Centre of Excellence in Urban Transport

IIT Madras

INTELLIGENT TRANSPORTATION SYSTEMS

Synthesis Report on ITS Including Issues and Challenges in India

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December 2010

This work was carried out as part of the activities in the Centre of Excellence in Urban Transport at IIT Madras sponsored by the Ministry of Urban Development. The contents of this report reflect the views of the authors who are responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official views or policies of the Ministry that funded the project or IIT Madras. This report is not a standard, specification, or regulation.

INTELLIGENT TRANSPORTATION SYSTEMS
Synthesis report and issues and challenges under Indian conditions

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December 2010

Executive Summary

The rapidly increasing vehicle population in India, spurred by the population boom and economic upturn lays a critical burden on traffic management in the metropolitan cities and towns of the country. The cumulative growth of the Passenger Vehicles segment in India during April 2007 – March 2008 was 12.17 percent. In 2007-08 alone, 9.6 million motorised vehicles were sold in India. Economy-induced automobile usage is complicated further by the constant influx of rural population into urban areas, thus making enormous demands on the transportation infrastructure in an overloaded region. The heterogeneity of economy and the physical limit on how much additional infrastructure a city can hold complicate transport management further. World Bank reports that the economic losses incurred on account of congestion and poor roads alone run as high as $6 billion a year in India.

Intelligent Transportation Systems (ITS) is an established route to resolve, or at least minimize traffic problems. ITS encompass all modes of transportation - air, sea, road and rail, and intersects various components of each mode - vehicles, infrastructure, communication and operational systems. Various countries have developed strategies and techniques, based on their geographic, cultural, socio-economic and environmental background, to integrate the various components into an interrelated system. In general, any of the ITS applications uses a Traffic Management Centre (TMC) where data is collected, analysed and combined with other operational and control concepts to manage the complex transportation problems. Typically, several agencies share the administration of transport infrastructure, through a network of traffic operation centres. There is often, a localized distribution of data and information and the centres adopt different criteria to achieve the goals of traffic management. This inter-dependent autonomy in operations and decision-making is essential because of the heterogeneity of demand and performance characteristics of interacting subsystems.

The major objective of ITS is to evaluate, develop, analyse and integrate new sensor, information, and communication technologies and concepts to achieve traffic efficiency, improve environmental quality, save energy, conserve time, and enhance safety and comfort for drivers, pedestrians, and other traffic groups. The adoption of location and information based technologies into vehicles, infrastructure, traffic management and traveler information services have shown dramatic improvements in the safe, and efficient mobility of people and freight in USA, European nations, Japan, Middle East and Canada.

While India has already made a foray into ITS in organizing traffic, more extensive and urgent integration of advanced technology and concepts into mainstream traffic management is imperative. ITS is still in its infancy in India, with decision-makers, key planners and agencies in the process of understanding its potential. A number of prototype ITS projects have been introduced in various cities in India which have focused on isolated deployments of parking information, area-wide signal control, and advanced toll collection. Most of these are single-city based pilot studies. At present, there are only few fully developed ITS applications with traffic management centers in India.

Developments in ITS are driven strongly by socio-economic needs, and environmental demands. In India, the diverse range of vehicular velocities (pedestrian, bicycle, LMV's, HMV's, animal drawn carts), wide variety of vehicles (including pedestrian traffic), and poor lane discipline (partially resulting from the first two factors and partially due to cultural reasons) and a very high population density makes adoption of Western ITS standards and architecture difficult. The Indian ITS must be designed to suit the Indian scenario and will ideally be an interplay of public and private sectors. On the public sector front, ITS will be designed based on regional and national standards to suit the specific region. On the private side, new technologies would be fuelled by the consumer market. The design of an intensive ITS program in India should encompass developments in technology, modelling, interconnectivity of multiple branches of engineering including transportation, communication, electronics, and IT, and human capital development.

The development and implementation of advanced technologies include electronic devices such as sensors, detectors and communication devices and application of global navigation satellite system (GNSS). This in turn hinges on cooperative work among the Government, academic research institutions, and industry. A thorough understanding of the traffic system is important to the successful implementation of ITS in India. Cost effective detection techniques must be developed for real-time road-wide data collection rather than lane-wise collection that are suitable for traffic flow following fixed lane divisions. Once such an automated data collection system is developed, the data generated can be archived and can be used for model development that will facilitate several ITS applications. Seamless interconnectivity of the various nodes of the transportation sector is essential to provide effective, efficient and secure movement of goods and services while improving the conservation of natural resources and reducing environmental impacts such as the effects of carbon emissions. ITS technology can play a vital role through information gathering and sharing to ensure such seamless interconnectivity. Another important approach to ITS is to advance public transportation to make it more attractive than private transport. India is the second largest producer of buses, accounting for 16 percent of world's total bus production. However, the share of public transportation in Indian cities has been on a steady decline over the last few decades. Improving the quality of public transportation through ITS technology will encourage more usage and therefore help in transportation management. ITS in India should closely work with the energy sector in the promotion of fuel efficient transport policies and practices, including the use of alternative transport fuels. Fuel efficient policies and practices will assist the country in achieving sustainable economic and environmental benefits through the application of intelligent transportation services. The ability of the work force to develop, manage and safely implement existing and emerging technologies is essential for ITS design and wide-spread implementation.

The main social and institutional issues facing the deployment of ITS in India are: an underdeveloped road network, severe budget restrictions, explosive urbanization and growth, lack of resources for maintenance and operation, less demand for automation, lack of interest among policy decision makers, and lack of user awareness. Some of specific actions required to meet the challenges to ITS in India include:

- Evolving a national ITS standard for different ITS applications and their components
- Setting up a national ITS clearinghouse that documents all ITS projects with details on the design, implementation, lessons learned/best practices, and cost-benefit details
- Setting up fully functional Traffic Management Centres for coordinating the urban and regional ITS activities,
- Developing and implementing automated traffic data collection methodologies,
- Developing a national ITS data archive,
- Developing models and algorithms suitable for ITS implementations
- Fostering more interaction between academia, industries and governmental agencies to generate more interest and in turn projects in the ITS area.

Full potential of ITS can be achieved only by implementation at a network level rather than in small corridors. Overall, the existing implementations show promise and potential for the deployment of ITS in India and give an initial empirical basis and data on ITS deployment highlighting the data, methodological, practical and research challenges for Indian conditions.

Acknowledgements

This synthesis report on ITS was developed as part of the activities at the Centre of Excellence in Urban Transport (CoE-UT), IIT Madras, sponsored by the Ministry of Urban Development, Government of India. We thank the Ministry of Urban Development for sponsoring the CoE-UT at IIT Madras. We also thank the Director, Dean (Industrial Consultancy & Sponsored Research), the Head of the Department, Department of Civil Engineering for their support and guidance to the Centre. We thank the Centre Co-ordinators for providing us the opportunity to work on this report. Special thanks to Valardocs for the prompt and professional technical editing support.

INTELLIGENT TRANSPORTATION SYSTEMS

I. Introduction

An important metric for economic growth of any country is its burgeoning vehicle ownership. However, the indirect effect of vehicle ownership is acute traffic congestion. India has, in the past decade, seen an astronomical increase in vehicle ownership and associated road blocks and traffic snarls in its metropolitan cities. The variety of vehicles in India – two, three and four wheelers, in addition to a large pedestrian population, complicates the situation [Figure 1].

Figure 1: Complexity of Traffic in India [1]

The principal reason for traffic congestion in India is that the road space and infrastructure have not improved on par with the traffic [2]. The seriousness of the problem is reflected in the report of World Bank that estimates the economic losses incurred on account of congestion and poor roads alone run as high as $6 billion a year in India [3]. The direct solution for this problem by improvements in infrastructure is constrained by space availability and other logistic problems. There is, therefore, an urgent need to explore and develop better traffic management options to ease traffic congestion.

Intelligent Transportation Systems (ITS) is a tested route to mitigate traffic congestion problems. ITS can be broadly defined as the use of technology for improving transportation systems. The major objective of ITS is to evaluate, develop, analyse and integrate new technologies and concepts to achieve traffic efficiency, improve environmental quality, save energy, conserve time, and enhance safety and comfort for drivers, pedestrians, and other traffic groups [4-6]. An overview of ITS can be schematically represented as shown in Figure 2. State-of-art data acquisition and evaluation technology, communication networks, digital mapping, video monitoring, sensors and variable message signs are creating new trends in traffic management throughout the world. The synergy of data acquisition, analysis, evaluation, and information dissemination helps in developing an all-encompassing system of traffic organization that enables information sharing among the managers and users of traffic.

Although the origin of formal ITS dates back to the 1970s, the first ITS world congress in Paris, in 1994, catalyzed the development and application of ITS to develop and improve the existing traffic control systems in many countries around the world. ITS activities aim at the development of a sustainable, multi-modal surface transportation system that will establish a connected transportation environment among vehicles, the infrastructure, and portable devices. Such a cooperative setup leverages technology in order to maximize driver safety and mobility while improving environmental performance and focusing on deployment. ITS encompass all modes of transportation - air, sea, road and rail, and intersects various components of each mode - vehicles, infrastructure, communication and operational systems. Various countries develop strategies and techniques, based on their geographic, cultural, socio-economic and environmental background, to integrate the various components into an interrelated system.

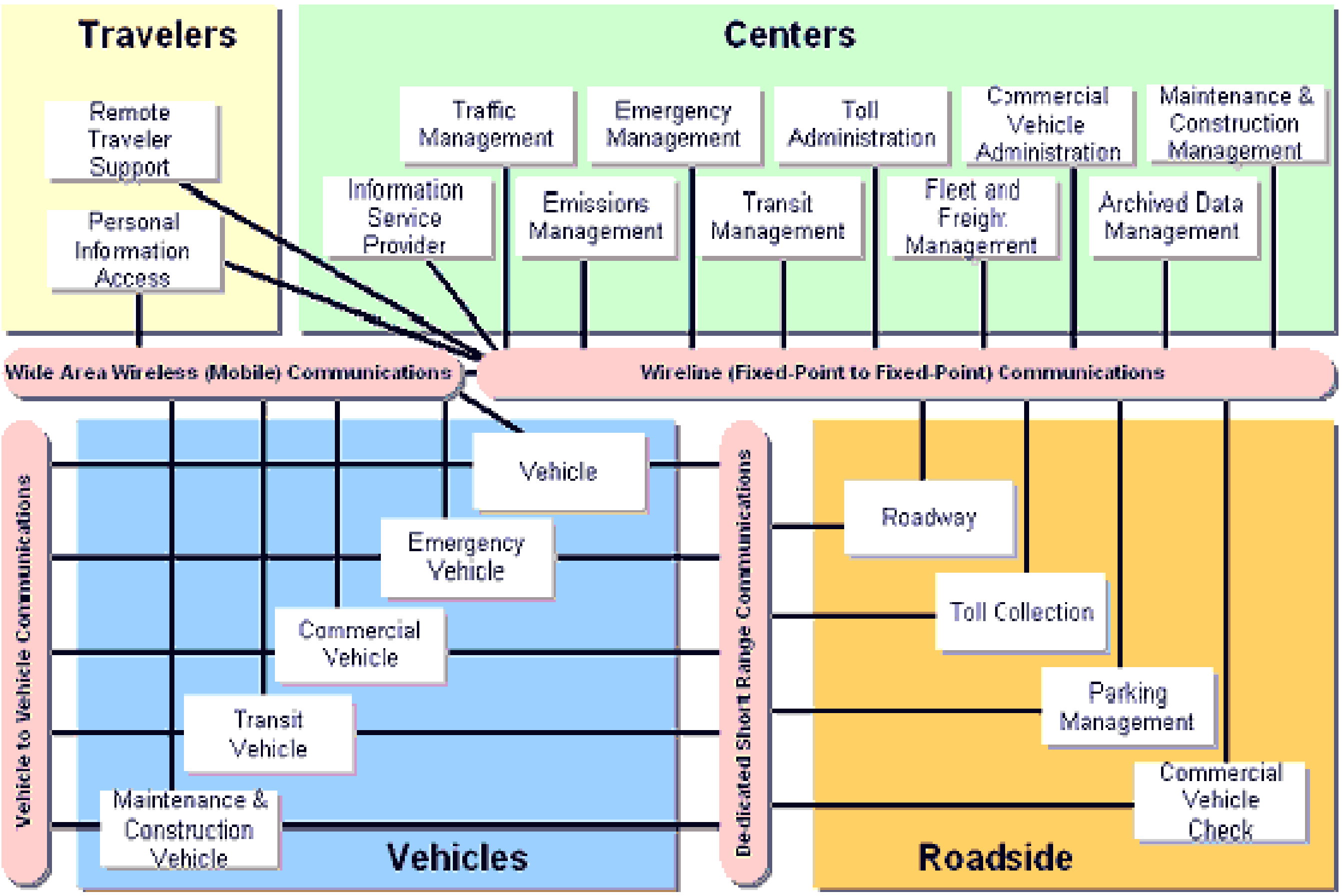


Figure 2: Broad Overview of ITS [6]

II. History of ITS

The origin of the formal ITS program dates back to the nineteen sixties with the development of the Electronic Route Guidance System, or ERGS in the United States, to provide drivers with route guidance information based on real-time traffic analysis. The system used special hardware located at various intersections across the road network, on-board 2-way devices in vehicles that would form the hub of communication between the driver and the ERGS system, and a central computer system that processed the information received from the remote systems. During the early seventies, the ERGS program led to a more sophisticated, automated system comprising interactive visual digital maps called the Automatic Route Control System or ARCS. The Urban Traffic Control System was developed concomitantly, connecting various traffic signals and computer generated predetermined signal timings for better traffic organization.

The same era saw the development of the Japanese Comprehensive Automobile Traffic Control System (CACS) program, presumably one of the earliest public-private partnership effort in the world to test an interactive route guidance system with an in-vehicle display unit. The Autofahrer Leit and Information System (ALI) in Germany was a dynamic route guidance system based on real traffic conditions, employed in the seventies. This was followed by AMTICS and RACS projects that heralded the era of high-tech traffic management in Japan [7].

Meanwhile, the United States strove to formulate the Federal Transportation Bill, the successor to the Post Interstate Bill of the fifties, to solve issues of growing traffic congestion, travel related accidents, fuel wastage and pollution. In 1986, the Intelligent Vehicle Highway System (IVHS) was formulated that led to a spate of developments in the area of ITS. The General Motors-funded Highway Users Federation for Safety and Mobility Annual Meeting (HUFSAM) was held in Washington DC in November, 1986 to partner with the US DOT in sponsoring a National Leadership Conference on "Intelligent Vehicle Highway System (IVHS)". A Federal Advisory Committee for IVHS was incorporated to assist the US-Department of Transportation and was aimed to promote orderly and expeditious movement of people and goods, develop an efficient mass transit system that interacts smoothly with improved highway operations and an active IVHS industry catering to both domestic and international needs. This laid the foundation for the formal Intelligent Transportation Society of America (ITS America) in 1991 as a non-profit organization to foster the use of advanced technologies in surface transportation systems.

In Europe, the Program for a European Traffic System with Higher Efficiency and Unprecedented Safety (Prometheus) was designed by auto manufacturers and this was followed by Dedicated Road Infrastructure for Vehicle Safety in Europe (DRIVE) project, set up by the European Community. A brief overview of the ITS developments towards the end of last century, in three key geographic areas of the world is shown in Table 1.

A more detailed account of ITS deployments around the world is given at a later section.

