Module 4
ITS-SAFETY, SECURITY & SUSTAINABILITY

4.1 ITS and changing Transportation Institutions

Urban transportation planning in India is subject to myriad and often inconsistent rules and regulations. There are multiple agencies in charge of planning and execution. With billions of rupees invested in these projects, one gets to see these agencies and the people in-charge desperately trying to out-do each other. This occurs in the form of agency heads approving their pet transportation projects which will form part of their legacy. At the end of the day, it is the citizens, commuters, tax-payers and other stakeholders who have to bear the brunt of these decisions. A robust, transparent and flexible institutional structure could help create a comprehensive transportation policy for urban areas. Agencies often overlook the institutional issues they may encounter in deploying and maintaining intelligent transportation systems (ITS) technologies, yet these issues can be as complex and challenging as the technological challenges. Agencies frequently encounter political and organizational challenges with funding, system ownership, and legal requirements, among others. Institutional arrangements need to be implemented during the planning stages of an ITS project to ensure success. Institutional challenges have plagued ITS projects since their advent. Numerous papers and reports document lessons learned from ITS projects that encountered institutional issues over the past two decades. ITS projects that were not proceeding well were the ones that suffered from institutional problems. Though agencies will still encounter new challenges in deploying ITS technologies, much can be learned from previous experiences.

4.1.1 Elements of Institutional Environment

There are three main elements that comprise the institutional environment. These include:

a) Governance institutions that define the distribution of power and authority between levels of governments, organizations, and other actors. They also specify rules of business for organizations including how they conduct dealings with other organizations and actors;
b) The legal institutions that refer to statutes, constitutional provisions, laws, regulations and rules, and high-level administrative orders governing the sector; and
c) Social and organizational culture within which the organizations and other stakeholders play their role. It also includes personal and group dynamic relationship between the organizations and the private sector, and various pressure groups that influence the decision environment and the allocation of resources.

4.1.2 Institutional Issues

The gap between planning and implementation by multiple agencies under different levels of government cannot be bridged without necessary institutional reforms, capacity building and streamlining of the overall procedures in planning, policy formulation and implementation. The national government can play an important role in promoting sustainable transport development by creating an institutional environment for the implementation of national policy

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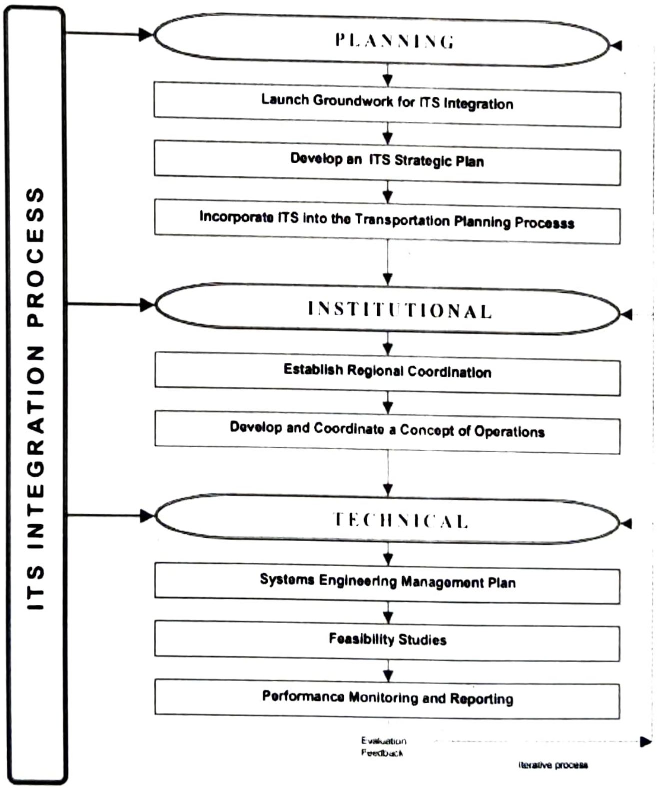
framework at all levels – national, provincial and local. The deficiencies in governance institutions defining the relationship between responsible agencies and other actors responsible for transport development are a major hindrance against their collaboration and cooperation to develop integrated transport systems. ITS can redefine how transportation agencies and managers think about system investment and operation. It changes the role of agencies and expands the opportunity to coordinate and collaborate across systems, disciplines, and industries. ITS applies technologies developed by industry, universities, government, and military researchers and inventors to maximize transportation system safety and efficiency. The major institutional issues in sustainable transport development are:

- Formulation of integrated policies reflecting the multi-sectoral nature of transport and the necessity of vertical and horizontal coordination of actions
- Inherent weaknesses of the transport planning processes - national or urban (basically have remained "technical processes")
- Integration of public transportation and land use
- Absence of a programmatic approach to development
- De-linkage between planning and financing
- Institutional capacity and incentives to translate good knowledge into effective actions
- Decentralization of powers and responsibilities

4.1.3 ITS Integration

The following figure shows steps that can be followed to achieve ITS Integration:

Figure ES-1: Process for Achieving ITS Integration



4.1.4 Benefits of Institutional Integration

Transportation agencies are discovering that if they coordinate with each other to plan, deploy and operate ITS components in an integrated fashion, there are tangible benefits to be gained. Likewise, integrated technologies make it easier for agencies to work together, allowing them to share information and resources so that they can each do their job better and often at a reduced cost. The primary benefits of integration include the following

- Improved Traffic Flow from highway management systems is particularly effective in reducing congestion.
- Enhanced Route Planning for Travelers is improved from real-time information on traffic, road, and weather conditions to select the best routes, modes, and times for travel.
- Improved Emergency Response and Security for Transit can reduce personal safety concerns for transit riders.
- Cost Savings, Improved Productivity and Better Customer Service for Transit can be provided when advanced technologies are integrated together.
- Improved Incident Response is provided by the integration of advanced technologies accelerating incident detection, response, and clearance through shared information.

4.1.5 Institutional issues associated with ITS deployment

Institutional issues associated with ITS deployment, as noted below:

- Business Processes - Includes formal scoping, planning, programming, and budgeting.
- Systems and Technology - Includes systems architecture, standards, interoperability, and standardization and documentation.
- Performance Measurement - Includes the definition of measures, data acquisition, data analysis, and use of data.
- Culture - Includes technical understanding, leadership, policy commitment, outreach, and program authority.
- Organization and Workforce - Includes organizational structure, staff capacity, development, and retention. Institutional issues related to organization and workforce are covered in this module under "Workforce Issues."
- Collaboration - Includes relationships with public safety agencies, local governments, MPOs, and the private sector.

