

ITS APPLICATIONS

Intelligent Transport Systems (ITS) refers to the use of information and communication technologies in transport. The development of ITS is still evolving. The extent to which these technologies are used – and the degree of sophistication in their deployment – varies from one country to another. Transport professionals around the globe need to understand the principal applications and capabilities of ITS so they can assess potential advantages, associated costs and how ITS may best be deployed.

Intelligent Transport Systems (ITS) are the control and information systems that use integrated communications and data processing technologies for the purposes of:

- improving the mobility of people and goods
- increasing safety, reducing traffic congestion and managing incidents effectively
- meeting transport policy goals and objectives – such as demand management or public transport priority measures

The definition covers a broad array of techniques and approaches that may be achieved through stand-alone technological applications or through integration of different systems to provide new (or enhancements to) existing transport services. ITS provides the tools to transform mobility and improve safety – and is particularly relevant in the context of road network operations.

FUNCTIONS

ITS aims to serve the user of the transport system by providing – for the individual – more reliability and comfort for individual mobility and – for the operator of the transport system – more effective operations and decision making. The overall function of ITS is to improve the operation of the entire transport system (often in real-time) for transport network controllers, travellers, shippers and other users.

ITS deployment is influenced by commercial interests and policy initiatives at the international, national, regional and local level – which impact on the business practices of stakeholders in the public or private sector.

ITS provides a flexible approach to addressing common transport problems – one that emphasises the use of information, optimal decision-making and a high level of system adaptability. This compares with the more traditional approach of building additional road infrastructure and adding physical capacity. ITS offers alternatives to meeting future travel demand in situations where conventional approaches may not work – for example in heavily built-up locations or in areas subject to stringent environmental regulations.

More specifically, ITS includes a variety of tools, such as sensing, communications, and computing technologies – which can be applied in an integrated way to the transport system to improve its efficiency, safety, sustainability and the resilience of network operations in the events of serious disruption.

ITS APPLICATIONS

ITS has the potential to relieve some of the most difficult problems that affect road transport today. In general ITS applications have the capability to:

- improve traffic flow by reducing congestion
- quickly detect incidents and appropriately respond to them
- improve air quality by reducing pollution levels locally and minimising travel delay
- improve safety by providing advance warning before potential crash situations
- minimise the impacts of environmental, highway and human factors that contribute to accidents

ITS can also make travel more convenient by providing travellers with accurate and timely information about the traffic conditions on the network, and available transport options. It can also foster economic growth in a region, by improving mobility, enhancing travel time reliability and reducing energy consumption.

ROAD NETWORK OPERATIONS

Many ITS applications have a role to play in effective road network operations – the aims of which include:

- making best use of the capacity available on the road network
- ensuring that the road network operates in the most efficient, safe, and sustainable way possible

In general, ITS applications that are designed to improve the efficiency, safety and/or sustainability of road networks are the applications most frequently adopted. Examples include:

- systems for managing traffic and travel demand – such as traffic control, incident management, electronic payment, travel demand management, parking management and control
- traveller information systems applications that allow road users to make informed decisions on their travel choices – such as driver information and route guidance

The concept of connected autonomous vehicles is becoming feasible and gaining support which will have major implications for road network operations – which will need full evaluation.

ITS BENEFITS

All road users, including drivers and their passengers, pedestrians and cyclists – across all modes of road transport, including private cars, buses, coaches and commercial vehicles – can benefit from greater use of ITS. For example, ITS applications support:

- commercial vehicle operations of commercial operators, regulatory and tax agencies and road users – providing benefits such as electronic administrative processes and automated roadside safety inspections
- public transport from the perspective of both operators and travellers – providing benefits such as improved observance of time-tables, optimised operations, improved security on-board vehicles and at terminals – and a higher standard of service by providing real-time schedule information to travellers.

ITS APPLICATIONS AND SERVICES

The use of technology to manage transport systems, and to improve their efficiency and safety, has a long history that predates the first use of the term “ITS” in the 1990s.

Among the first examples of technology applied to road transport were urban traffic signal control systems – with increasing levels of sophistication over time (in terms of sensing vehicle presence and control logic). Their purpose was to control traffic at road intersections to improve traffic flow and safety. Other early ITS applications were for motorway incident detection and improving the information available for travellers – with real-time traffic alerts and roadside Variable Message Signs.

In the 1990s, there was increased recognition of the negative impacts of road transport (such as congestion, accidents and pollution) and the search began for solutions to the challenges that facing large, congested, metropolitan areas. The traditional solution of adding capacity by improving the road infrastructure was often no longer viable – for example, because of environmental concerns or the unavailability of space. These factors combined to motivate transport professionals to investigate the potential for utilising advanced technologies – such as sensing, communications and computing – to improve the performance of road networks.

ITS deployment is now almost ubiquitous in developed countries and has begun to take root in many emerging economies as well. The range of potential applications for ITS, has dramatically increased. Whereas initially the focus was on stand-alone applications, there are now examples of truly integrated systems – solutions that look at the transport system as an integrated whole – for example, integrated multimodal ticketing.

THE EARLY YEARS

The early years of ITS were championed by a handful of countries – including the United States, Canada, a number of European countries, Japan and Australia. In the USA, for example, several transport reauthorisation bills – from the 1991 Intermodal Surface Transportation Efficiency Act (or ISTEA) onwards, encouraged the deployment of ITS and the search for advanced technology applications in transport. A number of Field Operational Tests (FOT) were also undertaken – designed to test the feasibility of implementing the technology-based solutions, as well as provide information on their likely costs and benefits.

ITS TODAY

A decade or so ago the means for disseminating information to travellers were rather limited (such as Dynamic Variable Message Signs, Highway Advisory Radio, Television, and phone systems). Today, with the almost universal market penetration of smart phones and other mobile devices, it is much easier to reach travellers with the correct information.

Recent years have witnessed a renewed and increased interest in the topic of connected and autonomous (self-driving) vehicles – which can be regarded as the latest phase in the evolution of ITS. Third and fourth generation digital mobile telecommunications have enabled higher levels of connectivity between vehicles and the infrastructure, coupled with greater automation within vehicles. This may radically change the way that motor vehicles are driven and the way that road traffic is managed.

ITS service Areas

The principal applications of ITS – that contribute to road network operations are:

- traffic and road network management
- traveller information systems
- public transport systems
- commercial vehicle applications
- vehicle safety applications
- maintenance and construction management applications
- emergency management
- archived data management

EXAMPLES OF APPLICATIONS BY ITS SERVICE AREAS

The table below illustrates the eight main ITS service areas – and provides examples of service applications in those areas.

Service Area	ITS Related Applications	Operational Goal
Traffic management	Incident management; traffic control.	Manage and control traffic on roadways to optimize its operation.
Traveller information	Pre-trip traveller information, en- route traveller information.	Provide trip related information to travellers before, or during their trips
Public transport	Transit vehicle tracking; transit security.	Improve public transport services to encourage their use
Commercial vehicle operations	Commercial vehicle administrative processes, Automated roadside safety inspection, hazardous material incident response	Improve public sector fleet management; improve public sector administration of commercial vehicle operations
Vehicle safety	Vision enhancement, longitudinal and lateral crash avoidance; intersection crash avoidance.	Improve the safety of the transport system by supplementing drivers' abilities to maintain alertness and control of the vehicle, and enhancing crash avoidance capabilities of vehicles
Construction and maintenance operations	Fleet management; work zone management.	Improve management of vehicles associated with construction and maintenance; managing work zones, managing roadways for supporting construction and maintenance

Service Area	ITS Related Applications	Operational Goal
Emergency management	Emergency notification; emergency vehicle management.	Support emergency management functions with faster identification of emergencies and response
Archived Management	Data Data depository	Collect and compile data for traffic prediction, system performance monitoring and policy analysis

ITS SERVICE CHARACTERISTICS

ITS-based services share some general characteristics:

TIMELINESS

Time is a critical element in ITS services which often make use of real-time or near real-time data. The time frame for collecting and processing live data is limited, although historical data is frequently used. For example, traffic information – such as travel time, link speed and information about incidents blocking lanes – is only useful to travellers if it is made available in real-time or predicted near-future time.

CAPACITY ENHANCEMENT

Many ITS services can enhance the capacity of existing road infrastructure by means of operational improvements that avoid the need for expenditure on major improvements – such as constructing new roads or adding additional lanes. For example, on congested motorways – managed lanes and speed control can benefit safety leading to fewer traffic incidents and improved traffic throughput. Strategic re-routing can divert traffic from congested roads to less congested roads at certain times of the day. Traffic signals can be made to be adaptive to real-time traffic demands to improve efficiency and capacity of signalized intersections.

DECISION-MAKING SUPPORT

Data collected through ITS – such as traffic speed, traffic volume and vehicle tracking data – can be used for real-time decision support for individual travellers, road network operators and vehicle fleet managers. Data collected through ITS can also be used in algorithms and models that assess current and future network conditions – which provide decision support. Data collected through ITS can also be archived until needed for planning purposes.

EFFECTIVE APPLICATION SCENARIOS

ITS services are most valuable and effective in unfavourable conditions – such as during an incident, evacuation, congestion or disruption of services. For example, an incident may cause significant delays and contribute to

secondary traffic accidents. ITS services – such as quick detection of an incident, faster response and incident scene management – may reduce the duration of an incident, which will contribute to reductions in traffic delays and a lower probability of secondary accidents.