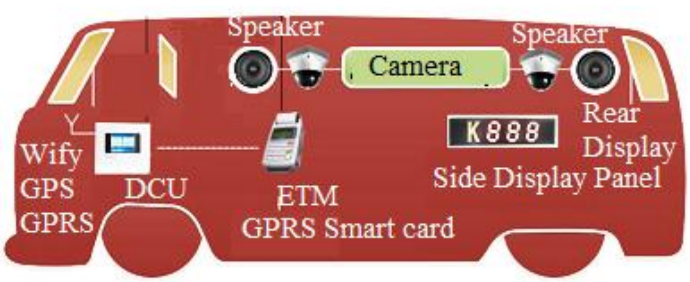
Table 1: ITS Developments in Europe, USA and Japan at the turn of the century [Adapted from 7]

	First Stage	Second Stage	Third Stage
Europe	ALI	PROMETHEUS DRIVE	PROMOTE TELEMATICS CENTRICO
USA	ERGS ARCS UTCS	IVHS MOBILITU2000	ITS
Japan	CACS	AMTICS RACS ARTS VICS SSVS	ITS
Year	70 75	80 85 90 91 92 93 94	95 96

III. ITS Taxonomy

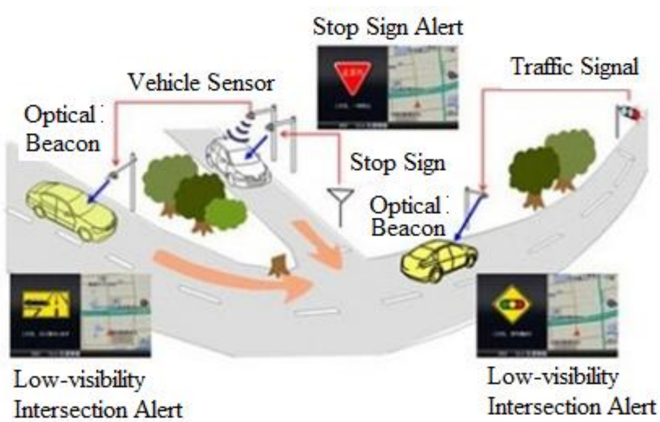
The most commonly used classification of ITS is based on the positioning of the system as given below.

Vehicle Level



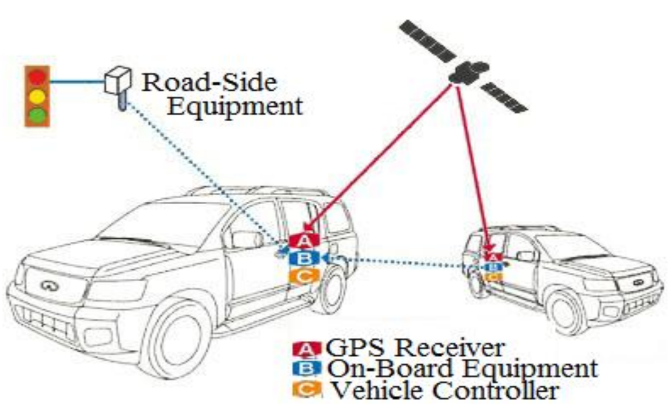
Technologies deployed within vehicles, including sensors, information processors and displays that provides information to the driver.

Infrastructure Level



Sensors on and by the side of roads collect important traffic data. Tools of communication provide drivers with pertinent information to manage traffic better. These tools include roadside messages, GPS alerts and signals to direct traffic flow.

Cooperative Level



Communication between vehicles, and between infrastructure and vehicles involving a synergic combination of vehicle level and infrastructure level technologies.

The commonly adopted functional taxonomy of the ITS is as follows [8]:

Advanced Traffic Management Systems (ATMS) integrates various sub-systems (such as CCTV, vehicle detection, communications, variable message systems, etc.) into a coherent single interface that provides real time data on traffic status and predicts traffic conditions for more efficient planning and operations. Dynamic traffic control systems, freeway operations management systems, incident response systems etc. respond in real time to changing conditions [Figure 3].

Figure 3: Examples of ATMS [9]

Advanced Traveler Information Systems (ATIS) provide to users of transportation systems, travel-related information to assist decision making on route choices, estimate travel times, and avoid congestion. This can be enabled by providing different information using various technologies such as:

- GPS enabled in-vehicle navigation systems
- Dynamic road message signs for real time communication of information on traffic congestions, bottlenecks, accidents and alternate route information during road closures and maintenance
- Website to provide a colour-coded network map showing congestion levels on highways (a.k.a. congestion index).

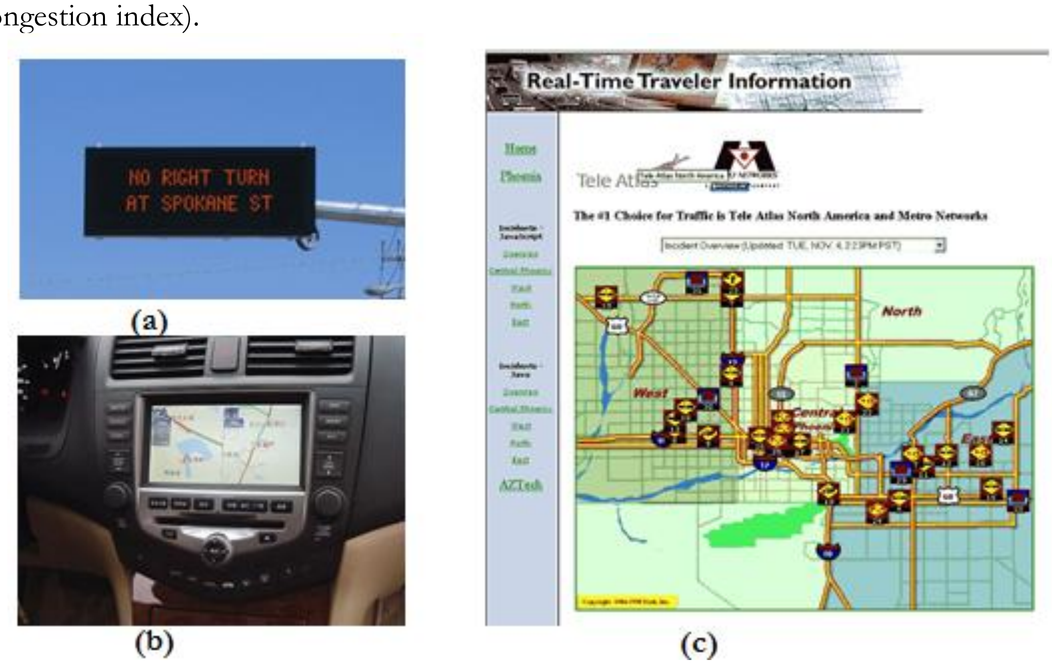


Figure 4: Examples of ATIS [10]

Advanced Vehicle Control Systems (AVCS) are tools and concepts that enhance the driver's control of the vehicle to make travel safer and more efficient [10]. For example, in vehicle collision warning systems alert the driver to a possible imminent collision. In more advanced AVCS applications, the vehicle could automatically break or steer away from a collision, based on input from sensors on the vehicle. Both systems are autonomous to the vehicle and can provide substantial benefits by improving safety and reducing accident induced congestion. The installation of high tech gadgets and processors in vehicles allow incorporation of software applications and artificial intelligence systems that control internal operations, ubiquitous computing, and other programs designed to be integrated into a greater transportation system

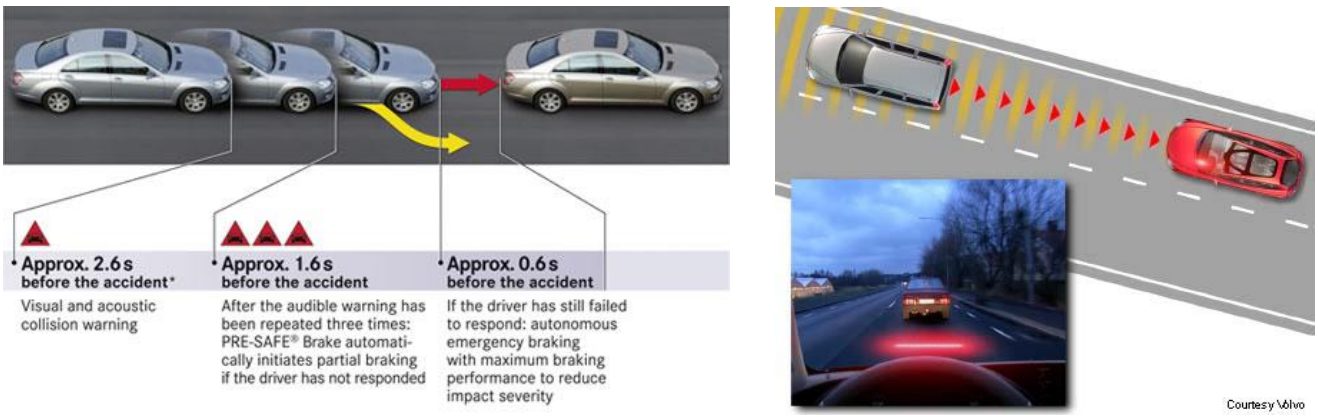


Figure 5: AVCS [11]

Commercial Vehicle Operations (CVO) comprises an ensemble of satellite navigation system, a small computer and a digital radio, which can be used in commercial vehicles such as trucks, vans, and taxis. This system affords constant monitoring of truck operations by the central office and provides traceability and safety.

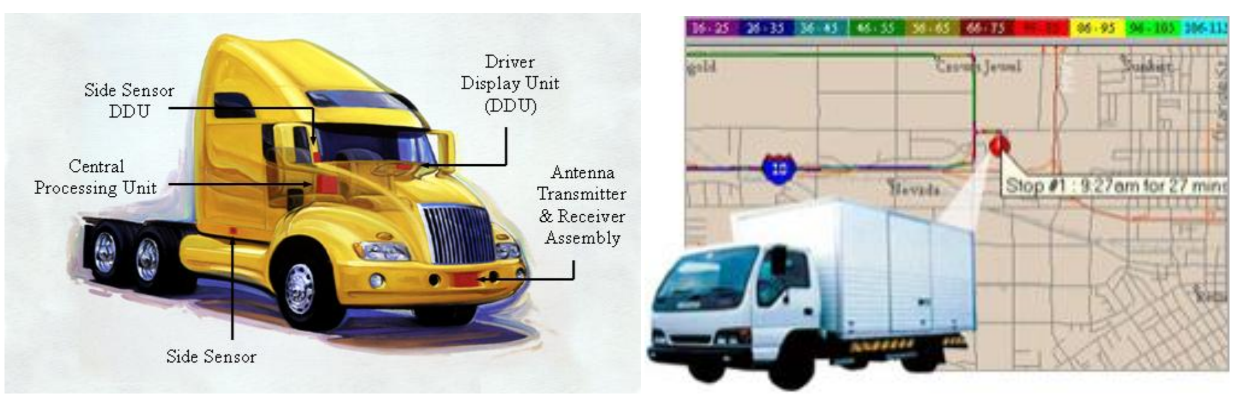


Figure 6: CVO [12]

Advanced Public Transportation Systems (APTS) applies state-of-art transportation management and information technologies to public transit systems to enhance efficiency of operation and improve safety. It includes real-time passenger information systems, automatic vehicle location systems, bus arrival notification systems, and systems providing priority of passage to buses at signalized intersections (transit signal priority) [13].

Figure 7: Digital announcement of transit arrival [Images adapted from [14]]

Advanced Rural Transportation Systems (ARTS) provide information about remote road and other transportation systems. Examples include automated road and weather conditions reporting and directional information. This type of information is valuable to motorists travelling to remote or rural areas. This has been widely implemented in the United States and will be a valuable asset to countries like India, where rural areas are widely distributed.

(a) (b)

Figure 8: ARTS implemented in USA [15]

IV. Components of ITS

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

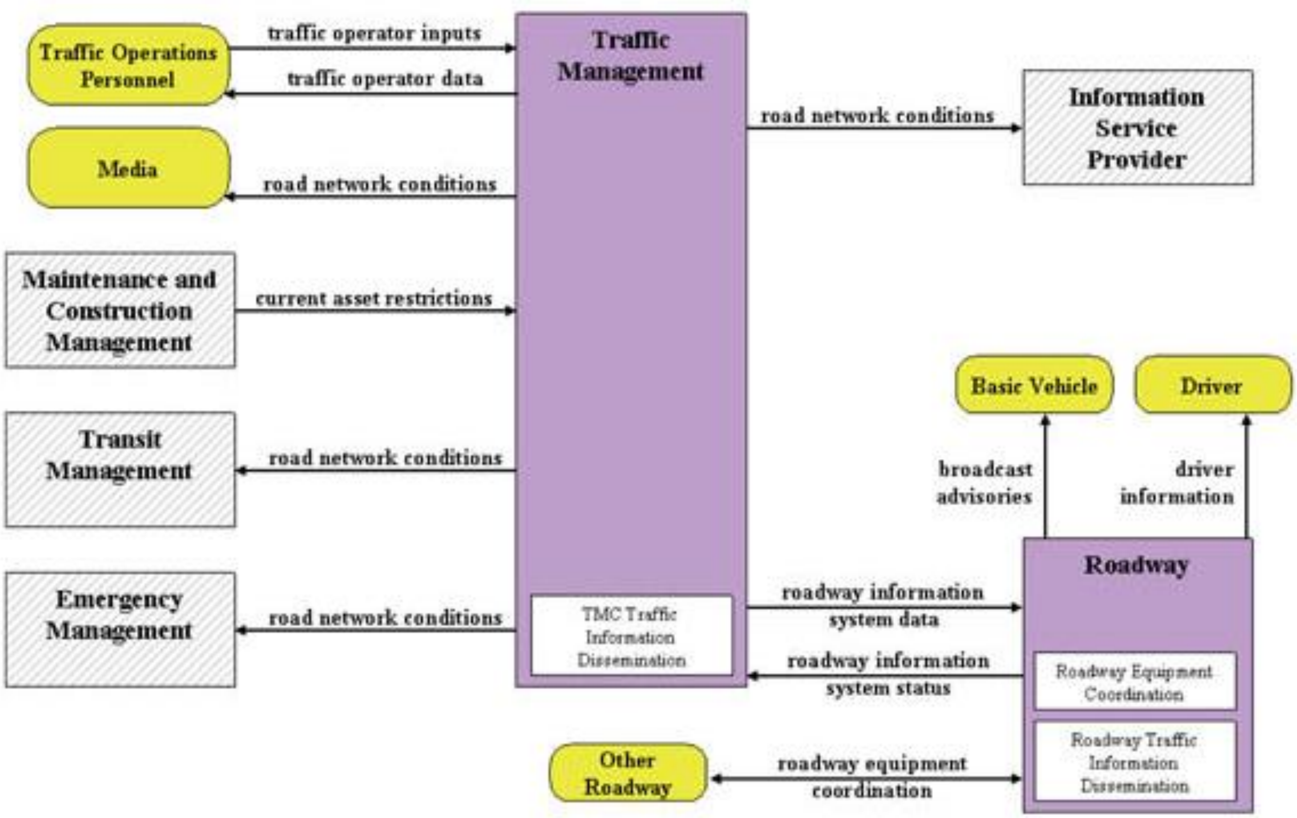


Figure 9: Schematic of the workings of a TMC [6]

The effective functioning of the TMC, and hence the efficiency of the ITS, depend critically on the following components:

- Automated data acquisition
- Fast data communication to traffic management centres

- Accurate analysis of data at the management centres
- Reliable information to public/traveler

Data Acquisition

Rapid, exhaustive and accurate data acquisition and communication is critical for real-time monitoring and strategic planning. A good data acquisition-management-communication system combines tested hardware and efficient software that can collect reliable data on which to base further ITS activities. The different ITS hardware/equipment commonly used include sensors, cameras, automatic vehicle identifiers (AVI), GPS based automatic vehicle locators (AVL), and servers that can store huge amounts of data for meaningful interpretation. A few of the state-of-art, critical components are described below.

a. Sensors

Sensors and detectors have been used for highway traffic counts, surveillance, and control for the last 50 years. Early sensors relied on visuals (e.g. optical detectors), sound (acoustic detectors), and vehicle weight induced pressure/vibration (seismic/piezoelectric sensors) on the road surface. Advances in detector technology now enable use of a variety of detectors such as magnetic detectors (based on geomagnetism), infrared, ultrasonic, radar, and microwave detectors (based on reflection of radiation), inductive loop detectors (based on electromagnetic induction), seismic, and inertia-switch detectors (based on vibration), and video based detectors, in addition to the more traditional sensors used over the years. These detectors measure the change in magnetic/seismic/ optical/acoustic fields caused by the passage of vehicles and calculate traffic parameters based on these measurements. Many of these detectors are intrusive and are placed in the subsurface of the roadway and provide real-time traffic information on that point of the road [16]. The volume, occupancy and speed of the vehicle are the commonly obtained traffic parameters. The three main types of vehicle detectors used in current practice are inductive loop detectors magnetic detectors, and magnetometers [Figure 10].