Reforms necessary in institutional framework are:

- Integrated land use and transport planning
- Investments in public and non-motorized transport
- Coordinated planning for urban transport
- Innovative financing methods to raise resources
- Establish regulatory mechanisms for a level playing field

4.2 Safety and ITS

Today, road transport is by far the most dangerous mode of transport. The strictest safety criteria should be applied, in order to reach the safety levels. There are two ways to improve road safety by means of ITS: systems that influence safety in a direct way and systems that influence safety in an indirect way. Examples of promising direct systems are for example incident detection and warning systems using variable message signs, violation detection and enforcement systems, electronic licences, invehicle black boxes (crash recorders), variable speed limits and intelligent speed adaptation. Indirect systems are, for example, those that change the exposure or mode of traffic, debiting systems, and systems giving priority to public transport. It is not enough to develop ITS that might offer safety improvements as a secondary benefit. A number of ITS aimed specifically to enhance safety and reduce fatalities, injuries and crashes must be developed and tested. Systems must influence the major safety variables. There are two main types of safety countermeasures: actions aiming at preventing crashes (often called active safety measures) and actions aiming at reducing the consequences of crashes (often called passive safety measures).

4.2.1 Influence of ITS on road safety

A number of safety relevant areas that may be influenced by the introduction of ITS. Their list may be summarised as follows:

- Direct in-car modification of the driving task by giving information, advice, and assistance or taking over part of the task. This may influence driver attention, mental load, and decision about action (e.g. driver choice of speed).
- Direct influence by roadside systems mainly by giving information and advice. Consequently the impact of this influence is more limited than of in-vehicle systems (e.g. change of route).
- Indirect modification of user behaviour in many, largely unknown ways. The driver will always adapt to the changing situation. This is often called behavioural adaptation and will often not appear immediately after a change but may show up later and it is very hard to predict. Behavioural adaptation may appear in many different ways (for 24 example, by change of usage of the car, by change of headway in a car following situation, by change of expectation of the behaviour of other road users).
- Indirect modification of non-user behaviour. This type of behavioural adaptation is even harder to study because it is often secondary. Non-equipped drivers may for example change their behaviour by imitating the behaviour of equipped drivers (for example, driving closer or faster than they should, not having the equipment).
- Modification of interaction between users and non-users. ITS will change the communication between equipped road users. This change of communication may influence the traditional communication with non-equipped road users. To a large extent this problem may appear in the interaction between drivers and unprotected road users.
- Modification of road user exposure by, for example, information, recommendation, restrictions, debiting. This is certainly an area where introduction of ITS will have a large impact for example by changing travel pattern, modal choice, route choice, etc.
- Modification of accident consequences by intelligent injury reducing systems in the vehicle, by quick and accurate crash reporting and call for rescue, by reduced rescue time.

4.2.3 ITS Technologies which Reduce Crash Risk

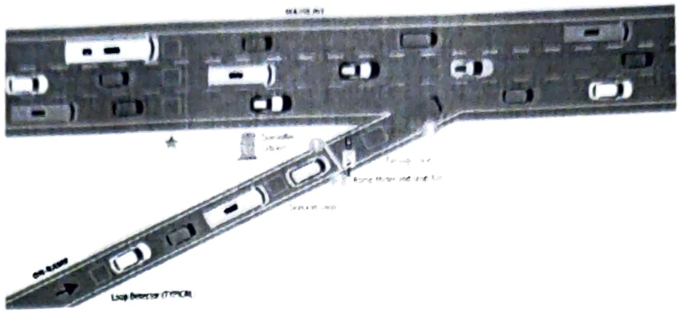
The following systems would appear to have significant potential to reduce injuries and fatalities by at least 10 percent, with variable speed limiting systems having the highest safety potential of all systems.

- in-vehicle variable speed alerting and limiting systems
- in-vehicle driver impairment monitoring systems such as the European Union-developed SAVE system (which includes driver vigilance monitoring)
- in-vehicle forward collision warning (incorporating headway feedback)
- in-vehicle collision avoidance systems generally (when they become commercially available)
- incident management systems
- automated speed enforcement (e.g., speed and red-light cameras)
- roadside speed control systems with variable speed limits
- urban traffic control
- motorway control systems (i.e., variable speed limits, roadside incident detection, weather warnings)

4.2.4 Crash Prevention Methods using ITS

The following are the various ITS technologies/methods which can be used to prevent Crash/accidents:

- **Radio Notices:** Radio stations provide regular traffic reports to communicate information on congested roads and other hazards along with possible routes to avoid these delays. Drivers can tune in to a specific AM radio station to receive information about these delays or road closures. While this does not prevent any one type of accident, it helps drivers make more informed decisions.
- **Digital Message Sign:** A digital message sign displays messages to drivers about hazards on the road ahead of them. They can either be mobile or permanent, and messages can be changed to address different situations. While this does not prevent any one type of accident, it helps drivers make more informed decisions.
- **Red Light Cameras:** Red light cameras take pictures of the front and back of a car after a sensor detects it running a red light. First responders are notified if a crash results from a vehicle running a red light. This improves response time and decreases the chance of an accident caused by congestion resulting from the initial crash.
- **Wrong Way Driving Cameras:** Wrong way driving cameras use infrared technology to detect vehicles travelling in the wrong direction. Digital message signs can be used in concert with these cameras to notify other drivers of the potential hazard ahead. This helps minimize head on collisions due to wrong way driving.
- **Ramp Metering:** Ramp metering uses traffic signals installed on freeway on-ramps to help control the rate at which cars enter the freeway based on the volume of traffic as seen in Figure. Ramp Metering helps to limit the number of rear end collisions, accidents that occur because of crowded merging lanes, and accidents caused by to failing to yield to the right of way.