ENHANCEMENT OF TRIP EXPERIENCE

ITS provides an opportunity to enhance reliability and safety of a trip. ITS services – such as satellite navigation, incident management and adaptive traffic signal control – can reduce delays and improve the reliability of a trip. Similarly, ITS services geared towards safety – such as speed warning and enforcement and intersection collision avoidance – can decrease the probability of an accident.

ROAD TRAFFIC MIX

ITS services have been developed for more than one mode of transport – and can target different types of vehicle. For example, roadway network monitoring services keep track of passenger cars, buses, emergency vehicles and commercial vehicles. ITS services can also determine priority routing for specific vehicle types – for example, buses and coaches can be prioritised with a green light at traffic signals along a corridor. Similarly, signal pre-emption technology can allow emergency vehicles to receive -of-way through an intersection by directly communicating with the traffic signal control equipment.

FURTHER

INFORMATION

Miles J.C. (2014) *Intelligent Transport Systems: Overview and Structure (History, Applications, and Architectures)*. Automotive Encyclopedia ISBN: 9781118354179 Wiley on-line Library.

Table of contents can be accessed on-line at: <http://onlinelibrary.wiley.com/book/10.1002/9781118354179/toc>

TRAFFIC AND ROAD NETWORK MANAGEMENT

A common feature of ITS – when applied to traffic and road network management – is the use of real-time, conventional and historic data sources to produce information on the existing and future status of the road transport system. ITS applications play an important part in the way road networks are managed to improve the efficiency and reliability of transport operations and reduce negative environmental and energy consumption impacts.

Examples of ITS applications in road network operations are:

- traffic management
- commercial vehicle operations
- public transport operations management
- traveller information

Traffic and road network management applications aimed at improving road transport efficiency includes electronic payment to remove the need for vehicles to come to halt before paying a road toll and to simplify fare payment for public transport.

Electronic tolling systems also provide the flexibility needed to implement innovative road pricing and congestion charge schemes.

The principal ITS applications that support traffic and road network management include:

TRAFFIC CONTROL

Traffic control aims to manage and control the movement of traffic on roads to optimise the use of existing road capacity. ITS applications include:

- urban traffic control that is demand-responsive and may incorporate transport policy elements – such as public transport prioritisation or queue management
- adaptive signal control systems along arterial roads that adjust signal timings to current traffic conditions – such as those caused by special events or incidents
- freeway control systems that use ramp metering and lane control techniques to smooth traffic flow
- integration of highways and network signal systems for the purpose of corridor or “area-wide” optimisation of traffic flow

The implementation of effective traffic control strategies requires timely and accurate traffic information. The better the data, the more effective the control strategies that can be implemented. Information is gathered from various sources – such as detector loops in the road pavement, roadside and overhead sensors and analysis of digital camera images. The data can be combined and used to decide upon the best (or optimal) course of action for managing traffic on the network.

Traffic control is one of the most basic building blocks of an intelligent road transport system, since it requires detection, control, communications and support systems – that are fundamental to the operation of several other ITS services. Traffic control and traffic operations centres (TCCs and TOCs), responsible for these functions, now exist all over the world.

INCIDENT MANAGEMENT

ITS plays a significant role in improving incident management, particularly on highways, motorways and other high speed roads. This is because it uses vehicle sensors (such as inductive, buried, loops, radar and CCTV cameras), data processing and communications technologies to quickly detect and verify an incident. Sophisticated decision support systems then help traffic managers to decide how to best respond to any given incident. Using ITS in this way can improve safety and network efficiency, saving lives and money.

ELECTRONIC PAYMENT

One of the application areas where ITS has achieved great success is in the area of electronic payment. Among

the prime examples of electronic payment are Electronic Toll Collection (ETC) systems such as the EZPass System in the USA or the European Electronic Toll Service. These systems allow drivers to pay road tolls without stopping or slowing down their travel speed – minimising delays and improving air quality in the vicinity of toll plazas.

ETC systems can take various forms such as:

- a mainline toll plaza with payment at the barrier;
- an open highway collection system where tolls are collected at main-line speeds;
- a closed system where tolls are charged based on entry and exit locations.

These systems can impose different tolls for different classes of vehicles, and can provide for the automatic enforcement of violations. Other examples include integrated payment systems – designed to allow a traveller to pay for different services (for example driving on a toll road, paying for parking, paying for transit) using the same medium or device.

TRAVEL DEMAND MANAGEMENT

ITS can be applied to implement strategies aimed at increasing the frequency of Multiple-Occupancy Vehicles (MOVs) and promoting the use of High-Occupancy Vehicle lanes (HOVs). ITS can help make the operation of HOV lanes more effective and adaptive to changing traffic conditions – by adjusting vehicle occupancy requirements at different times of day, based upon current traffic and congestion levels. ITS also can help implement congestion pricing strategies – where toll charges are adjusted to influence demand. For example, tolls can be increased during peak hours in urban areas or in the vicinity of environmentally sensitive tourist attractions in rural areas.

PARKING MANAGEMENT AND ACCESS CONTROL

ITS can be applied to better manage the allocation and price of parking spaces. This helps improve the travel experience of drivers by providing real-time information on spaces in parking lots. ITS-based parking information systems can be integrated with city-wide traffic management and control – to minimise parking search times and optimise traffic management overall. Electronic toll tags can also be used as a means of controlling access to a controlled parking area.

EMISSIONS TESTING AND MITIGATION

ITS can help improve the environmental sustainability of road transport. Some ITS applications use environmental sensors to collect information about exhaust emissions from vehicles at a certain location, or over a wide area. The information can then be used to intelligently divert traffic away from areas where air quality has fallen below an acceptable threshold – or by not letting vehicles access these environmentally sensitive areas. The information can also provide valuable input to the development of air quality improvement strategies – and to alert vehicles' operators if their vehicles are not compliant with adopted emissions standards. ITS can also be used to manage congestion and reduce delay – which has beneficial impacts on emissions and air quality.

HIGHWAY-RAIL INTERSECTION

The purpose of a highway-rail intersection ITS application, is to provide improved warning and safety control devices where a railway (railroad) crosses a road or highway at a level crossing (an “at-grade” crossing). On the approach roads to the crossing, any signalised intersections can be connected to the control and warning devices at the highway-rail intersection (HRI), so that signals can be coordinated to manage queuing and divert traffic. The technology can also monitor the “health” of HRI equipment – and report any detected malfunctioning.

EMERGENCY OPERATIONS

ITS system and service applications have an important role to play in emergency situations:

- emergency notification and personal security applications;
- emergency vehicle management;

Emergency notification and personal security applications include systems that:

- allow a driver to initiate a distress call in the event of an incident (emergency and a non-emergency such as mechanical breakdown);
- enable the vehicle itself to automatically notify emergency management services (EMS) personnel in the case of a collision.

The European eCall and American OnStar systems are good examples:

- eCall: <http://ec.europa.eu/digital-agenda/en/news/ecall-all-new-cars-april-2018>;
- OnStar: <https://www.onstar.com/web/portal/home?g=1>).

Emergency vehicle management focuses on applications intended to reduce the time from the receipt of an emergency notification to the arrival of the emergency vehicle at the scene of the incident. This is accomplished through:

- optimal emergency fleet management – to identify the locations of emergency vehicles in real-time and dispatch the vehicles that can reach the scene of the incident most quickly;
- dynamic route guidance – to guide the emergency vehicle to the fastest route to the incident scene or a suitable hospital;
- signal priority or pre-emption – to give priority to trams and buses.

TRAVELLER INFORMATION SYSTEMS

Traveller information systems is an application area that has seen numerous ITS developments and heavy investment.

There are five of the leading applications:

PRE-TRIP TRAVEL INFORMATION

The goal of pre-trip travel information is to provide travellers with information about the status of the transport network *before* they begin their trip. The information provided can be limited to road or multimodal transport – and can include:

- real-time flow conditions (average traffic speeds or point-to-point travel times)
- road incidents and suggested alternative routes
- scheduled road construction and special events
- transit routes, schedules, fares and transfers
- park-and-ride facilities, locations and availability

In the early years of [ITS](#), travellers were able to access this information at home or work (via a computer or a telephone system) and at places generating traffic (for example, a shopping mall – via a touch-screen kiosk). Nowadays, with the proliferation of smart phones and mobile devices connected to the internet, travellers can access travel information anytime, anywhere. More advanced versions of these systems can provide users with predictive travel conditions, as well as help with trip planning.

EN-ROUTE DRIVER INFORMATION

En-Route driver information is aimed at providing drivers with travel-related information *after* they start their trip – *during* the journey. Traditionally, this has been achieved by means of Variable Message Signs ([VMS](#)), radio broadcasts and Highway Advisory Radio ([HAR](#)). More recently with the widespread introduction of smart phones and mobile devices – and with the interest in developing Connected Vehicles – more effective means are available to provide travel information and to personalise it for the traveller specific to the journey and locations.

The development of Connected Vehicles that will be able to communicate with the infrastructure as well as with other vehicles, will allow greater opportunity for the delivery of advisory and warning messages to drivers (for example, warning motorists of unsafe conditions such as sharp curves, wet pavements, icy conditions – and alerting motorists if they exceed the safe speed limit and alerting drivers to unsafe weather conditions.)

