments, public safety agencies, city planners, law enforcement, and emergency services. A clear governance structure facilitates decision-making and resource sharing.
- **Cross-Border Collaboration:** For regional or national ITS systems to function, coordination between different jurisdictions (e.g., neighbouring states or countries) is essential. For example, toll systems, traffic management, and emergency response should be aligned across borders.
- **Public-Private Partnerships (PPP):** Encourages collaboration between government agencies and private entities (such as technology companies, vehicle manufacturers, and infrastructure providers) to leverage resources, expertise, and innovations.

1.2.3.4 Public Awareness and Education:

Educating the public and stakeholders about the benefits and use of ITS technologies is essential for widespread adoption

- **Public Engagement and Awareness:** Institutional efforts must include public outreach programs to inform and educate the public on the benefits and implications of ITS. This helps build public trust and ensures that users understand how to interact with new systems, such as autonomous vehicles or electronic tolling.

- **Private Sector Collaboration:** Key players in the private sector, including automakers, technology companies, telecommunications providers, and infrastructure firms, must be engaged to ensure that the technology is implemented effectively and evolves with market needs.
- **Academic and Research Institutions:** Collaboration with universities and research bodies helps to foster innovation, pilot new technologies, and provide objective analyses for government and industry stakeholders.

1.2.3.5 Sustainability and Environmental Goals

- **Sustainability Policy Integration:** ITS projects often aim to reduce carbon emissions and encourage the use of electric vehicles, public transport, and sustainable modes of travel. Institutions play a role in aligning ITS with broader environmental policies.
- **Eco-Friendly Incentives:** Encouraging the adoption of eco-driving, electric vehicles, and reduced emissions through policy incentives like tax breaks, rebates, or infrastructure investments.
- **Long-Term Urban Planning:** ITS is integrated into broader urban planning initiatives to ensure the system meets future environmental and sustainability goals.

1.2.3.6 Monitoring, Evaluation, and Feedback

- Performance Monitoring: Institutions establish mechanisms to continuously monitor the performance and effectiveness of ITS systems, including traffic flow, safety improvements, and public satisfaction.
- Evaluation Frameworks: Regular assessments and audits of ITS projects are conducted to evaluate the economic, social, and environmental impact of the technologies. This allows for adjustments and improvements in policies.
- Public Feedback Mechanisms: Institutions must create channels for public feedback, allowing citizens to report issues, suggest improvements, or evaluate the success of ITS implementations.

1.2.3.7 International Collaboration and Standards

- **Global Standards Alignment:** As transportation systems become more global, ITS must adhere to international standards for communication, data transfer, and infrastructure.
- **International Research and Best Practices:** Learning from global ITS deployments helps nations and cities implement systems based on proven success stories and avoid common pitfalls

1.3 BENEFITS OF ITS

Enhanced Traffic Flow:

- ✓ ITS uses real-time data to optimize traffic signals, improve road usage, and reduce congestion.
- ✓ Dynamic traffic management systems can respond to real-time conditions, reducing bottlenecks

Improved Traffic Efficiency:

- ITS optimizes traffic flow, reducing congestion and travel times.
- ITS provides travellers with real-time information about traffic, alternative routes, and travel times, allowing them to plan better.
- Parking assistance systems can help drivers find available parking spots, saving time and reducing frustration.

Enhanced Safety:

- Through real-time monitoring and communication, ITS can reduce accidents and improve response times in case of incidents.
- Collision avoidance systems and early warning alerts help drivers react faster, reducing accidents.
- Technologies such as smart traffic signals and real-time hazard warnings contribute to safer driving environments.

Environmental Benefits:

- ITS can contribute to reduced emissions by optimizing traffic flow and promoting the use of eco-friendly transportation options.
- ITS can decrease fuel consumption by reducing idling and optimizing traffic flow.
- Public transportation systems can be made more efficient, reducing the number of cars on the road and lowering greenhouse gas emissions.

Economic Advantages:

- Reduced travel times and fuel consumption lead to cost savings for both individuals and businesses.
- Reduced fuel consumption and optimized traffic flows lead to lower vehicle operating costs for drivers and transportation agencies.
- Reduced congestion also translates to lower infrastructure maintenance costs.

Increased efficiency in Public Transportation:

- ITS can improve the reliability and efficiency of public transit systems, making them more attractive to users.
- ITS improves public transit schedules by providing real-time updates on bus and train arrivals.
- Passenger information systems make public transportation more reliable and convenient for users.

Better Incident Management

- Real-time monitoring of traffic conditions enables quick detection and management of incidents, such as accidents or breakdowns.
- Emergency services can be dispatched faster and more effectively, reducing response times.

Improved Freight and Logistics

- ITS helps in tracking and managing the movement of goods, making logistics more efficient by reducing delays and improving route planning.

Data Collection and Analytics

- ITS generates valuable data that can be analyzed to improve future transportation planning, policy-making, and system optimization.

1.4 ITS Data Collection Techniques

1.4.1 DETECTORS

Intelligent transportation systems (ITS) use a variety of data collection techniques, including

- Vehicle detection
- Inductive loops
- Video cameras
- Radio-frequency id (rfid) sensors
- Acoustic sensors
- Other Sensors

1.4.1.1 VEHICLE DETECTION

- **FLOATING CAR DATA:**

  This method uses information and communication technology to provide traffic data. In this method the driver tries to float in the traffic stream passing as many vehicles as pass the test car. If the test vehicle overtakes as many vehicles as the test vehicle is passed by, the test vehicles should, with sufficient number of runs, approach the median speed of the traffic movement on the route. In such a test vehicle, one passenger acts as observer while another records duration of delays and the actual elapsed time of passing control points along the route from start to finish of the run.

- **MULTI SENSOR DATA FUSION:**

  This technique combines data from multiple sources to create a better understanding of the situation. Multi-sensor data fusion is the process of combining data from multiple sources to create a unified representation for decision-making. In road transport, multi-sensor data fusion can be used to improve traffic information, estimate vehicle state, and detect sensor failures:

- **Traffic information**
  Multi-sensor data fusion can improve the estimation of traffic state in real-time by reducing uncertainty from individual sources. For example, data from different FCD providers can be fused to improve travel time and average segment speeds estimation.
- **Vehicle state**
  Multi-sensor data fusion can be used to estimate vehicle state in real-time navigation and control. For example, data from onboard sensors can be fused to compensate for GPS errors.
- **Sensor failures**
  Multi-sensor data fusion can detect changes in the extrinsic calibration of the sensors and potential sensor failures. This feature is important for ensuring the functional safety of the sensors for autonomous driving.