- **Variable Speed Limits:** Variable speed limits are digital speed limit signs that can be changed from a control station to help drivers adapt to road conditions such as rain or snow. Some of these systems use technology like section speed to calculate the average speed of cars and adjust the speed limit to decrease speed variance between vehicles. It can also be paired with roadside weather information systems (RWIS) to change the speed of roads during extreme weather conditions. This helps decrease accidents due to excessive speed.
- **Radar speed monitors:** These are signs that show the fixed speed limit as well as the speed of an approaching driver as seen in Figure. If a vehicle is speeding, lights on top of the monitor will flash to alert the driver. The monitors help to minimize accidents due to excessive speed.

- **Lane Management:** Lane management is a system of overhead digital signs that indicate whether a lane is open or closed depending on road conditions and congestion. It can display a suggested speed for each lane. The shoulder of the road can be opened using a digital sign to provide additional capacity during times of congestion. These signs can be controlled from an operating center.
- **Smart Traffic Signals:** A smart traffic signal is a traffic light that utilizes V2I communications to detect approaching vehicles. This improved signal would optimize traffic flow by eliminating unnecessary stops and reducing congestion. It would also reduce the likelihood of a collision due to an improper turn.

4.2.5 ITS Technologies and High-Risk and Vulnerable Road Users

Very few ITS applications have been developed specifically for high-risk and vulnerable road users. The following conclusions can be drawn from this section of the review.

- ***Young novice drivers:*** Variable speed alerting and limiting systems and electronic driver's licences appear to offer the greatest potential safety benefit for novice drivers. Other systems which are either commercially available or are in the advanced prototype stage of development which are also likely to benefit this group are forward collision warning systems, seat-belt reminder systems, breath alcohol detection and advisory systems and intelligent restraint systems.
- ***Older drivers.*** A number of ITS applications have considerable potential in enhancing the safety of older drivers. Those having the greatest potential safety benefit are mayday systems, vision enhancement systems, rear collision warning systems and in-vehicle navigation and assistance systems, provided the latter system does not increase exposure to risk by creating new trips for older drivers. Technologies such as lane departure warning and lane change collision warning systems are also likely to enhance the safety of older drivers when they become more reliable.
- ***Pedestrians.*** The issue of pedestrian safety is one of the few areas in which specifically tailored ITS applications have been developed and recent ITS initiatives have focussed on developing systems to detect and protect pedestrians. Speed alerting and limiting devices are likely to confer the greatest benefits in reducing the incidence and severity of crashes involving pedestrians. Mayday systems are likely to indirectly benefit pedestrians in the near future as they reach the market in greater numbers as these systems can be activated in the event of a collision with a pedestrian. Adaptive signal control technologies, such as Puffin crossings, appear to provide relatively minor safety benefits to pedestrians. Re-designing vehicle structures to reduce impact forces on the pedestrian in the event of a crash, and developing systems which detect pedestrians and intelligently deploy countermeasures such as airbags to further minimise impact forces are likely to confer considerable safety benefits.
- ***Bicyclists.*** The ITS applications that are likely to benefit pedestrians are also likely to benefit bicyclists. Variable speed warning and limiting devices, along with mayday systems are likely to reduce the incidence and severity of crashes involving bicyclists and to enable more rapid emergency assistance. Vision enhancement systems, which are not too far away from being able to reliably detect bicyclists in low visibility conditions, are also likely to enhance the safety of bicyclists. The development of vehicle frontal structures which reduce impact forces on bicyclists in the event of a crash and the development of systems which detect bicyclists, warn the driver of an impending crash, and intelligently deploy airbags to reduce the impact of the crash, are also likely to confer considerable safety benefits.
- ***Motorcyclists.*** As for pedestrians and bicyclists, very few ITS applications have been developed specifically for motorcyclists. Those ITS applications considered to have the greatest positive effect on the safety of motorcyclists are variable speed alerting and limiting systems, electronic licences and mayday systems. Other systems that have potential safety benefits for this group are alcohol ignition interlocks, breath alcohol

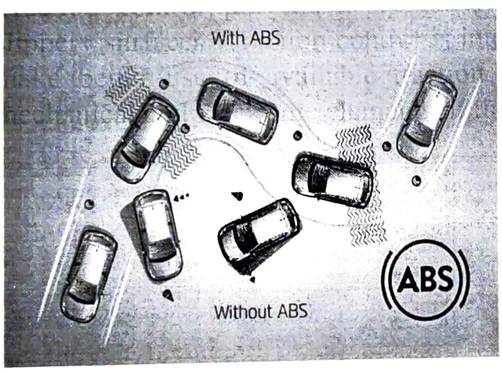
detection and advisory systems and night vision enhancement systems, although these systems will require further research and development before they can be deployed. Enhancements to existing traffic signal systems have the potential to reduce the incidence of right-hand turn motorcycle crashes at intersections.

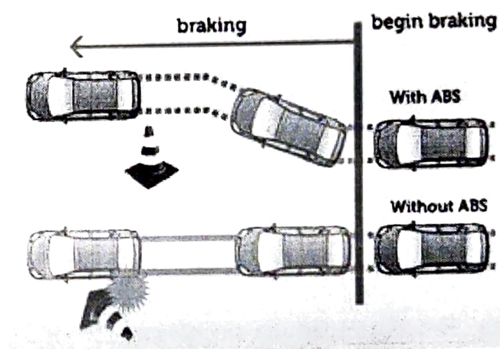
- ***Cultural minority groups.*** Child restraint wearing rates in the back seats of passenger vehicles, particularly for children of certain adults of non-English backgrounds, are low.

4.2.6 Advanced Vehicle Control Systems (AVCS)

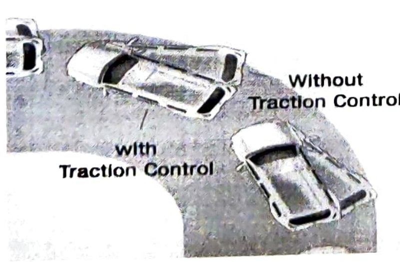
Approximately 90% of all accidents are caused by human error. Advanced Vehicle Control Systems (AVCS) encompass a variety of technologies which seek to prevent these accidents by offering advanced in-vehicle technological assistance. In addition to reducing the number and severity of vehicle crashes, AVCS promises the additional benefits of increasing highway efficiency and driver comfort. The following are the various ITS technologies under AVCS:

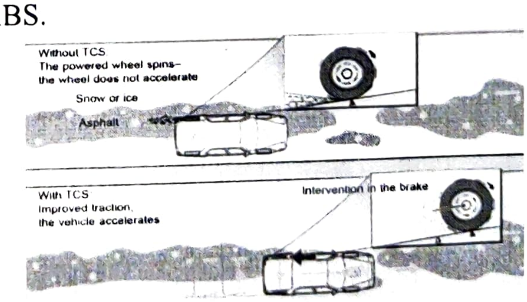
1. **Anti-lock braking system (ABS):** It is a safety anti-skid braking system used on aircraft and on land vehicles, such as cars, motorcycles, trucks, and buses. ABS operates by preventing the wheels from locking up during braking, thereby maintaining tractive contact with the road surface and allowing the driver to maintain more control over the vehicle.