ROUTE GUIDANCE

The widespread use of [GPS](#) navigation devices provides drivers with detailed turn-by-turn instructions on how to get to their destinations. These directions traditionally relied on static information – for example historic travel times for different road segments, held in a navigation database. More sophisticated guidance systems are dynamic – with directions responding to changing traffic conditions based on real-time information about traffic speeds and incident locations. The digital maps that support these device need to be kept up-to-date – for example, by downloading updates on new road links and traffic restrictions.

Route guidance is now widely available through in-vehicle systems, portable devices and smartphone handsets. The benefits include reduced travel delays arising from navigational errors and lower stress levels for drivers, especially when driving in an unfamiliar area. Problems can arise for local communities when a product – intended for the general motorist – is used by drivers of large or heavy vehicles and the recommended route is a road unsuitable for those vehicles.

RIDE MATCHING AND RESERVATION

Ride-matching and reservation is aimed at encouraging carpooling by providing real-time matching of the preferences and demands of users with providers – and by serving as a clearinghouse for financial transactions. A traveller can call a service centre and provide it with information about the desired trip origin, destination, and time. In return, the traveller will receive feedback on a number of ridesharing options from which to choose.

TRAVELLER SERVICES INFORMATION

Traveller service information is intended to provide travellers with “yellow-pages” information. This may include information on the location of services such as food, lodging, gas stations, hospitals, police stations – as well as information on the location of points of tourist attractions. Examples of these applications are already included in many GPS navigation devices and smart phone apps.

PUBLIC TRANSPORT SYSTEMS

ITS is widely deployed to improve the level of service offered by public transport – to make buses, coaches, metros, trams and trains more convenient and encourage their greater use as a means of transport.

Four examples of such applications are:

PUBLIC TRANSPORT MANAGEMENT

Public transport management applications use advanced communications and information systems to collect data to improve the:

- operation of the vehicles and facilities
- planning and scheduling of services
- management of personnel

Real-time data collected from vehicle tracking and location systems can be used to ensure schedule adherence – and to implement corrective actions when a particular vehicle is running behind schedule. Real-time information applications can also help facilitate passengers’ transfers at connecting stations. Off-line, the data collected can be analysed and used to revise schedules, to better plan routes, to satisfy contract reporting requirements, and to improve customer information systems.

EN-ROUTE INFORMATION

En-route information applications are intended to provide public transport travellers with information *after* their trips have started. Among the key pieces of information which are typically provided are:

- information on expected arrival times of transit vehicles
- transfers and connections
- ride-share opportunities

Various information dissemination devices could be used including signs and kiosks at bus stops, internet websites that can be accessed via smart phones and mobile devices, and various types of smart phone apps.

PERSONALISED PUBLIC TRANSPORT

Personalised Public Transport (PPT) is based on the idea of using flexibly-routed vehicles to offer more convenient services to travellers – in some cases door-to-door. There are two main types of PPT:

- flexibly-routed operations – in which fixed-route buses are allowed to deviate from their main route to pick-up or drop-off passengers
- random route operations – which operate with variable-routing based upon the pattern of service requests received.

Ideally, this type of application will offer journey reservations – and vehicle assignment and scheduling to be developed in real-time.

PUBLIC TRANSPORT SECURITY

Public transport security ITS applications are aimed at improving the security of public transport users, operators and support staff. This can be achieved by integrating vehicle location technologies and monitoring systems to provide a warning and response system to deal with security-related incidents. For example, transport stations and terminals, parking lots, bus stops and the inside of transport vehicles can be monitored with CCTV with image processing for surveillance – so that an alarm is triggered, either manually or automatically, by an “at-risk” event. Critical infrastructure, such as bridges, tunnels, rail track, can also monitored in this way as part of a public transport security strategy.

COMMERCIAL VEHICLE APPLICATIONS

ITS has been applied to improving the efficiency and safety of commercial vehicles. There are two broad areas of applications:

- those aimed at improving private-sector fleet management
- those designed to streamline government/regulatory functions

Specific examples include:

COMMERCIAL VEHICLE ELECTRONIC CLEARANCE

Electronic clearance is designed to allow compliant commercial vehicles to continue past checkpoints at mainline

speeds. As a vehicle approaches a checkpoint, communications between the vehicle and the inspection station take place – often by means of a dedicated short-range wireless link – allowing the authorities to check relevant information, such as the vehicle’s credentials, weight, safety status and cargo. This system allows enforcement personnel to select potentially unsafe vehicles for inspection, while permitting safe vehicles to bypass the commercial vehicle checkpoint.

AUTOMATED ROADSIDE SAFETY INSPECTION

As a complement to commercial vehicle electronic clearance, automated roadside safety inspection ITS applications use automated inspection capabilities to facilitate safety checks with greater speed and accuracy during a safety inspection at a vehicle inspection site. This helps reduce the amount of time spent by the vehicle examiners inspecting vehicles, whilst also providing more reliable data on the safety status of the vehicle.

ON-BOARD SAFETY MONITORING

Among the many ITS automotive engineering applications are systems that monitor the safety condition of a vehicle and cargo as well as the driver – without the need for the vehicle to slow down. The monitoring capabilities may include:

- sensing the condition of critical vehicle components, including brakes, tyres and lights
- sensing shifts in the cargo while the vehicle is in motion
- monitoring the time-on-task of drivers
- monitoring the drivers’ alertness level

Safety warnings are provided to drivers and can be made available to vehicle fleet managers or controllers and to roadside enforcement personnel.

COMMERCIAL VEHICLE ADMINISTRATIVE PROCESSES

ITS applications can smooth the administrative processes required of commercial fleet operators by government or regulatory bodies. They may allow the automatic purchase of credentials (such as a port permit or other selective access toll) and include automated reporting of mileage and fuel use. This saves the operator time and money.

HAZARDOUS MATERIALS INCIDENT RESPONSE

ITS has a part to play in the response to incidents involving hazardous materials (HAZMAT). Law enforcement and HAZMAT response personnel can be provided with timely, accurate information on cargo contents at the scene of an accident – so they know exactly how to handle the materials involved in an appropriate way. Emergency responders can be provided with access to this information – either through remote access to the relevant databases, or, in real-time, through the use of readers that communicate with the HAZMAT vehicle’s on-board transponder.

FREIGHT MOBILITY

ITS applications provide real-time communications between drivers, dispatchers and intermodal transport providers for the purposes of vehicle location identification, dispatching, and tracking – to help optimise freight operations and vehicle utilisation.

VEHICLE SAFETY APPLICATIONS

A number of ITS developments in the automotive sector are focused on improving the safety of the road transport system by complementing, or enhancing, drivers' abilities to maintain alert and in control of the vehicle – and improving the accident avoidance performance of vehicles. A major motivation in their development is recognition of driver error as a major factor in the majority of car accidents. Developments in this area are moving towards the concept of self-driving cars and automated vehicle-highway systems. Examples of this type of safety-related ITS applications include:

COLLISION AVOIDANCE

The automotive industry has been working on a variety of collision avoidance systems that are either already in production or close to market. These systems include:

REAR-END COLLISION AVOIDANCE

These systems monitor the separation distance between vehicles and warn drivers when sensors detect another vehicle that may be dangerously close. If the driver does not react appropriately, automatic vehicle control actions may be initiated. Examples of these systems are already installed in the vehicles of some automotive manufacturers, such as Mercedes and Volvo.

ADVANCED EMERGENCY BRAKING

Advanced Emergency Braking Systems (AEBS) detect the possibility of a collision with the vehicle ahead and warn the driver – using visual, audio or tactile feedback. If the driver takes no action, the system automatically applies the vehicle's brakes. At lower speeds AEBS acts to prevent a crash – at higher speeds it will reduce the severity.

ADAPTIVE CRUISE CONTROL

Adaptive Cruise Control (ACC) tracks the vehicle in front, and automatically maintains a desired minimum distance (or time headway) from that vehicle. So long as this minimum distance is maintained, the vehicle will travel at the set speed. If the separation distance falls below this minimum value, the ACC system adjusts the vehicle's speed to regain the minimum headway (in time or distance).

REVERSING COLLISION WARNING AND CONTROL

These systems detect slow moving or stationary objects and pedestrians that are in the path of a vehicle that is reversing – and warn the driver accordingly. Detecting these objects requires the use of relatively short-range sensors on-board the vehicles, such as a rear-view camera. Examples of these systems can be found fitted to many of today's vehicle models.

LANE DEPARTURE AVOIDANCE

Lane departure systems aim to help drivers avoid accidents that could result when a vehicle leaves its own travel lane and strays into the path of a vehicle in another lane. This is achieved by warning drivers and/or assuming temporary control of an at-risk vehicle. Among the most well-known of these systems are:

- Lane Change/Blind Spot Situation – Display, Collision Warning and Control, which provide drivers with information about the presence of vehicles in their blind spots, warns them of potentially dangerous lane change manoeuvres, and may assume temporary control of the vehicle's steering and braking to avoid collisions;
- Lane/Road Departure Warning and Control, which assist in keeping a vehicle in its proper lane – typically using vehicle-based technologies (such as video image processing and optical/infrared scanning).

INTERSECTION COLLISION AVOIDANCE

ITS technology has been tested in applications that will avoid, or to decrease the severity of, collisions at intersections. These systems track the position and status of vehicles within a defined area on approach to an intersection through the use of vehicle-to-vehicle communications and/or vehicle-to-infrastructure communications. If a potentially dangerous situation is detected that is likely to lead to a collision warning messages are delivered to the driver – for example, in cases where a vehicle fails to stop at a red light or attempts to make a turning manoeuvre in the absence of an adequate gap.