  Some advantages of multi-sensor data fusion include: Higher probability of detection, Ambiguity reduction, and Increase in detection accuracy

TRAFFIC CONDITION PREDICTION:

This is a key component of ITS, and can be done using neural networks. Traffic condition prediction is the process of using data analysis and artificial intelligence (AI) to forecast future traffic conditions and patterns. It involves predicting travel time, traffic density, and speed.

Traffic condition prediction is important for**:**

- **Transportation systems**: Improving transportation systems and reducing traffic congestion
- **Public transportation**: Planning public transportation and new infrastructure projects
- **Logistics and transportation**: Estimating times of arrival (ETAs) for fleet management and customer delivery
- **Mobility as a service (MaaS)**: Planning multi-modal transportation routes

REAL-TIME DATA COLLECTION

- Real-time data collection for road transport can be done through a variety of methods, including:
- **Fixed detectors**: These are placed along the road at strategic points to collect information such as traffic flow and vehicle speed.
- **Mobile phones and In-Vehicle GPS**: These can provide accurate real-time information over a large road network.
- **Sensor**s: These can be embedded in the roadway or mounted beside or above it. Intrusive sensors, such as inductive loop detectors, are embedded into the roadway. Nonintrusive sensors, such as radar, infrared, and ultrasonic, are mounted beside or above the roadway.
- ITS collects data from roads in real-time, processes it, and then transmits it to decision-making systems**.**
- **Closed-circuit television (CCTV) cameras**: These can be used to collect real-time traffic data.
- **Traffic management centers**: These can be used to collect real-time traffic data.
- **Mobile apps**: These can be used to collect real-time traffic data.
- **Third-party data providers:** These can be used to collect real-time traffic data.
- **Pneumatic tubes**: These are placed across the roadway and release a burst of air when a vehicle passes over them. This air pressure activates a data logger or sends an electrical signal to traffic counting software

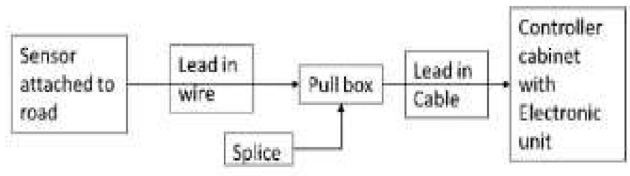
1.4.1.2 Inductive loops

These sensors are embedded in the roadbed and detect vehicles as they pass over them. They can count the number of vehicles, and more sophisticated loops can also estimate the speed, length, and class of vehicles.

Inductive loop detectors are one kind of traffic sensor used to identify the different vehicle classes using the induced current from the loop of a wire which is fixed to the pavement. These are extensively used in highways as they possess very high accuracy and are economical as well.

There are various types of detectors available based on their functionality and usage. They are Pressure type, Push button type, Magnetic, Magnetometer, Inductive loop, radar type, sonic type, radiofrequency type and light emission detectors. Out of all these Inductive loop and magnetometer types are widely used for various purposes.

Inductive Loop Mechanism



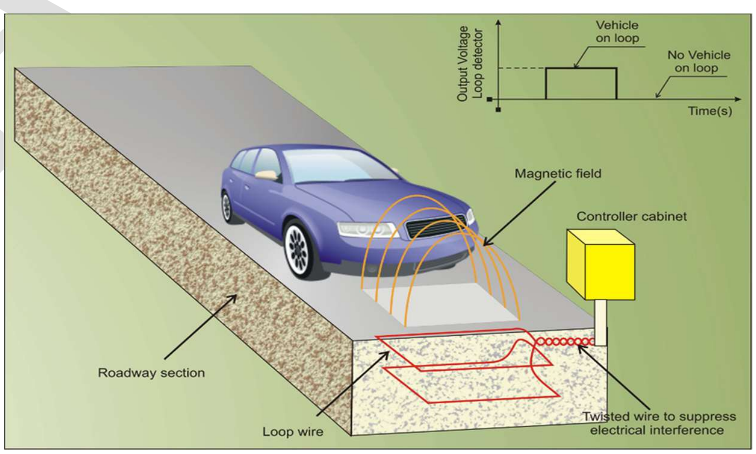
Inductive Loop Mechanism

There are mainly three components for loop detectors that govern the entire mechanism.

- Inductive loop detectors consist of one or more turns of wire in a saw cut slot in the road surface at the area where vehicles will pass and need to be detected.
- The ends of the loop are connected by a cable to an electronic amplifier which is usually placed in the controller cabinet.
- When the vehicle moves over the loop and disturbs the loop magnetic field, this, in turn, is sensed by the amplifier because the loop detector can detect either the presence or passage of the vehicle and it will introduce a new dimension to the traffic control.

Working of Inductive Loop

Inductive loops can be triggered when a heavy metal object or vehicle passes through the loop placed over the pavement. When the vehicle moves over the loop or stops over the loop it will generate a vortex current in the loop and thus decreases its inductance. The reduced inductance activates the electronics element output relay, which sends a current to the controller to inform the presence of a vehicle.