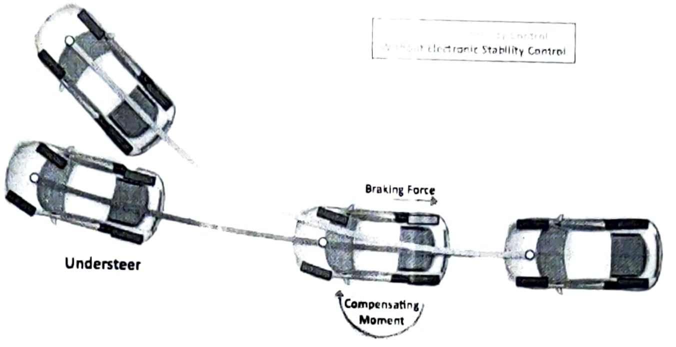


2. **Traction control system (TCS):** It is typically a secondary function of the electronic stability control (ESC) on production motor vehicles, designed to prevent loss of traction (i.e., wheelspin) of the driven road wheels. TCS is activated when throttle input and engine power and torque transfer are mismatched to the road surface conditions. Traction control prevents a vehicle's wheels from spinning excessively while on slippery surfaces. Traction control is intended as a driver aid which allows a vehicle to make better use of available traction on slippery surfaces. It shares many of the mechanical and electronic elements of the ABS.

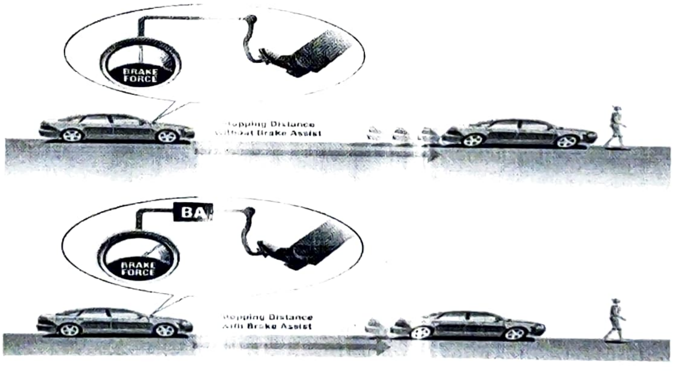




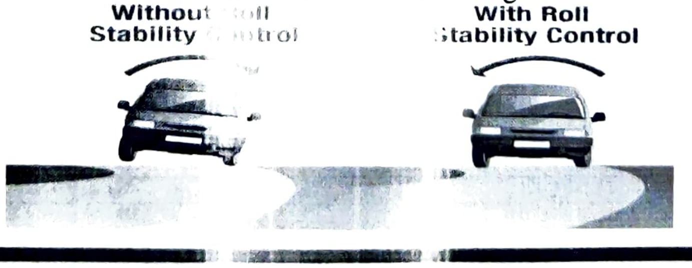
3. **Electronic Stability Program (ESP):** The electronic stability program helps improve cornering and control. By monitoring the slip at the wheels as well as the driver's steering and braking inputs, ESP can sense differences between the driver's intentions and the vehicle's direction in turns.



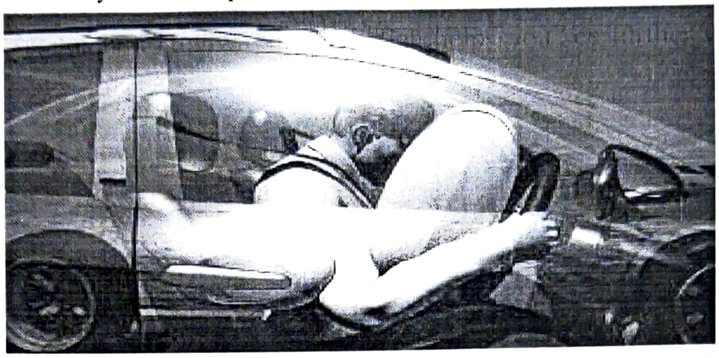
4. **Emergency Brake Assist (EBA):** Brake assist (BA or BAS) or emergency brake assist (EBA) is a term for an automobile braking technology that increases braking pressure in an emergency. By interpreting the speed and force with which the brake pedal is pushed, the system detects if the driver is trying to execute an emergency stop, and if the brake pedal is not fully applied, the system overrides and fully applies the brakes until the anti-lock braking system (ABS) takes over to stop the wheels locking up.



5. **Roll Stability Control (RSC):** Roll Stability Control (RSC) is a stabiliser system that minimises the risk of overturning, for example during sudden evasive manoeuvres or if the car skids. The RSC system registers if and how much the car's lateral inclination changes. This information is used to calculate the risk of the car overturning. If the car is at risk, its electronic stability control system engages, the engine torque is reduced and one or more wheels are braked until the car has regained its stability.

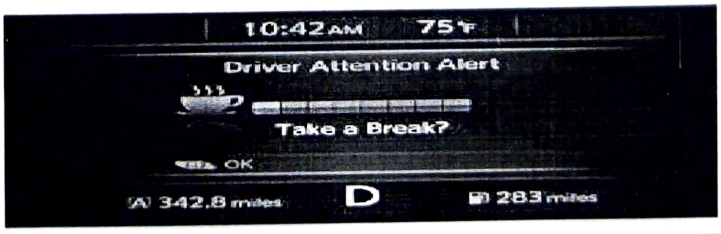


6. **Air Bags and Seat Belts:** Airbags were never intended to replace seat belts, they are supplemental restraints. Airbag design is made with the assumption that you're wearing a seat belt, so it will deploy to protect you while you're wearing it. To distribute the energy created by the impact around your body to protect it from severe impact.