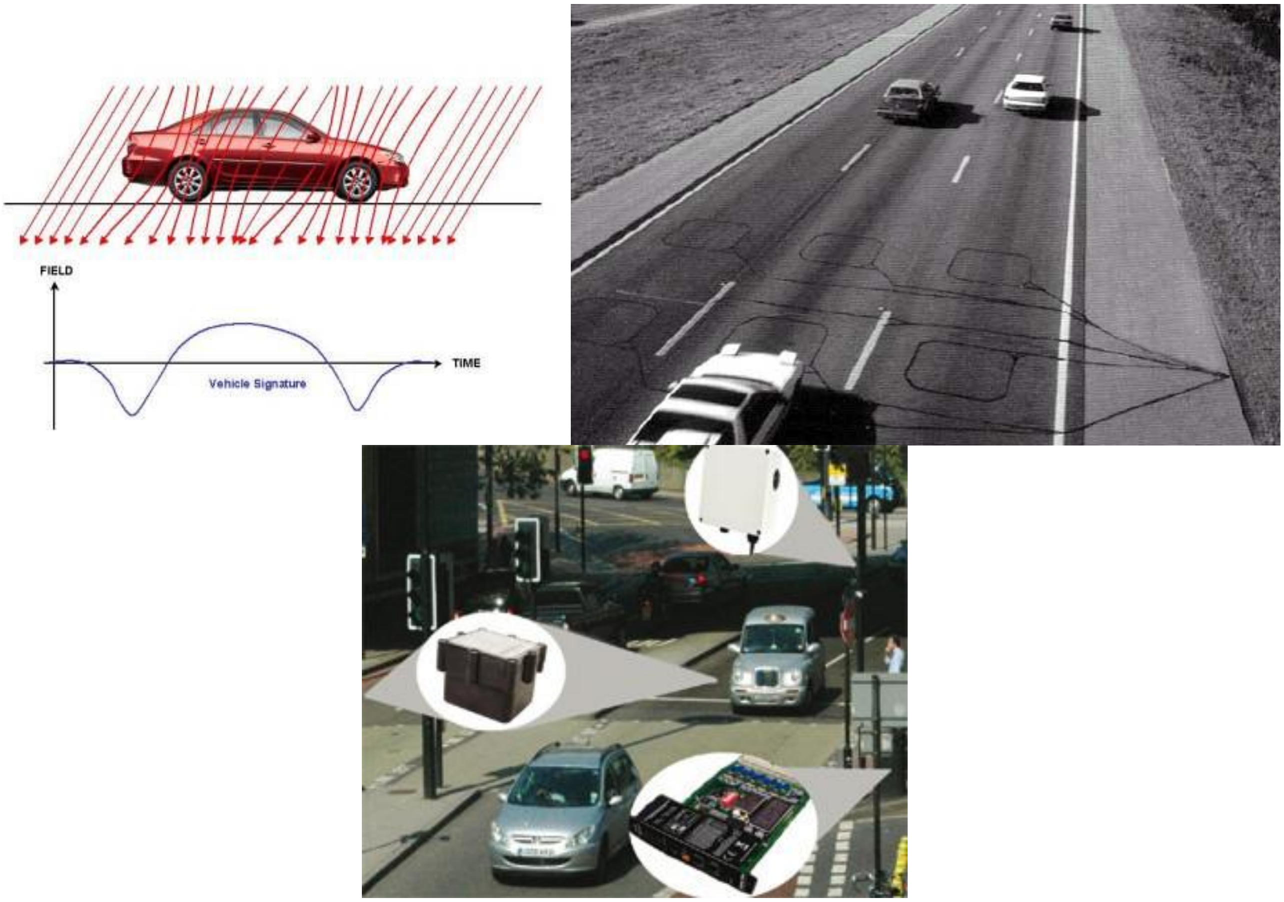


Figure 10: Some data acquisition devices [17]

The advantage of the above sensors/detectors is that, unlike technologies such as AVI, GPS etc., these are autonomous detectors and do not require voluntary participation by the travelling public. However, these sensors and detectors require periodic maintenance, replacement and repair due to deterioration of data quality over time. In addition, many of them are intrusive in nature and require cutting of road surface for installation and maintenance making the cost of installation and maintenance prohibitively high. This is leading to greater use of visual detectors such as video cameras in recent years. Video cameras were introduced to traffic management for roadway surveillance based on their ability to transmit closed circuit television imagery to a human operator for interpretation. Present day traffic management applications utilize video image processing to automatically analyse the scene of focus and extract information for traffic surveillance and control. A video image processor (VIP) system typically consists of one or more cameras, a microprocessor based computer for digitizing and processing the imagery, and software for interpreting the images and converting them into traffic flow data.

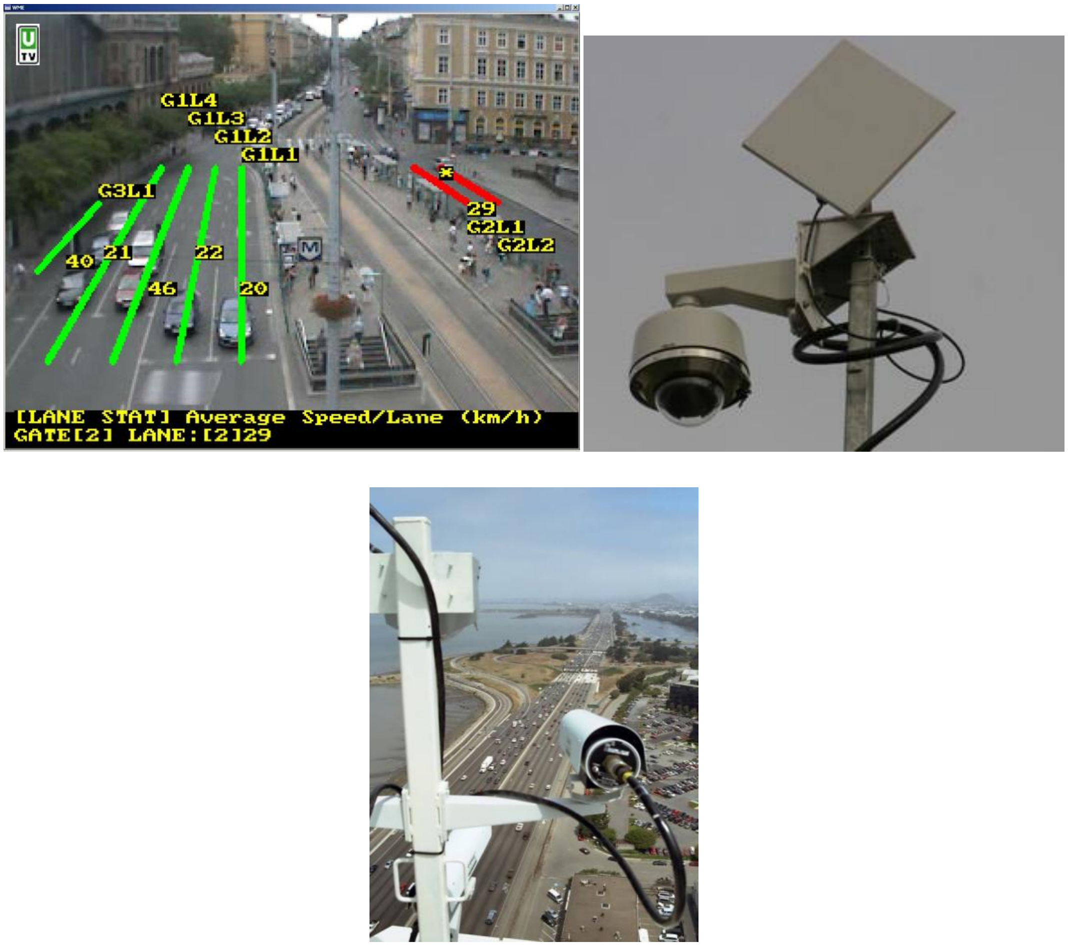


Figure 11: Cameras to monitor Traffic [18]

b. <u>Automatic Vehicle Identifiers (AVI) and Automatic Vehicle Locators (AVL)</u>

The AVI system uses a combination of AVI readers, AVI tags or transponders in the vehicles, and a central computer system. AVI readers/antennas are located on roadside or overhead structures or as a part of an electronic toll collection booth [Figure 12]. The antennas emit radio frequency signals within a capture range across one or more freeway lanes. When a probe vehicle enters the antenna's capture range, the transponders in the probe vehicles respond to the radio signal and its unique ID is assigned a time and date stamp by the reader. This data is then transmitted to a central computer facility, where it is processed and stored. In many developed countries, unique probe vehicle ID numbers are tracked along the freeway system, and the travel time of the probe vehicles is calculated as the difference between the time stamps at sequential antenna locations.

Figure 12: Overhead AVI Antenna [19]

AVI systems have the ability to continuously collect large amounts of data with minimal human resource requirements. However the data collection process is mainly constrained by sample size since it requires participation.

Figure 13: Smart card for vehicle identification [20]

c. <u>GPS</u>

The Global Positioning System (GPS) is a worldwide satellite navigation system that provides a fast, flexible, and relatively inexpensive data to determine a vehicle's position and velocity in real time. GPS is a US owned space-based system of twenty four satellites providing 24x7 monitoring of the earth. The 24 satellites are distributed uniformly in six orbital planes, at an altitude of approximately 20,200 km such that at least four satellites are visible at any time and from any point on the earth's surface [21]. GPS positioning is based loosely on three-dimensional positioning of manmade landmarks/"stars" using trilateration related techniques. GPS employs two fundamental observables for positioning and navigation, the code-phase or pseudo-ranges and carrier-phase. It provides fundamental location data in terms of latitude, longitude, elevation and UTC time. Based on these spatial and temporal data, traffic engineers can determine the most useful traffic information, including travel time, travel speed, travel distance and delay. To produce reliable traffic information from the GPS data, it is of significance to meet the sample size requirements and follow an appropriate field procedure.

Figure 14: GPS Unit in car [22]

<u>Communication Tools</u>

The efficiency of the ITS system depends not only on the collection and analysis of traffic-related data, but also on quick and reliable communication, both data from field to TMC and information derived using the data and models from TMC to the public. This involves communication between data collection centres to TMC and travel and traffic related announcements to vehicles through onboard units and to the travellers through media like VMS, web pages, SMS etc.

Dedicated Short-Range Communications (DSRC) provide communications between the vehicle and the roadside in specific locations (for example toll plazas). DSRC operate on radio frequencies in the Industrial, Scientific and Medical (ISM) band and comprise Road Side Units (RSUs) and the On Board Units (OBUs) with transceivers and transponders. Wireless Communications Systems dedicated to Intelligent Transport Systems and Road Transport and Traffic Telematics provide network connectivity to vehicles. Continuous Air interface Long and Medium range (CALM) provides continuous communications between a vehicle and the roadside using a variety of communication media, including cellular, 5 GHz, 63 GHz and infra-red links.

Data Analysis

Data analysis includes data cleaning, fusion, and analysis. The data from the sensors and other collection devices that are transmitted to the TMC must be checked. Inconsistent data must be weeded out and clean data has to be retained. Further, data from different devices may need to be combined or fused for further analysis. The cleaned and fused traffic data will be analyzed to estimate and forecast traffic states. These traffic state estimation methods will be used to provide suitable information to users.

Traveller Information

Travel advisory system facilities are used for relaying transportation-related information to the motoring public. These include: Variable Message Signs, Highway Advisory Radio, Internet, Short Messaging Services, automated cell phone messaging, public radio announcement, television broadcast and other modern media tools. Such systems can provide real-time information on travel times, travel speeds, delays, accidents, route closures and detours, and work zone conditions, among others [23].

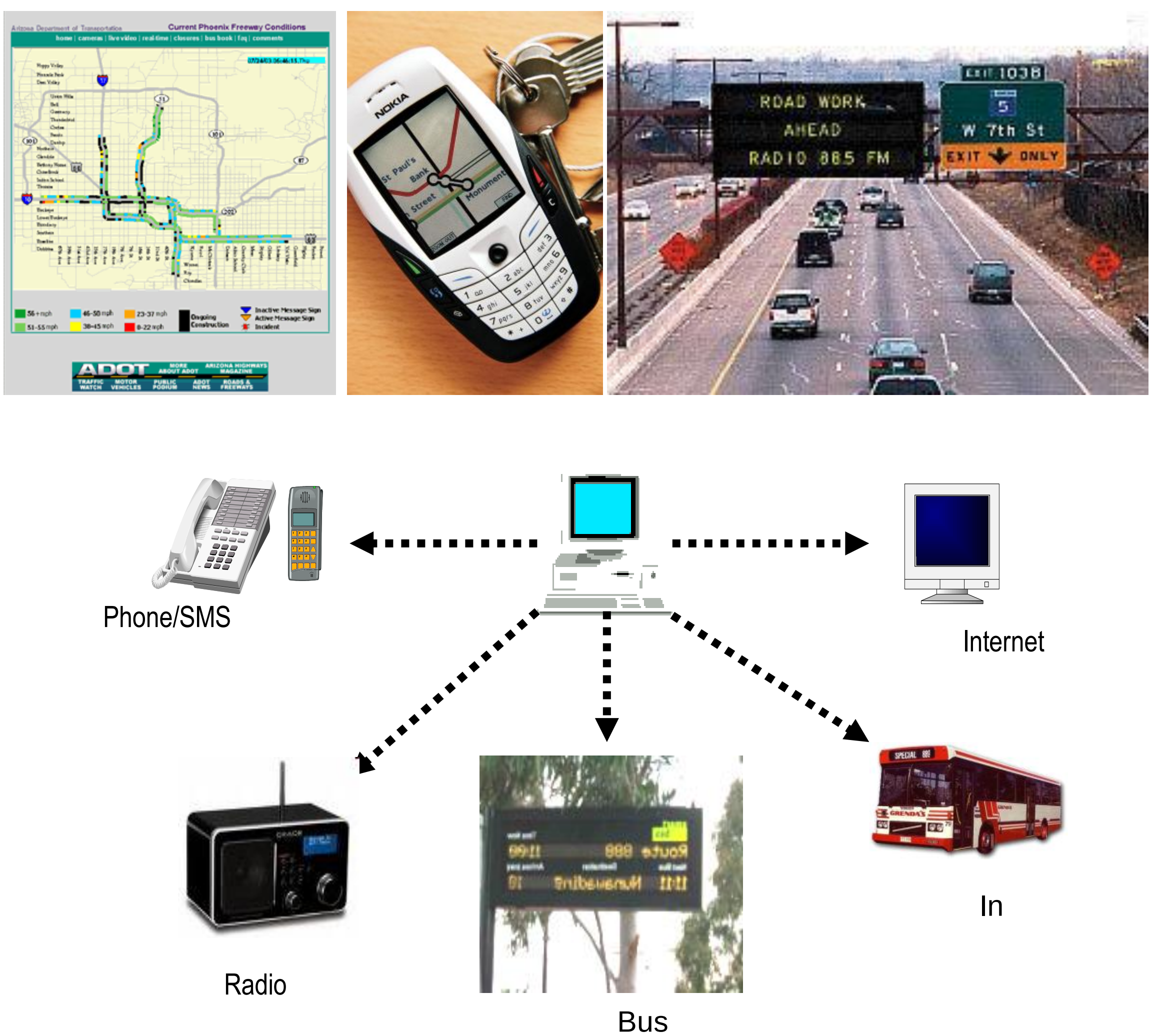


Figure 15: Tools of Travel Advice [Visualized from Ref. 23]

V. ITS Around the World

Numerous ITS applications have been developed by various organizations/institutions around the globe and tailored to offer transportation solution to meet their specific needs. In developed countries, road operators have become dependent on ITS for not only congestion and demand management, but also for road safety and improved infrastructure.