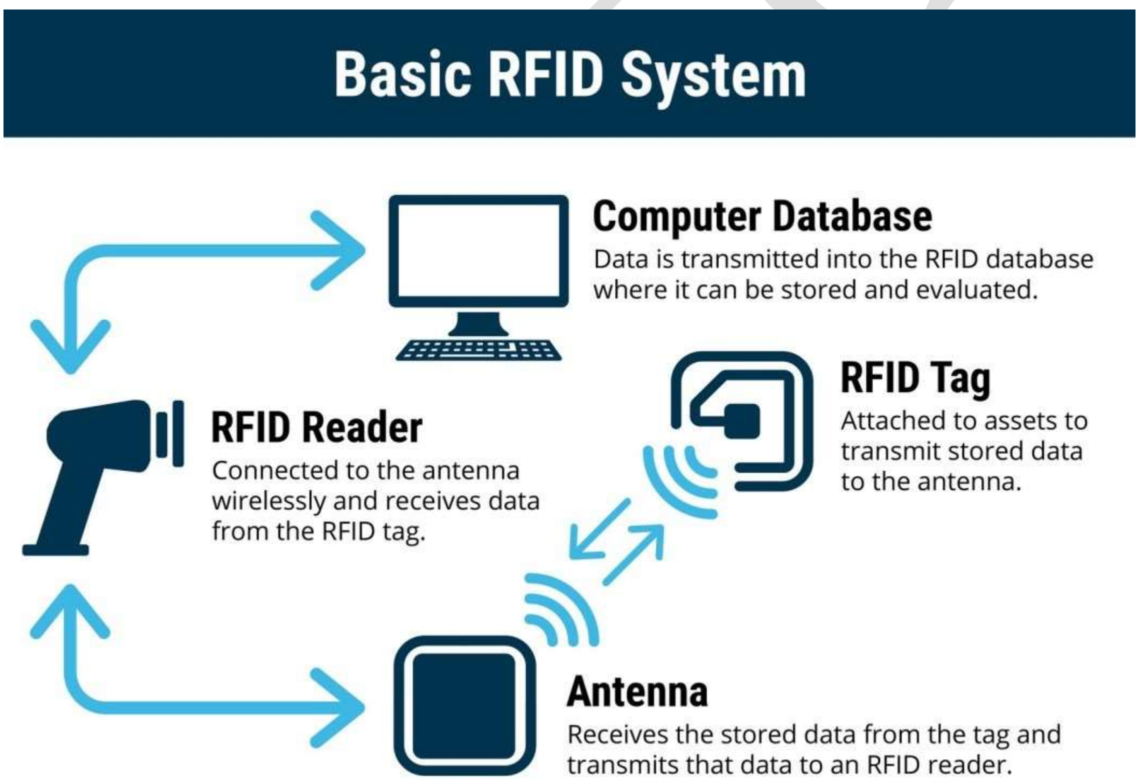
1.4.1.3 Video cameras

These cameras can be mounted on poles above the road and can be used to monitor traffic. Some cameras can be equipped with automatic number plate recognition systems.

1.4.1.4 Radio-frequency id (rfid) sensors

RFID (radio frequency identification) is a form of wireless communication that incorporates the use of electromagnetic or electrostatic coupling in the radio frequency portion of the electromagnetic spectrum to uniquely identify an object, animal or person. These sensors can automatically identify vehicles and collect their data. They can also be used for smart parking.

Radio-Frequency Identification (RFID), a technology that enables data to be transmitted from a micro silicon chip at very fast speeds and without the need for line of sight, as required by barcodes, is an established data-carrying and automatic identification technology used throughout industry.



Every RFID system consists of three components: a scanning antenna, a transceiver and a transponder. When the scanning antenna and transceiver are combined, they are referred to as an RFID reader or interrogator. There are two types of RFID readers -- fixed readers and mobile readers. The RFID reader is a network-connected device that can be portable or permanently attached. It uses radio waves to transmit signals that activate the tag. Once activated, the tag sends a wave back to the antenna, where it is translated into data

The transponder is in the RFID tag itself. The read range for RFID tags varies based on factors including the type of tag, type of reader, RFID frequency and interference in the surrounding environment or from other RFID tags and readers. Tags that have a stronger power source also have a longer read range

There are two main types of RFID tags:

- **Active RFID.** An active RFID tag has its own power source, often a battery.
- **Passive RFID.** A passive RFID tag receives its power from the reading antenna, whose electromagnetic wave induces a current in the RFID tag's antenna.

RFID CHALLENGES

RFID is prone to two main issues:

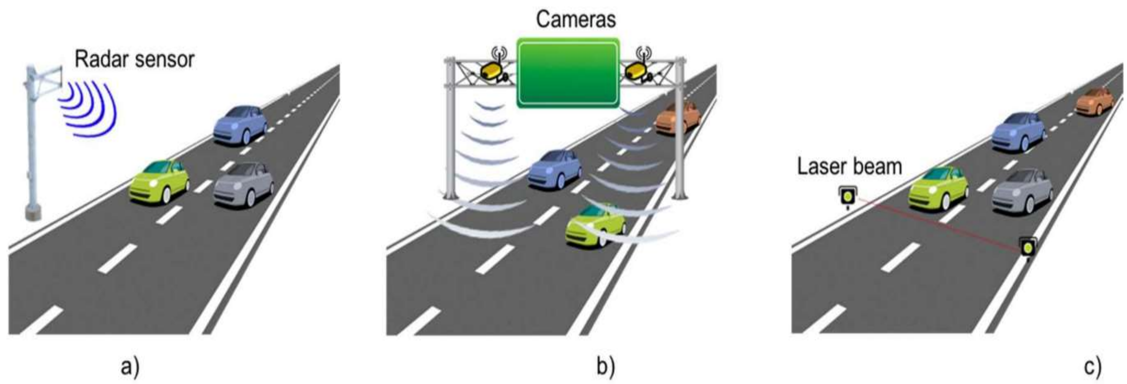
- **Reader collision.** Reader collision, when a signal from one RFID reader interferes with a second reader, can be prevented by using an anti-collision protocol to make RFID tags take turns transmitting to their appropriate reader.
- **Tag collision.** Tag collision occurs when too many tags confuse an RFID reader by transmitting data at the same time. Choosing a reader that gathers tag info one at a time will prevent this issue.

1.4.1.5 Acoustic sensors

These sensors can be used to calculate traffic volume, occupancy, and average vehicle speed.

- Acoustic sensors are used in intelligent transportation systems (ITS) to monitor traffic by analyzing sound waves emitted from vehicles. Here are some ways acoustic sensors are used in ITS:
- Traffic volume, occupancy, and speed: Acoustic sensors can replace magnetic induction loops to calculate these metrics.
- Vehicle classification: Acoustic sensors can be used to classify vehicles.
- Occupancy detection: Acoustic sensors can be used to detect the number of passengers in a vehicle

Acoustic sensors, also known as microphones or sound sensors, work by converting sound waves into electrical signals. They detect variations in air pressure caused by sound and transform those pressure fluctuations into electrical signals.