VISION ENHANCEMENT FOR COLLISION AVOIDANCE

ITS applications have been developed to help eliminate and/or reduce the severity of accidents that result from poor visibility – such as night driving, heavy rain or foggy conditions. These systems include in-vehicle sensors that can capture images of the driving environment and display them graphically to the driver, for example through a head-up display. One example that illustrates the concept is the Driver Assistance System for Snowploughs developed by the University of Minnesota <http://www.lrrb.org/media/reports/200313.pdf>.

SAFETY READINESS

The goal of safety readiness ITS applications is to eliminate and/or reduce the number of collisions caused by impaired drivers (though tiredness, alcohol or drugs), a failure of vehicles' components, or any degraded infrastructure conditions that could affect the safety of the vehicle. Systems are available that monitor the performance of the driver – and either warn or assume temporary control of the vehicle if a driver's performance is impaired. Other systems monitor the performance of critical components of a vehicle (such as the braking system), and warn drivers of their imminent failure. There are also systems that can monitor the roadway and

provide warnings to the driver of unsafe conditions – such as loss of tire traction on wet or icy road surfaces.

PRE-CRASH RESTRAINT DEPLOYMENT

Pre-crash restraint ITS applications anticipate an imminent collision and activate the appropriate passenger safety systems prior to the actual impact. For example, sensors are available to detect the rapid closing of distance between the vehicle and an obstacle. On detection, the system attempts to reduce the danger of the impact of the collision by settings restraints to absorb or dissipate the force of the impact – such as triggering an airbag.

AUTOMATED HIGHWAYS AND SELF-DRIVING VEHICLES

A long-term goal of vehicle safety systems is a fully automated highway-vehicle system (AHVS) – where specially equipped vehicles travel, under fully automated control, along dedicated highway lanes – or where a self-driving vehicle pilots itself through mixed traffic. The AHVS concept has the potential to significantly improve the safety, as well as the efficiency, of highway travel by reducing the number and severity of crashes, decreasing congestion, and reducing vehicle emissions and fuel consumption.

The safety risks associated with AHVS operations need to be analysed carefully so that the risk of mal- function is minimised. Many automotive manufacturers are currently involved in significant research and demonstration projects aimed at making autonomous (or self-driving) cars, a reality. A number of countries are preparing to test the readiness of driverless cars. Nissan, for example, has promised the production of autonomous cars by 2020 – and Google has sponsored the development of a self-driving car. Initiatives from public and private enterprises may help accelerate the deployment of self-driving cars. An example is here: <http://www.autoblog.com/2013/08/27/nissan-promising-autonomous-car-production-by-2020/>

MAINTENANCE AND CONSTRUCTION MANAGEMENT

ITS has a lot to offer in terms of supporting and facilitating the maintenance and management of highway infrastructure, winter maintenance operations, as well as improving the management and safety of road construction and work zones. Technology applications range from those aimed at tracking and routing support for maintenance and construction vehicles, to systems designed for monitoring and predicting weather conditions, to applications aimed at construction and work zone management. Some examples include:

VEHICLE TRACKING AND MAINTENANCE

ITS technologies can be used to keep track of maintenance and construction vehicles such as snow ploughs – so that operators can monitor whether required tasks are being carried out as planned. ITS can also be used to monitor the condition of maintenance and construction vehicles – using on-board sensors to alert users of any required maintenance or repair activities.

WEATHER DATA COLLECTION, PROCESSING AND DISSEMINATION

Using Road Weather Information Stations (RWIS) and other similar environmental sensors (whether fixed location or on-board maintenance vehicles), ITS can help collect accurate, localised information about the weather – including road surface conditions. ITS can also help in the processing of the data and in disseminating information to the public. Information from RWIS can help detect hazardous conditions – such as icy roads, high winds, dense fog – and to plan, more effectively, winter maintenance operations and optimise resource allocations.

WINTER MAINTENANCE OPERATIONS SUPPORT

Winter maintenance operations can be supported by systems that monitor and track routes for snow ploughs and grit spreaders – to determine the correct roadway treatment needed. This will be based on current and predicted weather information and information collected from environmental sensors.

WORK ZONE MANAGEMENT

ITS can play a key role in helping improve the safety of work zones and construction sites on highways – as well as better manage the flow of traffic through the work zone. Information collected from permanent and temporary ITS monitoring facilities can be used to better control traffic and to provide advisory and warning messages to drivers – for example through dynamic message signs (DMS). The traffic information collected from the work zone can also be shared with traffic operations centres and to support traveller information systems. (

INFRASTRUCTURE MONITORING

ITS technologies can be used to monitor the condition of critical infrastructure such as bridges and road tunnels. Information from fixed sensors as well as vehicle-based sensors play a part. One recent idea is to use information from probe vehicles – about their vertical acceleration – to determine the pavement surface condition and detect different types of distress, such as potholes or surface roughness.

BASIC ITS CONCEPTS

ITS is not only about the use of telecommunications and information processing in road transport operations. Many of the challenges that accompany the introduction of ITS are not about technology but about different ways of working – especially different organisations working together in new ways. There is now a large body of ITS 'know-how' that draws on the practical experience of substantial numbers of ITS projects and case studies.

To properly understand how ITS works, there are a number of issues to take into account:

ENABLING TECHNOLOGIES

For ITS to work, a number of technologies are needed.

DETECTION AND MONITORING

Collecting accurate information about the status of the transport system is a pre-requisite for almost all ITS applications. The problem needs to be identified before coming up with a solution. The front-line group of enabling technologies are those used for collecting real-time traffic information. Some of these are infrastructure-based and others are vehicle-based.

Infrastructure-based detection technologies include:

- inductive loop detectors
- non-intrusive detectors (for example microwave, infrared, ultrasonic, radar, and acoustic sensors)
- closed-circuit TV cameras and Video Image Processing (VIP)
- environmental sensors

Vehicle-based detection technologies include:

- vehicle probes
- police and citizens' reporting

TELECOMMUNICATIONS NETWORKS

Telecommunications may be compared with the nervous system in the human body. Communication networks link the different components of an ITS system together, allowing for the exchange of information and for the implementation of the different traffic management and control strategies. They also link the traveller to the system allowing for the dissemination of useful information.

DATA PROCESSING AND COMPUTING TECHNOLOGIES

To be useful, the real-time traffic and environmental data collected from the field must be processed, fused together with different sources and analysed. Data processing and computing technologies refer to the set of computer *hardware* and *software* that is needed to make sense out of the data, and convert the *data* into *information* that can support decision-making.

INFORMATION DISSEMINATION

Effective communication with travellers is an essential component of several, if not all, ITS applications. ITS uses several traffic information dissemination devices to keep travellers informed about current as well as expected travel conditions. These devices include Dynamic Message Signs (DMS), highway advisory radio (HAR), cable TV, traveller information websites, social media (Facebook, Twitter) and the internet, dedicated phone systems, and in-vehicle display devices.

LOCATION REFERENCING AND POSITIONING

The most common technology currently used for location and navigation are satellite navigation systems for location determination (latitude, longitude, and elevation). These triangulate ground position based on satellites signals – and are known as Global Navigation and Satellite Systems (GNSS). The most well-known is the USA's military Global Positioning System (GPS). The European Union is developing a compatible civilian system, GALILEO – aimed at providing higher availability and improved positioning accuracy.

Light Detection and Ranging (LIDAR), a remote sensing technology, can be used to generate three-dimensional information about different locations and their surface characteristics. LIDAR, either airborne, mobile or terrestrial, has been used in transport for various tasks, such as surveying, highway design and highway safety. With accurate mapping and positioning of roadway infrastructure, LIDAR can support various ITS applications – such as real-time roadway-weather monitoring and real-time evacuation support during emergencies.

CONTROL TECHNOLOGIES

Control technologies constitute another group of enabling technologies for ITS applications. They can be divided into two broad categories:

- infrastructure-based control technologies aimed at regulating and managing traffic – for example adaptive signal control systems, freeway lane control, and ramp metering
- vehicle-based control – such as Advanced Driver Assistance Systems (ADAS) and Adaptive Cruise Control (ACC)

ELECTRONIC PAYMENT

One of the most widely deployed ITS applications is in the area of electronic payment, which:

- allows drivers to pay tolls without stopping
- provides travellers with just one payment medium (for example a smart card) to use for paying for several transport services – such as bus fares and parking fees.

In terms of hardware, the most common technologies for electronic payment are: smart cards, transponders (such as a toll tag) and more recently, smart phones.

DATA ARCHIVING AND MANAGEMENT

This group of ITS enabling technologies includes those designed to support Archived Data Management Systems (ADMS) – or what are sometimes also known as ITS Data Warehouses. ADMS offers an opportunity to take full advantage of the data collected by ITS devices in improving transport operations, planning and decision-making – often at a minimal additional cost. The technologies supporting ADMS are designed to *archive, bring together (or fuse), organise and analyse* ITS data from different sources and can support a wide range of useful 'intelligent' applications.

STAKEHOLDERS

A feature of integrated systems that are designed to serve the mobility needs of people and goods distributed spatially over a large geographic area, almost always requires the collaboration of several stakeholders.

CLIENT AGENCY

Any ITS deployment generally involves a range of organisations. It is often the case that a **champion or client agency** will take the lead. This could be a road authority or a department of transport, local government, a public transport operations agency – or a coalition representing all these parties.