ITS employ modern communication, computer and sensor technology directly, and are also enabled indirectly by developments in materials technology and operations research, including network analysis and risk assessment. The vastness of the playing field makes the ITS a cooperative effort between the public sector, private sector, and academia. There is substantial emphasis on the central and critical role of local public-sector partnership with knowledge input from academic circles. Substantial changes have been made in the core competencies and perspective of these organizations and relationships for developing programmes towards a successful ITS.

In the public sector front, ITS are built on regional and national architecture to suit the specific region. On the private side, new technologies are fuelled by the consumer market. Advances in communication and Information technology have assisted the integration of the vehicle with the infrastructure, an essential requirement of the systemic nature of ITS. ITS fall within the framework of cyber-physical systems due to the intimate interaction between physical systems (vehicles) and a distributed information gathering and dissemination infrastructure (wired and wireless networks, sensors, processors, and the accompanying software).

Developments in ITS are driven strongly by socio-economic needs, and environmental demands. A research report titled "Intelligent Transportation Systems: A Global Strategic Business Report", published by Global Industry Analysts, Inc., provides a comprehensive review of trends, product developments, mergers, acquisitions and other strategic industry activities within the domain of ITS. According to this report, the global market for intelligent transportation systems (ITS) is projected to reach US $18.5 billion by 2015. The United States of America has the largest regional market for ITS, accounting for a share of almost 40% of global revenue generated. The market for ITS is promising in the Asia-Pacific and Latin American regions as well and is driven by rapid infrastructure developments. Among the various programmes of the ITS worldwide, advanced traffic management holds the largest demand followed by electronic toll collection systems.

Some implementations of ITS around the world are described in the following sections.

UNITED STATES OF AMERICA

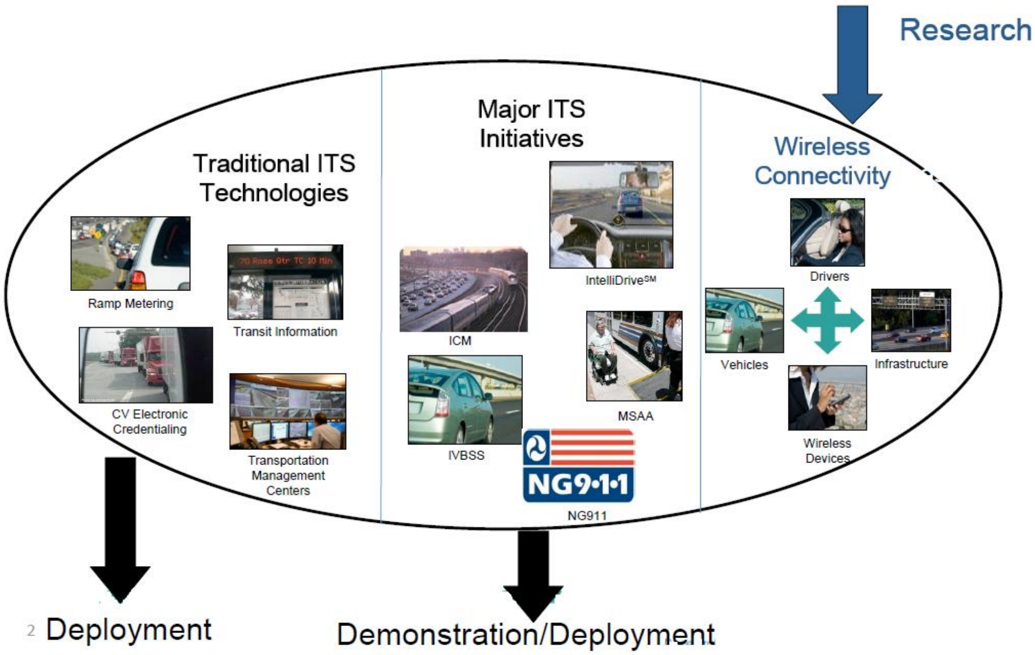


Figure 16: Overview of ITS-America [24]

The U.S. Department of Transportation coordinates the ITS research activities in the country through its Research and Innovative Technology Administration (RITA) wing. The RITA combines cutting edge research with technology transfer and aims to improve the country's transportation system. The main aims of RITA include:

- Coordinating, facilitating and reviewing research and development programs and activities of the in-house team as well as academic and industrial partnerships
- Developing innovative concepts for traffic management through academic and small business innovative research (SBIR) programs
- Performing comprehensive transportation statistics research, analysis and reporting; and
- Educating special groups and general public in transportation and transportation-related fields.

- Bureau of Transportation Statistics
- Intelligent Transportation Systems
- National Transportation Library
- Positioning, Navigation and Timing
- Research, Development and Technology
- Transportation Safety Institute
- University Transportation Centres
- Volpe National Transportation Systems Centre

List 1: RITA's contributors

RITA also coordinates the activities of many Federal and Private Agencies [List 1] and collates knowledge gained into developing ITS. Some US-ITS initiatives of special focus are Telephonic Data Dissemination, IntelliDrive^{SM}, Next Generation 9-1-1, Cooperative Intersection Collision Avoidance Systems, Congestion Initiative, Integrated Corridor Management Systems, *Clarus* Initiative, Emergency Transportation

Operations, Mobility Services for All Americans and Electronic Freight Management, some of which are briefly detailed below:

Organizations such as the American Association of State Highway & Transportation Officials, the American Public Transportation Association and the Intelligent Transportation Society of America (ITS America) partnered with the U.S. Department of Transportation and developed the Telephonic Data Dissemination scheme with the designation of a nationwide 3-digit telephone number (511) to disseminate current information about travel conditions, allowing travelers to make better choices - choice of time, choice of mode of transportation, choice of route. The IntelliDrive^{SM} is a multimodal initiative that leverages on wireless technology to enable communications among vehicles, the infrastructure, and passengers' personal communications devices [Figure 17].

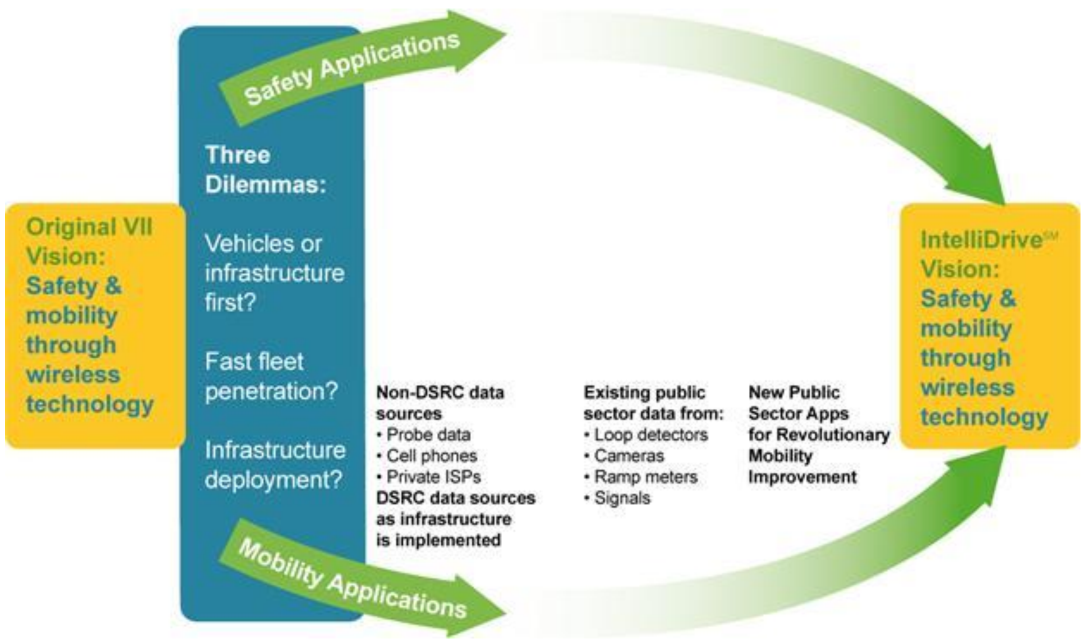


Figure 17: Vision of IntelliDrive^{SM} [25]

Next Generation 9-1-1 initiative is aimed at extending the current emergency 9-1-1 system to establish public emergency communications services through all forms of communication media [26]. The Cooperative Intersection Collision Avoidance Systems initiative is a partnership between US-DoT, automobile manufacturers and State and local departments of transportation aimed at developing an optimised combination of autonomous-vehicle, autonomous-infrastructure and cooperative communication systems that can address the full set of intersection crash problems.

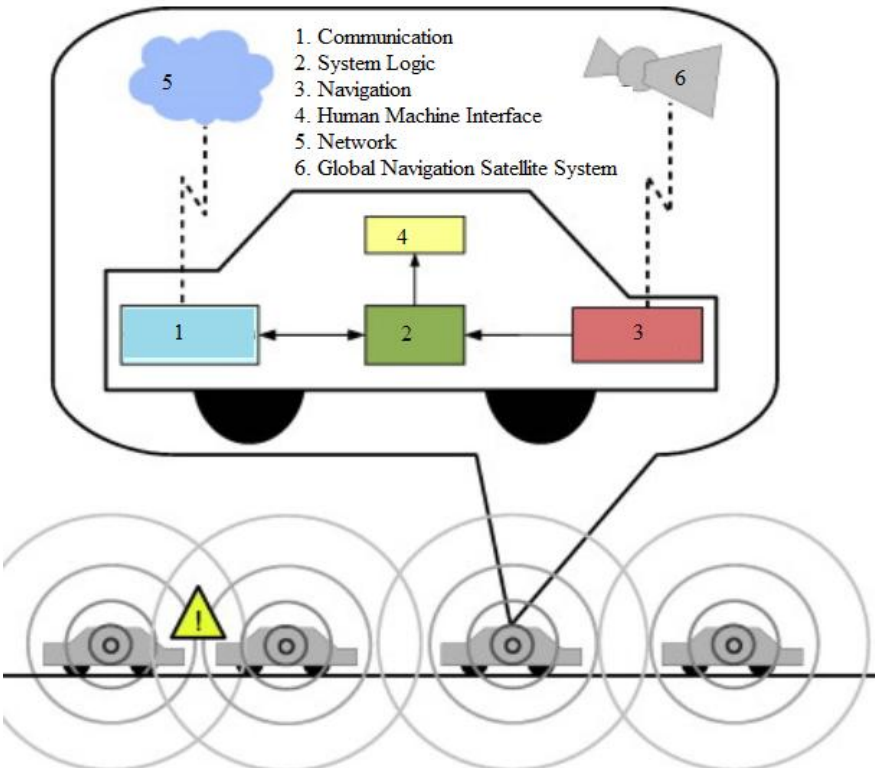


Figure 18: Generic Design of Distributed Collision Warning System [Adapted from [27]]

In USA, Congestion is typically caused by a variety of natural and artificial situations, as shown in Figure 19. The Congestion Initiative seeks to mitigate the problem through strategic planning.

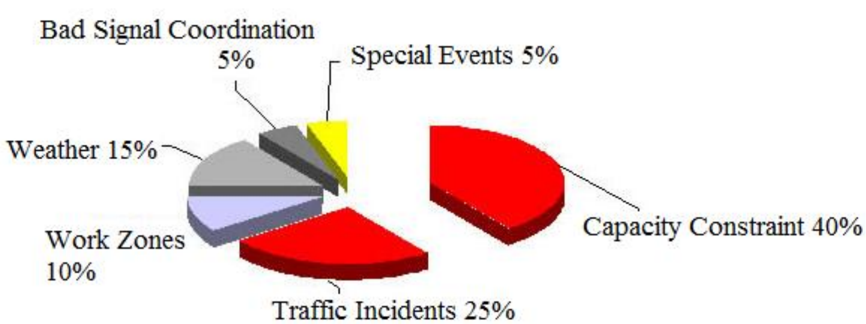


Figure 19: Common Causes for Congestion [28]

It comprises two elements, viz. Urban Partnership Agreements (UPA) program and follow-on Congestion Reduction Demonstration (CRD). Metropolitan areas implement four complementary and synergistic strategies that contribute to the relief of urban congestion:

- Tolling: Reducing congestion through fee payment
- Transit: Promoting use of trains, buses, ferries
- Telecommuting: Enabling work from alternate locations
- Technology: Applying of leading edge technologies in support of all congestion-reduction efforts

The Integrated Corridor Management Systems initiative aims to collaborate and coordinate with multiple organizations and program areas within the US-DoT to identify, test, and deploy appropriate technologies and techniques to create an interconnected system capable of cross network travel management. The program plan is described in the figure below.

The *Clarus* Initiative, as name (Latin "clear") suggests, aims at a system that can provide clear, accurate and relevant information about accidents, weather, road repairs and delays to users. The initiative will establish a coalition of private and federal weather forecasting agencies and industry such as the National Oceanic and Atmospheric Administration's [NOAA] National Weather Service [NWS] to provide weather information to road users.

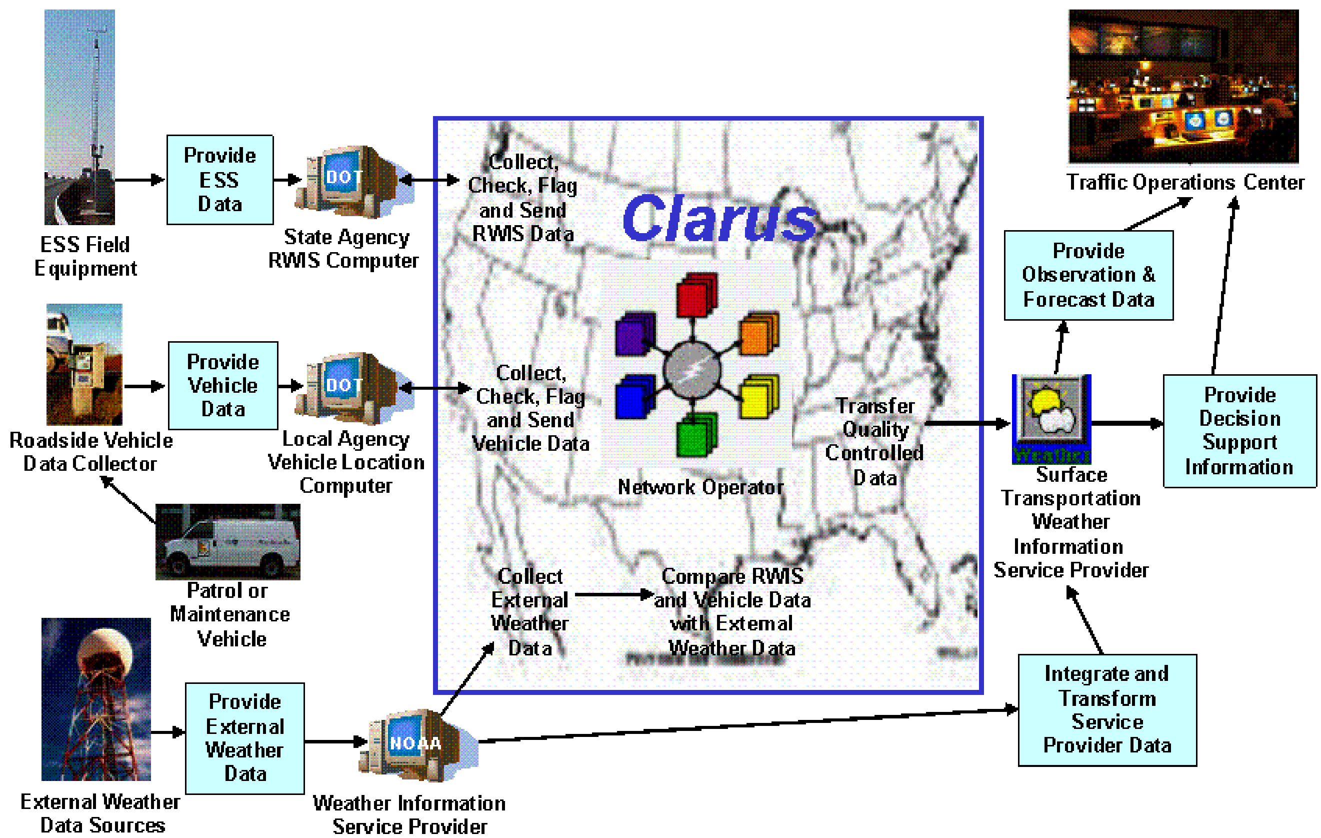


Figure 20: Schematic of the *Clarus* Initiative [29]

The Emergency Transportation Operations (ETO) is a continuous process that is defined by the probability an event will occur and the severity of the impact and complexity of response. ETO's three major areas of action include Traffic Incident Management, Traffic Management for Planned Special Events, Emergency Transportation Operations for Disasters. The Electronic Freight Management Initiative of the US-ITS is aimed at improving freight management through integration of cutting edge technologies.