1.4.1.6 Other Sensors

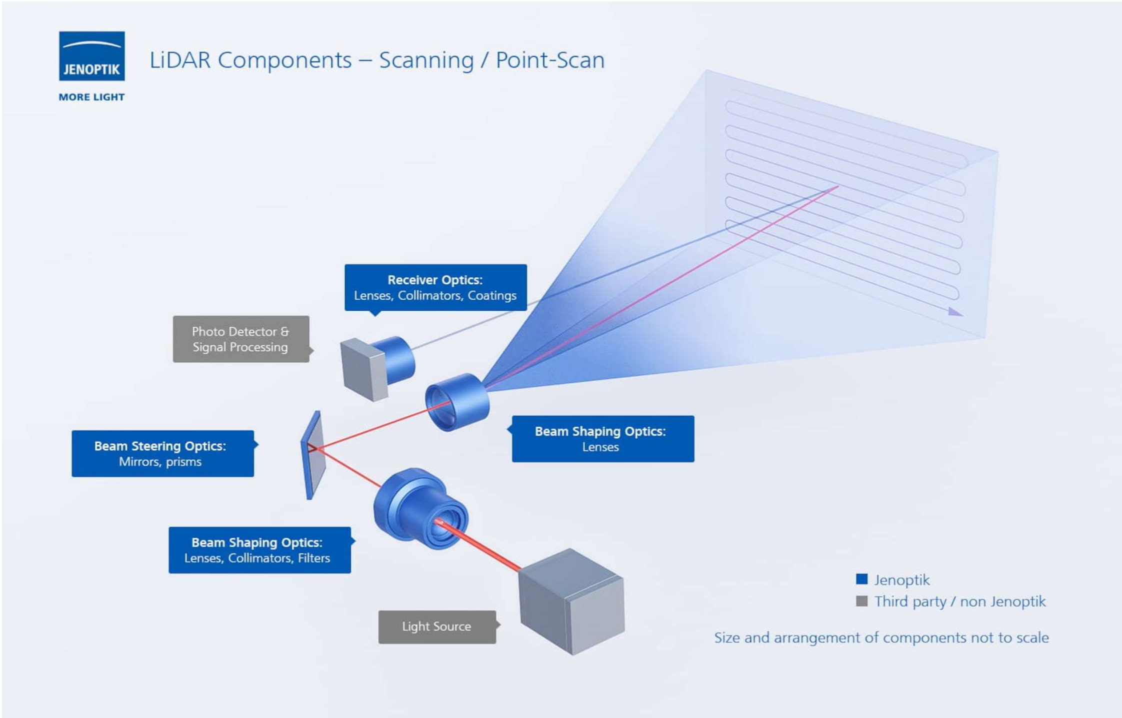
Other types of sensors used in ITS include:

- **RADIO RADARS**

  Radio radars use the Doppler Effect and have a second name - Doppler radars. This radar measures the change in frequency of the signal reflected from the object. By changing the frequency of the signal, the radial velocity of the object (the projection of velocity on the straight line passing through the object and the radar) is calculated. Doppler radars are widely used in various fields: for determining the speed of aircraft, ships, cars, hydrometeor and other objects

- **LASER RADARS**

  Laser radars, as well as radio radars, are used to determine the speed of vehicles. Abbreviation of the name is called as LIDAR. LIDAR is the technology of obtaining and processing the information about remote objects by means of active optical systems utilizing the phenomenon of light reflection and dispersion in transparent and translucent media. LIDAR is significantly smaller than traditional radar, but less reliable in determining the speed of modern cars: reflections from the inclined plane of complex shape distorted signal to the receiver LIDAR



- **PHOTO RADARS**:
  Photo radar has a number of opportunities for the registration of moving vehicles. This is the best method for measuring traffic flows and speeds. This type of radar can store information in some cases to pass this information via radio to a remote mobile post. There are problems with taking pictures at night, but the problem is solved by using infrared illumination.

- **PRESSURE SENSORS**:
  Pressure sensors are composed of two screw elements, which are separated by some distance. Once the transport front wheels crossed the first push element, the receiver gives the signal of start of timer. Once the front wheels reached the second transport screw element, the receiver command is ending the countdown. At the time and known a certain distance between sensors it is simply to calculate the values of a passing transport. It may be the speed, quantity and direction

- **ROAD SURFACE CONDITION SENSORS**
  These sensors use laser and infrared technologies to read road conditions, such as temperature and grip.

  Sensors are a key component of ITS, providing the data needed to operate the system. They are used to collect information about traffic conditions, which can then be used to improve transportation conditions

1.4.2 AUTOMATIC VEHICLE LOCATION (AVL)

1.4.2.1 Automatic vehicle location is a means for determining the geographic location of a vehicle and transmitting this information to a point where it can be used.
Most commonly, the location is determined using GPS and the transmission mechanism is a satellite, terrestrial radio or cellular connection from the vehicle to a radio receiver, satellite or nearby cell tower.
The tracking data is then transmitted using any one of a variety of telemetry systems. GSM and EVDO are the most common technologies used for telemetry because of the low data rate needed for AVL. The low bandwidth requirements also allow for satellite technology to receive telemetry data at a moderately higher cost, but across a global coverage area and into very remote locations not well-covered by terrestrial radio or public carriers
An automatic vehicle location (AVL) system uses GPS and telecommunication systems to track and monitor vehicles in real time. AVL systems can be used for a variety of purposes, including:

- Law enforcement: AVL systems can be used by law enforcement to discreetly track and monitor vehicles, reporting information such as location, speed, and stops.
- Bus transportation: AVL systems can provide real-time tracking of bus movement, which can be used to improve bus operations and provide passengers with expected arrival times.
- Fleet management: AVL systems can provide instant visibility into the whereabouts of each vehicle, which can help improve fleet management.
- Emergency response: AVL systems can help transport providers and authorities locate vehicles in case of an emergency.

Automatic vehicle location(AVL) is a powerful tool for managing fleets

Vehicles such as service vehicles, emergency vehicles, and construction equipment and public transport vehicles (buses and trains) are all using automatic vehicle location (AVL) systems or GPS tracking systems. It also is used to track mobile remote assets such as construction equipment, trailers, and portable power generators.

1.4.2.2 TYPES OF AVL SYSTEMS

- **DIRECTION FINDING**

  Amateur radio and some cellular or PCS wireless systems use direction finding or triangulation of transmitter signals radiated by the mobile. This is sometimes called radio direction finding, or RDF. The simplest forms of these systems calculate the bearing from two fixed sites to the mobile. This creates a triangle with endpoints at the two fixed points and the mobile. Trigonometry tells you roughly where the mobile transmitter is located. In wireless telephone systems, the phones transmit continually when off-hook, making continual tracking.

- **SIGN POST SYSTEMS**
  To track and locate vehicles along fixed routes, a technology called sign post transmitters was employed. This is used on transit routes and rail lines where the vehicles to be tracked continually operated on the same linear route. A transponder or RFID chip along the vehicle route would be polled as the train or bus traverses its route. As each transponder was passed, the moving vehicle would query and receive an ark, or handshake, from the signpost transmitter. A transmitter on the mobile would report passing the signpost to a system controller. These systems are an alternative inside tunnels or other conveyances where GPS signals are blocked by terrain.