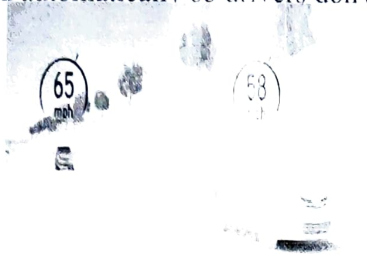


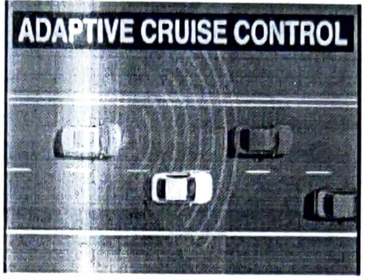
7. **Adaptive LED Head Lamps (ALH):** Adaptive LED Headlights (ALH) provide the ultimate in headlight technology, lighting up the road ahead as if it were daytime and allowing anybody to enjoy safe and stress-free driving at any time of day. The system increases visibility at night to help drivers stay vigilant by combining three technologies: Glare-free High Beams which automatically dim part of the illuminated area to avoid dazzling other drivers, Wide-range Low Beams which light up a wider area at low speeds and Highway mode which helps you see further when travelling at speed.

8. **Driver Attention Alert (DAA):** Driver Attention Alert is designed to reduce accidents caused by inattentiveness due to driver fatigue. The system comes into play at speeds above 65 km/h and begins to "learn" the driver's habits, watching inputs and the vehicle's movements in the early stages before fatigue is a factor. Later, if the system detects changes in vehicle behavior that suggest the driver may be losing concentration, it will suggest a rest stop by sounding a chime and displaying a warning in the Multi-Information Display.

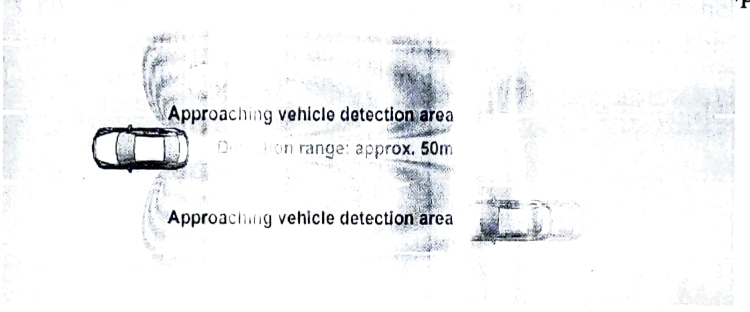


9. **Adaptive Cruise Control (ACC):** It is a system designed to help road vehicles maintain a safe following distance and stay within the speed limit. This system adjusts a car's speed automatically so drivers don't have to.

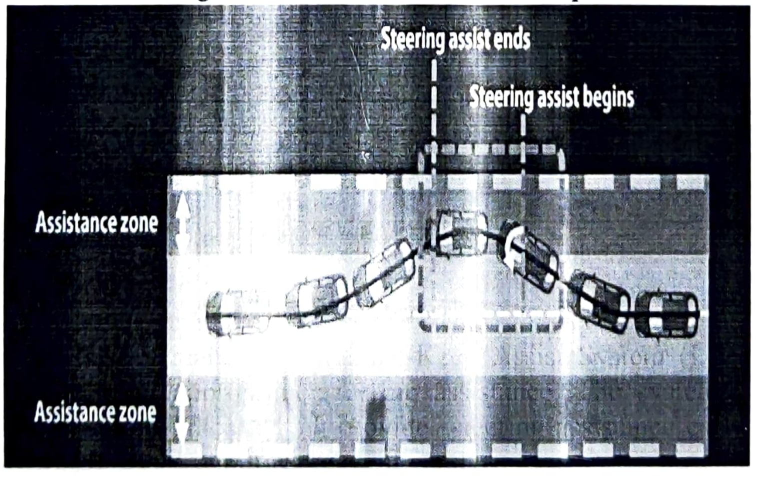




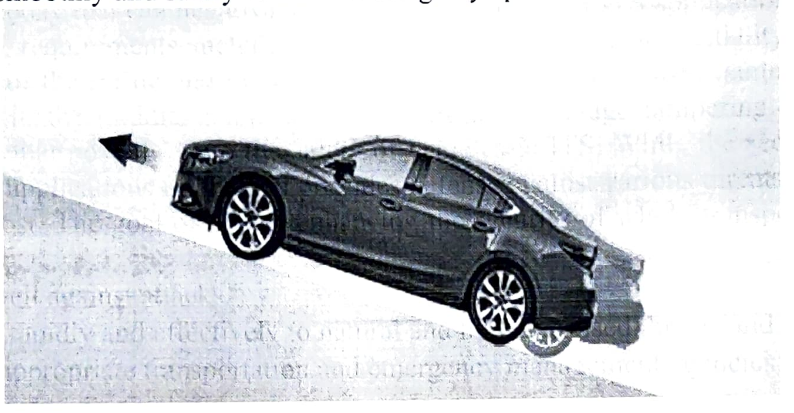
10. **BLIND SPOT MONITORING (BSM):** Blind Spot Monitoring (BSM) uses radars mounted in the rear bumper to detect vehicles approaching from behind and in the adjacent lane. It alerts drivers to the presence of vehicles in the blind spot on either side by displaying an icon in the appropriate door mirror. If the driver indicates to change lanes with a vehicle in the blind spot, the icon flashes and a warning beep is sounded.



11. **Lane Keep Assist System (LAS):** Lane-Keep Assist System (LAS) promotes safer driving by providing appropriate steering assistance. The system allows drivers to choose between Lane-Trace, which provides steering assistance early in order to help keep the vehicle centered in the lane and Lane Departure Avoidance, which only comes into play if the vehicle begins to leave its lane. LAS uses a windshield-mounted camera to recognize lane-markings on the road and activates at speeds above 60 km/h.



12. **Hill Launch Assist (HLA):** Hill Launch Assist (HLA) helps the driver take-off smoothly when stopped on a slope. When taking off on an slope, this function helps prevent the car from rolling backwards when the driver moves his or her foot from the brake to the accelerator pedal by maintaining an automatic brake. On gentle slopes the automatic brake releases immediately when the accelerator is pressed to ensure a smooth start. On steeper slopes the brake is released after sufficient torque has been generated. The system operates automatically when stopped on a slope so the driver can take off smoothly and safely without making any special effort.