Some of the other ITS projects that have been successfully implemented by the United States include use of variable rate highway tolling, electronic toll collection, certain advanced traffic management systems such as ramp metering, and active involvement of private sector in telematics and travel information. There are several private sector enterprises that have started providing traffic information related applications as a paid service to users. In fact, the USDOT ITS vision statement predicted in 2007 that 15 years from then, commercial entities, in the form of "Information Service Providers", or ISPs, will be built upon the early public sector foundations of ITS. These ISPs were expected to provide value-added services, by collecting data from various sources and creating valuable information products and services that consumers now see as just as necessary as their TV, on-line computer, and telephone services [30].

The current recognized weakness of the United States is the variability in implementation of ITS among states and regions, thus leading to sporadic, isolated, incremental, and a non-integrated ITS across the country [30].

JAPAN

ITS in Japan was formalised around the middle of the last decade. This period, called the initial stage of ITS, started the use of in-vehicle navigation systems and electronic toll collection. The second phase (2005) built on the discoveries and developments of Phase I efforts, provided more extensive and accurate public transport information for optimization of travel time and convenience. Core areas of development included rapid emergency and rescue activities, establishment of public transport organizations as part of the ITS and improvement of information services to improve the convenience of transportation. The ongoing third phase (2005-2010) involves improvement of infrastructure and in-vehicle equipment, and organization of legal and social systems pertinent to travel and transport. The future Fourth Phase (after 2010) would integrate all technology and concepts developed in the previous phases and apply them in synergy for a fully functional ITS. This would involve, among other activities, setting up a full-scale advanced information and telecommunications society with extensive optic fibre network and innovative social systems. Additionally, a reduction in business traffic will permit to relieve the roadside environment and the global environment.

The ITS efforts in Japan collates improvements in the following fields [31]

- Advances in Navigation Systems
- Electronic Toll Collection
- Assistance for Safe Driving
- Optimization of Traffic Management
- Increasing Efficiency in Road Management
- Support for Public Transport
- Increasing Efficiency in Commercial Vehicles
- Support for Pedestrians
- Support for Emergency Operations

The first ITS implementation was a computer-controlled area traffic control system in Japan and was installed in Tokyo in 1970. The traffic control system coordinated timings of traffic signal lights along 100 intersections, with 200 vehicle detectors. It is reported that the implementation has reduced travel time and saved man-hours and gas consumption in the order of 5.7 times the installation cost. After the success of the Tokyo Area Traffic Control System, nationwide installation of traffic control centres started in a series of Five-year Projects for Traffic Safety Systems [32].

The Comprehensive Automobile Control System (CACS), sponsored by the Ministry of International Trade and Industries was developed during 1973 – 1978. This involved the interaction between each vehicle and the management system such that road side management equipment communicated directions to each vehicle depending on its declared destination and ID. The directions or 'guide table' for every destination in the neighbourhood was stored in the road-side equipment and updated periodically according to traffic conditions so that the vehicle was guided to the best route. The vehicle ID was used to measure travel time between road-side equipment. The implemented CAS comprised the following five subsystems:

- Route guidance subsystem (RGS)
- Driving information subsystem (DIS)
- Traffic incident information subsystem (TIS)
- Route display board subsystem (RDB)
- Public service vehicle priority subsystem (PVP).

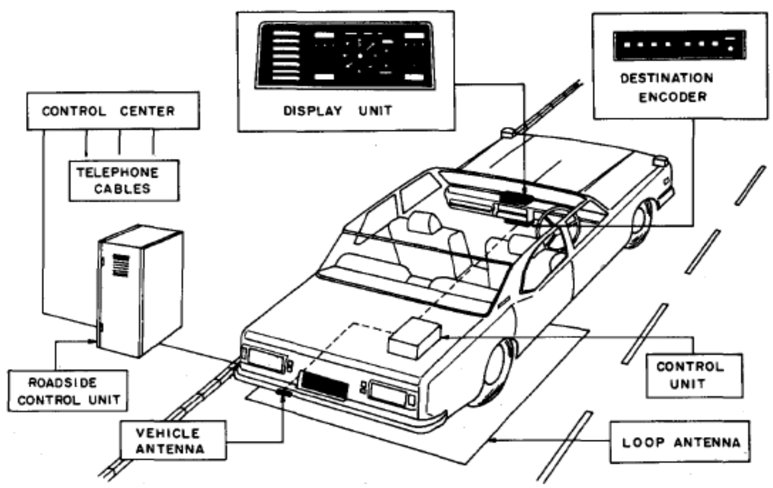


Figure 21: Essential features of the CACS [32]

Japan is a pioneer in vehicle based navigation system. The first navigation system was sold by Honda and equipped in its Accord model in 1981 using a gas rate gyroscope as a direction sensor. In 1987, Toyota Electro Multivision was installed in its Crown model, which was the first car using a Cathode Ray Tube to display the map. Today, Japan uses the largest number of navigation systems in its vehicles. According to a survey in 2006 by Cross Marketing Inc., more than 50% of Japanese cars use advanced navigation systems.

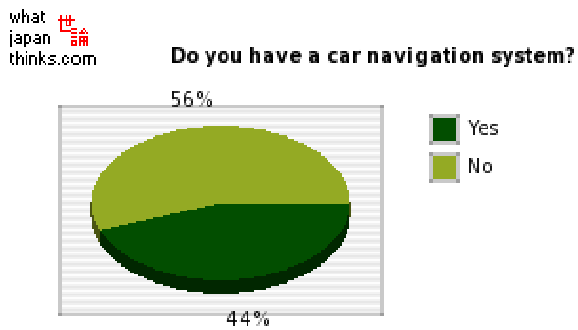


Figure 22: Results of 2006 survey by Cross Marketing Inc.[33]

The Road Automobile Communication System (RACS) was organised by Highway Industry Development Organization during 1984 - 1991 under the supervision of the Ministry of Construction. A series of field experiments with 91 road-side equipment were conducted in a 350 km^2 study area between Tokyo and Yokohama from 1987 to 1988. This was the foundation of current car navigation systems. A bi-directional communication test system comprising 60 meter long zone of road-side antenna with 512Kbps transmission rate was the heart of the communication system [34].

The Advanced Mobile Traffic Information and Communication System (AMTICS) was concurrently developed by Japan Traffic Management and Technology Association under the suggestion of the National Police Agency. It is an integrated traffic information and navigation system that displays on screen in each vehicle, traffic information gathered at Traffic Control and Surveillance Centres managed by the police in 74 cities of Japan.

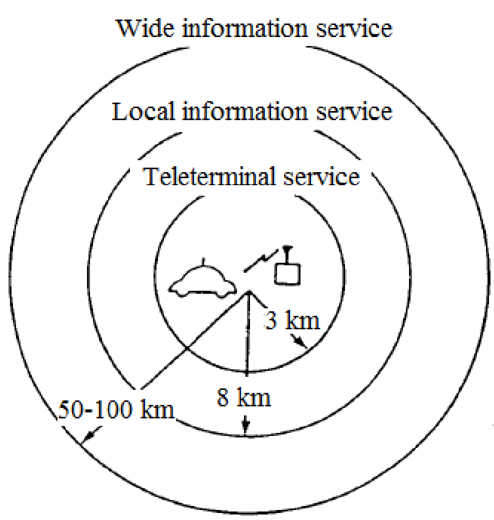


Figure 23: Coverage of Information Service of AMTICS [34]

In the early 1990's the RACS and AMTICS programmes were integrated under the common name of VICS and implemented by a conglomeration of government and private bodies such as the Ministry of Post and Telecommunications, the Ministry of Construction and the National Police Agency, academic organizations and private companies [Figure 24]. The VICS was implemented in the Tokyo Metropolitan area and Osaka around 1996 and in Aichi during 1997. Now it encompasses the entire country. VICS provides drivers with upcoming road conditions and alternative routes to avoid congestion through the use of state-of-art technology including radio, optical and IR beacons, FM multiplex broadcasting media, 2.5GHz radiowave data dissemination, and in-vehicle navigation systems and digital maps.

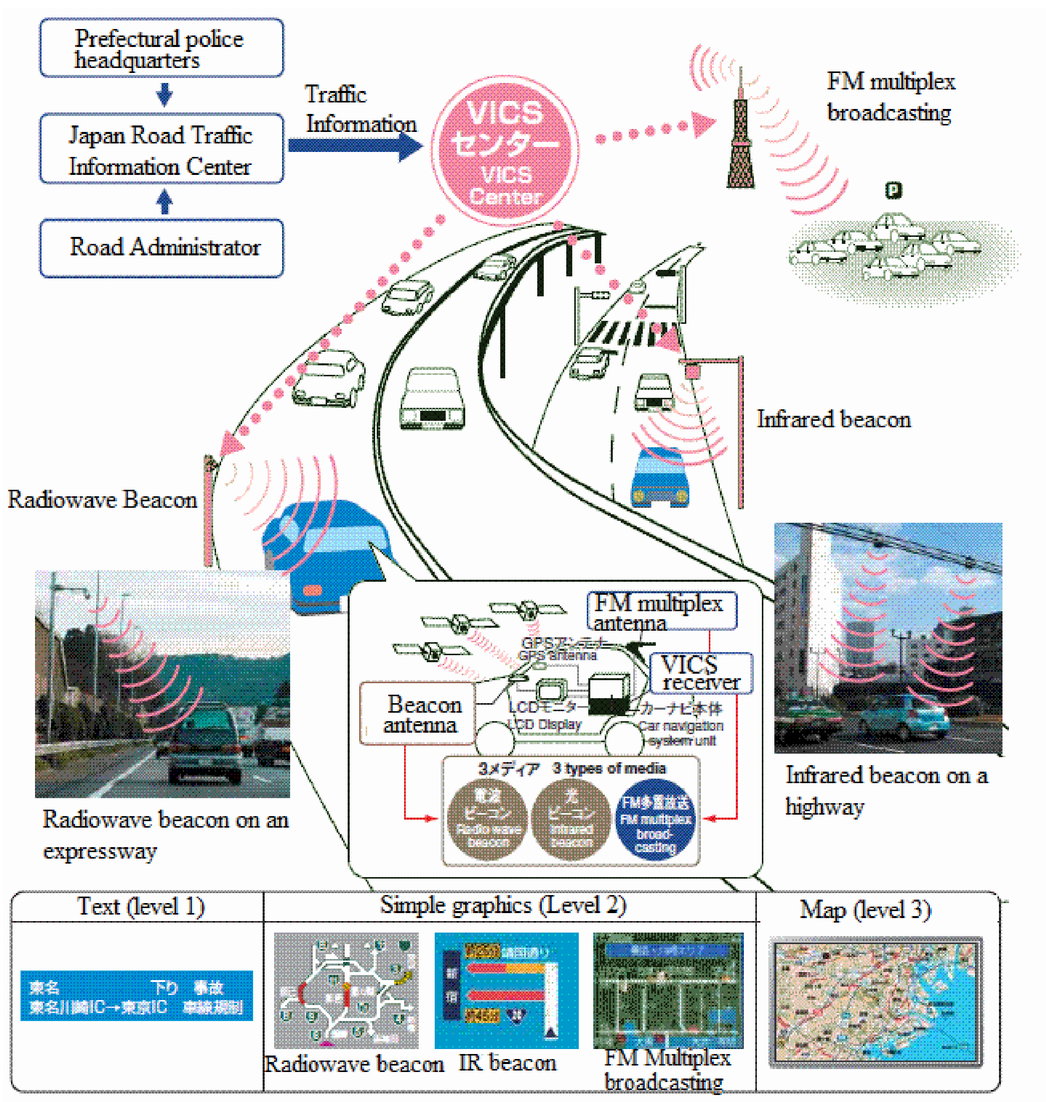


Figure 24: Schematic of the VICS [Adapted from Ref. 35]

The Universal Traffic Management System UTMS is another system that has been implemented in Japan by the National Police Agency since 1993 to provide drivers with real time traffic and guidance information [Figure 25]. The goal of UTMS is effective management of traffic flow. Two-way infrared beacons are used for both monitoring and communication activities.

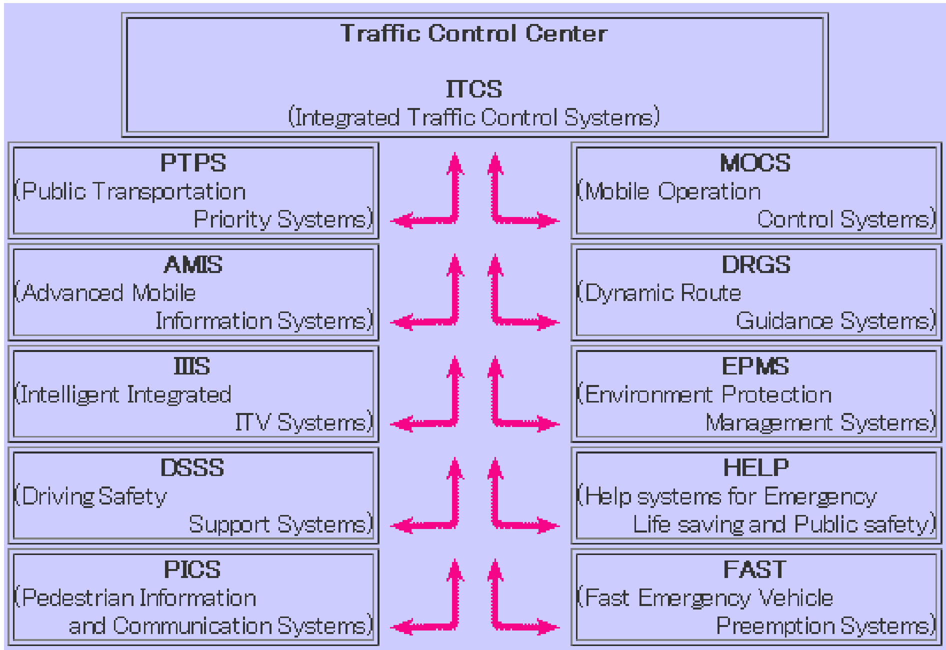


Figure 25: Organisation of UTMS [36]

The Automated Highway System (AHS) was developed with support from the Ministry of Construction in 1995, to minimize driver interface and shift the driving function to the vehicle through more intensive, automatic communication between vehicle and the highway infrastructure. The AHS system comprising features such as partial automated driving, platooning, collision avoidance and incident warning system was demonstrated at a 3 km stretch of a 6 km long loop test course in the Public Works Research Institute, Ministry of Construction, in Tsukuba City during the 2nd ITS World Congress in November 1995. A second demonstration was carried out between Komoro and Tobu ramps (1Km round trip) on the Joshinetsu Expressway in September 1996 just before the official start of operation of the Expressway in November [37].