SYSTEM INTEGRATOR

One method of ITS procurement will involve a specialist consulting firm acquiring a wide range of ITS equipment and technologies from a number of vendors and manufacturers of ITS technologies. The consulting firm would typically act as a **system integrator** bringing together all the technologies and components so they work as a truly integrated system.

SYSTEMS APPROACH

For ITS to be effective, its different components have to work together as one integrated system. The components have to be able to communicate with one another, and need shared data dictionaries and communications protocols. This underscores the importance of adopting a systems engineering approach to the design, deployment and management of ITS projects.

A systems approach will consider the context of ITS deployment and how all the component systems fits together. A fundamental aspect of the approach is that User Requirements are defined at the start – and taken into account in the design and development of the system. It is different to a technology led approach. It also explores the various system interfaces, the data that needs to be exchanged, the equipment and communication standards – and the building blocks that need to be in place for effective operations. A systems approach also considers how ITS would fit within the larger regional transport system, and investigates how to maximise the benefits from the system. The approach considers not just the technical challenges, but the institutional ones as well – which are key to integration and collaboration.

HUMAN FACTORS

Human factors are of great importance to ITS deployment and effectiveness – from the perspective of infrastructure, operations and vehicles. For vehicles, it is important to ensure that ITS applications do not distract drivers from their primary driving task – or overload them with information. This is particularly the case with Advanced Driver Assistance Systems (ADAS) – which continue to mature and increase in sophistication. Another important area is smart phone usage and “infotainment” applications. Many studies have shown the dangers of using a phone while driving (and worse still – texting while driving), and many countries have issued laws banning the use of cell phones and similar devices whilst driving.

The likely response of drivers and travellers to an ITS system recommendation is another key area. An ITS system may recommend to drivers, a certain speed or a specific route to arrive at their destination – but there is no guarantee that the driver will follow the system’s recommendation. Building trust in ITS systems is critical for public acceptance.

In terms of future development of ADAS, human-machine interaction is critical in ensuring that the driver interacts safely with the vehicle and the technology on board. The prospect of vehicles with various levels of automation – which may soon lead to partially or fully autonomous (self-driving) vehicles – makes this a more urgent issue.

INFORMATION SUPPLY CHAIN

ITS is all about acquiring data and information, the exchange of information, the processing of information, the use of information to support decisions – and the dissemination of information to travellers and other end-users.

It shows ITS using detection and monitoring technologies to collect data in real-time – about the transport system and other external factors (such as the weather). The ITS then uses its communication network to exchange this information between different traffic centres, different agencies, and different regions. The information gathered is then processed and analysed to understand how the transport system is operating – and to identify “optimal” management and control strategies aimed at improving system performance. The information is also disseminated to a wide range of ITS stakeholders – such as traveller information to the transport system users.

ITS applications include the information infrastructure that supports the collection, archiving, processing and distribution of a wide variety of data – for example about travel demand, traffic volumes and journey patterns.

Data is collected continuously by different ITS tools with different characteristics – such as quantity, frequency, timing (real-time, near real-time or historical), and reliability. By systematically validating, storing, archiving and fusing data from different sources, the compiled data can be mined and analysed to gain useful insights into how to best plan, operate and manage the transport system.

ITS data provides a very important resource for calculating performance measures to assess the quality of service provided by the road network – and any associated ITS applications, such as automatic incident detection.

Performance measurement is a topic that has received increased attention in recent years. Growth in the data sources for ITS – such as social media, GPS and communication-enabled connected vehicles – are coupled with changing security and privacy concerns. The impact on the planning, design and evaluation of ITS information infrastructure will be in the forefront of any ITS deployment consideration.

COORDINATION

The development, deployment and operation of ITS requires coordination and collaboration among a wide range of stakeholders. Those stakeholders typically include (amongst many others):

- road authorities
- ministries or departments of transport
- city planning organisations
- departments of public works
- police departments
- the freight industry
- emergency management organisations
- auto manufacturers
- manufacturers of ITS equipment and products
- telecommunications and information technology companies
- financial institutions
- Value-Added Service Providers (VASPs)

The deployment of ITS also needs a “champion” – or a strong leader – who believes in the vision and can inspire others. The first step in any ITS planning initiative is to identify the key stakeholders and build local partnerships (with memoranda of understanding if required) to allow for combined action and joint problem-solving.

ITS ARCHITECTURE

In ITS the term ‘architecture’ describes a structured framework within which the components of ITS systems are brought together so that the whole can function efficiently – much as construction products and services in a building.

ITS architecture is essential for the planning and design of an ITS deployment – that will meet the needs and requirements of users. An understanding of ITS architecture helps to define how the component systems need to interact with each other – and will clarify the roles of individual stakeholders in the implementation process. The analysis should be firmly based on an assessment of the functions and system performance that are necessary to meet user needs.

An ITS architecture can provide many benefits to a region as it begins to develop and deploy ITS-based systems and services. A properly designed ITS architecture will:

- enable interoperability
- help guarantee the proper exchange of information
- support the definition of a logical implementation plan
- identify opportunities for resource sharing

INTEROPERABILITY

The concept of interoperability is very important in ITS. For example:

- the road authority responsible for highways may need access to data, traffic camera images, incident alerts and other information from the adjacent city authorities
- a driver purchasing a device for an ITS service in one region, should be able to use the same device to communicate with roadside equipment in an adjacent region. The device might be a tag for non-stop electronic payment of tolls, or an in-vehicle navigation display with real-time information. This is only possible if the systems in the two regions are compatible with each other

To facilitate this kind of interoperability, an ITS architecture (where one has been adopted) will identify the system interfaces or information flows that need to be harmonised – and, if possible, standardised. The ITS architecture is an important tool for the success of this process, since it describes how the different components of a system should interact with one another.

The real advantage of interoperability becomes more obvious when the different ITS systems share and exchange data and information with each other. For example:

- the information collected by a traffic control system can be very useful to an emergency management centre in trying to determine the fastest route for an emergency vehicle to reach an accident scene
- similarly, the information collected by the emergency management centre on incidents can be used by a traffic control centre to adjust signal timings in response to the incident

The process of linking the different components of a system is typically referred to as “system integration.” This becomes a major issue as more and more ITS components are deployed.

USER SERVICES

Within the context of ITS, the term “*user services*” is used to describe what ITS does for the users of the transport system – including travellers, transport operators, planning organisations, road authorities, government ministries and departments of transport. The US National Architecture, for example, currently defines 33 ITS user services, grouped into eight major user services bundles as shown here: <http://www.iteris.com/itsarch/html/user/userserv.htm>.

ITS USER SERVICES

ITS user services share a number of basic characteristics.

- different user services can be regarded as building blocks for a region’s intelligent transport system. They can be combined for deployment in a number of different ways depending upon a region’s priorities and needs
- user services are made up of multiple technological elements – that may be shared with other user services. A prime example is an advanced communication system for transferring data among different transport system components
- the costs and benefits of a user service will depend upon the deployment scenario. For example, once the basic technological elements (such as communications and surveillance) are in place – deploying a new user service may require only a small incremental cost
- user services are not specific to a particular location – they can be adapted to meet the local needs of urban, suburban or rural areas

ITS USER SERVICE BUNDLES

In the US National Architecture, the different user services have been arranged or grouped into eight bundles, which define focus areas for ITS applications:

- travel and traffic management
- public transport management
- electronic payment
- commercial vehicle operations
- emergency management
- advanced vehicle safety systems
- information management
- maintenance and construction management

The European Frame architecture adopts a comparable approach based on user needs that are grouped into nine broad areas:

- electronic payment facilities
- safety and emergency facilities – which include both in-vehicle and roadside "eCall" plus the management of emergency services responses
- traffic management – which includes urban and inter-urban traffic management, plus parking, incident and demand management
- public transport operations – which include both regular and on-demand services, plus fare cards and vehicle sharing
- Advanced Driving Assistance Systems (ADAS) – which include support for in-vehicle services, some of which are part of cooperative systems
- traveller journey assistance – which includes both pre-trip and en-route planning, plus traveller information
- support for law enforcement
- freight and fleet operations
- support for cooperative systems

The Frame Architecture also provides for links to other modes of transport – for example, to provide travellers with multi-modal travel information, to manage mixed mode at-grade crossings (where a road or highway meet at a level crossing) and to respond to incidents that take place on other modes.

ITS BENEFITS

Evaluation studies and operational tests have shown that ITS applications have provided significant benefits across surface transport modes. In the road transport sector, ITS aims to improve the performance of roads and highways by using real-time and historic information on the status of roads and traffic. ITS applications can enable better road transport operations – more safely, efficiently and in a more sustainable way, with better inter-modal connections. Benefits include safety, journey time, travel reliability, energy consumption, emissions and customer satisfaction.

STAKEHOLDERS

ITS includes diverse stakeholders in terms of disciplines, business areas and ownership:

- discipline diversity – includes different areas of engineering, economics and public policies
- different types of businesses areas – includes government departments of transport (DOTs), enforcement agencies, original equipment manufacturers (OEMs) and communication service providers
- ownership – includes public and private entities depending on the type of applications. For example, management of public roads is the responsibility of public agencies with technical support provided by private companies

Traditionally, the public sector has been responsible for the operation and maintenance of roads and highway infrastructure. Public agencies, such as a road or highway authority or a public works department, have had primary responsibility for the planning, design, operations and maintenance. For example, public agencies are usually responsible for ITS enabled services – such as incident management and traffic signal operations.