4.3 Security and ITS

Security is a key challenge in the implementation of ITS applications. There exist a plethora of security attacks today that can negatively impact the reliability of ITS applications. Particularly, the ITS security requirements include availability, authenticity, confidentiality, integrity and non-repudiation of the traffic and mobility data. Denial of service (DoS), jamming, broadcast tampering, man in the middle, Sybil, eavesdropping and message tampering are few of the common attacks that pose threat to the safety of vehicles in ITS. While the security improves the reliability of applications in ITS and provides defense against various threats, it comes with a computation cost. The goal of ITS in enhancing the security of whole transportation system are:

- Protect well against attacks.
- Respond rapidly and effectively to natural and human caused threats and disasters.
- Support appropriate transportation and emergency management agencies.
- Move people effectively even during a crisis.
- To restore quickly to its full capacity.

The ITS America document discusses five broad areas where ITS can contribute to enhancing homeland security:

1. **Preparedness**: This area focuses on understanding where the existing vulnerabilities in the transportation system are and identifying existing technologies that can help reduce such vulnerabilities. It also focuses on developing tools and technologies to facilitate communications and coordination among the several agencies that would be involved in a time of crisis.

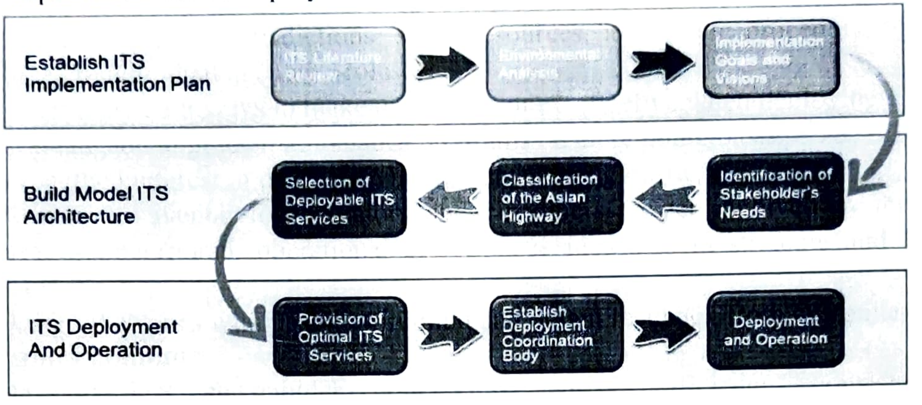
2. **Prevention**: Prevention refers to counteracting threats before they take place. The goal is to develop technologies that can detect and head off attacks along rails and roads. Example of such technologies would include the following:
   - Technologies against the misuse of commercial vehicles that would prevent the deviation of the vehicle from its preplanned route.
   - Surveillance technologies to protect the road and rail infrastructure from tampering.
   - Pattern recognition technologies.
3. **Protection**: It refers to preventing attacks and minimizing their consequences. To achieve this, this area focuses on developing tools and technology for on-site detection and response to threats to facilities and infrastructure systems, activating alternate routes during a crisis, and increasing the ability of agenecies to undertake protective activities.
4. **Response**: The goal here is to support responding agencies and increase their effectiveness. To do this, this area strives to develop technologies for the following:
   - Maintain communication among responding agencies.
   - Disseminate real-time information about the status of the transportation system.
   - Track the location of vehicles carrying hazardous materials that are close to a crisis scene.
   - Reroute traffic when parts of the transportation system are impaired.
5. **Recovery**: This involves the ability to restore the system to its original capacity after a disaster. Efforts in this are will focus on creating a flexible, reconfigurable transportation system that can meet the need of emergency situations. They will also involve using technology to allow for effectively executing plans for alternate routes and modes during a crisis and for making best use of available capacity.

4.4 ITS as a Technology Deployment Program

ITS deployment can impact transportation system performance in six key goal areas: safety, mobility, efficiency, productivity, energy and environment, and customer satisfaction. Hence while deploying any new ITS projects, lessons learned in previous projects are very much important. A lesson learned is the knowledge gained through experience or study. It is a reflection on what was done right, what one would do differently, and how one could be more effective in the future. This knowledge resource serves as a clearinghouse to document and share experiences of transportation practitioners in their planning, deployment, operations, maintenance, and evaluation of ITS to enable informed decision making regarding future ITS projects and programs.

4.4.1 Recommended Process for ITS Deployment

It is recommended to go through three main steps in the process of deploying ITS services, as shown in the following figure. The first step is to set realistic goals and visions for model ITS deployment. The goals and visions set out should be based on detailed review and analysis of the current socio-economic environment and level of road infrastructure of country. Once the goals and visions for the ITS deployment are determined, the second step is to develop a suitable ITS architecture to implement them. The last step is to deploy and operate the model ITS services. Real-world deployment and sustainable operation of ITS services would require realistic and detailed implementation strategies. In the development of ITS architecture as well as for the ITS deployment and operation, it is most important to learn from the participating countries' experiences in ITS deployments.



4.4.2 Key Lessons

The following lessons are to be kept in mind while deploying ITS:

1. **Management and Operations**
   - Coordinate across jurisdictions, share resources, and create procedures that do not threaten individual agencies' roles.
   - Continually seek ways to make operations more effective when deploying ITS.
   - Evaluate and upgrade maintenance programs on an ongoing basis.
   - Strengthen interest in data archiving systems among traffic managers.
   - Provide an avenue for operators and customers to get involved in the planning process, incorporate operational performance measures in strategic and long-range plans.
   - Design Web sites with usability in mind and obtain feedback from customers
2. **Policy and Planning**
   - Develop ITS stakeholder policies to ensure efficiency, consistency, and interoperability in deploying integrated systems.
   - Develop a formal ITS data sharing policy.
   - Learn the successful approaches to ITS planning.
   - Anticipate challenges in planning and deploying ITS in a rural environment.
   - Use the National ITS Architecture and other tools for effective ITS planning.
   - Include ITS in the country's long-range transportation plan to take advantage of project synergies and stable funding
3. **Design and Deployment**
   - Make use of flexible methods and accepted techniques for successful project management.