- **GPS BASED**
  The low price and ubiquity of Global Positioning System or GPS equipment has lent itself to more accurate and reliable tele location systems. GPS signals are impervious to most electrical noise sources and don't require the user to install an entire system. Only a receiver to collect signals from the satellite segment is installed in each vehicle and a radio to communicate the collected location data with a dispatch point are typically used.

1.4.2.3 HOW IT WORKS?

- AVL technology uses Global Positioning System (GPS) to enable a business or agency to remotely track the location of its vehicle fleet, using the Internet. It basically uses location technology and a wireless data communications system to transmit the real-time location of any moving vehicle (bus, train, van, boat) directly to the transit operations center. This is based on accurate real-time location information received from satellite signals for the purposes of navigation.

- Central software located at the transit operations center periodically receives these real-time updates on transit vehicle locations. The transit vehicle on the other hand is equipped with an on board computer including an integrated GPS receiver with wireless data communications capabilities. The AVL data can then be readily used for a variety of purposes such as daily operations or it can be archived for further analysis. Automatic vehicle location can be used for both fixed-route and paratransit (demand response) systems across a variety of different modes.

1.4.2.4 Benefits of the Automatic Vehicle Location Technology

- Transit agencies often use AVL systems due to their ability to enhance the utilization of their fleet and reduce fuel consumption, labor, and capital costs. The use of AVL in the transportation sector allows transport providers to establish a direct link between vehicles, operation control centers, and real-time passenger information systems.
- One of the greatest perks of AVL is the availability of more valuable data which essentially eases the management of transit systems and operations across the network. Since AVL isbecoming increasingly common, especially on bus transit systems, it is gradually shaping into an expected standard for fixed-route systems.
- They can be used to track vehicles in real-time, log on-time performance to be used in reporting, or help with computer-aided dispatch (CAD) operations. They are also used to inform **Real-time**

Passenger Information (RTPI) systems regarding arrival and departure times that are displayed at bus shelters, inside mobile apps, etc.

- Automatic vehicle location is perhaps one of the most adopted and highly praised systems by transportation agencies, no matter the size. It's the type of technology that has become a standard for any business or transit agency that wants to remotely track the location of its vehicle fleet, and improve the management of systems, operations as well as customer service

1.4.3 **AUTOMATIC VEHICLE IDENTIFICATION (AVI)**

Automatic Vehicle Identification (AVI) offers the opportunity to identify vehicles in various traffic situations in a secure, reliable and cost-efficient way. Different applications like electronic toll collection, access control and speed control, can benefit from AVI.A corresponding RFID tag in the license plate secures it as a government-issued document, protecting them from forgery and duplication. RFID readers could also determine which vehicles had a stolen license plate.

The principal goal of automatic vehicle identification (AVI) is to increase safety, security and oversight, while preserving the comfort and convenience of hands-free access for drivers entering or exiting a facility or parking area.

AVI is a hands-free access solution; it verifies a vehicle's credentials automatically, meaning drivers don't have to fumble for any identification cards or roll down their windows to interact with a guard.

In addition to enabling convenient and frictionless vehicle access, AVI also enables cost efficient and reliable vehicle and traffic management. Credential validation happens quickly and requires no human intervention. This results in fewer errors and greater reliability, and helps you maximize your return on investment.

Another significant advantage of AVI is the increased security it provides. Solutions can support the ability to automatically deny access to unauthorized vehicles. AVI also increases security by enabling increased visibility. With AVI, it's easy for operators and parking managers to maintain knowledge and information about the vehicles coming and going from a location.

In short, AVI is ideal for heightening security and streamlining operations, while at the same time preserving the comfort, ease and expediency of hands-free vehicle access.

There are two main technologies that are used in AVI applications:

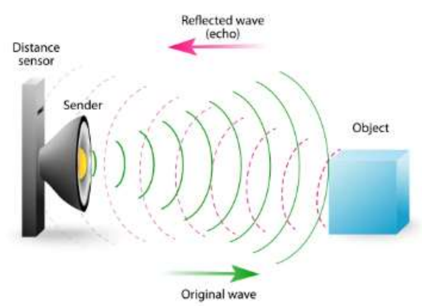
- Radiofrequency identification (RFID) and
- License plate recognition (LPR).

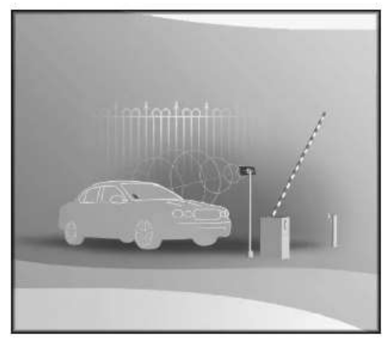
1.4.3.1 RFID

It involves a transponder or tag mounted onto a vehicle, and an RFID reader with an integrated antenna that detects the tag's signal and forwards the tag's ID information to an access or revenue system.

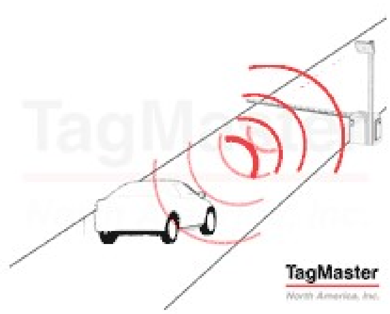
- An RFID system involves communication between an RFID reader and an RFID transponder or tag. In a typical long-range RFID application for vehicle access control, the tag is mounted to the vehicle, and the reader is installed at the entrance or exit of the area where a vehicle is driving. (There are, however, unique applications that require a different system design—for example, the readers might be mounted on heavy equipment, with the tags mounted at a stationary point.)

- The RFID reader has an integrated antenna that sends out a radiofrequency (RF) signal in search of a response from an RFID tag. An RFID tag is encrypted with unique identification information, which it transmits to the reader through its own RF signal.





When the reader receives an RF signal from the tag, the reader forwards the tag ID information to an access or revenue system, where the tag ID is validated in a database. From there, the system operates according to the rules it's been set to follow, granting or denying access to the tag ID and logging the credential ID, the time it was recorded, and any associated information supported by the access or revenue software, such as the name or category of the credential holder.