Similarly, the public sector has, in the past, taken full responsibility for the planning, design, investment, operations and maintenance of the dedicated ITS infrastructure (which includes management centres, field devices and communication infrastructure). Increasingly much is being out-sourced to the private sector under service contracts. Nevertheless the public sector continues to take the lead in long term planning for traffic and highway ITS infrastructure.

Experience shows that ITS involves an increasing number of organisations – as the full potential of new technology is realised. The table below illustrates this with examples of the more common objectives for investing in ITS – showing the varying degrees of complexity and stakeholder groups. Senior officials of public agencies and chief executives of private sector companies will often have a close involvement because of the level of commitment required.

EXAMPLES OF STAKEHOLDERS FOR ITS PROJECTS

Strategic Objective	Stakeholder Groups	Candidate <u>ITS</u> Applications
Improved urban traffic management	<ul style="list-style-type: none"> • Local traffic management agencies; • Regional transport authorities; • Private sector collective transport operators; • Police / enforcement agencies; • Emergency services Freight operators; • Other road users (pedestrian /cycle priorities); • Local businesses; • Owners and occupants of properties affected by the scheme (access, stopping, loading); • Local residents. 	<ul style="list-style-type: none"> • Real-time adaptive traffic signal control; • Integration of urban arterial and urban freeway traffic management systems; • Introduction of active bus priority schemes.

Strategic Objective	Stakeholder Groups	Candidate ITS Applications
Introduction of new automatic payment systems or access controls	Many of the above, plus: <ul style="list-style-type: none"> • Toll road operators and electronic payment managers. 	<ul style="list-style-type: none"> • Non-stop electronic tolling; • Congestion charging and price-related access control.
Strategic and tactical management of inter-urban traffic	Many of the above, plus: <ul style="list-style-type: none"> • Expressway, toll road and freeway operators and managers; • Traffic police and roadside emergency services. 	<ul style="list-style-type: none"> • Regional traffic control centres; • Better incident detection; • Emergency response; • <u>VMS</u> and driver information support.
Better integration of transport modes	Many of the above plus: <ul style="list-style-type: none"> • Operators of railroads, inland waterway terminals, sea-ports and airports. 	<ul style="list-style-type: none"> • <u>ITS</u> plus park-and-ride schemes; • Multi-modal traveller information systems; • Paperless intermodal trans-shipment.
Added-value services for private motorists and vehicle fleet operators	<ul style="list-style-type: none"> • Private driver information service providers; • Users of these services. 	<ul style="list-style-type: none"> • Freight logistics; • Driver information systems; • Dynamic (traffic responsive) in-vehicle navigation.

PRIMARY AND SECONDARY STAKEHOLDERS

Stakeholders can be categorised into primary and secondary stakeholders. Primary stakeholders are distinguished by the level and nature of their involvement:

- level of involvement – those with direct responsibilities in managing, operating and maintaining the system will be primary stakeholder. Others – with a lesser impact on the business practices and usage of a system – will be secondary stakeholders
- nature of involvement - service providers, service users and customers are always primary stakeholders:
 - private sector service providers include automobile manufacturers and their suppliers, commercial vehicle operators, private transport companies and value-added service providers
 - public sector service providers include government departments of transport, regional planning organisations, public transport planning agencies, local government and enforcement agencies
 - users or customer groups include drivers, passengers, pedestrians and customers receiving shipments

For example, in deliveries and commercial vehicle operations, the vehicle owners and delivery services providers and their customers are the primary stakeholders for ITS services to customers. Enforcement bodies such as the police and vehicle examiners are primary stakeholders in relation to weights and permits regulations and enforcement. From the public policy perspective local communities will also have an interest, albeit a secondary one unless there is public concern about the potential impact of operations.

Both primary and secondary stakeholders have roles in the planning, development, operations and maintenance of ITS projects. All stakeholders with a potential interest in the project must be identified and engaged – from planning to operations and maintenance stage of a project. Their input and participation is necessary for the successful realisation of an ITS project.

It is important to be aware of, and sensitive to, possible issues at all times – in what may be an evolving situation, as an ITS project develops. Secondary stakeholders can introduce issues which must be recognised and dealt with. Generally it is better to uncover interests and issues early on in the planning stages – so that proper adjustments can be made. An effective communication strategy with stakeholders provides the opportunity to develop contingency options.

ITS investments usually need political and public support. Public agencies must communicate the anticipated benefits of the ITS deployment in terms that policy makers and the public can understand. In the early stages of ITS deployment, a careful assessment of risk is essential covering the technology, market perspective, political and public acceptability. Some aspects may require a regulatory framework to ensure public safety, interoperability and rules for procurement – and where necessary an enforcement policy (such as speed control).

BUILDING PARTNERSHIPS

A priority for ITS is to consult the widest possible range of interests and to build local partnerships to achieve consensus on objectives and scope of investments in ITS – and joint problem-solving. Stakeholders are impacted by any failure or success of an ITS project. This means there is a need to develop an all-inclusive process to identify and engage all stakeholders from the start of the planning phase of ITS projects. This may lead to the involvement of new stakeholders, such as financial institutions, retailers, broadcasters, telecommunications providers and value-added service providers. Each stakeholder will have their own distinct business practices and goals – and should take ownership of their roles and responsibilities in any ITS project at each stage of the project.

There is often a role for an ‘ITS champion’ to take the initiative, drive forward consultation and keep all partners and stakeholders on board.

OPERATING CONTEXT

A total system approach to ITS deployment means paying attention to both technical concepts and institutional measures needed to integrate key technologies to deliver effective user services.

Successful ITS operations are enabled by a regulatory and institutional framework that is fit for purpose – with cooperative agreements between stakeholders that define clearly each party’s role and responsibilities. An equitable cooperative agreement between stakeholders – guided by suitable risk distribution, cost sharing and revenue or benefit sharing – may solve some of the regulatory and institutional challenges.

A self-contained ‘silo’ mentality within an organisation may frustrate the development of ITS services. A lack of attention to end-user needs and requirements and poor management and project control in a primary stakeholder organisation – may also undermine the planned ITS deployment and incur excessive cost. Deficiencies such as these, may make the ITS service economically unfeasible.

CONCEPT OF OPERATIONS

A cooperative agreement can take the form of a ‘Concept of Operations’ – where each stakeholder’s roles and responsibilities are described and each party agrees on the allocation of operational roles and responsibilities.

The agreement should be based on appropriate risk distribution, cost sharing and revenue or benefit sharing – according to the role and level of involvement of each stakeholder. This must be developed at the planning stage of an ITS project and may have an important place in defining any ITS architecture.

By way of example, the table below summarises a Concept of Operations that was developed for Bloomington/Monroe County in Indiana USA, as a part of the county’s regional ITS architecture. Stakeholders are mapped to different transport services and each stakeholder’s roles and responsibilities are specified.

Transport Service	Stakeholder	Role/Responsibility
Emergency Management	Public Safety Agencies	<ul style="list-style-type: none"> • Provide emergency call taking • Dispatch appropriate agency(s) to incidents • Coordinate various systems and agencies during emergencies
Freeway (Motorway) Management	Highway Operator	<ul style="list-style-type: none"> • Operate traffic information devices (DMS, <u>HAR</u>) • Monitor traffic conditions
Incident Management	Highway Operator	<ul style="list-style-type: none"> • Operate Freeway Service Vehicles • Provide information to travellers using traffic information devices (DMS, <u>HAR</u>) • Provide assistance to Public Safety Agencies responding to incidents on roads under INDOT’s jurisdiction
Public Safety Agencies	<ul style="list-style-type: none"> • Receive emergency calls for incidents • Dispatch appropriate agency(s) to incidents 	
Maintenance and Construction Management	Highway Operator	<ul style="list-style-type: none"> • Provide maintenance of national and regional (Interstate Routes) • Coordinate with other agencies that provide maintenance and construction
City/County Authority	<ul style="list-style-type: none"> • Provide maintenance of urban streets and rural roads • Coordinate with other agencies that provide maintenance and construction 	

Transport Service		Stakeholder	Role/Responsibility
Highway Management	Pavement	Highway Operator	<ul style="list-style-type: none"> • Collect data using roadside devices
Surface Management	Street	City/County Authority	<ul style="list-style-type: none"> • Collect data using roadside devices
Public Transport Management		Bus/ Coach Operators	<ul style="list-style-type: none"> • Provide fixed route bus service • Provide demand response (Paratransit) bus service • Monitor Public Transport assets (vehicle locations, video surveillance)
Traveller Information		Highway Operator	<ul style="list-style-type: none"> • Provide information to drivers (Dynamic message Signs, Highway Advisory Radio)

ADVICE FOR PRACTITIONERS

The leading stakeholders in an ITS deployment may parallel those involved in a construction project: the client, professional consultants, products and service suppliers, contractors and specialist subcontractors:

- the client can be a public authority or private operator – or, often, a multi-agency grouping under a lead agency
- ITS professionals who advise on, and manage, an ITS deployment – are typically drawn from the disciplines of civil, electrical or transport engineering and transport planning. Their specifications define project needs and anticipated costs, and guide the developers and suppliers – including computer software and hardware, detectors and sensors, communications networks, cameras and infrastructure equipment, fixed and portable devices
- system integrators may be needed for complex ITS projects – especially when the component systems must operate together reliably

Transport professionals who are responsible for launching ITS at project or programme level, may be unfamiliar with certain aspects of a deployment – either technical or institutional.