A sizeable population in Japan use toll roads, as shown in a survey by Dimsdrive Research [Figure 26]. The ETC uses radio signals between the in-vehicle equipment and the antenna at the toll gate to store data in the in-vehicle equipment, and calculates the fee instantaneously at the destination [38]. Initiated in 1995, ETC now encompasses 63 toll gates all over the country.

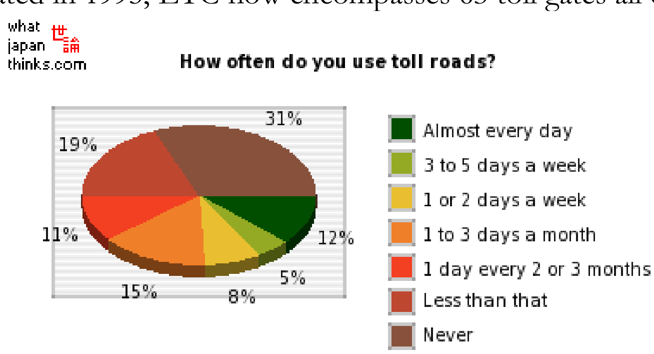


Figure 26: Results of poll on usage of toll roads in Japan [39]

EUROPE

Mainland Europe's Intelligent Transport Systems falls under the umbrella of Road Transport Informatics (RTI). RTI focuses on two interacting programs - Road Infrastructures for Vehicle safety in Europe (DRIVE) and PROgram for European Traffic with Highest Efficiency and Unprecedented Safety (PROMETHEUS). DRIVE falls under the control of the Commission of European Communities (CEC), and PROMETHEUS is part of the European Research Coordination Agency (EUREKA) platform, an industrial research initiative involving 19 countries and European vehicle manufacturers. System development is the primary goal of the PROMETHEUS project, while DRIVE focuses on human behavior issues and implementation of systems in the European community [40-42]. Other European Union (EU) public-private partnership focusing on specific safety applications of ITS technologies initiatives are eSafety, INVENT, and PReVENT.

The eSafety programme promotes the development, deployment, and use of Intelligent Vehicle Safety Systems to enhance road safety throughout Europe.

Figure 27: The Framework of eSafety [43]

The INVENT program works towards improving traffic flow and traffic safety by development of novel driver assistance systems, knowledge and information technologies, and solutions for more efficient traffic management, to prevent or minimise the severity of accidents. INVENT focuses on eight specific projects:

- **Detection and Interpretation of the Driving Environment** through the use of laser, radar, sensors and video image processing, and communicating the information to road users.
- **Anticipatory Active Safety** through automatic detection of crossing cyclists and pedestrians and warning drivers, and support the driver in lane changing and turning manoeuvers.
- **Congestion Assistance** through **a**utomatic cruise and headway control for regulation of speed to, maintenance of safe distance and detection of potential obstacles.

- **Driver Behaviour and Human Machine Interaction** measure the driver's reactions and response to new systems, to improve the human–machine interface.
- **Traffic Performance Assistance** through vehicle-based data collection and analysis of traffic state, and communication to upstream vehicles.
- **Network Traffic Equalizers** use dynamic route guidance and navigation systems to track traffic data and choose optimal route to destination.
- **Traffic Management in Transport and Logistics** enabled by intelligent route planning systems for deliveries, and optimised courier services taking into account mobility of customers and duration of trip, guaranteeing precise delivery times.
- **Traffic Impact, Legal issues and Acceptance** evaluate the economic and business implications of the new technologies, as well as potential legal conflicts.

The PReVENT programme integrates a number of safety functions in order to create a safety belt around the vehicle [Figure 28].

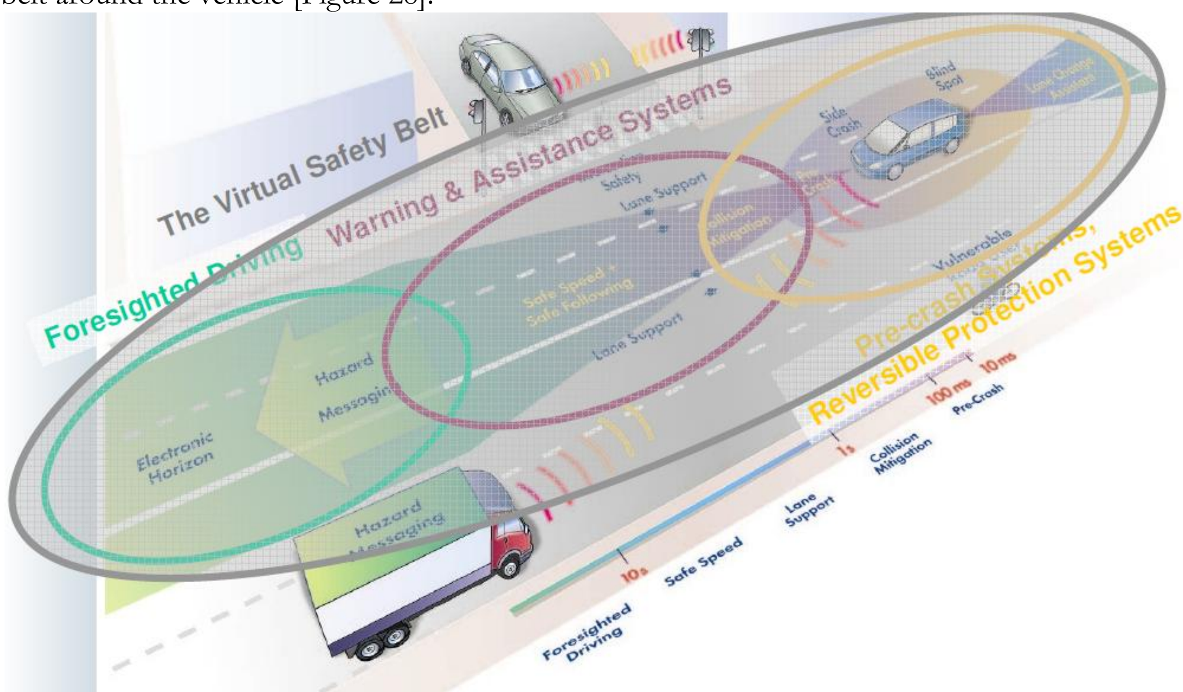


Figure 28: Features of PReVENT [44]

Some representative projects developed under the aegis of the European ITS are described below. This is by no means a comprehensive list, but merely serves as a pointer to the various kinds of ITS activities.

The AGILE project developed a global navigation satellite service in the mobility sector, using European Geostationary Navigation Overlay Service EGNOS and the European satellite navigation system - Galileo. AGILE's ultimate objective is to define a roadmap that will bring profitable EGNOS and Galileo-based applications to reality. High-quality positioning data (within five meters, rather than the current 20 meters), brought about by improving on American GPS and Russian Global Orbiting Navigation Satellite System (GLONASS) enabled the implementation of critical applications in areas in which safety is crucial, such as navigating trains, guiding cars and landing aircraft. The AIDE Project was a collaborative effort between research institutes and universities in Europe, to develop a model to predict behavioural effects of driver assistance and information systems and created a methodology for evaluating the safety benefits of adaptive human-machine interfaces. Adaptive integrated driver-vehicle interface was developed for road vehicles to enable safe integration of multiple IVIS and ADAS functions, including nomadic devices. The project organised a European "Nomadic Device Forum" to work towards a European consensus on the features and architecture of a "smart vehicle-portable device gateway", and to address safety and commercial issues for vehicle device integration. Funded through the EC Asia Information Technology and Communication Programme, the BITS project was designed to link ITS organizations and activities in Europe to those in China to implement ITS projects in the Chinese cities.

The CONNECT programme was aimed at uniting public authorities, road administrations and traffic information service providers, to coordinate and develop ITS in central and Eastern Europe. Austria, the Czech Republic, Germany, Hungary, Italy, Poland, Slovakia and Slovenia were some of the contributors to this project that helped improve cross-border traffic and transport through the use of ITS. The DELTA project, funded by EC 5th Framework IST Programme, worked towards the integration of the DSRC (dedicated short-range communication) link as standard in-vehicle equipment by developing a standardised interface between CEN-compliant DSRC units and the in-vehicle electronics. Another EC 5th Framework IST Programme supported project, DIAMOND, established the technical and commercial feasibility of multimedia ITS services provided over digital radio (DAB) in combination with mobile communication technologies (GSM, GPRS, UMTS) and appropriate positioning technologies for ITS applications. It applied a range of services for users at home, at work, or at leisure with access via devices such as terminals and kiosks and produced a European standard for multimedia ITS services using DAB. The DIAMOND Forum was established as a platform on technical and commercial issues, standardisation issues, and regulatory and frequency aspects.

The Digital Tachograph was a joint ERTICO-European Commission initiative to ensure free movement of EU vehicles in Central and Eastern European countries by informing national administrations, law enforcement agencies as well as social partners about the digital tachograph. The Tachograph is a control device recording and storing drivers' activities, as well as related data like vehicle speed, location, events and faults.

Supported by the European Commission 7th Framework Programme of Information Society Technologies, the eCall project developed techniques for automatic and prompt notification of emergency situations on the road to appropriate crisis management services to speed up emergency response, thus enhancing safety. The technology involved manual calling or automated message transfer through sensors activated by crash-suggestive events, such as airbag release. This project served as a launch pad for futuristic services such as the pan-European eCall. The project assessed the potential benefits of eCall, and its impact on congestion, secondary accidents, efficiency of rescue services and traffic management vis-à-vis national economy. Like the e-Call study, the E-MERGE project was aimed at developing an in-vehicle emergency call solution that ensures a manual or automatic call for assistance to a Public Safety Answering Point (PSAP). This was funded through the EC Information Society Directorate General and coordinated efforts with other groups working to enhance emergency call capabilities (e.g. E112 and the *e*Safety initiative), defined the public- and private-sector requirements to fulfil the goal of a pan-European emergency service chain, and designed the specifications for the working of an eCall service involving routing, the interfaces and all components of the system, such as vehicles, telecom operators, PSAPs, service providers and emergency agencies such as police, fire, and ambulance.

The ETNITE project, supported by EC Directorate General Education and Culture's Leonardo Da Vinci Programme, developed a targeted effort to improve the scope and quality of ITS training and education in Europe. The project supported the European Network on ITS Training and Education (ITSEduNet), a pan-European, multi-sector organisation that offered validated ITS training material. The tasks of the ETNITE team focused on developing educational resources and enhancing awareness of ITS among the public and private sector and promoting e-learning methodologies. The project supported European industry by ensuring the availability of state-of-the-art know-how in ITS and promote the worldwide reputation of European ITS products and services.

The EU-India project was funded by EC Directorate General Information Society & Media to introduce ITS solutions in India for improving road safety and the efficiency of the Indian transport system. The project brought together, European and Indian stakeholders from public authorities, industry and the research sector, and focused particularly on Intelligent Integrated Safety Systems (*e*Safety). The project laid the foundation for efficient traffic management solutions for major future events such as the New Delhi 2010 Commonwealth Games. The "STADIUM" programme being coordinated by Italy's ISIS helps monitor public transport services, in particular bus transport and feeder services consisting of auto rickshaws, in real time via interfaces with GPS positioning systems.

The NextMAP project evaluated the technical and commercial feasibility of enhanced map databases required for in-vehicle ITS applications. It defined and assessed new map requirements (geometric accuracy, additional information) for main Advanced Driver Assistance Systems (ADAS) applications. It has been demonstrated in Coventry (Jaguar), Stuttgart (DaimlerChrysler), Munich (BMW), Paris (Renault) and Turin (FIAT). The PReVENT-MAPS&ADAS improved digital maps, thereby enhancing the information that such maps feed into Advanced Driver Assistance Systems (ADAS). Through this project standardised interfaces were developed for ADAS applications and map data sources.

Supported by the EC Directorate General Information Society and Media, PReVENT developed, tested and spread awareness of Advanced Driver Assistance Systems (ADAS) for improved road safety. The objective was to accelerate the European-wide introduction of such ADAS applications for safety. The project included over 50 partners and was composed of subprojects covering specific road traffic and accident situations.

SpeedAlerts project worked towards harmonising the in-vehicle speed alert concept definition, and investigated the first priority issues to be addressed at the European level, such as the collection, maintenance and certification of speed limit information.The telematics forum developed the Global Telematics Protocol (GTP) for telematics service delivery, merging the two leading protocols, Application Communication Protocol (ACP) and Global Automotive Telematics Standard (GATS). It validated the outcome of the GST Integrated Project. The Forum brought together leading service providers, control centre operators, middleware providers, terminal manufacturers and the automotive industry to work on the definition and market adoption of enabling standards for telematics service delivery.

UNITED KINGDOM

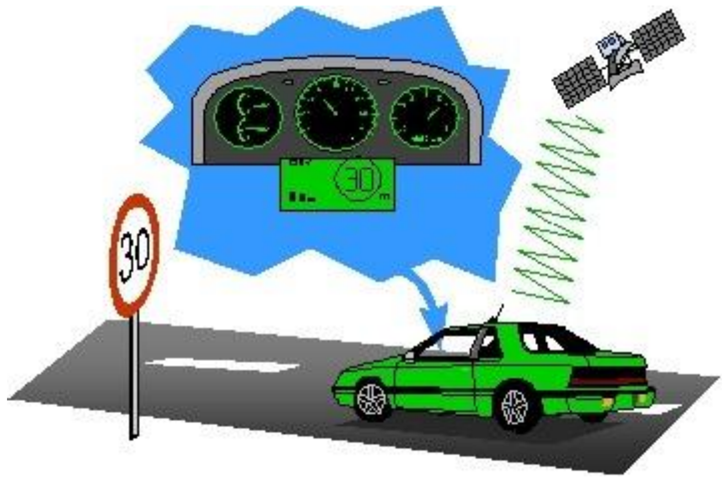
Some successful implementations of ITS-UK include [45]:

- Internet based maps aimed at freight transport. In London, "Transport for London" (TfL) have produced a digital map of all London's speed limits which is available free of charge to anyone who wishes to use the map for personal use, or to create commercial applications.
- Managed motorways: benefits of reduced emissions due to smoother traffic flow, of the removal of the need for additional road building (a carbon intensive activity), and of better design of road side equipment reducing energy consumption.
- Cameras: As part of the "Ring of Steel" program of Coucestershire Constbulary, cameras have been installed on major routes across the country to monitor journey times and traffic flow.

Figure 29: PIPS Spike camera as part of the "Ring of Steel" Programme [46]

- Television: Several tools have been developed to facilitate the "Strategic Road Network" programme, including motorway traffic viewer (MTV) and the web-based online MTV.
- Information services to support travel planning - for towns, workplaces, other activity centres, and individual
- Toll collection and management. Electronic toll collection has been implemented in the following regions of the country:
  - Ireland - Eazy Pass on national toll roads in Ireland
  - United Kingdom - DART-tag for the Dartford Crossing
  - United Kingdom - London congestion charge in London
  - United Kingdom - Fast tag Mersey tunnels: Queensway Tunnel and Kingsway Tunnel
  - United Kingdom - M6 Toll tag in the Midlands
  - United Kingdom - Severn TAG for the Severn Bridge crossing and Second Severn Crossing
  - United Kingdom - Tamar Bridge
- Point to point speed enforcement has been ensured by use of multilane cameras and automated information display for smoother and safer traffic flows
- Two kinds of Intelligent Speed Adaptation (ISA) applications are being implemented in London. Advisory ISA system takes the speed limit and displays the information to the driver via a dashboard unit. Voluntary helps the driver by making it difficult to accidently

accelerate beyond the speed limit. The key to both systems is that the vehicle is aware of its location on the road and the speed limit at that location. It does this using a Global Positioning System (GPS) signal and a digital speed limit map which is held within the ISA unit. A beta Advisory ISA system is now available for public download, including source code released under the GNU license.