Benefits of Long-Range RFID for AVI

Long-range RFID offers numerous benefits for AVI applications. Below are a few of the reasons RFID is an exceedingly popular solution for vehicle access control:

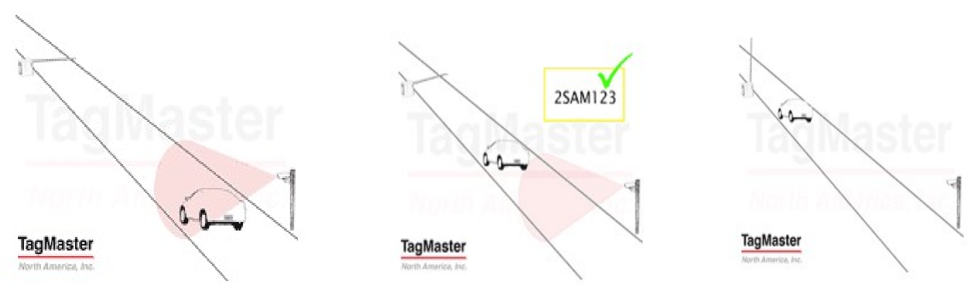
- **Hands-free access**: The RFID tag is mounted to the vehicle, allowing authorized users to keep their hands on the steering wheel and their windows rolled up for convenient, hands-free access.
- **Reliability:** With RFID, credential validation happens quickly and automatically. No human intervention is necessary, resulting in fewer errors and greater reliability.

Data collection: An RFID system improves visibility, logging every instance of access for a particular credential, along with access time and any associated information, such as credential holder name. This ability to easily record and report access data assists with streamlining oversight, process monitoring, revenue tracking and other important operations.

- **Increased security:** RFID automatically verifies credentials and can deny access to unauthorized vehicles, protecting a facility against instances of unauthorized vehicle access.
- **Increased safety:** In addition to added convenience, hands-free access also increases drivers' safety and comfort by allowing them to keep their windows rolled up when gaining access to a parking facility late at night. This increases driver focus and decreases instances of collisions with other vehicles or equipment.

1.4.3.2 LPR

It uses a vehicle's license plate as its access credential. LPR involves an intelligent camera that captures an image of a vehicle's plate. The camera then uses the image to process the license plate characters, and forwards the license plate ID to an access or revenue system.



In an LPR application, the vehicle's license plate serves as its identification credential, eliminating the need to administer any additional credentials or mount any tags to the vehicle. An LPR camera's job is to capture an image of the vehicle's license plate, and use the plate image to accurately process and identify the license plate characters. The camera can then forward the plate ID information to an access or revenue system.

Benefits of LPR for AVI

LPR offers numerous benefits for AVI applications. Below are a few of the reasons LPR is increasingly popular as a vehicle access control solution:

- **Hands-free access**: The vehicle's license plate is automatically identified and processed by the LPR system, allowing authorized users to keep their hands on the steering wheel and their windows rolled up for convenient, hands-free access.
- **Cost effective:** With LPR, license plate validation happens quickly and automatically. No human intervention is necessary, making LPR a cost effective vehicle access control and management solution.
- **Data collection:** An LPR system improves visibility, logging every instance of access for a particular license plate credential, along with access time and any associated information supported by the LPR software, such as the name of the vehicle's owner or the visitor category. This ability to easily record and report access data assists with streamlining oversight, process monitoring, revenue tracking and other important operations.
- **Increased security:** An LPR system can automatically verify credentials and deny access to unauthorized vehicles, protecting a facility against instances of unauthorized vehicle access. And a vehicle's license plate can be captured by an LPR camera even if the license plate does not exist in the database, providing additional security when attempts to gain unauthorized access are recorded.
- **Increased safety:** In addition to added convenience, hands-free access also increases drivers' safety by allowing them to keep their windows rolled up when gaining access to a parking facility late at night. This increases driver focus and decreases instances of collisions with other vehicles or equipment.

Automatic Vehicle Identification: The reliable identification of vehicles is crucial in many situations:

- Tolling systems
- Billing in car parks
- Access control to restricted areas
- Fleet management
- Anti-theft protection

In all these cases, systems for Automatic Vehicle Identification are very effective. They save costs and time and ensure accurate and convenient vehicle identification. In addition, such a system can simplify the identification of stolen vehicles as an anti-theft protection tool.

1.4.4. GEOGRAPHIC INFORMATION SYSTEMS (GIS)

Transportation is a crucial component of society that plays a crucial role in the movement of people, goods, and services from one place to another. It significantly impacts economic growth, social development, and environmental sustainability. GIS technology has immensely impacted transportation by refining practically every aspect of the transportation system. Authorities in many developed countries now actively use GIS for highways and transport management, mainly due to the benefits of sinking operational costs and growing ease. The most important objective of using GIS is visualization achieved through maps. With visualization of real-time data, transport planners can make navigation easier, identify potential issues that can be addressed more efficiently and economically than with the conventional methods. Through detailed GIS maps, this information can also be easily conveyed to stakeholders more effectively.

Uses of GIS in Transportation

GIS can overlay multiple layers of Geospatial data and aid transportation managers in tracking the location and condition of various infrastructures, buildings, roads and other assets. This information can be used to optimize navigation, maintenance schedules, reduce interruption, planning and extend the lifecycle of assets.

Some of the key uses of GIS in improving the transportation system are:

- **Point of Interest Data Creation:** GIS can collect information and identify points of interest within the transportation network. This is done by geocoding the collected addresses to obtain accurate latitude and longitude coordinates. Geocoding can convert addresses into spatial coordinates that can be represented on maps and put to specific uses.
- **Digitization of road and street data:** Roads and streets information can be collected through survey. This data and related attributes can be stored in GIS and can be used as per requirement. Classification of roads and streets is one such use.
- **3D Building Landmark Data Creation (3DLM):** 3DLM is an exclusive combination of GIS and multimedia technologies that creates geocoded real time 3D models of the landmarks such as schools, religious places, establishments etc. GIS enables the incorporation of these models into maps for better visualization and navigation.
- **3D City Model:** GIS can perform accurate georeferencing of various features of a city. This data can be linked with attributes at various levels to provide an in-depth estimation of potentials of numerous buildings, landmarks, roads etc.
- **Route planning:** GIS enables the calculation and comparison of multiple routes based on various factors like distance, traffic patterns, road conditions, and speed limits. By integrating real-time data, such as traffic flow and congestion, GIS helps identify the most efficient routes, reducing travel time and fuel consumption.
- **Environmental Impact Assessment:** GIS enables the integration of various geospatial data layers, including topography, land cover, vegetation, hydrology, and sensitive ecological areas. By overlaying these layers, GIS helps visualize the potential environmental impacts of roads and other transportation infrastructure on the adjacent environment.
- **Asset Mapping:** GIS facilitates the inventory and management of transportation assets, including landmarks, crossings, streets, building conditions etc. By mapping and monitoring these assets, transportation agencies can prioritize maintenance and repairs based on their condition, ensuring the safety and longevity of the infrastructure.