BUSINESS PERSPECTIVES

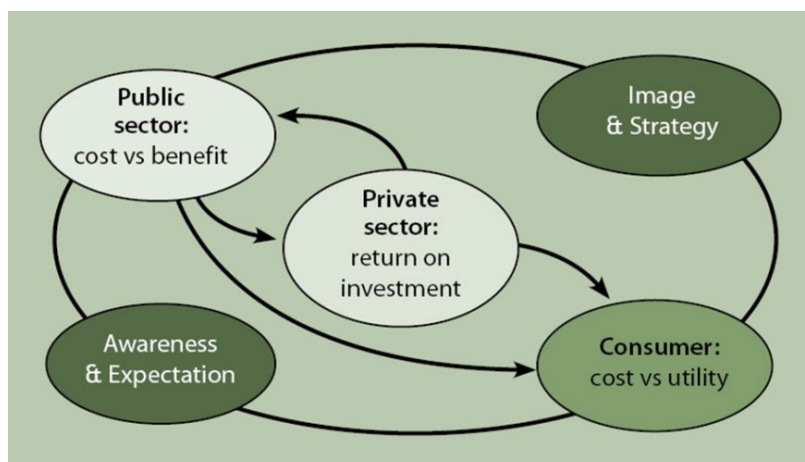
ITS covers a wide range of systems and services. Different players are involved – so stakeholder roles and attitudes and the legal and institutional issues vary for each sector. There will be wide variations between different applications and individual institutions, but there are three broad groups of stakeholders that invest in ITS:

- **users and consumers of ITS** (corporate or individual) require systems and services that meet their real needs. They have high expectations of service quality, reliability and availability. The willingness to pay for ITS systems and services strongly depends on the actual and perceived utility of the service – as well as on its public image. The acceptable price may not correspond to the actual costs of service generation and delivery. For example, people expect travel information services to be free at the point of use but the cost of service provision is very high
- **public sector** adopts ITS to deliver various public services, objectives and strategies. Public interests require that ITS service development should contribute to positive impacts on traffic management and modal shift, economic development, business location and social inclusion. Public authorities seek to involve the private sector in order to benefit from the entrepreneurial culture, to limit public expenditure and increase transport efficiency
- **private sector players** seek to sell equipment and services to the public sector and to market consumer-based ITS products and services – capitalising on market development potential to create profitable businesses. The private sector has to be responsive to framework conditions established by the public sector – which are often seen as an obstacle to free market competition

These three groups adopt very different evaluation systems when they consider whether to invest and allocate their budgets to ITS deployments:

- the **public sector** has to justify investment in ITS on public service criteria or on the basis of benefits to the community – including affordability of the initial capital spend and any maintenance and long-term operating costs
- the **private sector** is concerned with the forecast return on the investment needed to bring ITS equipment, products and services to market – and the extent and reliability of any revenue streams
- the **consumer** (any individual or organisation that uses an ITS system or service) evaluates the usefulness of the equipment or service in relation to the buy-in cost, and any recurring fees and charges that have to be paid

The interactions between these very different requirements is illustrated below. For ITS projects to be viable, they will often require justification against at least two, if not all three of the underlying value criteria. Failure to meet one or other of the investment tests will produce a classic “chicken and egg situation” – who goes first, the supplier or the purchaser in making a commitment to the system or product?



Inter-dependencies between the public sector, the private sector and consumers (© World Road Association)

COMMERCIAL BUSINESS CASE

Private sector involvement is generally motivated by the opportunity to generate revenue and/or make a profit. Commercial businesses must be able to generate a profit through their activities to survive in a competitive market place. The continuing development of technology and advances in user needs and expectations means that the potential for new products and services is always there. The private sector can provide these new products and services, as and when time demands. Increasingly, the public sector is looking to the private sector, for the investment in ITS infrastructure and the delivery of certain ITS services – such as providing travel data. The private sector business case will largely depend on risk assessment of several factors.

It is likely that the private sector will wish to develop market opportunities for new service needs arising from public sector investments in ITS. For example, a company might make use of traffic data (advisory and predictive) collected by public agencies to develop customised, real time travel information as a value added service for its customers. Arrangements of this kind – if they are exclusive to one provider – can become problematic unless they have been awarded on the basis of fair and open competition.

PUBLIC PRIVATE PARTNERSHIPS

Private investment in road infrastructure and traffic services is growing as many public agencies struggle to meet increased travel demand within limited budgets. For example, toll roads and traffic control centres are often implemented through a partnership contract or franchise.

Private sector participation offers new opportunities and challenges to the transport industry.

The challenge in a public private partnership lies in how to achieve a balance between the policies and objectives of public agencies – while satisfying the business goals of private companies. To achieve a successful public private partnership, various issues need to be addressed:

- defining and agreeing the roles and responsibilities of the public and private sector in each phase of the life cycle of the project
- sharing the development and operational risks
- ensuring that both benefit from the partnership
- cost sharing
- private sector interest in the transport service
- public sector support for the private sector's business case

In preparation for negotiations with private industry, public agencies need to determine their requirements – which may be encapsulated in an ITS regional architecture. By defining requirements before entering into a resource sharing agreement the stakeholders will be in a stronger position to conduct the negotiations.

Motivating factors for public private partnerships in ITS include:

- the opportunities that ITS offers as a market for the development of new products and services by the private sector – based on access to publicly owned data (open data) and permission to install equipment on the road network
- mobilising private sector investment in ITS deployments – which would otherwise be a challenge for public sector budgets to meet.

Examples of viable partnerships which benefit both sectors include:

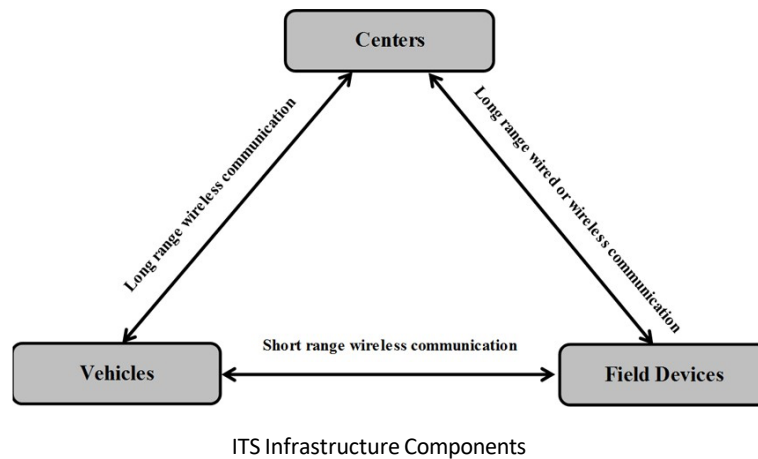
- a cellular phone company that provides telecommunications support to public agencies for their ITS infrastructure connections – in the expectation of business growth from road users (such as travellers) accessing traveller information services through their wireless mobile devices
- a public agency that gives permission to telecommunications companies to construct cellular communication towers or install fibre optic cables on publicly-owned land alongside a highway – in return for in-kind ITS programme-related hardware, software and services up to an agreed value

ITS INFRASTRUCTURE

ITS works when the supporting infrastructure – which includes roads, ITS devices, vehicles, terminals, management centres – communicate with each other and with users. For a road authority, the ITS infrastructure components can be divided into four different categories: field, centre, vehicle and telecommunications.

- field devices include roadway devices, such as:
 - traffic cameras and sensors
 - parking management systems which include real time parking occupancy detectors
 - roadway payment system such as automated toll collection system which includes radio-frequency identification (RFID) receivers
 - security monitoring devices such as surveillance cameras and intrusion detectors
 - signal controllers and traffic lights
- centre infrastructure, such as:
 - a traffic management centre coordinating real time roadway operation functions – for example, incident management and traffic rerouting.
- vehicle infrastructures, such as:
 - emergency vehicles responding to a severe traffic incident
 - mini-buses, buses, trams and coaches – for example, the vehicle location systems that support real-time scheduling and travel information
 - maintenance and construction vehicles deployed in a work zone
 - taxis and other vehicle fleets used as probe vehicles to determine traffic characteristics
- telecommunications infrastructure, which can be:
 - wired, such as a fibre optic cable network
 - wireless, such as cellular or WiMAX technology

The diagram below shows how field, centre and vehicle infrastructures connect to each other. Centres may communicate with each other and with field devices through wired or wireless technology. Vehicles communicate with centres and field devices through wireless infrastructure.



IMPORTANCE OF ITS ARCHITECTURE

ITS Architecture plays an important part in Road Network Operations. The ITS architecture is a primary element in ITS planning. Two types of ITS architecture are typically defined:

- a high level architecture (which can be either a Framework or Model Architecture), often for publicly funded ITS deployments in a national, regional or local area
- a low level architecture (project-level) for specific ITS deployments, such as a Regional Traffic Control Centre

A high level ITS architecture provides the framework for the deployment of ITS across a wide geographical area with multiple jurisdictions and different stakeholders participating in common or inter-dependant operations. The architecture specifies how the various ITS components interact with each other to address the transport problems. It provides the basis for planning, designing, deploying, maintaining and integrating systems to realise transport objectives.

An ITS architecture does not specify the ITS scheme design in detail. Nor does it require a particular design approach. Instead it does the important job of specifying the performance criteria that the system components must satisfy – and defines a general framework from which several alternative designs or design options may be developed. These distinct designs will conform to the common ITS architecture.