- **Figure 30:** Concept of ISA [47]

- The London Road Safety Unit (LRSU) manages the London Safety Camera Partnership (LSCP), which uses cameras to enforce speeds and reduce the number of people running red lights.

- **Figure 31:** One of the 100 Speed Cameras installed in London as part of London Safety Camera Partnership (LSCP) [Image adapted from Ref. 48]

- London's TfL is also working on designing a futuristic bus shelter that uses solar power to operate CCTV and a real time passenger information display.
- Step-free access tube stations in London are equipped with ramps and escalators

- **Figure 32:** Stepfree Access Stations [49]

- The public transportation buses in London are being slowly converted to hybrid vehicles. It is being planned that all new buses entering service after 2012 will be hybrid powered.

Figure 33: Hybrid double decker bus in London [50]

MIDDLE EAST

Inspired by the traffic efficiency and safety in European roads due to the introduction of ITS, the Middle East, whose transportation sector is expanding faster than anywhere else in the world, has begun introducing and implementing ITS systems since last decade. The flagship conference of the ITS-Arab Organisation, focusing on ITS issues and required developments in the Middle East was held during December 2006 in Dubai. This conference with the theme 'Shaping the Future with ITS' established the foundation of a formal ITS program in the Middle East. The ITS system is supported by Gulf Traffic Intelligent Systems, Canada; Intelligent Transport Systems India; South African Society for Intelligent Transport Systems and ITS America [51].

Dubai Municipality started the implementation phase I for project ITS Dubai, which is considered to be the first comprehensive ITS project in the Middle East, and one of the most sophisticated ITS projects currently being implemented in the world. This ITS is expected to serve a rapidly growing population and the potential for phenomenal economical growth has attracted investors and businesses from all over the world.

Several integrated approaches are being implemented to achieve ITS in Dubai, such as constructing new roads and interchanges, promoting public transportation, and enhancing road network. The ITS project by the Dubai Municipality has been working on this project since Mid 2002, and the project has currently reached the tendering stage, having successfully completed planning, study, preliminary design, and final design phases.

The ITS is designed such that the municipality is automatically alerted of incidents on its roadways by a combination of real-time traffic flow information via 63 freeway monitoring stations. Point detection using radar sensors and wide area detection using video image processing are expected to be installed, particularly along bridges, within tunnels, and at key interchanges. Stations are designed to be non-pavement intrusive, for easy maintenance and relocation if necessary.

The ITS is designed such that once an incident is detected and verified, a software will search through the response planning bank and will recommend to the operator the best way to deal with the incident. The municipality is also slated to rebuild the existing Traffic Control Centre to a State of Art Comprehensive Traffic Management Centre.

Figure 34: State-of-Art Traffic Control Centre [52]

The system will be capable of conducting hundreds of complicated tasks simultaneously. Some of the tasks that will be handled are:

- Advising motorists ahead of a traffic jam to alter routes
- Diverting traffic safely and with least inconvenience, away from accident induced blocked lanes
- Automatic moderation of speed limits during incidents or congestions.
- Implementation of pre approved and tested plans jointly with Police Department and
- Establishing easy and rapid approach to accident locations and hospitals during incidents.
- Prioritising signals to support traffic incidents and civil defence vehicles y

- Handling equipment to guarantee reaching injured drivers and passengers as soon as possible.
- Automating traffic management plans to reduce congestion during special events.

Relevant traffic related information is provided to the drivers through LED-based Dynamic Message Signs "DMS" that are located upstream of decision points. State-of-the-art graphical information with concise English and Arabic text are designed [Figure 35].

Figure 35: Bilingual Traffic Signs [52]

Nearly 300 real time lane use control signals and speed control signals are being installed along critical segments and bridges and tunnel approaches.

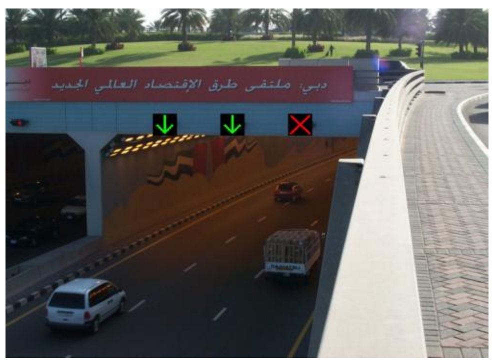


Figure 36: Lane Control Signals [52]

Real-time wireless messaging including SMS [Figure 36] and WAP services are being provided to compatible mobile phones in partnership with Etisalat. Map-based information on the internet, showing travel times and congestion information and video images from DM cameras are being designed for efficient communication of travel-related data to the public.

Figure 37: Travel Information through Cell Phone [53]

The Municipality of Dubai has also developed a dynamic navigation system for vehicles. The testing phase has been completed and the CD is set to be released in the market soon.

Figure 38: The Dynamic Navigation System developed by Dubai Municipality [53]

Traveller information kiosks with touch-screen navigation, are also located in shopping malls and other public areas to provide important travel related information to the public.

Figure 39: Traveler Information Kiosk [53]

CANADA

Canada has been in the forefront of intelligent transport for more than half a century [54]. The world's first computer-controlled traffic signal system operated in Toronto in 1959. The world's first all-electronic, open-access toll highway, the 407 ETR (electronic toll route) opened in Greater Toronto in 1999. Other ITS innovations in Canada have included ramp metering on the Queen Elizabeth Way (QEW) and the COMPASS freeway traffic management system on the QEW and Highway 401, the main route through Toronto and one of North America's busiest highways. The very successful Combo smartcard has been used on the Burlington, Ontario transit system since 1995 [Figure 40a].

Figure 40: (a) COMBO Card (b) COMPASS Advisory [55]

Transport Canada is part of the Transportation, Infrastructure and Communities (TIC) portfolio of the Government of Canada to develop regulations, policies and services in the transportation sector in Canada. Transport Canada has been responsible for the development of a "Border Information Flow Architecture (BIFA)" in partnership with the U.S. Federal Highway Administration, to ensure that technologies deployed at border crossings interact efficiently with each other. The development of the BIFA followed the regional ITS architecture practices widely used throughout Canada and the U.S. The BIFA was developed in conjunction with federal, state and provincial agencies from both sides of the border. Transport Canada is a leader in developing technologies, and promoting strategies and policies that help persons with disabilities, seniors and other citizens with unique needs use the national transportation network without undue obstacles.

The User Services of the ITS Architecture for Canada are organised into 8 User Services. The individual user services and the sub-services under each are given below

1. Traveller Information Services
    1.1. Traveller Information
    1.2. Route Guidance and Navigation
    1.3. Ride Matching and Reservation
    1.4. Traveller Services and Reservations

2. Traffic Management Services
    2.1 Traffic Control
    2.2. Incident Management
    2.3. Travel Demand Management
    2.4. Environmental Conditions Management
    2.5. Operations and Maintenance
    2.6. Automated Dynamic Warning and Enforcement
    2.7. Non-Vehicular Road User Safety
    2.8. Multi-Modal Junction Safety and Control

3. Public Transport Services
    3.1 Public Transport Management
    3.1.1 Transit Vehicle Tracking
    3.1.2 Transit Fixed-Route Operations
    3.1.3 Passenger and Fare Management
    3.1.4 Transit Maintenance
    3.1.5 Multi-Modal Co-ordination
    3.1.6 Multi-Modal Connection Protection

4. Electronic Payment Services
    4.1 Electronic Payment Services

5. Commercial Vehicle Operations
    5.1. Commercial Vehicle Electronic Clearance
    5.2. Automated Roadside Safety Inspection
    5.3. On-board Safety Monitoring
    5.4. Commercial Vehicle Administrative Processes
    5.5. Intermodal Freight Management
    5.6. Commercial Fleet Management

6. Emergency Management Services
    6.1. Emergency Notification and Personal Security
    6.2. Hazardous Material Planning and Incident Response
    6.3. Disaster Response and Management
    6.4. Emergency Vehicle Management

7. Vehicle Safety and Control Systems
    7.1. Vehicle-Based Collision Avoidance
    7.2. Infrastructure-Based Collision Avoidance
    7.3. Sensor-Based Driving Safety Enhancement
    7.4. Safety Readiness
    7.5. Pre-Collision Restraint Deployment
    7.6. Automated Vehicle Operation

8. Information Warehousing Services
    8.1. Weather and Environmental Data Management
    8.2. Archived Data Management

In a joint venture by Transport Canada, TransLink and IBI group, three bus rapid transit (BRT) services have been developed in Canada: the 99 B-Line along Broadway, the 97 B-Line linking Coquitlam, Port Moody and Burnaby to the Millennium SkyTrain line, and the 98 B-Line linking Richmond, the Airport and downtown Vancouver. The 98 B-Line is the first BRT service that incorporates the following state-of-art ITS technologies:

• **Transit Management:** The system incorporates Automatic Vehicle Location (AVL) and schedule adherence monitoring, supported by voice and data communications to the Surrey

Transit Centre (STC) intended to optimise TransLink's efficiency in managing the 98 B-Line fleet of buses, as well as buses on other routes.
• **Traffic signal priority (TSP)**: The system allows buses to receive priority at traffic signals when running behind schedule, reducing the number of stops at intersections, as well as the amount of delay experienced at traffic signals, improving trip time reliability, while also contributing to reduced operating costs.
• **Real-time Passenger Information:** The system provides "next bus" arrival time information to customers at the 98 B-Line stations, updated in real time based on vehicle locations and schedule adherence – thus increasing passenger convenience and accessibility to the system.
• **Automated Voice and Digital Next Stop:** On board the buses, automated voice and digital displays provide "next stop" announcements to on board passengers.

The ITS office of the Ontario Ministry of Transportation is implementing an ITS deployment analysis system known as IDAS, a computerised benefit/cost model that estimates the impacts of alternative ITS-based transportation solutions in urban, freeway and intercity situations. IDAS uses output from traditional transportation planning models to replicate an existing or future transportation network. The user can then deploy ITS improvements directly on the links of the 'network model' or, in the case of some transit services, by districts, to generate cost/benefit impacts for various ITS scenarios. The library of "typical" ITS deployments and associated "average" equipment costs and benefits were derived originally from a nation-wide survey conducted by the US. DOT for the ITS National Architecture which is being updated on a continuing basis from case studies being collected in the U.S., Canada and Europe.

A Canada-wide university research network, led jointly by the University of Toronto ITS Centre and Testbed, and the University of Montreal Centre for Research in Transport, has Europe and US partners. A few successful projects by the network are given below.

- CoastView (BC) enhances management of hazardous materials and dangerous goods to improve transport safety.
- Video Traffic Management and Traveller Information (Edmonton, Alberta) deploys CCTV to provide information for traffic and incident management, and traveler information images via TV and a website.
- Traffic Signal Priority for Buses and Automatic Vehicle Tracking System (Calgary, Alberta) focuses on bus priority at traffic signals, and collection and analysis of data for validating and adjusting transit schedules.
- Reduce Single Occupant Vehicle Travel in Region of Waterloo (Regional Municipality of Waterloo, Ontario) is a pioneering public-private partnership aimed at implementing, monitoring and evaluating the effectiveness of employer based transportation demand management.
- ITS for School Bus Drivers (Quebec and New Brunswick) is using ITS to detect children around school buses and warn drivers.
- The Confederation Bridge (Prince Edward Island-New Brunswick) has introduced ETC transponders identical to those used elsewhere in the Atlantic provinces to facilitate interoperability.

INDIA

The ITS program in India is aimed at ensuring safe, affordable, quick, comfortable, reliable and sustainable access for the growing urban and rural population to jobs, education, recreation and such other needs. A few ITS applications have been introduced in India in metropolitan cities like New Delhi, Pune, Bangalore, Chennai etc. focusing on stand-alone deployments of area-wide signal control, parking information, advanced public transportation, toll collection etc. However, all of these are small scale pilot studies limited to major cities and are in the beginning stage of deployment. Thus, at present, there are no exhaustive fully developed ITS applications with traffic management centers in India [56-58].

A brief description of some of the existing applications of ITS is given below:

<u>Trial of advanced Traffic Management System (Tamil Nadu, Sep 2009)</u>

This involved a trial run of the fully automated Traffic Regulatory Management System (TRMS), involving usage of surveillance cameras in the city of Chennai. This project involved installing sophisticated cameras, wireless towers and poles, under the Rs. 3-crore-State government-funded project. Automatic Number Plate Reader (ANPR) cameras were installed in 28 out of 42 vantage points in the city, while 'Pan Tilt Zoom' (PTZ) cameras were deployed in 10 out of 12 busy junctions identified. The traffic police also plan to install 40 CCTV cameras at various junctions. This is to warn motorists who blatantly violate rules and monitor traffic on arterial roads during peak hours.

Figure 41: TRMS in Chennai [59]

<u>Automated Traffic Control (ATC)</u>

ATC has been setup in many cities in India including Delhi, Pune, Mumbai etc.

<u>Mumbai:</u>

The Area Traffic Control Project of the Mumbai Traffic Control Branch focused on synchronising major junction and was implemented through the Mumbai Metropolitan

Region Development Authority (MMRDA) and Municipal Corporation of Greater Mumbai (MCGM) with financial aid from World Bank. Modern gadgets such as Speed Check Guns and Multi Radar C comprising Smart Cameras, Radar sensor, Screen, Manual control unit, Flash generator, Flash light, Power Box and Tripod were used in this project.

Chennai:

The Chennai traffic police set up the city's first Automatic Traffic Control (ATC) system at 26 major traffic signals around the new secretariat complex. The system monitors and regulates traffic without any manual intervention and helps police regulate VIP routes. The ATC is designed to be capable of changing signal duration in accordance with the volume of the traffic by analysing the number of vehicles at three adjoining junctions and synchronising the signals. Manual intervention if required is designed to be performed from the control room. A VIP movement can be managed by creating a green corridor by automatically synchronising the signals along the VIP route.

Figure 42: ATC in Pune [60]

ATIS

The objective is to inform road-users of latest traffic updates and better management of traffic. SMS, internet and radio have been employed for updates. The update protocols in a few Indian cities are as follows

a. Bangalore and Hyderabad [61]

- Internet (June 2008)

This project provides a platform for the public to check the real time traffic situation at important junctions and arterial roads, through the net. Real time images of traffic at busy junctions are available. It covers 40 busy traffic junctions and the informations are updated every 15 seconds [62].

- SMS(October 2009)

To keep commuters informed about traffic congestion and bottlenecks in real time, Bangalore Traffic Police have made arrangements to send SMS. The facility is available free of cost to all those who register for it. Everyday two SMS will be sent during morning and evening peak hours to the subscribers, indicating congestion points and bottle necks. In addition, reasons and alternatives will also be communicated. Additional messages will be sent whenever there are man-made disruptions in traffic like agitations, serious accidents etc.

b. Chennai

- FM radios

Traffic updates are being provided on FM radio to convey critical information such as obstruction and road damage due to rain.

c. Delhi

- 'The Traffic People' (April 2009)

'TheTrafficPeople' provides real time traffic updates to residents in the Delhi – NCR region. It gives time-to-time information on traffic situations through websites. Latest information on traffic jams, processions or rallies resulting in slow vehicular movement and on any sort of diversion can be obtained from the website. As of now it provides updates only during peak hours during mornings and evenings, but will expand coverage as need arises. They also share traffic updates with radio channels that makes it possible to reach a broader audience. An SMS alert subscription costs about Rs. 99/- per month.