- **Geospatial Data Integration:** GIS enables the integration of various geospatial data sources, such as satellite imagery, aerial photographs, drone images and GPS data. This integration improves the accuracy of transportation planning and related activities

Even though the advent of Geographic Information Systems (GIS) has significantly enhanced transportation systems, yet numerous untapped potentials of GIS for the transportation industry remain undiscovered. As our transportation needs increase, GIS will help us plan, manage and grow intelligent transportation systems.

1.4.5 **VIDEO DATA COLLECTION**

These cameras can be mounted on poles above the road and can be used to monitor traffic. Some cameras can be equipped with automatic number plate recognition systems.

Video based sensor systems can play a key role in delivering data for better road planning and traffic management. Smart road technologies will largely depend on data quality and quantity in the future. Video based detection systems, being an indispensable part of intelligent traffic systems (ITS), show huge potentials as they do not only offer a flexible way of data acquisition but are also being developed at a huge pace due to recent evolutions in hardware and software technology. In order to give a better understanding on the methods and potentials of this technology, a structured review is presented which not only includes current applications but also shows future use cases by analyzing the techniques of image processing and extrapolating their results to the future requirements of traffic engineering

Video cameras in Intelligent Transportation Systems (ITS) can help improve safety and mobility by detecting incidents and providing data for better traffic management:

- **Incident detection**

  Cameras can automatically detect incidents like congestion, stopped vehicles, and wrong-way drivers.

- **Alerts**

  Cameras can send real-time alerts to traffic management centers, which can then notify drivers on the road.

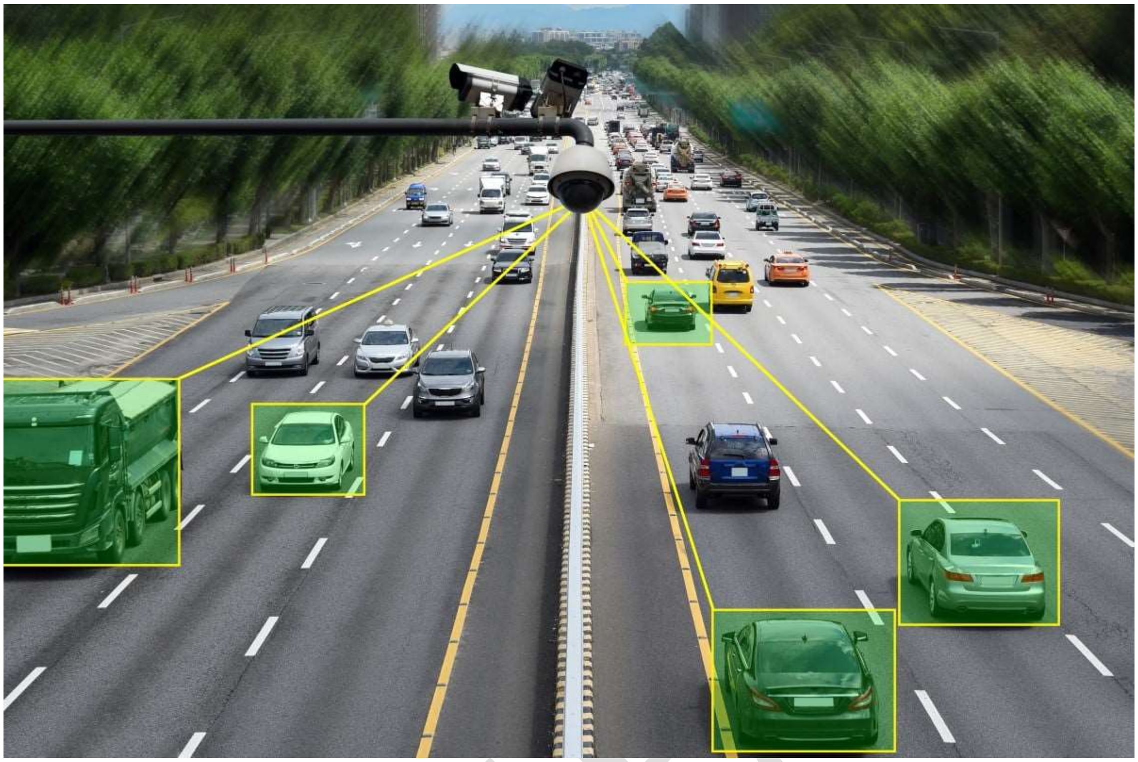
- **Data collection**

  Cameras can collect data on traffic patterns and congestion points, which can help with data-driven decision making.

- **Traffic management**

  Cameras can help manage traffic signals by detecting congestion and providing data on vehicle movements.

- **Road planning**
  Video-based sensor systems can provide data for better road planning.



MODULE 2

2.1 ADVANCED TRAVELLER INFORMATION SYSTEM (ATIS)

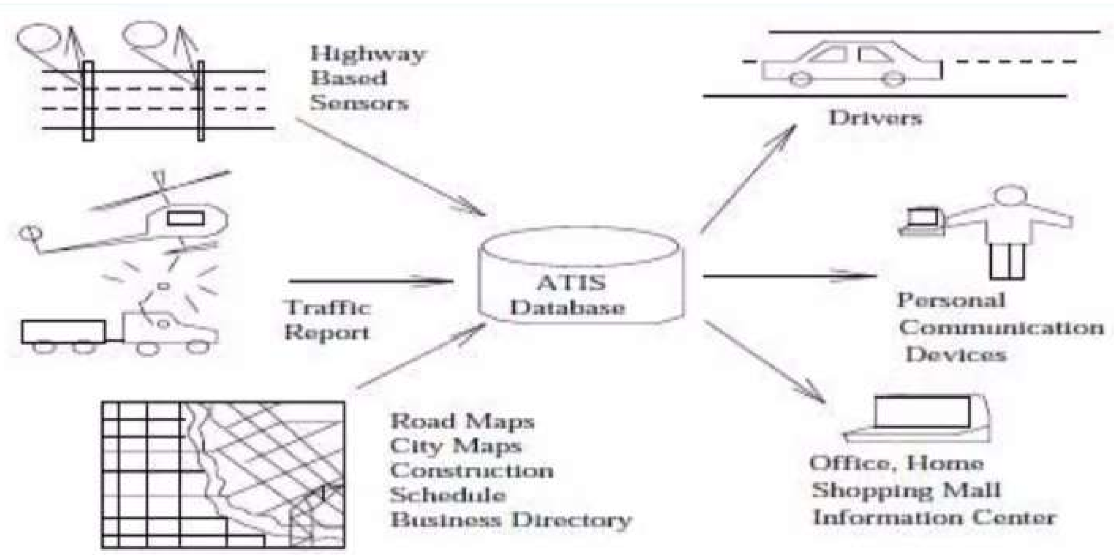
An Advanced Traveller Information System (ATIS) is a part of an Intelligent Transportation System (ITS) that provides travellers with information to help them move safely and efficiently from one place to another. ATIS systems collect, analyze, and disseminate information on a variety of transportation topics, including:

- Traffic: Information on traffic conditions, including queue length, travel time, and delay
- Incidents: Information on road traffic crashes and their locations
- Events: Information on road construction and demonstrations
- Weather: Information on inclement weather that may disrupt traffic
- Routes: Information on optimal routes
- Speeds: Information on recommended speeds
- Lane restrictions: Information on lane restrictions

ATIS systems can provide information to travellers in a variety of ways, including:

- In-vehicle displays
- Mobile devices
- Web portals
- 511 systems
- Roadside signage
- Radio and television
- Dynamic navigation systems
- Smart phone services

The goal of ATIS is to help travellers make better decisions about how to travel, which can lead to reduced traffic congestion and vehicle emissions



2.2 COMMERCIAL VEHICLE OPERATIONS (CVO)

Commercial vehicle operations (CVO) is an application of intelligent transportation systems (ITS) that allows for the automatic safety and inspection of trucks and buses while they are in motion. CVO aims to improve the safety and efficiency of commercial vehicle operations by using sensors to automatically check trucks for weight, credentials, and safety as they travel on the highway.

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

1. CV electronic clearance
2. Automated road side safety inspection
3. On-board safety monitoring administrative process
4. Hazardous material incident response
5. Freight Mobility

2.2.1 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.

2.2.2 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.

2.2.3 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.

2.2 .4 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.

2.2.5 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.

2.2.6 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.

Load-tracking systems use queuing theory, linear programming and minimum spanning tree logic to predict and improve arrival times. The exact means of combining these are usually secret recipes deeply hidden in the software. The basic scheme is that hypothetical routes are constructed by combining road segments, and then poor ones are eliminated using linear programming.

2.3 Components of CVO include:

- Fleet Administration
- Freight Administration
- Electronic Clearance
- Commercial Vehicle Administrative Processes
- International Border Crossing Clearance
- Weigh-In-Motion (WIM)
- Roadside CVO Safety
- On-Board Safety Monitoring

CVO Fleet Maintenance Some of the key functions of CVO include:

- **Electronic clearance**: Trucks can be electronically cleared for commercial use.
- **Automated roadside safety inspection**: Trucks can be automatically inspected for safety at roadside stations.
- **On-board safety monitoring**: Trucks can be monitored for safety while they are in operation.
- **Hazardous materials incident response**: Trucks can be responded to in the event of a hazardous materials incident.
- **Automated administrative processing**: Commercial vehicle operations can be processed automatically.
- **Commercial fleet managemen**t: Commercial vehicle fleets can be managed.

2.4 INTERMODAL FREIGHT

It involves the seamless integration of different transportation means—such as rail, road, sea, and air—into a single, cohesive journey without the need for handling the freight itself when changing modes

Intermodal freight is a system that uses multiple modes of transportation to move goods in containers from one place to another. The word "intermodal" is a combination of "inter", which means two or more, and "modal", which refers to the method.

Some examples of intermodal transportation include: Road-to-rail, Rail-to-ship, Air-to-rail, and Ship-to-rail.

Intermodal freight systems offer several advantages, including:

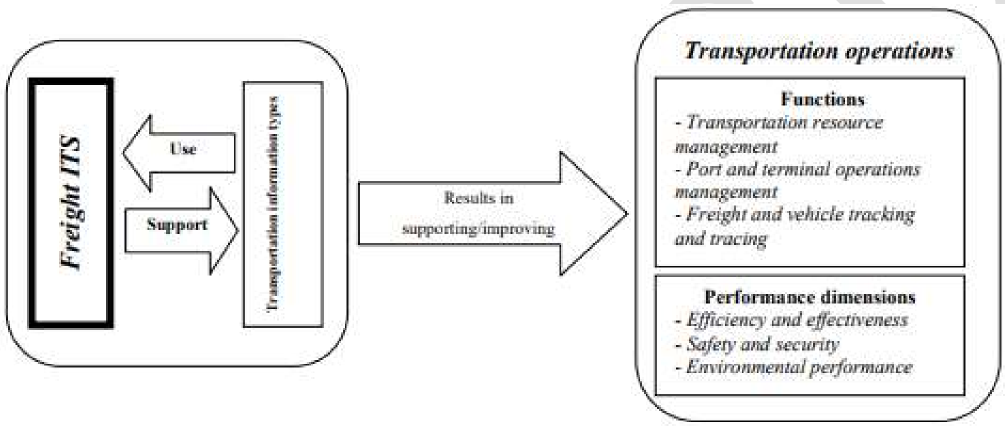
- **Reliability**

  Intermodal systems can be reliable in the event of supply chain disruptions.

- **Reduced traffic**

  A single freight train can transport more than 250 truckloads of goods, which reduces the number of trucks on the highway.

- **Lowered freight costs**
  Intermodal systems can use more fuel efficient and economic modes of transportation, such as rail.



	Transportation information types							Supported transportation functions			Supported transportation performance dimensions		
Freight ITS	*Traffic and infrastructure information*	*Vehicle and freight location information*	*Freight condition information*	*Freight positioning information*	*Warehouse operations and inventory information*	*Cargo information*	*Vehicle identity information*	*Transportation resource management*	*Ports and terminals operations management*	*Freight and vehicle tracking and tracing*	*Efficiency and effectiveness*	*Safety and security*	*Environmental performance*
Traffic control and monitoring systems	x						x	x	x		x	x	x
Weight-in-motion systems	x					x	x				x	x	x
Delivery space booking systems		x					x	x	x		x		x
Vehicle location and condition monitoring systems	x	x	x			x	x	x	x	x	x	x	
Route planning systems	x	x						x			x		x
Driving behaviour monitoring and control systems	x						x	x				x	x
Crash preventing systems	x											x	
Freight location monitoring systems		x		x	x	x			x	x	x	x	x
Freight status monitoring systems			x	x	x	x			x	x	x	x	x
Total	6	4	2	2	2	4	5	5	5	3	7	7	7