An ITS architecture should define the following:

- **functions:** that describe what the ITS system has to do to meet the user requirements – such as “collecting traffic data” or “providing incident information”
- **physical entities:** the locations where ITS functions are to be performed – such as a traffic management centre or traffic signal controllers
- **interfaces and information flows:** the interfaces showing data exchange connectivity (existing or proposed) and the information flows between physical entities. For example, an interface between a traffic management system and roadway traffic detectors might be two-way:
 - in one direction, speed data flows from the traffic detectors to the traffic management system
 - in the opposite direction, a sensor control command flows from the traffic management centre to the traffic detectors

INTEROPERABILITY

Maximum benefit from ITS requires interoperability and interchangeability of systems between regions and within a region. Interoperability refers to the condition where different types of systems can interface with each other to meet the system's functional requirements. Multiple brands of a device on the same communications channel is an example of interchangeability. One of the primary goals of ITS is to integrate a variety of previously independent systems to minimize redundancy and maximize efficiency – so adhering to ITS and other industry standards will satisfy the interoperability and interchangeability requirements and support future efficient system expansion. Legislative requirements to comply with industry and ITS standards in any ITS project will support interoperability, interchangeability and future cost-effective expandability of the system.

TECHNOLOGICAL CHANGE

Technology is changing at a rapid pace and this trend is expected to continue indefinitely. ITS builds on technology-based services – and the pace of technological change is an important consideration in planning and deployment. Three issues must be addressed when considering changes in technology for any ITS applications. These are: upgrade, legacy systems and systems integration.

UPGRADE

With technology changing rapidly, even during the course of an ITS project, it is important to anticipate the possibility of system upgrades. Newer technologies can improve the performance of an already deployed system – and may require a decision on whether to upgrade the system or replace it. Where it is possible to look ahead, work planning and design should allow for the possibility of upgrades so they can be accommodated efficiently and without technical complexity. A possible disadvantage is that system upgrades may require highly skilled professionals to operate and manage the new systems in the future.

LEGACY SYSTEMS

As new systems and upgrades come on line, they must be integrated with earlier “legacy” systems. The challenge lies in making the new systems interoperable. ITS architecture can show where and how established legacy systems will need to interface with new systems to deliver the desired (integrated) system functionalities and performance. A field evaluation plan for testing the interoperability between a legacy system and new systems will provide the basis for testing the integrated system after deployment.

SYSTEMS INTEGRATION

Systems integration is about how different systems are connected together so that they can perform the desired tasks in an optimal way. ITS requires different types of hardware and software (which may come from different manufacturers and be implemented at different times) to be integrated to satisfy user requirements.

Problems – that can pose a significant challenge to systems integration – technically and because of the cost, are:

- using hardware and software that are unique to one supplier
- system interfaces that do not follow industry and ITS standards

Adhering to established industry and ITS standards and the use of open architecture will support future cost-effective systems integration.

ADVICE TO PRACTITIONERS

A system-wide outlook at the inception of a project will help develop a deployment plan that supports a cost-effective implementation strategy:

- an ITS architecture that takes account of user needs regionally and nationally will support cost-effective project development locally, even when the projects take place at different points in the timeline. This is because the entire system, with its subcomponents and interdependencies, are considered at the outset of each project

If the design provides for interchangeability of components it will encourage competition and allow scope for future improvements in cost, design, functionality and safety:

- ITS technologies provide multiple options to address particular user needs or requirements. Availability of many options for the same set of requirements (for example electronic tolling equipment) may promote different products in different regions that are not compatible or interoperable with each other. A common architecture and a set of standards that have evolved from a common architecture can solve the problem of interoperability

ITS architecture can show where standard interfaces will bring significant benefits:

- it does not assume the use of specific ITS technologies or components. It should instead, be generic, to allow freedom for system developers to design what they see as optimum solutions – meeting appropriate standards and accommodating the interfaces needed for interoperability and likely future extensions

ITS architecture shows how different stakeholders are connected with one another through data exchange:

- ITS architecture helps to identify institutional interdependence that can assist in reaching regional goals. It can serve as a guide on how different agencies can share the same ITS infrastructure to achieve their own institutional objectives

The existence of an ITS architecture can assist in integrating systems coming on-line in different phases:

- it is not possible to meet all user requirements at any one time, with one project. ITS projects are usually completed in phases

ITS architecture can support security services related to disaster response and evacuation, freight and commercial vehicles, hazardous materials, rail, transit and transport infrastructure:

- in addition to supporting transport services, ITS architecture can contribute to regional and national security

ITS AND TRANSPORT OPERATIONS

Road Network Operations are part of a much wider activity known as “transport operations” – which comprise the methods and techniques used to support the movement of people and goods and maintain optimal conditions on a transport network. In general, this is achieved by measures that are designed to match transport supply – the capacity of the transport system – with transport demand. When transport demand exceeds the available capacity, the result is congestion.

Transport operations have many objectives including:

- optimising the flow of traffic
- ensuring safety of operations
- managing incidents, adverse weather and emergency situations
- minimising the impact of infrastructure maintenance and construction
- ensuring a high level of service to the users of the system

The objectives of “transport operations” are well-aligned with those of Intelligent Transport Systems (ITS) – and as a result, ITS has a lot to offer in terms of improving transport operations. The connection between ITS and transport operations is illustrated by the following three aspects of transport operations:

ROAD NETWORK OPERATIONS

The major functions of ITS-related road network operations are:

- road network monitoring and safety
- road network management
- traffic management
- mobility management and road users support

ROAD NETWORK MONITORING AND SAFETY

Road network monitoring and safety – involves all measurement, resources and procedures aimed at comprehensive management along the overall road network. It also focuses on road conditions and data collections in order to promptly react to events occurring in a specific place on the network. ITS services can make transport safer and more secure, maximising capability to contain and reduce the impact of disasters.

ROAD NETWORK MANAGEMENT

Road network providers and operators put in place a series of procedures and operations for the management of incidents and events, to re-establish normal conditions. This includes emergency management, winter services management and management of maintenance activities.

TRAFFIC MANAGEMENT

Road administrations are responsible for monitoring and controlling their road network. Management of traffic flows is a critical factor that influences the management of the overall network – and road users’ expectations. Besides taking action when traffic appears to be very congested, road network operators also

need to plan and forecast traffic flows – considering different analysis scenario and solutions, in order to provide road users with tangible improvements to their journey.

MOBILITY MANAGEMENT AND ROAD USERS SUPPORT

The publishing and distribution of information to road users on road network conditions and traffic flows, represent the interface between road operators/road administrations and public users. Data available to users tends to influence their behaviour on the network – and this needs to be taken into account as an important instrument to convey traffic flows. Information published can be: real-time or future-forecast.

USE OF ITS

ITS technologies lie behind good traffic management and information delivery for both urban networks and interurban roads. Pro-active and re-active measures can be applied. Pro-active measures focus on the prevention of incidents/congestion. Re-active measures focus on the detection/verification of incidents and unsafe road conditions, response and clearance, and recovery to normal operations. Other solutions include better road works planning, lane restrictions, bad weather and road conditions alerts, and automatic braking systems.

Many ITS applications can help support road network operations. Examples include:

- **network monitoring**, which performs a key function in gathering prevailing road network information and providing support for other network operation activities
- **traffic control and incident management**, which aim to maximise the efficiency of the transport system and the utilisation of existing capacity
- **toll roads and electronic payment**, which relieve the bottlenecks associated with traditional toll booths and which allow for the implementation of congestion pricing strategies to better operate and manage the transport network
- **travel demand management strategies** intended to reduce the travel demand on the network

PUBLIC TRANSPORT OPERATIONS

The goal of public transport operations is to help increase and retain ridership, cut down on the cost of operations (principally fuel and staff costs), and improve the level of service for passengers

Examples include:

- applications aimed at monitoring public transport vehicle operations to ensure schedule adherence and to facilitate passenger transfer at connecting stations
- the provision of information about the expected arrival time of a transport vehicle, transfers, and ride- share opportunities
- providing traffic signal priority for transport vehicles to help improve the quality of service and to provide incentives for travellers to use transport
- the use of smart fare cards to make it easier for travellers to pay for the service – whilst collecting useful data that can be used by the transport operators to better plan, manage and operate the transport system
- personalised public transit services such as flexible-route buses that are allowed to deviate from the main route to pick-up or drop-off passengers.

FREIGHT OPERATIONS

Optimising freight operations and the movement and distribution of goods is a central part of transport operations that is vital to a nation's economy. The effective operation of road networks directly benefits freight operations. Roads that are well-managed enable timely deliveries and reduce vehicle turnaround times and costs to freight operators. This has become more important with the spread of internet retailing and just-in-time stock management procedures. Freight operators may face additional challenges from local government policies – introduced to control heavy vehicle movements in urban centres.

ITS can contribute to improved efficiency and security of freight operations:

- real-time communications for vehicle location, dispatching and tracking
- automated control and information systems
- vehicle and load monitoring to track consignments for security and to keep customers up-to-date on progress
- in-vehicle data recording to monitor drivers' hours, alertness, performance and behaviour (for example, in obeying traffic rules) – with a view to offering training if necessary
- improving internal company efficiency

ITS can also help freight operators in other important ways – by identifying available parking and ensuring compliance with driving time and rest period regulations. The absence of available parking and of ways to identify it in good time, can create safety hazards – with truck drivers being obliged to park on roadsides or highway access ramps.