- Design and tailor system technology to deliver an ITS project that meets the needs of the users and the customers.
- Recognize interoperability as an important issue in achieving the vision of a nationwide system.
- Cultivate commitment by the Administration and/or other appropriate agencies at the Central Government level.
- Consider that advanced traveler information system deployment in rural and/or remote areas presents special challenges.
- Implement a limited-deployment fare pass system before implementing a region-wide fare card system.
- Conduct rigorous testing prior to deployment of an ITS project.
- Conduct a requirements analysis to determine the most appropriate ITS telecommunications solution.

4. **Funding**
   - Clarify funding regulations for projects that are service-oriented and do not deliver tangible products.
   - Distribute financial resources equitably according to agency capital cost shares.
   - Leverage Government assistance in the procurement and funding of ITS technologies for rural transit.
   - Consider partnering with neighboring agencies and non-traditional stakeholders.
   - Consider public-private partnerships and unique financing methods as ways to cover costs for ITS projects.
   - Examine multiple funding sources and anticipate unforeseen costs associated with deploying ITS.
   - Consider development impact fees, special assessments, and other innovative mechanisms to help finance ITS projects, and management and operations strategies.
5. **Leadership and Partnerships**
   - For regional ITS deployments involving multiple agencies, find an influential project champion for successful execution of the project.
   - Forge regional partnership agreements capable of addressing the specific characteristics of individual partner agencies and their customers.
   - Consider public-private, partnership-based unique financing methods as ways to cover costs for transportation projects.
   - Consider several forms of customer outreach services, with a focus on customer convenience.
   - Conduct systematic surveys of and interviews with customers periodically to reliably assess customer satisfaction and to design strategies to improve satisfaction.
   - Consider a consensus organizational model to help assure support and participation of partners in a regional ITS deployment, but beware of potential delays in implementation.
   - Clearly define the organizational structure and establish an ITS Program Coordinator to ensure an effective ITS program.

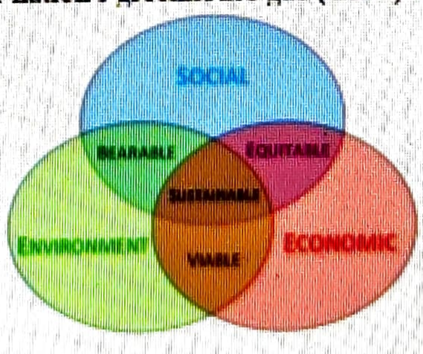
6. **Technical Integration**
   - Assess user needs and follow accepted usability engineering practices when developing interactive systems to develop usable systems.
   - Use ITS standards when developing systems to maximize vendor flexibility and data exchange compatibility, and ensure comprehension by agencies.
   - Create systems and plans that allow information sharing and coordination among regional agencies and states.
   - Consider developing an emergency response plan that coordinates command, control, and communications among regional agencies.
   - Comply with standards and select proven commercial off-the-shelf technology (hardware and software), when possible, to save money and facilitate integration with existing legacy systems.
   - To identify and resolve system integration issues with existing legacy equipment, plan on adequate development time and thorough system testing to ensure systems are working properly after system integration.
7. **Procurement**
   - Determine agency capability level when selecting the most appropriate ITS procurement package.
   - Maintain owner control to keep a project on time and on budget.
   - Utilize flexible procurement methods that allow for thorough and detailed negotiations.
   - Consider dividing a large ITS project into manageable task orders.
   - Consider performance-based contracts, including incentives and penalties, during the procurement process.
   - Create policies to specifically address software and technologies including intellectual property rights that are brought into, enhanced, and developed during a project
8. **Legal Issues**
   - Address intellectual property rights (IPR) early to develop a clear policy.
   - Understand the IPR issues concerning software development and technology and develop a clear policy to address these issues.
   - Develop written policies to address liability issues early.
   - Carefully consider data sharing issues to effectively balance information sharing needs with data security measures for ITS applications.
   - Plan and create policies and rules that address electronic toll collection, enforcement, and data sharing issues.
   - Develop a regional information sharing policy to help define information access and compensation arrangements.
   - Consider legislative authority and institutional arrangements to help affect policy changes.
9. **Human Resources**
   - Develop a staffing plan flexible enough to accommodate both routine and emergency conditions.
   - Consider different staffing arrangements to meet various scheduling demands at a transportation management center.

- Evaluate technical and support staffing needs to close gaps in ITS operational support.
- Involve staff in the ITS planning and deployment process.
- Create meaningful career paths and adopt optimal workload conditions for successful operations staff hiring and retention.
- Train staff throughout the deployment of a project to ensure successful implementation and use of ITS resources.
- Provide training to maintenance crews before introducing a maintenance decision support system.
- Implement cross-training mechanisms to allow task-transfer to handle variable staffing needs.

4.5 ITS and Sustainable Mobility

Transportation is an essential and integral component of a sustainable society. The Sustainable development is defined as the development that meets the needs of the present without compromising the ability of future generations to meet their own needs. There are several attributes associated with these sustainable mobility needs—a three-dimensional framework consisting of economic, social, and environmental considerations.

- ***Economic*** - Transportation has long been recognized as essential to economic development. Efficient and reliable movement of people and goods—that is, mobility—improves productivity and can spur economic growth.
- ***Social*** - People who are economically, socially, or physically disadvantaged need transportation options and choices to give them opportunities to work, learn, and participate in society. Related societal issues include the security and the safety of the transportation network.
- ***Environmental*** - On a global scale, the looming threat of climate change has focused attention on the environmental impacts of the transportation sector, which contributes more than 25 percent of our nation's greenhouse gas (GHG) emissions.



4.5.1 Reducing Greenhouse Gases

There are several ways to reduce transportation-related GHG emissions, including:

- **Improving the fuel economy of vehicles:** This can be achieved in vehicles with newer internal combustion engine (ICE) technology, such as regenerative breaking, start-stop technology (e.g., the engine automatically shuts off when the vehicle stops at a traffic signal, and turns back on when the accelerator is pushed), and in vehicles that use alternative fuels.