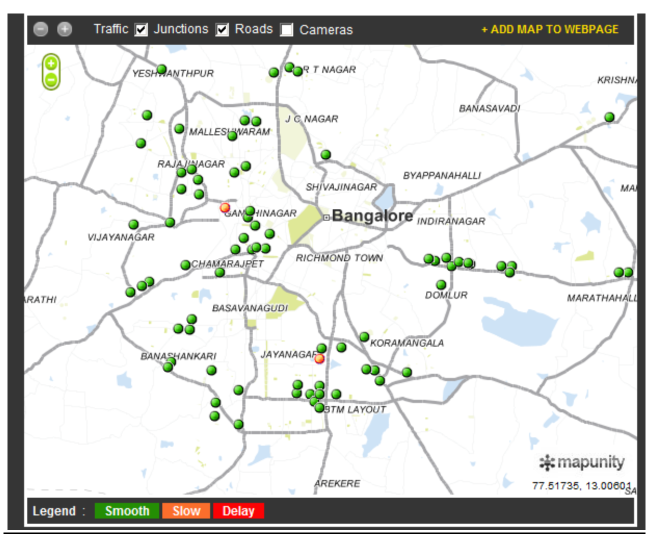


Figure 43: Real-time Traffic information available online [63]

Advanced Public Transportation System APTS

One application implemented in APTS area is GPS vehicle tracking system in public transport buses (Bangalore, Chennai, Indore) to monitor vehicle routing and frequency so that passengers do not have to wait long hours for a bus. The objective is to provide Global Positioning System based passenger information system to help passengers utilise their waiting time at bus stops more efficiently as well as to reduce the uncertainty and associated frustrations. Display boards with high quality light emitting diode in wide-view angle are provided at bus stops so that passengers can read the information. It displays the number and destination of the approaching bus, expected time of arrival, and messages of public interest.

Figure 44: Electronic display at the Metropolitan Bus Stand in Chennai [64]

Bus Rapid Transport (BRT)

Bus Rapid Transit (BRT) systems are viable alternatives to traditional light rail public transport. Instead of a train or metro rail, BRT systems use buses to ply a dedicated lane that runs lengthwise along the centre of the road. At specific locations, passengers can embark or disembark at conveniently located stations, which often feature ticket booths, turnstiles, and automatic doors. Studies have shown that a BRT is not only cheaper to build, but is also profitable for bus owners to operate and relatively inexpensive for commuters to use. The cities selected for implementing BRT include Ahmedabad, Pune, Rajkot, Bhopal, Indore, Visakhapatnam, Vijaywada and Jaipur [65].

a. Pune (Dec 2006)

The city of Pune was the first to experiment with a Bus Rapid Transit system. The project consists of 13 kms of bus lanes along the Pune Sastra Road using air conditioned, low floor Volvo B7RLE buses. The project has achieved success to certain extent. The funding for the project came from the Government of India under the Jawaharlal Nehru National Urban Renewal Mission.

b. Ahmedabad

Ahmedabad BRTS is a highly ambitious rapid transport system developed by Gujarat Infrastructure Development Board (GIDB), recognizing that no single mode would cater to the mobility needs of the city and that 'Bus' forms the most critical segment of the public transport system in the Ahmadabad city. GIDB has thereby entrusted the system design task to CEPT University. In August 2009, the Ahmedabad, India, bus rapid transit system, termed "Janmarg," or people's way, began trial operations, becoming India's first fully-featured BRT service with median stations, level boarding, and central control. Janmarg has the potential to help revive the image of public transport in Ahmedabad and in India. The enclosed stations of the BRT system have become some of the finest quality public spaces in the city. A part of first corridor connecting Pirana to R.T.O. was opened to public on October 14, 2009 by Chief Minister Narendra Modi on December 3, 2009 [66].

c. Chennai Rapid Bus Transit Ways (RBTW)

It is a part of the Medium-term and Long-term Transport Scheme proposed in the Second Master Plan by CMDA. This is not a part of Chennai BRTS which is proposed on a separate elevated road that is to be constructed as 15 circular corridors.

The RBTW is proposed along the following 7 routes, covering a distance of 100 km, would be taken up in the Medium-term Transportation Scheme [67]

- Rajiv Gandhi Salai (OMR/IT Corridor) [20 km]
- Taramani Link Road [5 km]
- MBI Road [15 km]
- Pallavaram - Thoraipakkam Road [15 km]
- Sardar Patel Road [10 km]
- NSK Salai (Arcot Road) - KS Road [20 km]
- St. Thomas Mount - Poonamalle (Mount. Poonamalle Road) [15 km]

The following 8 routes will be covered in the Long-term Transportation Scheme

- Anna Salai [30 km]
- Periyar EVR Salai [25 km]
- Jawaharlal Nehru Salai (IRR) [45 km]
- GNT Road [20 km]
- CTH Road [15 km]
- Chennai Bypass [20 km]
- Outer Ring Road (ORR) [62 km]
- CMBT - Sriperumbudur [25 km]

Table 2: List of BRTS Projects Proposed

City	BRTS
Pune	Pune BRTS;1 corridor (Katraj - Swargate - Hadapsar)
Delhi	Delhi BRTS; 1 corridor and 1 more planned
Ahmedabad	Ahmedabad BRTS; 1 corridor and 17 more under construction
Indore	Indore BRTS; 1 corridor
Mumbai	Mumbai BRTS 7(none are grade or lane segregated) Under Construction Systems
Hyderabad	Hyderabad BRTS; 2 Corridor
Bangalore	Bangalore BRTS;14 corridors planned
Chennai	Chennai BRTS;1 planned
Coimbatore	Coimbatore BRTS; 1 corridor planned
Jaipur	Jaipur BRTS; 4 corridors
Madurai	Madurai BRTS; 2 corridors
Nagpur	Nagpur BRTS; 1 corridor
Vijayawada	Vijayawada BRTS; 2 corridor
Visakhapatnam:	Visakhapatnam BRTS; 2 corridor

Figure 45: Some implementations of ITS in India [67, 68]

Electronic Toll Collection (ETC)

The Electronic Toll Collection (ETC) is designed to determine if a car is registered in a toll payment program, alert enforcers of toll payment violations, and debit the participating account. With ETC, these transactions can be performed while vehicles travel at near highway cruising speed. ETC is fast becoming a globally accepted method of toll collection, a trend greatly aided by the growth of interoperable ETC technologies. Technologies used in ETC are Automatic Vehicle Identification (AVI), Automatic Vehicle Classification (AVC), Video Enforcement Systems (VES) and Vehicle Positioning System (VPS).ETC systems are deployed in the following cities in India:

Location	Name of roadway	Type of roadway	Owned by	Operated by
Kharagpur	NH-6 toll road	Highway	NHAI	TollTrax Toll Collection System
Delhi	Delhi-Gurgaon Expressway	Highway	NHAI	Metro Electronic Toll Collection Systems
Chennai	IT corridor	Highway	TNRDC	Electronic Tolling with future plans for smart cards

Figure 46: Toll Collection in India [69]

Advanced Parking Management

State-of-art parking management system is set up by the New Delhi Municipal Council at Palika Parking in Connaught Place. This system allow vehicle users to be guided by a wide range of sensors, lights, signboards and directional displays to the closest vacant car space existing in the parking lot and similarly for identifying their car location at the time of exit. Apart from automatic online guidance at junctions, zone-wise sub-division of areas will assist easy identification. The guidance system operate throughout the three levels of parking at Palika, which has a capacity for 1,050 cars and 500 scooters.

Figure 47: Ongoing Advanced Parking Management Setup at Palika Bazar, Delhi [70]

VI. Issues and challenges of ITS in India

The rapidly advancing economy of India, in par with the rest of the world has resulted in a phenomenal increase in use of personal automobiles on Indian urban roads. The cumulative growth of the Passenger Vehicles segment in India during April 2007 – March 2008 was 12.17 percent. In 2007-08 alone, 9.6 million motorised vehicles were sold in India [71]. It is expected that India will surpass China as the fastest growing car market within the next few years.

Economy-induced automobile usage is complicated further by the constant influx of rural population into urban areas, thus making enormous demands on the transportation infrastructure in an overloaded region. In 2001, India had 35 cities with a population of more than one million people. [72]. The heterogeneity of economy and the physical limit on how much additional infrastructure a city can hold complicate transport management further.

Some of the main issues facing the deployment of ITS in developing countries like India, reported by a World Bank study are: an underdeveloped road network, severe budget restrictions, explosive urbanization and growth, lack of resources for maintenance and operation, less demand for automation, lack of interest among government decision makers, and lack of user awareness.

While a number of small scale ITS projects have been introduced in various cities in India - including New Delhi, Pune, Bangalore, Indore and Chennai - these systems have focused on isolated deployments such as of parking information, area-wide signal control, advanced toll collection, web based traveller information etc. (Eg. Ref 73). Most of these are small-scale single-city based pilot studies. At present, there are not many comprehensive, fully developed ITS applications with traffic management centers in India. Thus, it can be seen that the penetration of ITS in Indian road scenario is relatively less and much more is needed to be done. To make this a reality, there is a need for more systematic approach to the ITS implementation.

Apart from the applications that are already being developed/implemented, there are more ITS concepts that will be useful in the Indian scenario such as emergency management, congestion management, advanced traffic management systems, advanced traveler information systems, commercial vehicle operations, advanced vehicle control systems, etc. Full utilization of ITS can be achieved only by implementation at a network level rather than in small corridors. Overall, the existing applications shows an initial promise and potential for the deployment of ITS in India and give an initial empirical basis and data on ITS deployment highlighting the data, methodological, practical and research challenges for Indian conditions.

Some of specific actions required to meet the challenges to ITS in India include:

- Evolving a national ITS standard for different ITS applications and their components
- Setting up a national ITS clearinghouse that documents all ITS projects with details on the design, implementation, lessons learned/best practices, and cost-benefit details

- Setting up fully functional Traffic Management Centres for coordinating the urban and regional ITS activities,
- Developing and implementing automated traffic data collection methodologies,
- Developing a national ITS data archive,
- Developing models and algorithms suitable for ITS implementations
- Fostering more interaction between academia, industries and governmental agencies to generate more interest and in turn projects in the ITS area.

These can be achieved through improvements in the following areas:

Technology Improvements

ITS implementations in India cannot be carried out by reproducing what is done in developed countries because of a range of cultural, lifestyle and physical differences among them. The diverse range of vehicular velocities (pedestrian, bicycle, LMV's, HMV's, animal drawn carts), wide variety of vehicles (including pedestrian traffic), and poor lane discipline (partially resulting from the first two factors and partially due to cultural reasons) and a very high population density makes implementation of Western ITS standards and architecture difficult. Data collection techniques are difficult under Indian traffic conditions. For example detectors which are lane based are inapplicable due to the above reasons. Probe vehicle methods such as AVI and AVL are expensive and need public participation. Budgetary limitations make implementation of such methods hard. Video techniques can collect data despite lack of lane discipline and homogeneity. However, extraction software that can be used to extract data is available only for a limited class of vehicles and for lane based traffic. Such software to extract real time data from video under the commonly seen heterogeneous/mixed traffic conditions is not available making video also not a good data source for real time applications.

The pressing need towards developing a comprehensive ITS program for India requires the development of cost effective detection techniques for road-wide data collection rather than lane-centric collection that are suitable for a more orderly traffic flow. Further, the ITS data are not effectively utilised as of now. Once such a real time automated data collection system is developed the data generated can be archived and can be used for model development.

Infrastructure

Apart from data collection and management, there is a need to improve road and highway infrastructure to channel the burgeoning traffic into less congested routes. Major metropolitan cities are continually addressing this issue by building flyovers and subways, widening roads and designating one-way roads during peak hours. The infrastructure growth is, however, restricted by space constraints and cannot by itself solve the problems that plague the Indian roads today.

Another important approach to ITS is to advance public transportation as a competitive alternative to private transport. India is the second largest producer of buses, accounting for 16 percent of world's total bus production. Improving the quality of public transportation will encourage more usage and therefore help in transportation management [74].

Social Schemes

Carpooling is being increasingly considered in the developed countries to solve issues of pollution and traffic snarls during peak hours. A few arterial roads such as the beltway around Washington DC levy fines for travelling in carpool-only lanes as single occupants. There have been some trials on the enforcement of carpooling in a few Indian metros. For example, the Mumbai Environmental Social Network has promoted a web- and SMS-based pooling system [75]. Bangalore Transport Information System has a group-SMS version [76]. Since it is illegal for a private motorist to charge for lifts, Koolpool with the help of Hindustan Petroleum, has devised a scheme which permits pick-ups at its petrol pumps in return for a petrol voucher worth Rs.25 for giving a lift. Such schemes can be fine tuned to make it more profitable for the public and useful for the city's traffic.

Chennai in recent years, has seen the increased use of the "share auto", an automobile pooling convenience, not in the scale of buses, but less expensive than the common "auto rickshaw". Such schemes have caught on well and further developments along such ideas can provide a much needed breather for the traffic jams that characterise the cities.

Some other cities around the world such as Singapore and London have introduced congestion charging schemes to reduce traffic. Such schemes ensure optimal usage of those specific roads, provide financial backup for road infrastructure maintenance and encourage the use of public transportation.

VII. Conclusions

The rapidly increasing vehicle population in India, spurred by the population boom and economic upturn lays a critical burden on traffic management in the metropolitan cities and towns of the country. While India has already made a foray into intelligent transport systems in organizing traffic, more extensive and urgent integration of advanced technology and concepts into mainstream traffic management is imperative. The adoption of location and information based technologies into vehicles, infrastructure, traffic management and traveller information services have shown dramatic improvements in the safe, and efficient mobility of people and freight in USA, European nations, UK, Japan, Middle East and Canada. ITS is still in its infancy in India, with decision-makers, key planners and agencies still in the process of understanding its potential.

India's ITS cannot be entirely modelled on the existing successful ITS of other nations due to basic cultural, geographic and practical differences amongst the countries. The existing concepts have to be thoroughly understood in order to modify them to fit the Indian traffic scenario. The design of an intensive ITS program hinges on the following developments:

1. Technology: The development and implementation of advanced technologies is important to the successful management and operation of ITS in India. These technologies include electronic equipments such as sensors, detectors and communication devices and application of global navigation satellite system (GNSS). This in turn hinges on cooperative work between the Government, academic research institutions, and industry.

2. Modelling of Indian traffic – A proper understanding of the traffic system is important in the successful implementation of any reliable ITS systems. The existing models, developed for the western traffic conditions may not be suitable for the Indian traffic and hence there is a need to modify or develop models that can characterize the Indian traffic in a better way.

3. Supply Chain: Seamless interconnectivity of the various branches of the transportation sector is essential to provide effective, efficient and secure movement of goods and services while improving the conservation of natural resources and reducing environmental impacts such as the effects of carbon emissions.

4. Energy and Sustainability: The ITS in India should closely work with the energy sector in the promotion of fuel efficient transport policies and practices, including the use of alternative transport fuels. Fuel efficient policies and practices will assist the country in achieving sustainable economic and environmental benefits through the application of intelligent transportation services.

5. Human Capital Development: Human skills are important to ensure the development of seamless transportation systems. Given the population density of India and the varied skill sets available in the country, the ability of the work force to develop, manage and

safely implement existing and emerging technologies is essential for ITS design and implementation.

A plethora of issues and challenges have to be tackled before India can have a fully operating ITS system. The main challenges perceived include

- Establishing ITS standards applicable throughout the urban and rural sections of India
- Designing an ITS that encompasses the heterogeneous vehicle population
- Developing a comprehensive data collection system
- Establishment of a Data Centre
- Setting up active interaction between academia, industries and governmental agencies
- Government setting up rules and regulations of traffic that will aid in ITS implementation

To meet the challenges in setting up a comprehensive traffic management system, the following tasks have to be carried out.

- Measurement and monitoring the performance of existing transportation management systems throughout the country;
- Establishing aggressive, yet achievable, near and long-term performance goals for transportation systems;
- Optimizing the performance of transportation network through the use of real-time data, predictive traffic models, improved integration between individual systems, and other state-of-art tools and strategies for improving safety, mobility and the environment.

It is vital to plan key initiatives and activities which advance and improve the development and use of ITS in India. These include activities addressing the Global Navigation Satellite System (GNSS), encouragement of international standards development through liaison with the International Organization for Standards, work force development/training, and improved supply chain management processes in a sustainable fashion.

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