- **Reducing the carbon content of the fuel used:** Alternative fueled vehicles are generating significant interest and include all-electric vehicles and gas/electric hybrids (including plug-in hybrids). The future may also include hydrogen-powered vehicles.
- **Decreasing the amount of driving or VMT**: This may be accomplished via improvements in transit service alternatives to promote mode-shifts, demand management measures such a pricing, telecommuting measures to eliminate trips, and, in the longer term, land use policies that promote compact and transit-oriented development.
- **Transportation system operations can be improved through a variety of Management & Operation strategies and the supporting ITS technologies:** These include, synchronized and adaptive signal timing at intersections; active traffic management (ATM) systems providing variable speed limits and dynamic lane control; traffic incident and emergency management systems; transit signal priority systems; real-time traffic and multimodal travel information; dynamic routing; integrated corridor management; smart transit and parking systems; electronic and open road toll collection; and more.

4.5.2 Eco-Driving

Eco-driving is the concept of changing driving behavior and vehicle maintenance to impact fuel consumption and GHG emissions in existing vehicles. Below details are a summary of these best practices for eco-driving.

- **Driving**
  - Anticipate traffic flow (act rather than react)
  - Avoid rapid starts and stops (accelerate and brake smoothly)
  - Maintain an optimum highway speed for good mileage
  - Ride the green wave
  - Use cruise control
  - Navigate to reduce carbon dioxide
  - Avoid short trips
  - Avoid excess idling (turn off engine when stopped)
  - Use the highest gear possible
  - Minimize A/C use
  - Buy an automated pass for toll roads
- **Maintenance and Other Considerations:** Keep tires properly inflated
  - Obey your Check Engine light (regular service and maintenance)
  - Choose the right oil
  - Remove excess weight
  - Streamline vehicle's aerodynamics

4.5.2 Strategies for sustainable transportation system

Transportation affects fossil fuel (petroleum) reserves, global atmosphere, local air quality, noise pollution, level of mobility, congestion rate, and mortality rates (fatalities and crashes). As a result of these unsustainable aspects of transportation, there is a crucial need to develop new strategies to decelerate the current trend. Sustainable transportation ideas should be implemented in in all aspects of transportation to improve the Quality of Life of commuters. The sustainable transportation approach proposes some strategies to solve current problems, and Intelligent Transportation Systems (ITS) can assist with these strategies. The following five strategies which they believe play a significant role in achieving a sustainable transportation system:

i. **Traffic calming**: to slow vehicle traffic and create more urban, human environments better suited to other transportation modes.
ii. **Quality transit, bicycling and walking**: to create multimodal centers with mixed, dense land use that reduce the need to travel and that are linked to good transit usages.
iii. **Growth management**: to prevent urban sprawl and redirect development into urban villages.
iv. **Taxing transportation better**: to cover external costs and to use the revenues to help build a sustainable city based on the above strategies.

4.5.3 Requirements of Sustainable Intelligent Transport System

Table below presents the requirements of intelligent transport system and its application for sustainable transport system in smart cities.

No.	Requirements of Sustainable Transport System	Application of ITS
1	Realistic traffic information system for efficient and safe traffic movement	Developing Passenger Information System based on current traffic situation
2	Least travel time with minimum delays and stops	Developing synchronized traffic signal system with proper traffic management system
3	Environment friendly transport system for least environmental degradation i.e., air and noise pollution	Developing proper traffic control and management authority to check standards of vehicles for their registration and issue of license.
4	Safety of vehicles, drivers and pedestrians and reducing accident rate	Developing congestion free routes and safety and emergency management system
5	Reliable transport system	Developing passenger information system and economical public transport system
6	Proper parking spaces at affordable price	Developing intelligent parking system for economical and efficient parking
7	Efficient revenue collection with economical transport system	Developing electronic ticketing system, online booking system for public transport
8	Comfortable and affordable system to users	Developing terminal facilities and passenger information system at stops and intermediate sections.

4.5.3 Sustainable Transportation Technologies

The following are few of the examples of sustainable technologies that are presently being used in the field of transportation:

- **Autonomous driving, connected vehicles, electrification, ride-sharing, and mass-transit systems are set to change the face of mobility in cities.**

- Zero-emission vehicles are attributed to the transportation options not resulting in harmful emissions during vehicle operation. Typical examples are **electric** (battery-powered) **vehicles** and **trains, hydrogen-fuelled vehicles**, and **human/animal powered transportation**.
- At a higher level, improving traffic control could contribute to the reduction of pressure on the infrastructure, improve the air quality, and make cities more liveable. To this aim, **alternative models of transportation, active traffic management**, and **connected vehicles into an intelligent transportation system** are being studied.
- The focus of smart transportation is to connect the different transportation modes into an integrated system in order to provide the citizens with valuable information to make the right choices of the form of travel. Smart transportation allows the control of the flow of traffic and provides added value with the best routes for emergency and law enforcement personnel.
- Cities rely on a massive **system of IoT sensors, cameras, and mobile devices to gather data** about incidents, traffic, and weather. A multitude of devices is connected to **networks** acquiring massive amounts of data that is managed through **high-tech transactional services, unified communications, cloud, big data, and cybersecurity services.**
- Building smart transportation networks involves, as a first step, connecting the traffic light systems. Connecting all the data captured **in one single data management service** allows for flow optimization based on traffic routing. Then, the selected traffic user groups (buses, trucks, cars, etc.), are connected by installing **onboard units**.
- **Device health management services** are provided to monitor and manage smart devices and sensors. A managed **multi-cloud service** is used for data handling to ensure data accessibility.
- Also, innovation in last-mile freight and parcel delivery solutions could yield significant benefits for cities by reducing traffic congestion in urban centres, improving public health by lessening greenhouse gas emissions (GHG). From the manufacturer's plant or warehouse or a supplier or retailer location, the last mile of delivery is the final stage in the shipping process, culminating with the arrival of the package or good to the customer's destination. Innovation in short distance deliveries represents a major opportunity for smart cities. **Human-powered, robotic, and semi-autonomous vehicles** should have an important role in the parcel delivery role.
- Other improvements would be the design of **advanced algorithms and analytics** such as integrated inventory management, dynamic routing, courier collaboration, and proof-of-delivery tools. Looking to the future, **drones and autonomous vehicles** are expected to be integrated. Also, **autonomous ground vehicles (AGVs)** with parcel lockers would be introduced.

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Note: Refer Textbooks.